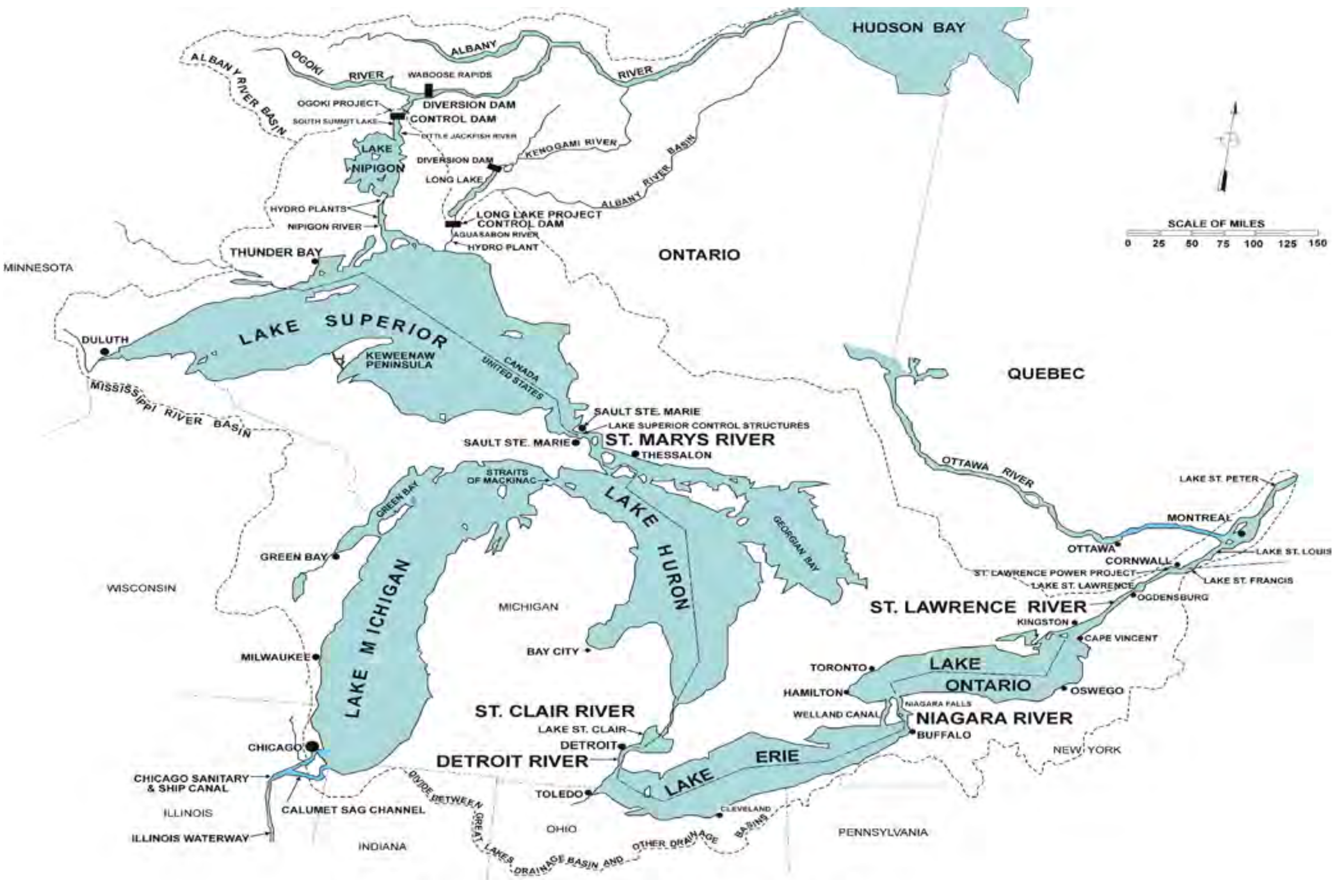
SUPPLEMENTAL RECONNAISSANCE REPORT

February 2010

GREAT LAKES NAVIGATION SYSTEM REVIEW



Great Lakes - St. Lawrence River System

US Army Corps of Engineers®

Great Lakes &
Ohio River Division

Supplemental Reconnaissance Report
Great Lakes Navigation System Review

Executive Summary

For more than half a century, the Great Lakes Navigation System (GLNS) has served as a vital transportation corridor for the single largest concentration of industry in the world. Straddling the Great Lakes Basin, North America's industrial heartland depends on this system of locks, channels, ports and open water. Yet the waterway is facing new challenges that could not have been anticipated when it came into full operation in 1959. Changes in the economy and in the transportation industry have altered product demand, traffic patterns and shipping volumes. Although these developments have transformed the economic drivers underlying the system, it continues to fulfill a vital transport function not only for the Great Lakes region, but also for the entire industrial core of the North American economy. Given its ongoing importance, it is essential that the system be maintained as a safe, reliable, efficient and sustainable component of the continent's overall transportation network.

A system as large and complex as the GLNS inevitably affects the environment around it. Generally, society has become far more aware of such environmental impacts, exacerbated as they are by the parallel pressures of population growth, urbanization and lifestyle changes. Recent scientific research has yielded a better understanding of the cumulative effect of human action on the environment. It has also led to a deeper appreciation of unique environments such as those existing in the Great Lakes Basin, and has transformed the way in which such ecosystems are studied and evaluated.

The infrastructure of the GLNS is starting to show its age. After 50 to 70 years of service, the system of locks and approach channels shows wear and tear from the passage of tens of thousands of ships. Other parts of the system is over a century old. As the system ages, the demands for maintenance grow, as do the costs. Recognizing this, Congress authorized the U.S. Army Corps of Engineers (Corps) to conduct an analysis of Great Lakes Navigation System via Section 456 of the Water Resources Development Act (WRDA) of 1999. The initial reconnaissance report was completed by the Corps Detroit District in 2002 and submitted to the Corps' Great Lakes and Ohio River Division (CELRD) regional Headquarters on February 3, 2003 for review and comment. The study also was forwarded to the Corps' Washington DC headquarters (USACE-HQ) for review and comment.

After the review, CELRD informed the Detroit District that the initial Reconnaissance Report was tentatively approved to support a recommendation to proceed to the feasibility phase. However prior to initiation of a more detailed feasibility study, further information was required by USACE-HQ. It was mandated that a Supplement to the Reconnaissance Report must be prepared in order to clarify the "Without Project Condition" (to establish a baseline) and the more definitive determination of the Federal interest. The "Without Project Condition" scenario would assume that nothing would be done to expand the GLNS beyond routine maintenance and upgrades over the coming 50 years.

Separately, but on a similar path to the Supplemental Reconnaissance report, a joint Canadian/United States study (the bi-national *Great Lakes St. Lawrence Seaway Study)* was begun in May 2003, following the signing of a Memorandum of Cooperation (MOC) between Transport Canada and the U.S. Department of Transportation. The MOC facilitated a binational study partnership that included Canadian and United States departments and agencies with expertise in transportation policy and economics, navigation-related infrastructure engineering and environmental science. These experts acted as the members of the Project Delivery Teams for the study.

The bi-national study (which is discussed in greater detail in Section 4.5) facilitated an international, collaborative effort to produce a wide-ranging investigation that addresses the fundamental question: *What is the current condition of the GLNS, and how best should we use and maintain the system, in its current physical configuration, in order to remain competitive in the world market while facing the challenges that will present themselves in coming years?*

Furthermore, there are two common findings in reports written recently by the Brookings Institute, the RAND Corporation, the National Academy of Science, and various U.S. and Canadian departments; the first being that the GLNS is at a tipping point that will see the industry either flounder or flourish in the next several decades; the second, that success of the system hinges on coordinated planning and action between all stakeholders. This report, designed to supplement a June 2002 (Revised February 2003) Corps of Engineers *Reconnaissance Report - Great Lakes Navigation System Review*, recommends that the Corps proceed with a feasibility level study that would catalyze actions to achieve a healthier Great Lakes environment and a more productive GLNS for the good of North America.

Each of the referenced reports looks at the region from a slightly different perspective, focus and intent. Collectively, they indicate that the future viability of the GLNS will come directly from maintaining the value and function of the existing infrastructure, while bringing more containerized cargo into the Great Lakes, and exploring options to alleviate congested overland travel.

The point of view for managing the system in a way that focuses on economic growth is compelling. Trends indicate that the population and wealth of North America will be greater in the future. More raw materials and goods will be delivered. These materials and goods can be transported on railroads, trucks or ships. Highways are heavily congested now and will be more congested in the future. Some rail systems are underutilized while others are congested. Expanding rail or roadways almost always requires widening existing routes, which is extraordinarily costly because it requires rebuilding bridges across the wider routes. It is estimated that the Great Lakes Navigation System is at about half capacity and could accept more traffic without expansion. Also, Ships use less fuel per ton to carry the same cargo and produce less atmospheric carbon; the European Union touts inland shipping as the green alternative.

There are clear disadvantages to shipping as well. Ships are slower than terrestrial or airborne transportation, and delivery speed is an important financial factor for finished, perishable and high value goods. Further, water-borne shipping, especially ocean-lake transit, is considered the leading cause for the introduction of invasive species that have caused enormous financial and environmental disruption. This risk can be reduced but not eliminated.

The GLNS infrastructure (locks, dams, breakwaters) is old, risking serious and costly delay, which makes shipping even less attractive for moving high value cargo. Winter ice impedes or stops navigation each year, meaning that shippers have to employ a winter alternative to waterborne transit. The inhibiting effect of conflicting and restrictive laws is touched on in several of the recent reports, but no one has systematically analyzed the institutional constraints or suggested the particular ways the multiple governments involved could overcome them. Shorelines are impacted by the wakes of these big vessels; more ship traffic means more impacts. And while climate change may someday allow year round navigation on the Great Lakes, it could also lower lake levels, and that in turn would reduce the amount of cargo some ships can carry. If the climate model predictions verify, warmer air and water temperatures would affect the ecosystems throughout the Great Lakes as migratory ranges change and conditions rebalance to favor one species over another.

The environmental health of the Great Lakes is the central issue in some of these reports, with commercial navigation treated as an important driver on a critical issue, invasive species. Navigation is a small but not negligible driver of water pollution; the primary causes of pollution are airborne substances, agricultural runoff and human waste.

Navigation requires dredging of shoal material, most of which has to be stored in confined disposal areas because it is contaminated from past industrial discharges. The paradox is that Great Lakes pollution is connected to the region's growth and prosperity before the environmental awakening in the 1960s, but limited funding, targeted to remediation of such problems in the Great Lakes, has kept the region from solving these problems.

The themes shared by both the navigation and environmental-centric reports is that the best chance of a better future will be advanced by more effective, better coordinated management of the GLNS, and the benefits of solving these problems can far outweigh the costs. As such, binational and Supplemental Reconnaissance reports both conclude that the GLNS remains an important element in the North American economy, with a transportation rate savings of approximately $3.6 billion (U.S. only) per year (not including the St. Lawrence Seaway). Its ongoing value and future prospects certainly justify the costs of maintaining its infrastructure. Moreover, future operation and maintenance of the system can be performed in a manner that minimizes environmental impacts.

Referenced reports serve their intended purpose by providing an authoritative assessment of what is and what could be, but by themselves they will not trigger the coordinated actions that can make the future of the GLNS better. While the Corps is just one of many entities that must be involved, this Supplement to the Reconnaissance report discusses that, because of the authorities that define the Corps' mission area (which includes commercial navigation), the Corps should initiate and facilitate such investigations and actions to develop a holistic blueprint for the future of the GLNS. To do that, the Corps will have to:

- coordinate with Canada, the eight Great Lakes states, the two Great Lakes provinces, affected tribes and cities, the more than two dozen Great Lakes "integrating" organizations, and the many non-governmental organizations and stakeholders representing all other uses for this water;

- consider the future health of the Great Lakes environment, the effect of the environment on economic prosperity and vice versa, and the effect different navigation practices will have on the environment;

- approach the situation from a systems view, looking at navigation throughout the Lakes, (while considering actions by government and the private sector) with modifications in particular harbors dependent on their own initiatives and the value they provide the system.

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1. Study Authority

The June 2002 U.S. Army Corps of Engineers (Corps) Great Lakes Navigation System Review (revised February 2003) reconnaissance report, and this supplemental to that report, were prepared as an initial response to Section 456 of the Water Resources Development Act (WRDA) of 1999, which authorized the Great Lakes Navigation System Review. The full text of the Act is as follows:

> *"In consultation with the St Lawrence Seaway Development Corporation, the secretary shall review the Great Lakes Connecting Channels and Harbors Report dated March 1985 to determine the feasibility of undertaking any modification of the recommendations made in the report to improve commercial navigation on the Great Lakes navigation system, including locks, dams, harbors, ports channels, and other related features."*

The Great Lakes Connecting Channels and Harbors study was authorized by two separate resolutions of the Senate Committee on Public Works in 1969 and 1976. The study was originally to determine the advisability of further improvements in the Great Lakes Connecting Channels and Harbors in the interest of present and prospective deep-draft commerce with particular consideration of improvements for the safe operation of vessels up to the maximum size permitted by the St. Marys Falls Canal. The study was expanded by the 1976 resolution to also determine the advisability of providing additional lockage facilities and increased capacity at the St. Marys Falls Canal at Sault Ste. Marie, Michigan.

The separate resolutions of the Senate Committee on Public Works for the Great Lakes Connecting Channels and Harbors study read as follows:

> *"Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested to review the report of the Chief of Engineers on the Great Lakes Connecting Channels, published as Senate Document Numbered 71, Eighty-Fourth Congress, and other pertinent reports, with a view to determining the advisability of further improvements in the Great Lakes Connecting Channels and Harbors in the interest of present and prospective deep-draft commerce, with particular consideration of improvements for the safe operation of vessels up to the maximum size permitted by the St. Mary's Falls Canal".*
>
> (Sponsored by Senator Stephen M. Young of Ohio, adopted 2 June 1969.)
>
> and:

"Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested to review the reports of the Chief of Engineers on the Great Lakes Connecting Channels, published as Senate Document Numbered 71, Eighty—fourth Congress, and other previous reports, with a view to determine the advisability of providing additional lockage facilities and increased capacity at St. Mary's Falls Canal, Michigan".

(Sponsored by Senator Hugh Scott of Pennsylvania, adopted 30 April 1976.)

2. Study Purpose and Scope

This supplement to the Corps' *Great Lakes Navigation System Review, Reconnaissance Report* was developed to further define the baseline condition ("Without Project Condition") for the U.S. Great Lakes Navigation System (GLNS), excluding the St. Lawrence Seaway; and to better describe the "Federal Interest" to justify proceeding into further participation in study of the system.

The Detroit District of the Corps received funding for the study in both Fiscal Years 2001 and 2002 to conduct the initial Reconnaissance phase of the study. The Corps' Reconnaissance Report was completed in June 2002, and reviewed internally among the study partners. While the focus was on the GLNS, the importance of the St. Lawrence Seaway and the need to holistically examine the Great Lakes St. Lawrence Seaway System (GLSLS) was recognized. Funding limitations did not allow full examination of the Seaway, specifically the identification of a Seaway "without-project" (baseline) condition in the June 2002 report.

The draft study was then submitted to the Corps' Great Lakes and Ohio River Division (CELRD) regional Headquarters on February 3, 2003 for review and comment. The study also was forwarded to the Corps' Washington DC headquarters (USACE-HQ) for review and comment. After the review, CELRD informed the Detroit District that the initial Reconnaissance Report was tentatively approved to support a recommendation to proceed to the feasibility phase. However prior to initiation of a more detailed feasibility study, further information was required by USACE-HQ. It was mandated that a supplement to the Reconnaissance Report must be prepared in order to clarify the system-wide "Without Project Condition" (to more clearly establish a baseline) and the more definitive determination of the Federal interest. The "Without Project Condition" scenario would assume that nothing would be done to expand the GLNS beyond routine maintenance and upgrades over the coming 50 years. Specific issues to be addressed within the Supplemental Report included:

1. Clarifying the "Without Project Condition" (GLNS baseline) for the environment as well as for economic and engineering features;
2. Clearly specifying the Federal interest;
3. Conducting additional public involvement and coordination;

4. Determining the scope of the feasibility study, including costs, schedules and the production of a Project Management Plan; [†]
5. Continuing ongoing coordination and identify future partnering opportunities with Canada.

Separately, but on a similar path to this Supplemental Reconnaissance report, a joint Canadian/United States study (the bi-national *Great Lakes St. Lawrence Seaway Study)* was begun in May 2003, following the signing of a Memorandum of Cooperation (MOC) between Transport Canada and the U.S. Department of Transportation.

The MOC facilitated a binational study partnership that included Canadian and United States departments and agencies with expertise in transportation policy and economics, navigation-related infrastructure engineering and environmental science. These experts acted as the members of the Project Delivery Teams for the study.

Bi-national Project Delivery Teams investigated and reported on the engineering, economic and environmental conditions of the waterway to establish the baseline conditions for the GLNS, and the St. Lawrence Seaway. This information was used to determine the requirements to maintain the integrity of the navigation system and environmental sustainability of the waterway for (at least) the next fifty years. Also, this work looks at how other factors such as modal integration, trade facilitation, congestion mitigation and overall sustainable transportation might affect future commercial navigation on the system.

The bi-national study (which is discussed in greater detail in Section 4.4.) provided a significant portion of the material in this report, including the significant effort that was required to thoroughly analyze the existing system, in order to establish the base condition. This is an important step because the value and benefit of any modification to the system cannot truly be measured for worthiness without being compared to a base condition. Also, several other coincidental studies and initiatives have been enacted in the interim, which have added insight and information toward the development of this Supplement. See *Section 4 - Prior Reports* for a list of significant studies and initiatives that provided information used to satisfy USACE-HQ's mandates.

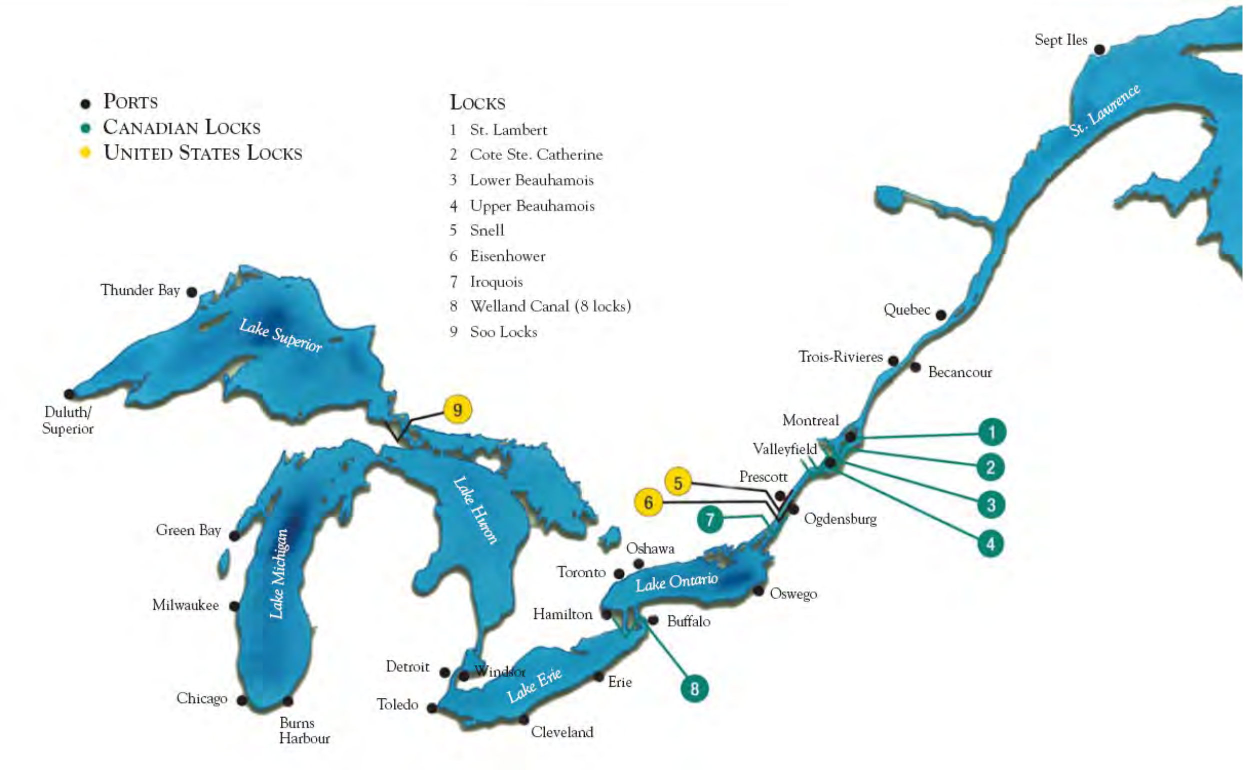
Given that the determination at the end of this Reconnaissance Report Study and Supplement is to proceed with further study, a scope, including cost and duration, and the development of a Project Management Plan will be developed during the review period of this Supplement. Since the GLNS is a unique bi-national waterway, coordination with Canada that occurred during the development of the Reconnaissance Report and Supplement will continue during additional study phases connected with this work, or future studies.

[†] These actions will be addressed in this report, but not initiated until after the review process for this report is underway.

3. Location and Congressional Districts

The study area is located within the Great Lakes St. Lawrence River Basin, which includes the U.S and Canadian Great Lakes-St Lawrence Seaway System (GLSLS). The upper Great Lakes portion of the system encompasses the upper four Great Lakes and the connecting channels (rivers) between Lake Superior and Lakes Michigan and Huron, and Lake Erie.

Figure 1 - The Great Lakes St. Lawrence Seaway System with Its Major Ports and Locks.



The St. Lawrence Seaway portion of the system encompasses the Welland Canal, Lake Ontario and the St Lawrence River. The GLSLS borders the following U.S. states; Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and the Canadian provinces of Quebec and Ontario. The U.S. commercial navigation-oriented portion of this system, which is the focus of this report, is defined as the GLNS. Specifically, the GLNS encompasses all five of the Great Lakes and the Great Lakes connecting channels, excluding the Canadian-owned Welland Canal. The GLNS is an interconnected system of locks, navigational connecting channels, ports and harbors.

3.1 Study Area State Representation in the U.S. Congress

The study area lies within the jurisdiction of the following Congressional Districts:

Illinois:
Senator Richard J. Durbin, (D); Roland W. Burris (D)

1st Bobby L. Rush (D)	6th Peter Roskam (R)
2nd Jesse Jackson, Jr. (D)	7th Danny K. Davis (D)
3rd Daniel Lipinski (D)	8th Melissa Bean (D)
4th Luis Gutierrez (D)	9th Janice D. Schakowsky (D)
5th Michael Quigley (D)	10th Mark Steven Kirk (R)

Indiana:
Senator Paul Evan Bayh, (D); Senator Richard Lugar (R)

1st Peter J. Visclosky (D)	3rd Mark Souder (R)
2nd Joseph Donnelly (D)	

Michigan:
Senator Carl Levin, (D); Senator Debbie Stabenow, (D)

1st Bart Stupak (D)	10th Candice Miller (R)
2nd Peter Hoekstra (R)	12th Sander Levin (D)
4th Dave Camp (R)	13th Carolyn Kilpatrick (D)
5th Dale Kildee (D)	14th John Conyers (D)
6th Fred S. Upton (R)	15th John Dingell (D)

Minnesota:
Senator Amy Klobuchar (D)

8th James L. Oberstar (D)

New York:
Senator Charles Schumer, (D); Kirsten E. Gillibrand (D)

23rd John McHugh (R)	27th Brian Higgins (R)
24th Michael Arcuri (D)	28th Louise M. Slaughter (D)
25th Daniel Maffei (D)	29th Eric Massa (D)

Ohio:
Senator Sherrod Brown, (D); Senator George V. Voinovich, (R)

4th Jim Jordan (D)	11th Marcia Fudge (D)
5th Bob Latta (R)	13th Betty Sutton (D)
8th John Boehner (R)	14th Steven LaTourette (R)
9th Marcy Kaptur (D)	16th John Boccieri (D)
10th Dennis J. Kucinich (D)	17th Tim Ryan (D)

Pennsylvania:
Senator Arlen Specter, (D); Senator Bob Casey, Jr. (D)

3rd Kathy Dahlkemper (D)
5th Glen Thompson (R)

Wisconsin:
Senator Russell Feingold, (D); Senator Herbert Kohl, (D)

1st Paul Ryan (R)
2nd Tammy Baldwin (D)
4th Gwen Moore (D)
5th James Sensenbrenner, Jr. (R)
6th Thomas E. Petri (R)
7th David R. Obey (D)
8th Steve Kagen (D)

4. Prior Reports

Aside from the publication of the Corps' *Reconnaissance Report - Great Lakes Navigation System Review* in 2002, (revised in February 2003), several major studies on the economic and environmental future of the Great Lakes have been authored (and referenced for this report) addressing both the potential benefits and harm that could come from commercial navigation on the Great Lakes in the future.

4.1 Reports Reviewed in Development of the June 2002 (Revised February 2003) Reconnaissance Report

Several more reports were used in the assessments of the reconnaissance study but are not revisited for this supplemental reconnaissance effort. These summaries were copied from the reconnaissance report for the convenience of readers:

(1). Great Lakes Connecting Channels and Harbors, Final Feasibility Report and Environmental Impact Statement, September 1985, (Revised January 1986). Determine the advisability of further improvements in the Great Lakes Connecting Channels and Harbors in the interest of deep-draft commerce. The study also determined the advisability of providing additional lockage facilities and increasing capacity at the St. Marys Falls Canal at Sault Ste. Marie, Michigan.

(2). St. Lawrence Seaway Additional Locks Study, Preliminary Feasibility Report, July 1982. Determined the adequacy of the existing locks and channels in the U.S. Section of the St. Lawrence Seaway.

(3). Fox River Channel, Green Bay Harbor, Wisconsin, Reconnaissance Report, Commercial Navigation Improvements, April 1991. Determined the feasibility of modifying the existing commercial navigation harbor at Green Bay, WI, to modernize the harbor for large vessels and international trade.

(4). Menominee Harbor and River, Michigan and Wisconsin Reconnaissance Report, Commercial Navigation Improvements, March 1991. Determined the feasibility of implementing improvements to the existing commercial navigation harbor at Menominee, WI and MI, that was authorized in 1960.

(5). An Overview of the Commercial Navigation Industry of the United States on the Great Lakes, June 1992, IWR Report 92-R-6.

(6). Great Lakes Harbors Study. The Final Report by the U.S. Army Corps of Engineers, dated November 1966, together with 38 interim reports, included recommendations that 30 harbors be improved and one harbor be built to provide a 27- draft depth commensurate with the 27—foot depths provided in the connecting channels, the Welland Canal, and the St. Lawrence River. These reports contain the economic and physical data and analyses used to justify improvements made during the late 1950's and early 1960's.

(7). Great Lakes-St. Lawrence Seaway Navigation Season Extension Study. Several reports were prepared and completed under this study by the U. S. Army Corps of Engineers as authorized by Section 107(a) and Section 107(b) of the 1970 River and Harbor Act. They include four Demonstration Program Annual Reports, 1972—1975; a Demonstration Program Report Summary, 1976; and a Special Status Report, July 1974. Also included are: the Final Demonstration Program Report, completed September 1979, which documented the results of the Demonstration Program that was conducted under a cooperative effort among several Federal agencies and non-Federal public and private interests. The Interim Feasibility Study, (House Document 96-181) forwarded to the Congress on 3 August 1979 by the Secretary of the Army, recommended Federal participation in an extended navigation season on the upper four Great Lakes and their connecting channels to 31 January, plus or minus two weeks, using existing operational measures; The Final Survey Report recommended a 12—month navigation season on the upper three Great Lakes and their connecting channels, up to a 12—month navigation season on the St. Clair River—Lake St. Clair-Detroit River system and Lake Erie, and up to a 10—month navigation season on Lake Ontario and the International Section of the St. Lawrence River.

The Final Survey Report was completed in August 1979 and forwarded to the Board of Engineers for Rivers and Harbors for Washington level review in January 1980. The Board completed its review in February 1981, and forwarded the report to the Chief of Engineers. The Chief of Engineers has forwarded his report to the Secretary of the Army for subsequent coordination. The Secretary of the Army stated that the season extension is primarily an operational matter with which the Corps has adequate authority.

4.2 Reports Reviewed in Development of the Corps' Supplemental Reconnaissance Report

A) Reconnaissance Report: Great Lakes Navigation System Review

The scope of the original June 2002 Corps' Reconnaissance Study was to determine if there is a Federal interest in providing commercial navigation improvements to the GLNS.

In response to the study authority, the Reconnaissance Study was initiated on 15 January 2001. This phase of the study resulted in the finding that there is Federal interest in continuing the study into the feasibility phase and that the proposed improvements to the system are found to be consistent with Corps policies. The purpose of the Reconnaissance Report is to document the basis for this finding and establish the scope of the feasibility phase.

After conducting stakeholder coordination, it became apparent that the primary concerns among stakeholders are (but not limited to) the restrictions on vessel drafts and preventive port depths, narrow channels (applicable specifically to the Chicago Sanitary and Ship Canal), restrictive lock sizes, channel depths on the St. Lawrence Seaway, and the future reliability of lock structures on the Welland Canal and Montreal-Lake Ontario (MLO) section of the Seaway. The Corps formulated five action alternatives using input from surveys and discussions with stakeholders:

1. To analyze the many combinations of improvement alternatives for the Great Lakes connecting channels and harbors combined with eventual replacement of the Seaway locks at current dimensions, to maximize system efficiency with no expansions. Average annual benefits were estimated at **$87 million**; no costs were estimated.

2. Same plan as alternative 1 above, coupled with construction of a deeper (35' draft) and larger (110'x 1200' lock chambers) Welland Canal. No benefits or costs were estimated.

3. All of alternative 2 plus replacement of the Montreal to Lake Ontario section of the Seaway with a deeper and larger system of locks and channels, and by extending the 35' draft system up to Detroit. Average annual benefits were estimated at **$885 million**; no costs were estimated.

4. All of alternative 3, but with a 35' draft channel past Detroit into Lake Michigan and Lake Huron by the deepening of the entire Saint Clair/Detroit River system. Average annual benefits were estimated at **$1.417 billion**; no costs were estimated.

5. Extends the 35' draft throughout the whole GL/SLS system, adding the deepening of the St. Marys River and lowering the sill depth of the Soo locks. Average annual benefits were estimated at **$1.51 billion**; no costs were estimated.

The 2002 Corps Reconnaissance Report recognizes the past environmental degradation caused by the GLNS and the fact that navigation can still introduce invasive species into the Great Lakes, a risk that would increase if more ocean going ships traversed the Seaway. The report also notes the positive environmental impacts that marine transport provides by using less fuel (resulting in lower emissions than either rail or truck for equivalent cargoes and distances), and the potential to design barriers to invasive fish into the new lock structures.

The report concluded there was a Federal interest in further study and estimated feasibility study costs at $20 million. Because a Great Lakes system analysis was being conducted under the authority of the concurrently-occurring John Glenn Great Lakes Basin Program and duplication of effort between the studies was a concern, Corps Headquarters mandated that the recon target smaller scale feasibility studies that could be pursued separately when a non-Federal sponsor could be identified:

1. Investigating the benefit of deepening individual ports and modifying existing port infrastructure.

2. Investigating proposed modifications to the Chicago Sanitary & Ship Canal including the replacement of two bridges over the canal to facilitate barge shipments between the Great Lakes and the Mississippi River.

3. Determining the feasibility of designing and implementing a St Clair River Ice Boom, and its effectiveness in aiding navigation and reduce flood damages.

4. Investigating the benefit of improved access to historic and real time water level information, especially important for piloting ships loaded near capacity.

5. Investigating the feasibility and benefit of replacing buoys with permanent beacons. The beacons may have a lower life cycle cost than buoys and would provide increased shipping safety at the beginning and towards the end of the shipping season, when buoys are not in place.

B) An Ocean Blueprint for the 21st Century

This September 2004 report was developed by the U.S. Commission on Ocean Policy, created by the Oceans Act of 2000. Like the Great Lakes Regional Collaboration Strategy (page 10) the Oceans Commission report represents an authoritative center for U.S. oceans policy that explicitly includes the Great Lakes and speaks to Great Lakes issues such as invasive species. Like the GLRC, funding to realize the intent of this report will be difficult to secure, but it is safe to say that any initiatives to reform ocean policies and laws will be channeled through the framework and institutions created by this Commission, including Ocean U.S., IOOS (Integrated Ocean Observing System), and the regional association for the Great Lakes, GLOS (the Great Lakes Observing System).

C) Great Lakes Regional Collaboration (GLRC) Strategy

This December 2005 report is the central design for the future of Great Lakes environmental responses. The goal of this collaboration at the highest levels of the Federal government and Great Lakes states, cities and tribes is to protect and restore Great Lakes ecosystems, and can be viewed as the central organizing piece for collective action to improve the "without project" environmental health of the Great Lakes. Recognizing the political and academic support for the Collaboration Strategy, studies, such as the "America's North Coast" Study and the Great Lakes Habitat Initiative (page 16) have explicitly applied the issues structure of the GLRC to their analysis

The GLRC Strategy was the outcome of a process set into being by Executive Order (EO) 13340, signed 18 May 2004, by President George W. Bush. The EO established the Great Lakes Interagency Task Force, composed of Secretaries from the Departments of State, Army, Agriculture, Commerce, Housing and Urban Development, Homeland Security, Interior, Transportation, the Environmental Protection Agency (represented by the Administrator) and Council on Environmental Quality. The Assistant Secretary of the Army for Civil Works (ASA(CW)) is the Department of Army's representative on this Task Force.

The Task Force worked with the Governors of the eight Great Lakes States, Mayors and Tribal leaders to establish the GLRC. This partnership of Federal, state, tribal, and local governments was officially formed in December 2004 in a ceremony attended by the ASA(CW) who signed the Collaboration Charter. The first goal of the GLRC was to develop this strategy, which addresses eight of the nine priorities that had been established by the Great Lakes Governors and Mayors (the water use priority was not addressed because the states already had an ongoing initiative on this issue). Over 1,500 stakeholders from Federal, state, tribal, and local governments, industry, and interest groups participated on eight teams organized around these issues. The identified priorities (issue areas) are:

- Aquatic Invasive Species
- Habitat/Species
- Coastal Health
- AOC's/Sediments
- Nonpoint Source Pollution
- Toxic Pollutants
- Indicators and Information
- Sustainable Development

Strengthening the arguments made in many of the reports listed here, the GLRC responded to criticism in Government Accounting Office (GAO) reports on the lack of coordination in addressing environmental issues facing the Great Lakes. The first report "An Overall Strategy and Indicators for Measuring Progress Are Needed to Better Achieve Restoration Goals, GAO-03-515" (April 2003) reported "there are 148 Federal and 51 state programs funding environmental restoration activities in the Great Lakes watershed. Most of these programs involve the localized application of national or state environmental initiatives that do not specifically focus on watershed concerns."

The second, "Organizational Leadership and Restoration Goals Need to Be Better Defined for Monitoring Restoration Progress GAO-04-1024" (September 2004) found that current monitoring of projects in the Great Lakes does not provide the comprehensive information needed to monitor restoration progress and assess the degree to which the parties are complying with various requirements and objectives. The recommendations here for the feasibility phase stress the need for any Corps navigation study to be part of a larger continuum of action; the innovative alternatives (more container traffic, short sea shipping) will not occur without coordinated action.

D) IJC Lake Ontario-St. Lawrence River Regulation Study

This five year, $20 million International Joint Commission (IJC) Lake Ontario study was designed to revise the rules for regulating Lake Ontario. It included an analysis of how water levels affected shipping costs, including extreme levels under the current and changed climate. The climate change analysis downscaled the projections of global circulation models under the doubling of carbon dioxide (CO_2) scenario that is commonly used.

Although the forecast of CO_2 emissions is in itself highly uncertain, this scenario is often thought of as occurring by 2050. In order to develop outlooks of climate change water supplies for Lake Ontario, supplies for the Upper Lakes had to be developed then routed through water balance models. As a result, these climate change water supplies are already available for a new IJC study of regulation on Lake Superior. Early analysis on the upper lakes shows that climate change could bring water levels three to four feet below low water datum on Lakes Michigan-Huron that persist for years if not decades.

A good portion of the current Great Lakes fleet has been specifically designed to be loaded to (at least) low water datum (zero gage). These ships would have to be light loaded persistently under these climate change assumptions, increasing the cost of shipping, and probably stimulate basic changes in shipping as we know it. One possibility would be to build new Great Lakes vessels that would be better suited to shallower draft; another would be for the Great Lakes to lose viability to other transportation alternatives. The Study Board of the Upper Great Lakes Study is actively engaged with the navigation community and is just beginning to design an adaptive management program that would help shippers anticipate and cope with climate induced water level changes.

E) Great Lakes-St. Lawrence Seaway; New Cargoes/New Vessels; Market Assessment Report

MARAD (the MARitime ADministration) of the U.S. Department of Transportation produced the *Great Lakes-St. Lawrence Seaway; New Cargoes/New Vessels; Market Assessment Report* in January 2007. Since May 2003, the U.S. Department of Transportation and Transport Canada have been involved in a comprehensive bi-national study (see Section 4.4 below) to evaluate the infrastructure needs of the GLSLS System, including the engineering, economic, and environmental implications of those needs as they pertain to commercial navigation. The New Cargoes / New Vessels (NCNV) Market Assessment has been a major investigation of the bi-national GLSLS Study. A primary objective of the assessment has been to provide information and new insights into the role of the Great Lakes and Seaway as part of the bi-national region's integrated transportation network, particularly along major trade corridors. The report envisions three new market groups for shipping containers via the Great Lakes.

1. From Halifax and Montreal inland to ports like Hamilton, Ontario, on Lake Ontario and Cleveland, Ohio, on Lake Erie. Expansion at Montreal is possible now; Halifax would have to wait until the change in global traffic delivers it more goods from Southeast Asia.

2. Intermodal service from the eastern half of the GLNS and St. Lawrence Seaway to the Midwest and far west, including ports such as Seattle and Vancouver using the Burlington Northern Santa Fe, Canadian National and Canadian Pacific rail lines.

3. GLNS Connector service in which Great Lakes ships would replace trucked shipments between GLNS ports.

This is a substantial and credible study, conducted by the RAND Corporation and TEMS, Inc., that uses computer models based on stated preference surveys that assess demand.

TEMS has created transportation studies for road, rail, port and intermodal systems in the Great Lakes and along the ocean coasts. The study goes well beyond conjecture and assumption, using survey data on shippers' preferences and simulation models of cargo movements to support their projections. There is an in-depth assessment of each of the modes on all of the alternative routes, with discussions of non-port alternatives such as the "CREATE" project to decongest rail traffic around Chicago. The report does not address possible negative environmental or social impacts, or provide many specific ideas about how individual ports would collaborate with each other to increase system wide traffic.

F) State of the Great Lakes Report, SOLEC, 2007

U.S. E.P.A. and Environment Canada jointly host a State of the Lakes Ecosystem Conference (SOLEC) every two years and sponsor the production of a family of technical reports every year that report quantitatively on progress in addressing the key Great Lakes environmental issues. SOLEC was an outgrowth of the binational Great Lakes Water Quality Agreement. This report is the latest overall assessment by SOLEC; the 2008 Conference was held in October 2008 and the overall 2008 report will be published soon. SOLEC is the single most authoritative source for estimating the current and future environmental health of the Great Lakes. The "without project environmental future condition" described in this report relies heavily on the 2007 report as well as individual papers developed for the SOLEC 2008 Conference.

- *SOLEC Indicator Papers 2008*

In addition to the complete SOLEC 2007 assessment described above, detailed papers on individual subjects were published for the October 2008 biennial SOLEC conference and referred to extensively in the "Without Project" future for the environment discussion.

(G) America's North Coast: A Benefit-Cost Analysis of a Program to Protect and Restore the Great Lakes

This report was published by the researchers from the Brookings Institute and the University of Michigan in September 2007. Using the analytic framework of the Great Lakes Regional Collaboration (GLRC), the authors led a team of economists and scientists to assess the costs and benefits of implementing the measures enumerated in the GLRC Strategy. The study concludes that it would cost $26 billion to implement the GLRC strategy and the measures would return over $50 billion in long term benefits to the national economy and between $30 and $50 billion in short term benefits to the regional economy. The authors also concluded that implementing the strategy would lead to the development of new technologies and industries that would provide additional benefits. The benefits are summarized by category in Table 1 - Summary of the Economic Benefits of Great Lakes Restoration on the next page.

Table 1 - Summary of the Economic Benefits of Great Lakes Restoration

Improvement	GLRC effect (relative to the baseline)	Affected Value	Present value benefit (relative to the baseline)
Increased fish abundance	30-75% increase[a]	Improved catch rates for anglers	$1.1-$5.8 billion or higher
Avoided dislocation of sport-fishery workers and assets	20% reduction or higher	Maintenance of sport fishery wages and profits	$100-$200 million or higher
Reduced sedimentation	10-25% reduction	Lower water treatment costs for utilities	$50-$125 million
Reduced bacterial and other contamination leading to fewer beach closings and advisories	20% reduction	More swimming activity	$2-$3 billion
Improved water clarity at beaches	5% improvement or higher	More swimming and improved enjoyment of swimming activity	$2.5 billion or higher
Improved wildlife habitat leading to more birds	10-20% improvement[a]	Improved opportunities for birding[b]	$100-$200 million or higher
Improved wildlife habitat leading to more waterfowl	10-20% improvement[a]	Improved opportunities for waterfowl hunting[c]	$7-$100 million
Removed contaminated sediment in Areas of Concern	All toxic sediment contamination remediated	Basin residents benefit directly or indirectly from ADC restoration	$12-$19 billion or higher
Total quantified specific benefits			$18-$31 billion or higher
			Potentially single digit billions or more.
Use values (e.g. health related and recreational) and non-use values (e.g., "existence" and "bequest" for unquantified resources.	Unquantified	Multiple	
Aggregate Long-Run benefit Estimate			$29-$41 billion or higher
Short Term Multiplier Effect			$30-$50 billion
a – Equals the sum of eventual avoided percent decreases and eventual percent increases in population levels, where percent levels are relative to current levels. We assume that avoided decreases and eventual increases would occur gradually over 20 years and 10 years, respectively.			
b – Based on the estimate of one birding trip to the Great Lakes per year per birder.			
c - Based on the estimate that 5 percent of waterfowl hunting trips in Great Lakes states depend on the Great Lakes either directly or indirectly.			

H) Great Lakes Shipping, Trade, and Aquatic Invasive Species

The National Research Council of the National Academy of Sciences February 2008 produced a report that was prepared by a selected "Committee on the St. Lawrence Seaway" (names of committee members are shown in figure 2 below). It is valuable because the committee is expert, diverse and collectively impartial, and their analysis addresses all three issues (shipping, trade and invasive species) in a systematic, balanced way. Key findings and recommendations include:

- The St. Lawrence Seaway had reached its design life, and age related service interruptions could reduce the amount of shipping as traders seek cheaper and more reliable routes. The Research Council says that Transport Canada estimates investments of $2 billion are needed through 2050.

- Consideration should be given to developing a new saltwater port in Sydney, Nova Scotia, to access some of the traffic from Southeast Asia through the Suez Canal and Atlantic Ocean. Currently only 0.1% of tonnage through the Montreal-Lake Ontario section is containerized, although the Seaway is operating at only 50% of capacity and has room to handle much more. The Seaway would be handicapped, though by the fact that ships are slower than trains and trucks and cannot operate year round.

- There should be better coordination of truck and train connections with shipping to offset reductions in ocean vessels that enter the fresh water Great Lakes and St. Lawrence River (i.e. "salties"). Government backed loans and subsidies could be used to restart underused rail facilities as a substitute for seaway salties.

- Collaboration as well as competition among ports should be encouraged, since some ports are better suited to specific hinterland points than others. There is an existing collaboration named H20HWY that is credited with bringing in an additional 500,000 metric tons of cargo in 2006.

Committee on the St. Lawrence Seaway: Options to Eliminate Introduction of Nonindigenous Species into the Great Lakes, Phase 2

Jerry R. Schubel, *Chair*, Aquarium of the Pacific, Long Beach, California
Richard M. Anderson, Duke University, Durham, North Carolina
Stephen W. Fuller, Texas A&M University, College Station
Trevor D. Heaver, University of British Columbia, Vancouver, Canada (emeritus)
Geoffrey J. D. Hewings, University of Illinois, Urbana–Champaign
Philip T. Jenkins, Philip T. Jenkins and Associates, Ltd., Fonthill, Ontario, Canada
Hugh J. MacIsaac, University of Windsor, Ontario, Canada
Steven W. Popper, Rand Corporation, Santa Monica, California
Frank H. Quinn, Consultant, Tecumseh, Michigan
Thomas D. Waite, Florida Institute of Technology, Melbourne
M. Gordon Wolman, Johns Hopkins University, Baltimore, Maryland
Joy B. Zedler, University of Wisconsin, Madison
Ann P. Zimmerman, University of Toronto, Ontario, Canada

Figure 2 - NRC Committee on the St. Lawrence Seaway

- Bonding authority in U.S. ports (Canadian ports don't have that authority) could be used to encourage directly or indirectly related investments in things like shore based ballast water treatments or other industrial facilities. But the Committee is not optimistic about the effectiveness of these techniques.

- The U.S. and Canada should guarantee that the seaway would stay open with an international agreement and use that to provide a sure base for related policies such as investments in ballast water treatment, improved coordination of shipping regulations and (unspecified) encouragement to cruise vessels for ecotourism.

- Both countries should account for the costs of externalities and turn this to the benefit of Great Lakes shipping, perhaps through a carbon tax on commercial shipping.

- Both countries should subsidize the costs of new aquatic invasive species measures so that shippers do not abandon the Great Lakes, eventually forcing up shipping costs because the loss of the Great Lakes system reduces competition.

I) Great Lakes Habitat Initiative (GLHI)

This June 2008 initiative builds upon the recommendations of the December 2005 Great Lakes Regional Collaboration (GLRC) Strategy to Restore and Protect the Great Lakes. The study objective is to develop tools for project tracking and funding, along with a short term implementation plan for the protection and restoration of wetlands and aquatic habitat.

The GLHI seeks to bridge the gap between the regional needs identified in the GLRC Strategy and the programs that provide funding for "on-the-ground" actions. The potential for this program, which continues with limited funding, is that it integrates the design and management of habitat restoration projects no matter the agency or organization, for a collective set of management goals spelled out in the GLRC Strategy.

J) Great Lakes Navigation System Five Year Development Plan

The Five Year Development Plan (FYDP) guides the Corps in planning for the GLNS needs over a given five-year span, defined in this report as the years 2009-2013. The intent is to implement a program that thoroughly engages stakeholders and focuses resources on the system's most critical needs in terms of reducing risk and providing optimal reliability.

The refinement of metrics that can fairly and accurately be used to prioritize system needs in a constrained funding environment is a critical component of the FYDP process. The value of the FYDP rests on best utilizing available funds while meeting Federally-mandated performance-based budgeting requirements.

In the past, commercial cargo tonnage has been a primary criteria used to prioritize investment in the GLNS. Many stakeholders have objected to this approach on the grounds that it does not accurately reflect the full and true value of the system as a whole or as individual system components.

The Corps' Great Lakes Navigation team continues to refine and improve prioritizing criteria (metrics). New metrics need to account for 'interconnectivity to other ports' or 'a system-based approach'. Clearly, the Corps' primary mission in this area is to support commercial navigation but other valid, supporting metrics include: harbors of refuge, input from the US Coast Guard on public safety, and other commercial activities (e.g. ferry boat activity and commercial fishing).

The annual FYDP report is an information report for the purpose of eliciting the expertise of Great Lakes navigation stakeholders regarding the identification and reporting of navigation system needs and priorities, and is a starting point in the formulation of each year's annual budget request. This report does not represent a recommendation for funding in the President's budget and does not include consideration of other national funding needs.

4.3 Headquarters Approval and Directives

The Corps Headquarters (USACE-HQ) approved the GLNS Review Reconnaissance Report in a 13 February 2003 memorandum, but also required a Supplemental Report be prepared "as a basis for further study needed to support a Federal decision on whether to proceed with feasibility phase studies."

This Supplemental Report satisfies the requirement to provide the additional information required by USACE-HQ to determine whether or not to proceed to the feasibility phase. Specific clarification was required in the development of the "Without Project Condition", a better explanation of how the Federal interest was determined; an outline of the proposed feasibility study; and a description of coordination and public involvement that complemented this Supplemental Report, especially coordination with Canada.

4.4 Memorandum of Cooperation (M.O.C.) Between Transport Canada and the U.S. D.O.T.

As discussed in Section 2, above, after the initiation of this Supplemental Reconnaissance report, a joint Canadian/United States study (the bi-national *Great Lakes St. Lawrence Seaway Study)* was begun in May 2003, following the signing of a MOC between Transport Canada and the U.S. Department of Transportation. The bi-national study was conducted concurrently with the development of this Supplemental Reconnaissance Report – Great Lakes Navigation System Review. The binational study partners included the following Canadian and U.S. agencies:

- Transport Canada
- U.S. Army Corps of Engineers
- U.S. Department of Transportation
- St. Lawrence Seaway Management Corporation
- Saint Lawrence Seaway Development Corporation
- Environment Canada
- U.S. Fish and Wildlife Service

Along with the creation of the study (Project Delivery) team, a binational Steering Committee was also set up to oversee the study. The Steering Committee is comprised of senior-level representatives from each of the study's participating organizations.

4.5 Bi-national Great Lakes St. Lawrence Seaway Study

The Study Team began development of this joint study to evaluate the infrastructure needs of the Great Lakes St. Lawrence Seaway (GLSLS) system. The engineering, economic and environmental implications of those needs were investigated by three teams of experts drawn largely from the participating agencies.

The bi-national *Great Lakes St. Lawrence Seaway Study* (GLSLS Study) – Fall 2007 – assesses the ongoing maintenance and the long-term capital requirements to ensure the continuing viability of the GLSLS Navigation System as a safe, efficient, reliable and sustainable component of North America's transportation infrastructure. This report also explores alternative ways to use and maintain the system in the future without changing its physical features.

Primarily the report addresses the current state of the system, including a comprehensive examination of the infrastructure and environmental conditions along the lower portion of the system (including the St. Lawrence Seaway) which was largely unaddressed in the 2002 Corps Reconnaissance report. The bi-national summary report is included as Appendix B to this report.

It should be noted that since the Corps played a major role in the development of the GLSLS report, many of the individuals contributing to this report were also involved in the bi-national study.

The objectives of the bi-national GLSLS Study were as follows:

- Evaluate the condition and reliability of the GLSLS, including the relative benefits and costs of continuing to maintain the existing transportation infrastructure.

- Assess the engineering, economic and environmental factors associated with the current and future needs of the GLSLS and the transportation infrastructure on which it depends.

- Identify factors and trends affecting the domestic and international marine transportation industries serving the GLSLS, including evolving intermodal linkages and transportation technologies.

The scope of the study was limited to the evaluation of the existing marine transportation infrastructure. It is important to note that the focus of the study was the optimization of the existing infrastructure based on the system's current configuration and that the evaluation of major infrastructure modifications, such as an expansion of the Seaway locks or an increase in channel dimensions, were not part of the study. Further consideration of such improvements was ruled out in part based on stakeholder concerns raised during public review of the initial Corps Reconnaissance Study, and during stakeholder engagement activities associated with the initiation of the bi-national study.

Primary of these concerns is the potential negative impact of a deepened and widened shipping system on the ecologically-sensitive Thousand Islands region. Negative impacts to this region from additional ship traffic, would include, but not be limited to, disturbances from more frequent vessel wakes, an increased threat of invasive species and the greater likelihood of vessel accidents and spills. In addition, most of the St. Lawrence Seaway infrastructure that would need to be reconstructed is Canadian owned and Canada is not interested in system expansion. However, both Canada and the U.S. recognize the need to address the condition of the existing infrastructure in order to ensure the system can continue to be operated in a safe and reliable manner.

The report estimates that the system saves about $3.6 billion per year (2009 data) in transportation costs and offers needed capacity to supplement roads and rail lines servicing trade between Canada and the United States. The report raises possibilities for exploring two types of trade that are not common in the Great Lakes now, "short sea shipping" (for example, moving freight by ship across Lake Ontario from Toronto to Rochester rather than trucking it from Toronto to Fort Erie to Buffalo and then to Rochester) and containerized shipping.

The containers would travel on large ocean going vessels from East Asia through the Suez Canal to Atlantic seaboard ports in the U.S. or Canada then would be reloaded onto smaller inter-lake vessels for delivery to Great Lakes cities where they could be destined or further shipped by truck or rail to other destinations. As discussed elsewhere in this report, both short sea shipping and Great Lakes container trade would help reduce congestion on rail and road routes, and could reduce the carbon emissions, fuel use and danger associated with travel by rail or truck on congested routes.

The bi-national report asserts that the Great Lakes have the capacity to absorb this cargo but are not currently competitive with other routes despite their congestion. The lakes may offer a cost savings, but the travel times tend to be longer and the waterway closes in the winter.

The Engineering work group assessed the maintenance needs of all navigation structures in the GLSLS and also the costs of losing service from each of the features. It then conducted simulations to compare the lost time costs compared to various maintenance strategies.

The least expensive maintenance program is to wait until a component fails, but the lost service costs are much higher using that approach. The study team concluded that an aggressive maintenance program would cost far less than the service losses avoided. In addition to the travel cost savings from existing shipments, a more reliable GLNS would be more competitive in attracting new cargo.

Such cargo could be transshipped onto carriers that move them through the GLNS and into the heart of North America. Given that most GLNS shipping has traditionally focused on bulk commodities, a key determinant of success would be the ability of GLNS vessels and ports to handle containerized cargoes. If such capabilities are ensured, containerized traffic in the GLNS is expected to double over the next half century.

The Study promotes a balanced approach, which is reiterated here. The binational study partnership was comprised of Canadian and U.S. Federal departments and agencies with expertise in transportation policy and economics, navigation-related infrastructure engineering and environmental science. The study partners recognized the importance of ensuring that both public and private interests are adequately heard with respect to the engineering, economic and environmental aspects of the study.

To this end, the GLSLS Study incorporated stakeholder engagement to inform public and private sector stakeholders about the study. The St. Lawrence Economic Development Council (SODES) and the Great Lakes Commission (GLC) acted as the co-secretariat of the International Association of Great Lakes and St. Lawrence Mayors and, in this capacity, have developed a strong binational working relationship with many important stakeholders in the Great Lakes basin and St. Lawrence River.

The GLSLS Study Management Team fully committed to pursuing stakeholder engagement as part of the study process and it participated in many stakeholder meetings to ensure that public and private interests were also satisfied in that the study's objectives and work scope. Additional information on the binational GLNS Study is available through the study website: www.glsls-study.com

4.6 History of Public Involvement and Coordination (Recon & Bi-national)

Stakeholder engagement was an important component of the bi-national GLSLS study process, as discussed in Section 4.4 above, and in more detail in Section 6 Plan Formulation under "*Public Interest and Stakeholder Engagement*". Given its size and scope, there was clear recognition from the outset of the need to consult stakeholders in order to determine their interests and identify issues of concern. Meetings were held in June and July 2004, with interested parties from both the public and private sectors, and followed with additional meetings in September 2005. A website was also established to keep the public apprised on the progress of the study, plus additional stakeholder and public meetings were held frequently.

These sessions were instrumental in engaging stakeholders, informing them about study objectives and soliciting input regarding their comments and concerns. The session helped to gather information and expertise from public and private sector stakeholders, especially as it related to marine transportation and commercial navigation on the GLNS. The meetings also served as a forum for dialogue and the exchange of ideas, notably on certain important environmental issues and concerns. The input gathered at these sessions was transmitted to the management committee, to the study teams and to all study partners for their consideration.

5. Current Conditions

The Great Lakes St. Lawrence Seaway system (GLSLS) is considered the entire U.S. and Canadian-territory Great Lakes surface waters, including harbors and connecting channels, from Lake Superior through the St. Lawrence Seaway to the Atlantic Ocean. The GLSLS contains the U.S. owned, operated and maintained Great Lakes Navigation System or GLNS. The GLNS, as described here, encompasses the commercial navigation system in the Great Lakes and their connecting channels that are in the U.S. territory and/or maintained by the U.S. Federal Government.

The GLNS encompasses all five of the Great Lakes and the Great Lakes connecting channels, excluding the Canadian-owned Welland Canal. The GLNS is an interconnected system of locks, navigational connecting channels, ports and harbors. The navigable portion of the U.S. system links Lakes Superior, Michigan, Huron and Erie through locks at Sault Ste. Marie and the channels of the St. Marys, Detroit and St. Clair rivers, and is operated and maintained by the U.S. Army Corps of Engineers (Corps). Critical to the Lake Superior link of the GLNS are the two operational Soo Locks maintained by the Corps at Sault Ste. Marie, Michigan, located on the St. Marys River. The Corps also maintains ports on Lake Ontario.

The GLNS as it exists today is the culmination of centuries of systematic enhancements designed to move ships easily across a vast expanse of territory in which water falls more than 555 feet as it flows from Lake Superior to upstate New York. Since most of this change in elevation occurred naturally over rapids or falls, a series of canals and locks have been built to raise and lower vessels across these natural barriers. In addition to locks, the system depends on channels through the Detroit, St. Clair and St. Marys Rivers, and the man-made Welland Canal. These are dredged where necessary to provide adequate depth (draft) for vessels moving through these passages. The existing wide range of supporting infrastructure and services include:

- Federal harbor access channels, river channels and vessel turning basins;
- confined disposal facilities for contaminated dredged material from maintenance of Federal channels and harbors;
- structures built to safeguard navigation in Federal harbors from waves and ice (breakwaters, piers, revetments, etc.);
- Federal navigation lock operation and maintenance (SOO Locks, Chicago Lock, Black Rock Lock in Buffalo, NY);
- port terminals, docks, loading facilities and port authorities;
- port services (docking, loading, unloading, etc.);
- marine navigation services, pilotage, and ice-breaking services;
- shipping companies, and shipping and logistic service providers.

The ports of the GLNS serve as nodes in a vast multimodal transportation network that also includes more than 40 highways and 30 railway lines. As a result, the GLNS is deeply embedded in the transportation infrastructure of the entire region.

In essence, the GLNS exists today as it did when the St. Lawrence Seaway opened in 1959. The only significant capital improvement since then was the construction of the Poe Lock at Sault Ste. Marie, Michigan, in 1968. There has been no comprehensive redesign or renewal of the aging infrastructure on the waterway since its original construction. The navigation locks on the system, some of which were constructed as long ago as 1913, are routinely exposed to various factors which affect concrete durability. This includes watering/dewatering cycles, thermal effects, hydro-mechanical effects, steel reinforcement corrosion and ship impact. Also, many GLNS structures were constructed prior to the introduction of air entrainment in concrete, which reduces the amount of freeze/thaw cycle induced spalling and deterioration of concrete in northern climates.

Along with an extensive discussion on the status of the existing features of the Great Lakes Basin, the Corps' June 2002 *Great Lakes Navigation System Review Reconnaissance Report* includes a description of what the system will be like into the future if no alternative strategies or projects are implemented to improve the system above and beyond previously planned upgrades and normal repairs (i.e. "No Action" or "Without Project Condition").

In response to the conditions described in the February 13, 2003 approval letter from the Corps of Engineer's Headquarters in Washington D.C., (attached to this report) this supplemental report further defines the "Without Project Condition" for the environment, further clarifies the determination of the Federal interest, and includes updated information from the Corps Great Lakes Navigation System - Five Year Development Plan and the 2007 bi-national Great Lakes St. Lawrence Seaway Study. One of the key issues discussed is the relationship between system reliability and maintenance investments.

This supplemental reconnaissance report also considers the current problems facing the Great Lakes (which are similar to the problems listed in the June 2002 Reconnaissance Report).

Additional issues are included based on evolving conditions during this decade and as a result of coordination with stakeholders throughout the region undertaken as part of the above-referenced studies. The general problems facing the system are:

- Extended periods of low water levels;
- Non-indigenous (invasive) species;
- Non-navigation environmental stressors and their impacts;
- Shoaling of harbors and channels;
- Inadequate capacity in Confined Disposal Facilities;
- Physical deterioration of locks
- Inconsistent demand for bulk service;
- Environmental impairments in the Great Lakes;
- Regional congestion on the basin's land transportation routes.

A more detailed discussion of Problems and Opportunities can be found in Section 6.2 of this report.

5.1 - Without-Project Condition

The June 2002 Corps Reconnaissance Report identified the *"*Future Without-Project Condition" for the GLNS, which is described below:

"The future Without-Project Condition" (No Action) for the Great Lakes Navigation System (GLNS) assumes the construction of a new Poe-sized lock at the current site of the Davis and Sabin locks, while maintaining the status quo elsewhere on the U.S. portion of the GLNS. The Soo Locks are defined as four parallel locks (only two are currently operational), located on the St. Marys River, at Sault Ste. Marie, Michigan.

On the GLNS, a minimum draft of 25'6" LWD at all locks and connecting channels is maintained over the next 70 years. On the Seaway, a 26'3" draft is maintained. The aging Seaway locks are first maintained through normal O&M, then limited rehabilitation, and ultimately major rehabilitation. Each successively more aggressive approach to maintenance is phased in as the condition of Seaway locks deteriorates, requiring longer closures, which through time begin to occur during the navigation season, sometimes without advance notice to shippers. The single lock configuration in most locations makes the reliability of the overall system an even greater concern than it might be for dual- lock systems. The consequences of a major lock failure likely would cause traffic disruptions of the entire waterway.

The locks on the Welland Canal are at least seventy years old, while the locks on the Montreal/Lake Ontario (MLO) portion are forty- four years old. Maintaining the locks will likely result in repairs that address immediate concerns, however, these repairs may not be sufficient in scope to deal with the underlying structural problems. A comprehensive program with major expenses in lock rehabilitation will have to be initiated to keep the locks functional. Before a decision is made to make investments of this magnitude, an analysis should be completed to determine if it makes economic sense to rehabilitate the locks versus building new locks. Ultimately, the locks may face closure if a wide-ranging program to rebuild or repair the locks is not initiated.

With respect to the individual ports and harbors, the future without-project condition will be to maintain the existing project depths in the channels through ordinary operations and maintenance.

5.1.1 Typical Cargo Distribution

The GLNS fleet carries mostly bulk cargo. As of 1998, iron ore and steel comprises about 40% of the total tonnage. The iron and steel and cement manufacturing industry in the Great Lakes region would be significantly smaller if not for the ability to ship on the Great Lakes. The proximity of the steel industry helps support the automobile factories in Michigan and Ontario (Great Lakes plants produce about 70% of the autos made in North America). Almost all American iron ore is mined in Minnesota and Michigan, and three quarters of that is shipped on the Great Lakes. Coal constitutes 19% of total shipment weight, and is mostly used for coal-fired electrical plants around the lakes.

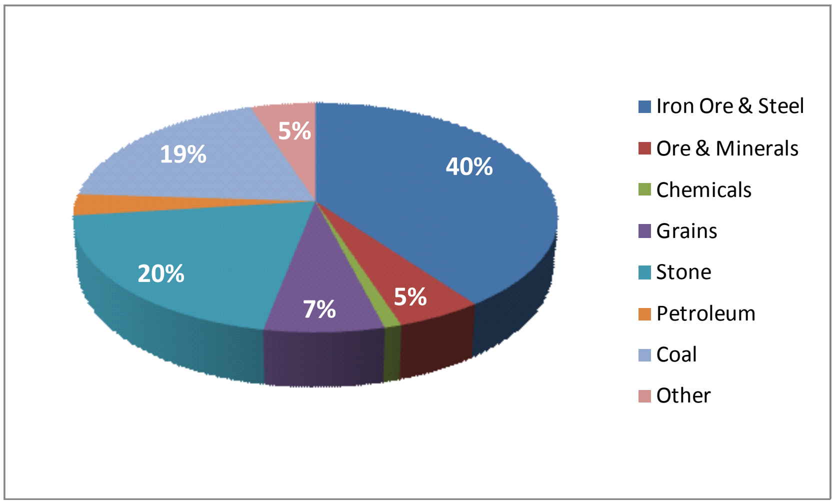


Figure 3 – Typical Cargo Distribution on the Great Lakes.

Based on the bi-national GLSLS report, in 2005 the system handled about 39 million tons of coal worth approximately $1.8 billion. Other commodities shipped through the system include limestone, coke, salt, petroleum products, chemicals, processed iron and steel as well as a variety of goods carried in containers. The vast majority of cargo moves solely within the Great Lakes basin, the bulk of which is U.S. only. A smaller percentage is cross border, and then even a lesser percentage is Canadian only. Overseas shipments comprise the smallest percentage of the total load. Montreal is a major and fast growing port for container ships, but while they do traverse the Seaway they are not common throughout the entire GLNS.

5.2 Engineering Analysis of the Current GL Navigation System

The marine transportation infrastructure of the GLNS system involves several interdependent components, including lock systems, ports and terminals, channels, bridges and tunnels, systems for control and communication, as well as interfaces to other transportation modes. Collectively, this constitutes an integrated system that needs to be optimized if it is to contribute to solving the transportation needs of the future.

While the initial assumption of "status quo" for the majority of the system was acceptable for the purpose of evaluating potential improvements, the true baseline condition needs to reflect that the existing navigation infrastructure has aged and that constrained operation and maintenance budgets have limited the extent to which the existing system needs have been addressed. The baseline condition also needs to reflect changes that are likely to occur even without new Federal involvement. Each of the following components represents a distinct set of requirements, all of which need to be managed in an integrated fashion to ensure the continued competitiveness of the GLNS.

***Locks*:** Because of their age, locks need to be subjected to a maintenance schedule that deals with potential failures in a way that sustains traffic with the fewest possible interruptions and preserves overall system integrity.

***Shipping channels*:** The normal flow of water inevitably carries silt deposits that must be removed to maintain channels at currently-authorized depths for shipping. Also, important is the maintenance of guide wall structures, such as those that exist at the "Rock Cut" at the West Neebish Channel in the St. Marys River.

Ports: Ports and terminals which are likely to support shortsea shipping or to serve as nodes in multimodal networks will require appropriate loading and unloading facilities and equipment together with seamless links to other forms of surface transportation.

***Bridges and tunnels*:** There are a number of bridges and tunnels spanning the locks and channels of the GLNS that must be maintained in ways that do not impede traffic.

Control and communication: Logistics systems today depend on advanced electronic systems to monitor movements and track shipments in real time.

Vessels: In addition to the traditional bulk carriers, there will be a need for ships capable of loading, carrying and unloading containerized cargoes. While all of these diverse systemic elements form part of an integrated whole, each demands its own investments, technologies and scheduling. Planning must factor in the specific requirements of each element in a way that harmonizes the components of the whole system.

It is clear that burgeoning trade, a capacity crunch, aging transport infrastructure and increasing pressures on transportation in urban settings are concerns of the marine transportation system. The locks, ports, terminals and other infrastructure of the GLNS are now critical components of North America's transportation gateways and, as such, they require investment and tools to respond to market forces in a timely manner if they are to continue supporting Canadian and U.S. international and domestic trade.

Importance of Maintaining the GLNS Components

If the GLNS is to remain reliable and competitive, its infrastructure will have to be maintained. All of the diverse systemic elements form part of an integrated whole, each demanding its own investments, technologies and scheduling. Planning must factor in the specific requirements of each element in a way that harmonizes the components of the whole system.

A review of the current condition of the system was performed as part of the development of the bi-national GLSLS report, with special attention devoted to the lock structures located throughout the system. The process included the development of a "criticality index" of system components that included factors such as availability of replacement parts, current condition, likelihood of failure and impact on navigation. The index provided a standardized and systematic way of evaluating the current condition of the system's infrastructure, but did not specifically economically evaluate each structure and its benefit to the nation.

The condition of approximately 160 components of the GLNS/GLSLS was examined: the review included locks, approach walls, water-level control structures, road and railway bridges as well as tunnels. Analysis found that overall, the system has held up reasonably well. Moreover, despite differences in construction and maintenance strategies, the rankings for the sets of locks were similar from region to region. Each lock region, however, has several significant components that have been rated as high priority and in need of repair, rehabilitation and/or replacement. The majority of components are still serviceable, with several in need of major maintenance in future years.

During the analysis process, models were developed that predict when components are likely to fail. Criticality assessments coupled with reliability data have identified and prioritized key operating components with an elevated risk of failure and significant consequences. Knowing this allows for the adoption of a maintenance strategy that proactively anticipates problems rather than dealing with them once they have occurred. It is possible to maintain the system by focusing on ongoing, routine maintenance, with components being replaced after they reach the limit of their useful life. Such an approach, however, does run a higher risk of unanticipated failure.

A more proactive strategy, however, uses reliability data to anticipate when components are statistically likely to fail and rehabilitate or replace those components before failure occurs, thereby increasing overall system reliability. Reliability is critical because the GLSLS is essentially a series of structures that must be transited with no alternatives (except at the Welland Canal flight locks and the dual chambers at Sault Ste. Marie, although only the Poe Lock is large enough to accommodate the largest vessels on the system). As a result, closure of one of the structures in the series closes the entire system. Moreover, a closure or a sequence of closures during the navigation season can result in incomplete vessel trips from origin to destination and back.

The consequences of service disruption vary by shipment and depend on the service disruption type (closure or service time increase), location of the disruption (at a single or dual lock chamber site), duration and timing (beginning, middle or end of the navigation season). Impacts from a service disruption can include not only shipment delay, but also return trips to unload a shipment for rerouting on an alternative transportation mode, vessel idling, stockpile depletion and plant shutdowns. For example, only the Poe Lock at Sault Ste. Marie has the necessary dimension to pass all Great Lakes vessels that are currently in operation. In the event that the Poe Lock is out of service, approximately 70 percent of commercial tonnage would be unable to transit the facility without offloading cargo to smaller vessels or other forms of transportation. The Cleveland-based Lake Carriers' Association has described the Poe Lock as the "single point of failure that can cripple Great Lakes shipping."

It is estimated that a 30-day unscheduled closure of the entire Soo Locks complex would have an economic impact to industry (transportation savings reduction) of $160 million (from *Transportation Rate Analysis: Great Lakes & St Lawrence Seaway 2005* dated Aug 2005, and *Transportation Rate Analysis 2005, Great Lakes and St. Lawrence Seaway Study* dated 2 November 2006). Without the Poe Lock, America's steel industry would be without its major source of iron ore; power plants throughout the Great Lakes would not have sufficient coal to supply electricity to major cities such as Detroit and Toledo. There are two major efforts underway to ensure the reliability of the Soo Locks: maintaining the existing infrastructure through the Asset Renewal program and adding redundancy with the construction of a new lock with the same dimensions as the Poe Lock.

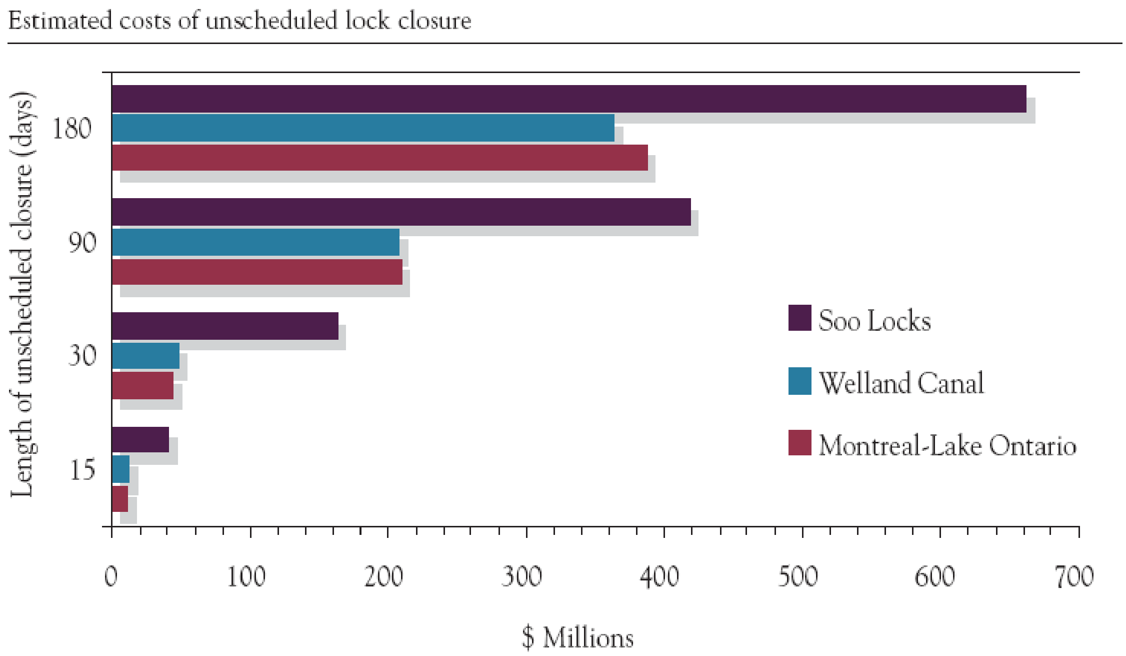


Figure 4 – Estimated Costs of Unscheduled Lock Closures.

For a closure lasting up to 30 days, the primary impact would likely be delays in the movement of cargoes since shippers would be more likely at this level to wait out the closure. Closures in excess of 90 days, however, would result in a modal shift to rail or truck, or both and they could also involve shifting cargoes to different ports on the East Coast or the Gulf of Mexico. Generally, long-term closures would lead shippers to select an all-overland transportation option. The estimated costs incurred by shippers due to the various unscheduled closure scenarios are presented in the figure above.

This information provides an estimate of the benefits of providing a reliable system. Saving money by implementing a more rigorous maintenance plan has to be balanced against the frequency of unexpected closures, which result in higher transportation costs. The trade-off between upfront investment in infrastructure and transportation savings is the heart of the economic analysis.

One important finding of this closure analysis comes from analyzing the daily cost of closure. As seen in Figure 4 above, short closures (15 days or less) cost less than the annual average daily benefit offered by the system (Figure 5 - Transportation savings offered by the GLSLS by region) since most shippers just wait out the closure. Long closures (90-180 days) cost the same per day as the average daily benefit (as would be expected). The response to a 30-day closure is somewhat different, because of the cost implications of a short-term re-routing.

Figure 5

Transportation savings offered by the GLSLS by region

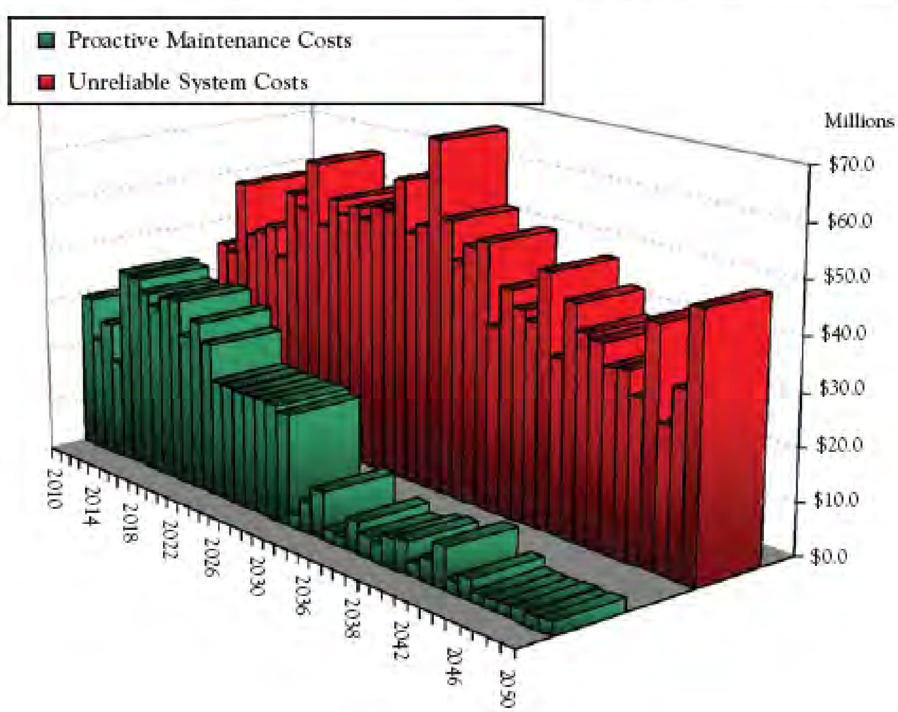
Commodity Group	*Sample size Tons*	*Savings/ Ton*	*Total savings**
Soo Locks	83,921,100	$12.98	$1,089,296,000
Welland Canal	29,746,000	$20.11	$598,277,000
Montreal-Lake Ontario	26,822,000	$22.74	$609,812,000
Internal Great Lakes Traffic not transiting a lock	69,832,000	$15.37	$1,073,488,000
* numbers rounded to nearest 1,000			

From the Great Lakes St. Lawrence Seaway Study, Final Report, Fall 2007; produced by the Great Lakes St. Lawrence Seaway Management Team Committee.

The key, then, is to adopt a maintenance strategy that minimizes the possibilities of disruption and maximizes overall system reliability. This is shown in Figure 6 below, which compares the projected maintenance costs of addressing system components in a proactive manner with the projected impacts of system disruptions.

Figure 6 – Proactive vs. Reactive System Costs

Scheduled costs under the reliable system scenario versus expected unscheduled repair costs and transportation costs from under funding the priority components



The unreliable system costs are significantly higher and even these are considered conservative inasmuch as they assume that vessels incur no return trip and unloading costs, no vessel idling costs, no stockpile depletion costs, no plant shutdown costs, and assuming unmet tonnage flows are able to acquire alternative mode transportation (when needed) at their long-run least-costly all-overland alternative rate. The comparison shows the value of scheduling the expenditure needed to maintain system reliability in a proactive manner.

The general conclusion to be drawn from this modeling is that a proactive maintenance strategy will avoid the additional costs of unscheduled maintenance repairs and general system unreliability. Its real benefit, however, lies in avoiding the additional transportation costs associated with unanticipated failures: such failures lead to waiting and queuing; switching to more expensive alternative transportation modes during closures; and ultimately switching permanently to costlier modes if the system is perceived as unreliable. A more reliable GLNS system with less disruptive lock events (closures, speed reductions, etc.) is likely to attract more commercial traffic, which will, in turn, make the system more cost-effective.

5.2.1 Needs of the Current Navigation System

The Corps has managed the GLNS since the 1820s. In recent years however, shrinking Federal budgets combined with aging infrastructure and lower lake levels have strained the Corps' ability to adequately maintain the system. Consequently, a backlog of maintenance needs has accumulated, including rehabilitation and modernization of the Soo Locks, dredging of over 17 million cubic yards of material from harbors and channels, construction or expansion of many critical dredged material disposal facilities, and repairs to many of the over 100 miles of breakwaters on the system. In addition, construction of a new lock at the Soo is essential to maintaining the reliability of the system.

Aging infrastructure, persistent low water levels, and constrained budgets have combined to produce a situation in the Great Lakes navigation system where over half the harbors and projects are rated either failing or failed - that is, are not adequately serving the navigation needs for which they were designed. Figure 7 (below) illustrates the deteriorating situation, with harbors rated as failing or failed shown in red.

Figure 7 – The State of Aging Infrastructure in the Great Lakes. – the critical needs in the aging Great Lakes Navigation infrastructure are illustrated in red, indicating more than 50% of the infrastructure is rated as "poor" (failed or failing).

The Corps has taken the condition assessment illustrated above and identified the critical needs of this regional system. The needs for just the next five years have been estimated in a GLNS Five Year Development Plan (FYDP) that has been developed to serve as a program implementation guide to engage stakeholders and focus resources on the system's most critical needs in terms of reducing risk and optimizing reliability. The plan describes the investments required for the GLNS for the years 2009-2013. The goal is to develop a regional asset management plan in coordination with stakeholders that articulates system priorities. The plan focuses on the following five components:

1. **Restoration of Locks**
2. **Construction of a new Lock at the SOO Locks Complex**
3. **Removal of Dredging Backlog**
4. **Expansion and Construction of Dredged Material Disposal Facilities**
5. **Repair of Breakwaters and Structures**

The following sections describe each of the specific needs of the Great Lakes system in detail, and explain the risks and consequences of not meeting those needs.

Locks: Lynch Pins of the System

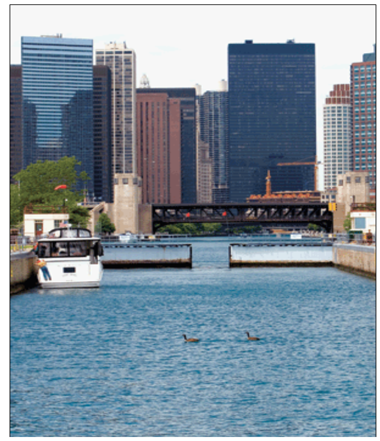


Figure 8 – The Chicago River

As introduced in Section 5 "Current Conditions", The Corps operates and maintains three lock systems on the Great Lakes: The Soo Locks (Poe and MacArthur Locks), the Chicago Lock, and the Black Rock Lock in Buffalo. The Chicago Lock is one of the busiest locks in the nation with 12,000 annual lockages. Over 35,000 commercial and recreational boats, with 680,000 passengers and 125,000 tons of freight pass through the lock annually.

The lock allows safe passage of boats navigating the 2- to 5-foot water level difference between Lake Michigan and the Chicago River. The lock also serves as a flood damage reduction structure with gates that must reliably open when needed to prevent flooding of downtown Chicago from the Chicago River. Routine annual operation and maintenance activities do not support needed repairs to the lock, which include the replacement of the four sector gates and the associated operating machinery and electrical systems.

Figure 9 – Black Rock Lock, Buffalo, NY.

The Black Rock Lock in Buffalo, New York provided safe passage for 328 commercial and 1,377 recreational boats in 2007. The Black Rock Lock and the Black Rock Channel, located where Lake Erie drains into the Niagara River, provides for vessels of all types a protected waterway around the reefs, rapids and fast currents that exist in the upstream portion of the Niagara River. The lock and channel permit pleasure craft and commercial vessels to travel between Buffalo Harbor and Tonawanda Harbor. Routine annual operation and maintenance activities do not support needed repairs to the lock, which include replacement of the gate sills and fendering.

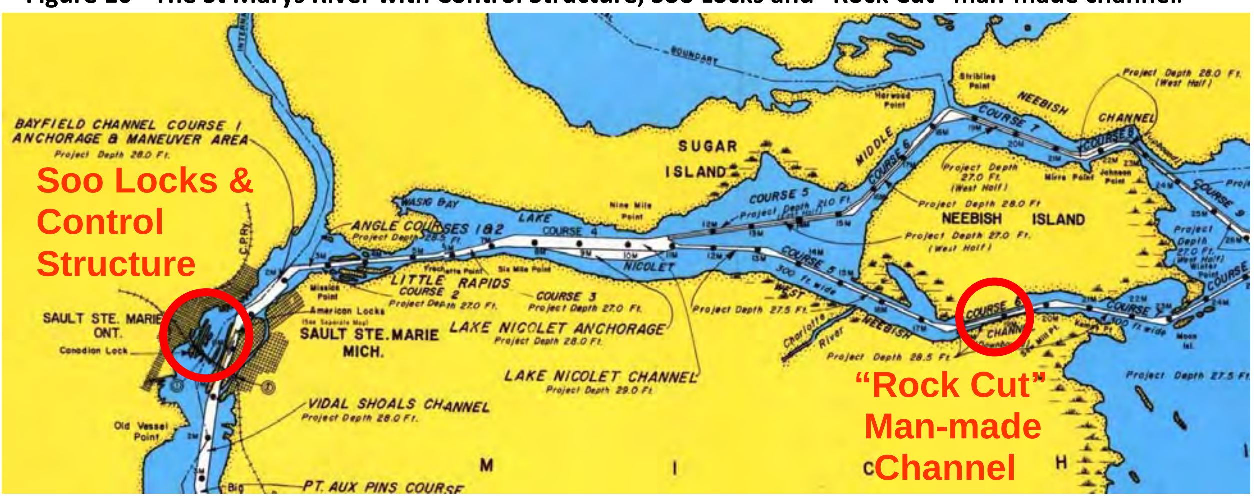
The Soo Locks are located on the St. Marys River at Sault Ste. Marie, Michigan on the international border with Canada. The locks allow ships to navigate the 21-foot drop in the St. Marys River between Lake Superior and Lake Huron. There are two operating locks at the Soo: the 65-year old MacArthur Lock and the 40-year old Poe Lock. The St. Marys River is a water bridge connecting Lake Superior with Lake Huron as well as a critical link in the Great Lakes St. Lawrence Seaway System. Over 80 million tons of commercial commodities pass through the Soo Locks annually. The specific needs at the Soo Locks are discussed in more detail later.

Connecting Channels

The Great Lakes are like a series of interconnected reservoirs, the outflows from which increase as water levels rise in an upstream lake but are limited by the size of their outlet channels. As water moves through the Great Lakes-St. Lawrence River system, it passes through progressively larger outlets, draining all the lakes above it in the system. The outlet from Lake Superior, at the top of the system, passes about 76,000 cubic feet of water per second on average. By comparison, the outlet from Lake Ontario, the last lake in the chain, passes about 243,000 cubic feet per second on average.

The outflow from Lake Superior is controlled near the twin cities of Sault Ste. Marie, Ontario and Michigan. The outflow began to be changed as early as 1822, when water was diverted from above the St. Marys Rapids for the operation of a sawmill. A ship canal was constructed in 1855. Subsequently, various expansions to these facilities took place. The current flow control facilities consist of three hydropower plants, five navigation locks and a 16-gated control structure, called the Compensating Works, at the head of the St. Marys Rapids.

Figure 10 - The St Marys River with Control Structure, Soo Locks and "Rock Cut" man-made channel.



The St. Clair and Detroit River system (connecting channels) are naturally regulated; flows in the St. Clair and Detroit Rivers are limited by the size of their natural river geometry and navigation channels, as well as the levels of Lake Huron upstream and Lake Erie downstream.

The St. Clair River is an interconnecting channel between lakes Huron and St. Clair, running approximately 39 miles from its head between Port Huron, Michigan, and Sarnia, Ontario to its very extensive delta in Lake St. Clair. The St. Clair River has a 5-foot fall over this distance.

The Detroit River receives inflow from Lake St. Clair and discharges into the west end of Lake Erie, running approximately 32 miles. Over this distance, the water surface drops nearly 3 feet.

Modifications of the St. Clair-Detroit system began in the late 1800's and continued through the early 1960's. These modifications involved the enlarging or deepening of navigation channels to allow ships to move more efficiently, quickly and safely. Without dredging, most rivers and harbors would be inaccessible for commercial navigation. Dredging has increased the flow capacity of these rivers and, as a result, has permanently lowered the levels of lakes Michigan and Huron by approximately seven inches. Other non-Federal mining and dredging in the early 1900's led to another seven inches of level reduction.

Figure 11 - The St. Clair and Detroit River System

The Niagara River flows approximately 35 miles between lakes Erie and Ontario. Hydropower plants take advantage of the abundant energy potential represented by the nearly 330-foot difference in elevations between lakes.

These facilities are owned and operated by the New York Power Authority, Ontario Power Generation and Canadian Niagara Power. The plants divert water from the Niagara River above Niagara Falls and return it to the river below them. The Welland Canal is a deep-draft navigational waterway that joins Lake Erie and Lake Ontario. Originally built in 1829 and since modified several times, the canal allows ships to travel between the two lakes, bypassing the falls and rapids of the Niagara River. The canal also provides water for hydropower generation.

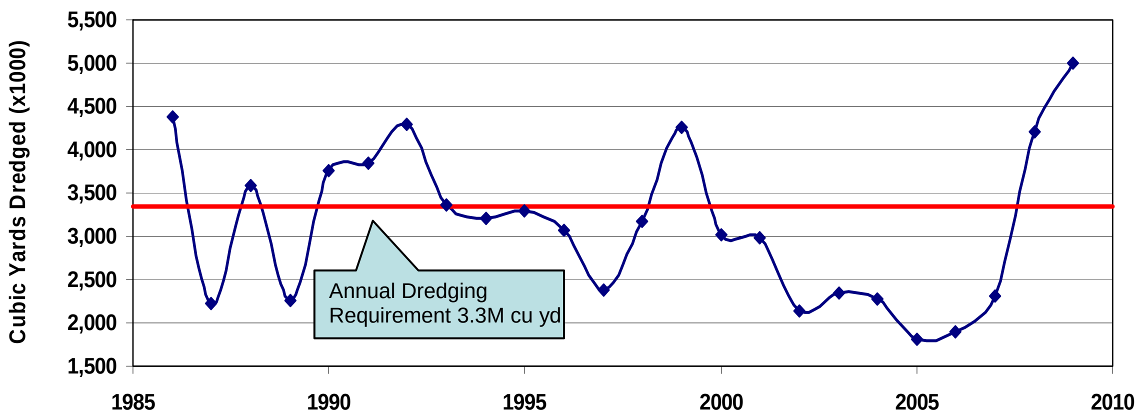
Figure 12 – Sharing Waterways

All of the navigation infrastructure associated with the Welland Canal is owned, operated and maintained by Canada, and as such these needs are not reflected in the GLNS FYDP, however, there are Federal ports located on Lake Ontario that are the responsibility of the Corps. Maintaining the connecting channels, even in stressed budgets, is always a top priority for the Corps. Strike removal (sounding for, locating, and removing boulders and other obstructions from the Federal channel) is a continuous activity. Strike removal is the primary activity for two of the Corps' five floating plants (crane barges and tugs) on the Great Lakes during the navigation season. The connecting channels need to be maintained to their Federally-authorized depths for safe vessel passage. Connecting channels are pinch-points of the GLNS, along with the lock system.

Backlog Dredging: Restoring Channel Functionality

Dredging is vital to the maintenance of the connecting channels and harbors of the GLNS. Constrained funding since the mid 1990's has allowed a critical backlog in major navigation channels and harbors to grow to an unprecedented level. The growing backlog, especially combined with low water levels in the system over the past 10 years, increases costs to shippers and industry. When harbors and channels shoal, ships have to light load, increasing transportation costs because more trips are required. Over time, harbors can close completely due to severe shoaling.

Figure 13 - Annual Great Lakes Dredging 1986-2009



Approximately $40 million are required annually to keep up with the annual dredging requirement. Over $200 million in additional funding is required to remove the current dredging backlog and additional funding would be required above that to restore the harbors, channels, breakwaters and other navigation features to full functionality.

In 2008, for the first time in eight years, the Corps was provided funds that allowed some backlog material to be dredged. In addition to the increased funds, the Corps was also given flexibility in terms of regional dredging provisions, which proved to be an efficient means to meet critical system needs and optimize scarce dredging funds. The provisions allowed the Corps to work with stakeholders in an open, technically-based process using current shoaling conditions, water levels, and contractor's bids to discuss needs and decide on the best allocation of scarce dredging funds. These provisions increased the flexibility and improved the effectiveness of the FY 2008 dredging program. The provisions allowed the Corps and stakeholders to take a holistic view of the system and apply the funds to the most critical needs. This unexpected increase in maintenance funding allowed for dredging more than the annual requirement, which reduced the backlog by approximately 1 million cubic yards, to bring the backlog back down to 17 million cubic yards.

This trend continued in 2009 with a robust Great Lakes dredging budget that will allow dredging of approximately 5.0M cubic yards of material (removing 1.7M cubic yards of backlog). Funding in 2009 came from increased funds in the Omnibus Bill plus funds from the American Recovery and Reinvestment Act. The Omnibus bill also contained a regional provision for harbors in Michigan, which again proved to be very beneficial in allowing the Corps to apply the funds to the most critical needs.

The three Great Lakes Districts of the Corps have made significant progress developing and using performance metrics for prioritizing dredging needs and funding. Similarly, the Corps' dredging philosophy is adapting to the changing requirements, policies and practices when it comes to managing this system in a balanced manner. The following is a sampling of the adaptive management the Corps is employing in regard to the future of dredging in the system:

- ✓ Using a system-based approach: A system-based approach recognizes the GLNS is interdependent. Simply stated, the "big, high priority" harbors are dependent on the '"smaller, lower priority harbors" and vice versa. Tonnage and commerce at a small or medium sized harbor is likely destined to or originated from a larger harbor. A unique aspect of Great Lakes shipping is that much of the commerce originates from and is transported to American ports.

- ✓ The FY2008 Energy and Water Development Appropriation included a provision for $6.5M funding for dredging of commercial harbors on the Great Lakes. This allowed the Corps to prioritize dredging needs based on maximizing transportation net benefits, taking into account the relationship among harbors, and to consult with Appropriations Committees and other interested parties. This regional provision allows the Corps to work with stakeholders to identify the greatest needs relative to system benefits. This approach is a small step in the direction of a system-based funding approach.

Breakwaters and Coastal Structures: Providing Critical Protection

There are over 130 coastal cities and towns on the Great Lakes with Federal navigation projects that include breakwaters; 64 of these projects currently support commercial navigation. Originally built to safeguard navigation in the Federal harbors from waves and ice, these structures also provide critical flood and storm damage protection for buildings, roads, facilities, and municipal infrastructure. In many cases, cities and downtowns have 'grown up' behind and are now safeguarded by Federal breakwaters.

Over 50 percent of the coastal structures on the Great Lakes were built prior to World War I (1918) and 80 percent are older than their typical 50-year design life. Federal funding for maintenance of projects is prioritized based on economic benefits related to commercial navigation. Federal breakwaters at harbors with small amounts of commercial navigation are a low priority for funding. Funding for structure repairs at harbors with significant levels of commercial navigation has also been significantly reduced for the last decade. The Corps' floating plant performs some preventive maintenance and minor repairs but does not have the capacity to perform major repairs or reconstruction.

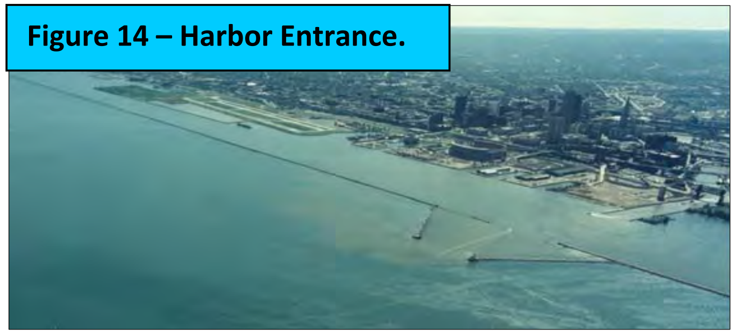


Figure 14 – Harbor Entrance.

On average, the total O&M system need is over $200 million per year. Low lake levels coupled with this aging infrastructure have necessitated this need for significant investment for repairs or reconstruction of navigation structures in deep draft harbors.

In 2007 the three Great Lakes Districts of the Corps formed a regional, multi-disciplined breakwater assessment team that developed technical assessment criteria and began inspecting and rating breakwaters around the Great Lakes. The breakwater assessment team's work will allow the Corps to prioritize these needs on a regional level so that the most urgent structures are given priority in the budget process each year. Based on condition assessments completed to date, Table 2 provides a list of prioritized structures in need of repair.

Figure 15 – Damaged Breakwater.

Table 2 - Prioritized Navigation Structures in Need of Repair. (SI = Structural Index calculation)

Rank	Project	Structure	SI	Condition Level
1	Chicago Harbor	Outer B/W - Reach E	4.81	Poor
2	Cleveland Harbor	West Pierhead	4.80	Poor
3	Cleveland Harbor	East Breakwater	4.80	Poor
4	Conneaut Harbor	East Breakwater	4.70	Poor
5	Oswego Harbor, NY	West Arrowhead	4.59	Poor
6	Black Rock Channel, NY	Bird Island Pier	4.17	Poor
7	Cleveland Harbor	Finger Pier	3.99	Poor
8	Sturgeon Bay Harbor	South Breakwater	3.99	Poor
9	Milwaukee	North Detached B/W	3.88	Poor
10	Buffalo Harbor, NY	South Breakwater	3.88	Poor
11	Cleveland Harbor	East Breakwater, West End Section	3.74	Poor
12	Calumet Harbor	Detached B/W - Reach C, Section 1	3.60	Poor
13	Duluth-Superior Harbor, MN, WI	Superior Entry - N. Entrance Pier	3.25	Fair
14	Marquette Harbor, MI	US Concrete Breakwater	3.00	Fair
15	Duluth-Superior Harbor, MN, WI	Superior Entry - N. Breakwater	2.52	Fair

The reliability of many Corps structures has degraded and the subsequent risk of failure has increased due to advancing age and insufficient funding for regular maintenance and rehabilitation. This has provided additional motivation for more rigorous asset management applications, critical components of which are: knowledge of the structures' condition, their functional reliability, and the risks and consequences of poor performance or failure. The Corps is requiring greater use of risk-based analytical methods in evaluating the engineering and economic performance of its proposed investments with the intent of improving the quality of its decisions.

There are nearly 104 miles of navigation structures that form the 117 Federal harbors operating within the GLNS. Over two-thirds of the existing navigation structure components were built prior to World War II. Approximately 58.4 miles of the Great Lakes Federal navigation structures have not had a major rehabilitation effort completed within the past 50 years. Of that group, approximately 19 miles have never had any major rehabilitation effort performed. Among the roughly 45.5 miles of "newer" structures, major rehabilitation efforts were completed 40 years ago or more for approximately 30 percent. In general, approximately 70 percent of Federal navigation structures are ending their design life, or have been in service for periods long past the design life that was originally anticipated, and their collective deterioration is substantial. The hypothetical analysis presented in section 10 of the Economics Appendix serves to illustrate the complexities involved in performing a risk-based evaluation of a coastal breakwater.

Dredged Material Disposal Capacity: Ensuring Dredging Ability in the Future

Currently, dredged material is managed using one of several methods on the Great Lakes. Clean sand is generally used for beach nourishment; it is placed on the beach or just offshore in shallow water. Beneficial uses such as beach nourishment or use as upland fill are pursued whenever practical. Other clean sediment is disposed of in open water at a limited number of locations.

Sediment that is not suitable for beneficial use or open lake placement is commonly deposited in Confined Disposal Facilities (CDFs) or Dredged Material Disposal Facilities (DMDFs). Where CDFs are not available, upland disposal in commercial landfills is used. Highly contaminated sediments are cleaned up under EPA environmental programs or under the authority of Section 312 of WRDA 1990, as amended; the disposal of highly contaminated material is site specific. CDFs provide important environmental benefits in that they serve as a secure storage facility for material that is not suitable to remain in the open environment.

Figure 16 – Active CDFs on the Great Lakes

Dredged material from about 40 percent of the harbors and channels on the Great Lakes must be disposed in CDFs. There are 23 active CDFs on the Great Lakes. However, as shown in Table 2 on the next page, eleven of the existing CDFs have no more than 5 years remaining capacity. Four CDFs have between 5 and 10 years of capacity. In total, 16 Great Lakes CDFs have 10 years of capacity or less remaining. Since it may take 5 years or more to plan for, locate and buy property, and construct a new CDF, new Dredged Material Management Plans (DMMPs) need to be initiated now (in some cases it may be too late to avoid indefinite suspension of dredging). It is estimated by the Great Lakes Navigation Team that the annual need for CDFs and DMMPs for GLNS deep draft harbors is between $25M and $53M annually.

Table 3 – Remaining Capacity in Major Great Lakes Disposal Facilities.

CDF	CY/Y 000s	Remaining Capacity	Sponsor	Status	Const Req'd
Cleveland	316	<5 years	Y	Fill Management to extend CDF life through 2014.	FY 12
Duluth	138	5-10 years	N	Fill Mgmt thru 2012. No Non-Fed sponsor yet	FY 13
Calumet Harbor	50	<5 years	Y	Fill Management to extend CDF life to 2014.	FY 15
Lorain	29	<5 years	Y	Fill Mgmt + newly dredged material likely goes to brownfields site.	N/A
Green Bay	210	5-10 years	Y	Potential for beneficial re-use (Cat Islands creation).	FY 12
Indiana	75	No CDF	Y	CDF under construction; anticipate completion in FY 10	N/A
Ashtabula	100	0	Y	Actively pursuing Contractor furnished disposal sites.	N/A
Toledo Harbor	850	<1 year (no disposal in CDF planned)	Y	Ohio EPA opposes open-lake placement and has proposed rule limiting open-lake disposal to 50,000 cy annually. Developing Section 204 project for placement of Dredged Material in Maumee Bay Habitat Restoration Units.	FY 12 (for Sec. 204 project)
Milwaukee	40	5-10 years	Y	GLLA Kinnickinnick River clean-up in progress, using old CDF. New DMDF on top of old CDF	FY 10
Waukegan	1	0	N	Working with USEPA to develop GLLA project for one time dredging (200,000 CY).	TBD
Saginaw Bay	201	5-10 years	N/A	Saginaw River DMDF completed FY 08. Fill Management to extend capacity of Saginaw CDF.	N/A

As illustrated in Table 3, without adequate CDF capacity, dredging operations will be limited, leaving shoaled material in the harbors and channels.

For example, dredging of Cleveland Harbor is constrained by CDF capacity as the Corps and local sponsor work through an expensive construction plan for a new CDF. If a new plan is not developed in time for any reason, the Corps would be forced to suspend dredging (once the CDF becomes full) until another placement option could be found.

This further exemplifies the need to fund programs and investigations into the beneficial reuse of dredged material. The physical properties of the dredged material and beneficial reuse opportunities are site specific, but in general the increasing cost of nearshore land, CDF construction and increased environmental concerns make beneficial reuse of this material increasingly important.

Finding beneficial uses for stored CDF material increases CDF capacity by removing the material from the CDF, extending the life of the facility. Programs that prevent soil erosion in the watershed can reduce sediment load to harbors, which decreases dredging needs. These initiatives have multiple environmental and economic benefits: a reduced need for dredging and reduced need for disposal capacity.

Figure 17 – Aerial View of Bolles Harbor CDF.

The long term future of dredged material disposal will be found in a combination of site specific solutions. A few possible solutions include expanding existing capacity, constructing new capacity, and extending capacity. In some cases, capacity can be extended indefinitely through beneficial reuse, dredged material management, and supporting programs that minimize disposal needs.

Another challenge that Great Lakes dredging faces is that environmental permitting for open-lake placement has become more restrictive. Currently, open-lake placement is only allowed by pertinent law and regulations on Lake Erie, Lake Ontario, and the southern end of Lake Michigan. Obtaining the required environmental permitting from these states for open-lake placement of even the cleanest material has become increasingly restrictive.

Soo Locks Asset Renewal Plan: Improving Efficiency and Reducing Risks

The Poe Lock is considered the weak link of the GLNS. If the Poe Lock goes down, 57 million tons of commerce would have to go by alternate modes of transportation. However, it is highly unlikely that the existing overland transportation infrastructure could support the vast quantities of tonnage that would have to bypass the lock. This underscores the tenuous situation that the Great Lakes shipping industry faces. Since the Poe Lock is a 40-year old facility, there are many potential points of failure.

Figure 18 – Soo Locks Facility

To reduce the risks of lock down time and vessel delays, the Corps is implementing a multi-year plan to rehabilitate and modernize the existing infrastructure of the Soo Locks facility. The identification of the most critical components was based in part on the results of risk and reliability analyses completed for the bi-national GLSLS Study. These analyses looked at a number of factors to identify the most critical components of the overall lock system, and then undertook reliability analyses to estimate the probability of unsatisfactory performance over time. The results of the reliability analyses, coupled with estimation of lock down time and associated vessel delay costs as a result of a component failure, provides the data necessary to make risk-based decisions as to which components need to be addressed and in what priority.

The Corps has developed a detailed six-year Soo Locks Asset Renewal Plan that defines the project requirements needed to maximize reliability and reduce the risk of catastrophic failure at the Soo Locks. This plan outlines the work necessary over the next six years to reduce the risk of unscheduled closures and to provide reliable infrastructure through the year 2035 at the Soo Locks. Although construction of a new lock discussed below provides redundancy, the new lock may not be operational for a minimum of 10 years from now. In the meantime, the Corps must conduct the Asset Renewal program on the existing infrastructure at the Soo to reduce risks of unscheduled closures even during new lock construction.

As an example, one critical component of the Soo Locks Asset Renewal Plan is to completely replace the Poe Locks hydraulics system. The Poe hydraulics system was responsible for four unscheduled outages in 2008, which delayed shipping on four separate occasions. The Poe Lock is currently equipped with 24 separate hydraulic power units. Each piece of equipment has its own hydraulic power unit, which has no redundant pump or motor.

The new hydraulic system will have only 4 hydraulic power units, each of which is equipped with a redundant pump and motor. Other items in the Asset Renewal Plan include a new air compressor system, which is critical for deicing the gates, purchase of stoplogs so that the Poe gates can be removed and repaired if necessary, and rehabilitation of the Neebish Channel (a.k.a. “Rock Cut”), a critical hard-bottom channel in the St. Marys River where the steep banks are in need of stabilization. Funding for the full Asset Renewal Plan is $70 million, approximately $12-15 million per year. This is a cost-effective investment considering that the economic impact (the cost of using alternative transportation) of a 30-day unscheduled outage of the Soo Locks complex is estimated to be $160 million.

5.2.2 Summary of Critical System Needs

Significant investments are needed to effectively and efficiently operate and maintain the GLNS for the benefit of the Great Lakes region and the nation (see Table 4, below). The combined needs of the system amount to over $200 million each year for the commercial projects (figures do not include any costs from the St. Lawrence River portion of the system). This amount also does not include an estimated $20-40 million per year for shallow-draft (recreational) harbors. Table 3 only identifies the operation & maintenance needs and specifically does not include Construction General funding that will be needed for any new facilities. The table below is a summary of critical funding required for the GLNS over the next five years to address the needs described above. Low lake levels, coupled with an aging infrastructure, have necessitated the need for significant investment for repairs or reconstruction of navigation structures in deep draft harbors.

Table 4 - GLNS Needs FY09-FY13 Operation & Maintenance (Commercial Harbors)

FY	Annual Maint. Dredging (x1000)	Backlog Removal Dredging (x1000)	CDFs & DMMPs (x1000)	Breakwater Prev. Maint. & Rehab. (x1000)	Soo Locks Asset Renewal (x1000)	Other Navigation O&M Costs (x1000)[1]	**Total System O&M Need (x1000)**
FY09	$40,200	$41,600	$31,000	$47,700	$12,900	$39,000	**$212,400**
FY10	$41,000	$42,400	$25,000	$48,500	$12,300	$39,800	**$209,000**
FY11	$42,000	$43,200	$37,000	$49,500	$19,000	$50,293	**$241,000**
FY12	$42,800	$44,200	$53,000	$50,700	$9,900	$41,200	**$241,800**
FY13	$43,700	$45,000	$48,000	$52,000	$8,300	$42,400	**$239,400**

[1] Other Navigation costs include routine operation and maintenance of locks, project condition surveys, environmental activities, real estate support, and other staff support: FY11 includes $10M for new gates at Chicago Lock.

5.2.3 Beneficial Uses Provided by Shallow Draft Harbors

Harbors of Refuge

Sixteen shallow draft harbors on the Great Lakes are dually classified as harbors of refuge, thus serving the public safety function of providing recreational boaters protection during severe weather events. Without them, the increase in boating accidents and fatalities would likely escalate, as would the costs paid by taxpayers for the U.S. Coast Guard, which performs search and rescue operations. The costs of dredging and maintaining harbors of refuge are a preventative measure against the loss of life and property from severe weather events. Of the 78 active Federally-authorized shallow draft harbors in the Great Lakes managed by the Corps, 17 (more than one fifth) are also harbors of refuge.

Recreational Harbor	Lake Basin	District	Harbor of Refuge?	Coast Guard Facility?
BURNS WATERWAY SMALL BOAT HARBOR, IN	Michigan	Chicago	Y	N
BARCELONA HARBOR, NY	Erie	Buffalo	Y	N
GREAT SODUS BAY HARBOR, NY	Ontario	Buffalo	N	Y
OAK ORCHARD HARBOR, NY	Ontario	Buffalo	Y	N
PORT ONTARIO HARBOR, NY	Ontario	Buffalo	Y	N
AU SABLE HARBOR, MI	Huron	Detroit	Y	N
BAYFIELD HARBOR, WI	Superior	Detroit	N	Y
BEAVER BAY HARBOR, MN	Superior	Detroit	Y	N
BIG BAY HARBOR, MI	Superior	Detroit	Y	N
BLACK RIVER HARBOR(GOGEBIC), MI	Superior	Detroit	Y	N
CHIPPEWA HARBOR, MI	Superior	Detroit	Y	N
EAGLE HARBOR, MI	Superior	Detroit	Y	N
GRAND TRAVERSE BAY HARBOR, MI	Superior	Detroit	Y	N
HAMMOND BAY HARBOR, MI	Huron	Detroit	Y	N
HARRISVILLE HARBOR, MI	Huron	Detroit	Y	N
LAC LA BELLE, MI	Superior	Detroit	Y	N
LITTLE LAKE HARBOR, MI	inland lake	Detroit	Y	N
LUTSEN HARBOR, MN	Superior	Detroit	Y	N
POINT LOOKOUT HARBOR, MI	Huron	Detroit	Y	N
PORT AUSTIN HARBOR, MI	Huron	Detroit	Y	N
PORT SANILAC HARBOR, MI	Huron	Detroit	Y	N
PORTAGE LAKE HARBOR, MI	Michigan	Detroit	N	Y
SHEBOYGAN HARBOR, WI	Michigan	Detroit	N	Y
TAWAS BAY HARBOR, MI	Huron	Detroit	N	Y
WASHINGTON ISLAND, WI (HARBORS AT)	Michigan	Detroit	N	Y
WHITEFISH POINT HARBOR, MI	Superior	Detroit	Y	N

Table 5 – Great Lakes Harbors of Refuge and/or Coast Guard Facilities

U.S. Coast Guard Facilities

Another national service provided by several shallow draft harbors is that they are home to Coast Guard Search and Rescue facilities. Five U.S. Coast Guard search and rescue facilities are located within shallow draft harbors on the Great Lakes (4 in the Corps' Detroit District, and 1 in Buffalo District). In other words, 6.4 percent of Great Lakes shallow draft harbors also allow the U.S. Coast Guard to provide its search and rescue missions. If these harbors were not dredged periodically and otherwise adequately maintained so that Coast Guard vessels could have shelter from and access to deeper unprotected waters, the search and rescue operations of the Coast Guard would be compromised in these locations.

Ferry and Other Transportation Services

At least ten Great Lakes shallow draft harbors are identified as locations for ferry and transportation services; nine of these shallow draft harbors serve as a means of transportation, locally and or regionally.

Table 6 – Great Lakes Recreational Harbors with Ferry and Other Transportation Services

Lake Superior	Lake Michigan	Straits of Mackinac	Lake Huron	Lake Erie	St. Lawrence River
Bayfield Harbor, WI	Saugatuck Harbor, MI	Mackinac Island Harbor, MI	Cheboygan Harbor, MI	Port Clinton Harbor, OH	Morristown Harbor, NY
	St. James Harbor, Beaver Island, MI	Mackinaw City Harbor, MI	Detour Harbor, MI		

As on land, the Federal government should consider the value of these transportation routes to service regional populations, as part of the nation's multi-modal Federal transportation network. Interestingly, these national services--harbors of refuge, home to the U.S. Coast Guard search and rescue facilities, or harbors with ferry and excursion services--are each located in different shallow draft harbors around the Great Lakes. Together, they account for 32 of the 78 active shallow draft harbors–41 percent of Great Lakes shallow draft harbors.

Subsistence Harbors

Five shallow draft harbors on the Great Lakes are also classified as providing a subsistence role to island communities. Washington Island, St. James Harbor at Beaver Island and Mackinac Island are subsistence harbors. Although technically not subsistence harbors, Whitefish Point and Little Lake are both known areas for Native American fishing. Washington Island, St. James Harbor at Beaver Island and Mackinac Island are subsistence harbors. The Federal government has an important role in maintaining waterborne access to and from subsistence-based communities who depend on access to Great Lakes waters and/or fishing for their livelihood, particularly those that serve Native American communities and reservations where the Federal government has had an historic role.

5.2.4 New Soo Lock: Providing Needed Redundancy

The continuation of the existing GLNS without anything more than routine maintenance, planned replacements and emergency repairs (or "Without Project Condition") also assumes the construction of a new Poe-sized lock in place of the obsolete Davis and Sabin Locks at the Soo Locks complex. Construction of this lock is viewed by many stakeholders as a necessary component of the overall plan to ensure continued safe, reliable navigation on the system. The authorization for a second Poe-sized lock was written into law by the Water Resources Development Act (WRDA) of 1986. This legislation authorized construction of a new lock; however, due to the lack of a non-Federal sponsor, funds were not provided until fiscal year 1995, at which time a project re-evaluation and design work were initiated. The 2007

Figure 19 – Aerial View of the Soo. The current configuration of the Soo Locks is on the left (4 locks) and the conceptual configuration (3 locks) is on the right.

WRDA bill authorized construction of the new lock at full Federal expense, which eliminated the need for a non-Federal cost-sharing sponsor. Primarily, the redundant lock would be constructed to provide uninterrupted shipments of raw materials to the U.S. steel-related and electrical power industries in the Great Lakes region. Without redundancy, failure of the Poe Lock would divert iron ore and coal movements to rail, likely causing severe and costly adjustments. As of today, the existing infrastructure is insufficient to support the vast quantities of tonnage that would have to bypass the locks should the Poe fail. 2009 funding of $17,000,000 will be used to award construction contracts for the coffer dams and downstream channel excavation - approximately $2 million and $8 million, respectively. The residual funds will be used to continue the design of the remaining project features and administer the construction contracts. Assuming adequate future funding of the total cost of $580.26 million, the project could be completed by September 2019.

The Poe Lock has been in service for over forty years, and the continued heavy use of the Poe coupled with the Corps' decreasing maintenance budget are impacting its serviceable life. The Poe Lock is the only lock able to allow passage of the 1000-foot ships that each carries 60,000 to 70,000 tons of cargo per load. Approximately 70% of the 80 million tons of cargo that annually transits the Soo Locks must pass through the Poe Lock.

5.3 Economic Importance of the Navigation System

"The Great Lakes Navigation System (GLNS) continues to play a decisive role in the economic life of North America. The nature and size of the traffic passing through it remains imposing. Moreover much of this traffic serves industries with specialized needs that make them highly dependent on the availability of cost-effective waterborne transportation. These industries are integrated into value chains stretching into virtually every sector of the North American economy, thus giving the traffic in the GLSLS a strategic significance beyond its already

considerable dimensions. What is more, those volumes will experience moderate growth in coming decades, reinforcing the system's value to the North American economy."

- Preface to Chapter 3 "The Economic Importance of the GLSLS". The Great Lakes St. Lawrence Seaway Study; (bi-national) Report, fall 2007.

The fate of the GLNS ultimately depends on the economic role that the system plays now and in the future. The size, significance, frequency, and nature of the traffic using the system will determine the type of maintenance strategy that is most appropriate for the needs of the GLNS.

Recognizing this, the Economics Team for the bi-national GLSLS Stud*y* focused on the economic role of the GLNS and its likely future evolution. It examined the size and nature of the traffic that has used the system since the middle of the 20^{th} century, looking at changes in its cargo mix and direction. It then used a variety of models to project the kind of traffic expected to use the GLNS over the coming half century. In developing these models, the Economics Team examined both the internal dynamics of the system as well as foreseeable external trends likely to influence traffic. Ultimately, the purpose of the Economics Section of the bi-national study was to define the general economic significance of the GLNS compared to the costs of maintaining and/or upgrading the infrastructure that will be needed to support Great Lakes-based economic activity into the future.

2002 Corps' Reconnaissance Report, Great Lakes Navigation System Review

The 2002 Corps' *Reconnaissance Report Great Lakes Navigation System Review*, (revised in February 2003) focused on possible improvements to channels within ports, channels connecting the individual Great Lakes and the Lakes to the Atlantic, and channels connecting the Great Lakes to shallow-draft inland waterway systems (most notably the Mississippi River System). Benefits as the result of improvements to individual harbors, the Chicago Sanitary and Ship Canal, and the St. Lawrence Seaway were estimated. A complete benefit-cost analysis was only prepared for a selection of GLNS harbors and for the Chicago Sanitary and Ship Canal. A benefit-cost analysis was not conducted for the St. Lawrence Seaway since costs had not been prepared for either the existing condition or for the improvement condition (a 35' deep Welland Canal and St. Lawrence River section of the St. Lawrence Seaway) because of limited funding. Thus, though overall benefits were reported for an improved Seaway, net benefits could not be prepared and presented in the 2002 report.

National Economic Development (NED) benefits presented in the 2002 GLNS Reconnaissance study were related to transportation cost savings for cargo movements, both current and projected, and emission reduction benefits. Projected cargo movements were based both on continuation of current commodity flows and on flows induced by an improved Seaway. These induced flows were both bulk and container flows, each the result of a separate study that examined the feasibility of these improvements. A focused Regional Economic Development (RED) analysis identified the regional job and income effects that might result from successful container service entering the Great Lakes and continued growth of the commercial, overnight cruise industry.

2007 bi-national Great Lakes St. Lawrence Seaway Study

Upon review of the 2002 Reconnaissance Study, Corps headquarters directed the study team to address navigation throughout the system and complete a depiction of the "Without Project Condition", specifically regarding the Seaway as a connector between the GLNS and the Atlantic Ocean. Concurrently, both the Canadian St. Lawrence Seaway Management Corporation (SLSMC) and the US Saint Lawrence Seaway Development Corporation (SLSDC) expressed an interest in collaborating with the Corps in examining future maintenance alternatives for the Seaway. Acting on their behalf, Transport Canada (which owns the Canadian locks) and the US Department of Transportation (which owns the two U.S. locks, which are both operated and maintained by the SLSDC) entered into a Memorandum of Understanding for joint development of the bi-national *Great Lakes St. Lawrence Seaway Study* (GLSLS 2007).

This joint study resulted in the screening-out of any improvement alternative for the St. Lawrence Seaway that would alter its current physical dimensions. A benefit-cost analysis of alternative maintenance plans was completed for the Seaway, as well as a set of forecasts for bulk and container traffic demand, given no change in Seaway dimension. This container traffic forecast is of particular interest because the ports involved are all located on the Great Lakes.

A decision was made by the study steering committee overseeing the 2007 bi-national study to exclude further consideration of any Seaway expansion (larger locks and/or deeper navigation channels). The decision to move away from considering expansion was based on several factors, including; stakeholder concerns related to environmental and social impacts (both construction related as well as impacts associated with any increase in ocean going vessels entering the system), a need to focus on the increasing maintenance requirements of the existing infrastructure, and the fact that the current system is underutilized. The study also concluded that the system can remain economically-viable in a scenario where only maintenance of the existing Seaway is required.

As part of this report as Appendix C – the *Great Lakes Navigation System Review, Supplemental Reconnaissance Report Economics Appendix* has two objectives: 1) to develop and present an expanded reconnaissance-level assessment of the value of the GLNS, and 2) to improve net benefit estimates for specific infrastructure investments. The investments examined are those related to harbors, jetties, breakwaters, and Dredged Material Disposal Facilities (DMDFs). The most comprehensive investment assessments were made for commercial harbors, where both cost and benefit estimates were available. Investment assessments for jetties, breakwaters, and DMDFs were not made; rather, frameworks for future evaluations were explored and presented. The commercial value of and investment in lock facilities, most notably the locks at Sault Ste. Marie, Michigan, are dealt with in other studies and findings from those studies. Similarly, the locks of the Welland Canal and St. Lawrence River section of the St. Lawrence Seaway are addressed by referencing the 2007 bi-national *Great Lakes St. Lawrence Seaway Study*.

The economic calculations update both the transportation savings estimates for the GLNS[1] and the net benefit estimates[2] for harbor improvements, and expand on the discussion of system benefits. Annual transportation savings for shippers using the GLNS, estimated annual accident reduction benefits (from loss of life and property damage), and annual health cost savings from reduced exposure to pollutant emissions, are estimated to total $4.2 billion.

The Great Lakes also provides unique and vast recreational opportunities. The scope of this effort did not allow for a NED recreation benefit estimate. However, it does report an estimate of regional economic benefits. The U.S. Army Corps of Engineers' December 2008 *John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating Report* was relied on to get an order of magnitude estimate of the direct regional benefits of recreational boating to the Great Lakes basin - an estimated $5.4 billion annually into the basin economy (3rd para., pg. 2, Executive Summary of Rec Boating Report).

The Supplement Reconnaissance also evaluates specific investments in the maintenance of the harbors (through dredging) and their supporting infrastructure (breakwaters, jetties, and Confined Disposal Facilities (CDFs)). Investment benefits from dredging are estimated using the GL-SAND model, which is described on page 60 of this report. Cost estimates for dredging alternatives at a number of harbors were developed in the Corps' GLNS 2002 report, allowing analysts to update the cost-benefit analysis for selected harbors in this GLNS report.

Estimating net benefits for breakwaters, jetties and CDFs was not possible at this time with the lack of comparable data. The framework for economic evaluation is under development and early efforts are presented as a means of documenting what has occurred to date. Further work by economists and engineers remains to be done before cost-benefit analyses of these investments can be completed.

Evaluating Significance

The Economics Team for the bi-national GLSLS report considered the size and scale of the traffic that flows through the GLNS today. On the Canadian side, half of Canada's 20 largest ports are part of the GLNS system. On average, these ports handle approximately 60 million U.S. tons (Mt) or 40 percent of Canada's total domestic marine trade by volume and close to 66 Mt or 50 percent of Canada's total transborder trade by volume with the U.S.

[1] In 2005, the Tennessee Valley Authority (TVA) conducted a transportation rate analysis under contract with USACE in support of the bi-national Great Lakes/St. Lawrence Seaway (GLSLS) study.

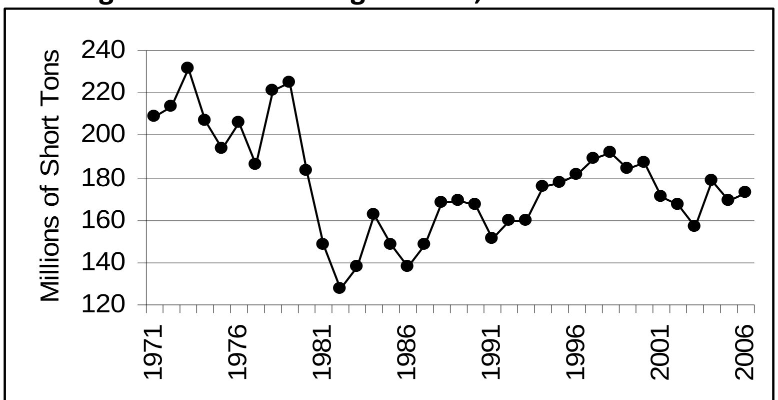
[2] It was possible (previously) with Great Lake Level Analysis of Port Operation and Maintenance (GLLAPOM), to make point estimates with much greater accuracy, and (currently) with Great Lake Levels System Analysis of Navigation Depths (GL-SAND).

5.3.1 Summary of Economic Conditions

The GLNS serves a diverse and dynamic economy in both the United States and Canada, although only U.S. commerce is discussed here. According to the U.S. Bureau of Economic Analysis, the gross domestic products of the states having a direct access to the GLNS total over 2.8 trillion U.S. dollars in 2004. The economic activity of the region is characterized by the durable goods manufacturing industry, especially in the steelmaking and automotive industries of Indiana, Michigan, Ohio, and Wisconsin.

The U.S. ports on the GLNS play a strategic role as part of the integrated North American transportation network for both domestic and overseas trade. Products shipped by land to one of the system's ports gain access to the global marketplace. This link plays a fundamental logistics role for industries of the region.

Figure 20 – GLNS Cargo Traffic, 1971-2006



Source: US Army Corps of Engineers, Waterborne Commerce Statistics Center

The figure above presents total GLNS cargo traffic between 1971 and 2006. Tonnage carried experienced a sharp decline in the years 1980 through 1982, dropping nearly 100 million tons in those three years. The severe declines in tonnage are attributable to the recession at that time and changes in the steel industry and grain exports. The 1980 – 1982 recession was the deepest post-war recession to that time. Additionally, this recession also coincided with the "rationalization" of the steel industry, a shift to foreign sources and heavier reliance on electric arc furnaces rather than integrated steel. The former Soviet Union, which had relied on imports of grain, collapsed and Russia moved quickly to self-sufficiency and stopped importing grain.

Since that time, GLNS traffic has experienced a fluctuation in tonnage. In more recent years, traffic peaked at around 192 million tons in 1998 then declined through 2003. Since 2003, traffic has continued to fluctuate, but trends toward an overall rise.

Commercial traffic in the GLNS is dominated by iron ore, coal and stone. As presented in Table 4 below, roughly 81% of all tonnage carried in the system is generated by these three commodity groups. Approximately 75% of the iron ore shipped throughout the GLNS is transported internally between ports on the Great Lakes, much of it originating from mines in Michigan's Upper Peninsula and northern Minnesota and destined for ports on Lake Erie and the southern tip of Lake Michigan. Over the last three decades, iron ore has come to represent a smaller percentage of tonnage carried throughout the system, mostly due to the decline of the domestic steel industry. In 1978, roughly 43% of GLNS traffic was iron ore. From 2002 to 2006, iron ore represented approximately 33% of GLNS traffic.

TABLE 7 - GLNS Traffic by Commodity (thousands of short tons)

Commodity Group	Year					Average
	2002	2003	2004	2005	2006	
Iron Ore	56,075	50,228	60,366	56,418	58,573	56,332
Coal	41,357	41,495	43,095	44,773	44,896	43,123
Stone	36,575	34,289	41,005	36,966	37,157	37,198
Cement & Concrete	6,874	7,102	7,179	7,140	7,151	7,089
Petroleum Products	4,290	4,691	5,069	4,593	5,067	4,742
Grain	4,028	3,671	3,550	4,040	3,871	3,832
Iron and Steel Products	3,486	2,781	4,150	2,820	3,687	3,385
Other	14,541	12,227	14,020	12,661	12,611	13,212
Total	**167,226**	**156,484**	**178,434**	**169,411**	**173,013**	**168,914**

Source: US Army Corps of Engineers, Waterborne Commerce of the United States, 2006.

Almost 47% of the coal transported in the GLNS is internal traffic, largely composed of thermal coal used for power generation. In the U.S., more than one-half the nation's electricity is generated by burning coal. Coal is mined in Montana and Wyoming and loaded in the port of Duluth-Superior; it is also mined in West Virginia, Pennsylvania, Kentucky, Ohio and Illinois and shipped from Lake Erie and Lake Michigan ports. The remaining coal shipped in the GLNS is mostly exports to Canadian ports along the St. Lawrence River and Lake Ontario. Over the last three decades, coal traffic has increased slowly, by about 5 million tons, and has increased as a percentage of GLNS traffic, representing roughly 17.3% of GLNS traffic in 1978 and averaging 25.5% from 2002 to 2006.

Stone represents a group composed of numerous commodities such as stone, limestone, sand and gravel. All of these products can have multiple usages and their origin-destination patterns vary significantly from year to year. Limestone is by far the most prominent of these, representing nearly 83% (30.8 million tons) of all stone traffic and over 18% of GLNS traffic. Another 14.5%, (5.4 million tons) of stone traffic is sand and gravel. Approximately 73.1% of stone traffic is internal to the GLNS, with almost all the remaining traffic composed of Canadian imports and exports.

Of the remaining commodities transported on the GLNS, grain traffic bears special mention as it has experienced marked declines over the last three decades. In 1978, over 19 million tons of grain, representing 8.7% of total traffic, was transported in the GLNS. From 2002 through 2006, grain traffic averaged 3.8 million tons annually, or 2.3% of total traffic. Grain is a heavily exported commodity throughout the GLNS, with roughly 38.4% of its annual traffic destined for Canadian ports and another 45.9% headed for overseas destinations.

Harbors

Approximately 62% of GLNS traffic travels internally on the GLNS. As discussed earlier, the GLNS is a network of channels connecting ports, wherein the traffic handled at any port is often linked to the traffic handled at another port in the System. All ports of the system have easy road access, making local or regional delivery a simple procedure. In cases where rail access becomes critical, numerous ports are equipped with infrastructure enabling the transfer of products to/from rail to/from marine transport. In the GLNS, almost every port is important to the economic health of another port and; therefore, the System. Even so, there are disparities in tonnages handled among the ports, with some ports handling many times more tonnage than others. The table below presents the tonnages carried at the ten most-trafficked ports in the GLNS. Approximately 86% of total GLNS tonnage moves through these ports annually.

TABLE 8 - GLNS Ten Most-Trafficked Harbors (thousands of short tons)

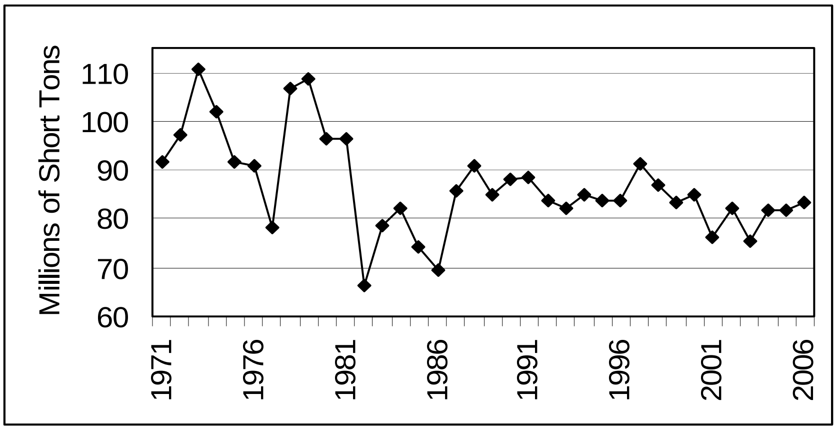
	Year					
Harbor	**2002**	**2003**	**2004**	**2005**	**2006**	**Average**
Duluth-Superior, MN	44,161	38,295	45,393	44,722	46,974	43,909
Indiana, IN	13,839	14,133	18,228	14,120	16,164	15,297
Cleveland, OH	11,412	16,621	15,775	13,641	15,187	14,527
Two Harbors, MN	14,895	13,033	13,473	10,959	13,420	13,156
Toledo, OH	11,115	9,864	9,862	10,504	11,162	10,501
Rouge River, MI	10,018	9,740	11,170	11,020	10,707	10,531
Presque Isle, MI	10,592	8,776	10,134	10,983	9,074	9,912
Ashtabula, OH	9,838	10,427	10,938	9,714	6,822	9,548
Burns, IN	8,621	8,069	9,802	9,812	8,954	9,052
Gary, IN	9,482	9,010	8,531	7,303	9,112	8,688
Total	**143,973**	**137,968**	**153,306**	**142,778**	**147,576**	**145,120**

Source: US Army Corps of Engineers, Waterborne Commerce Statistics Center

Traffic in bulk commodities, commodities that are not processed, fortified or bagged such as grains, oilseeds, cotton and beans, through the GLNS is expected to steadily increase through year 2050. On the Welland Canal, traffic is expected to grow by 0.54 % annually while traffic through the Seaway Locks is expected to grow 0.7% annually. Although the forecast only included traffic moving through a lock, all other GLNS traffic is expected to also experience slow but steady growth through the coming decades.

Soo Locks
Tonnage transited through the Soo locks fluctuated sharply from 1971 through 1982, however, over the last two decades, Lock traffic has risen and fluctuated less intensely. For example, traffic in 2006 stood at nearly the same level it did in 1996. Consistently, iron ore and coal comprise nearly 79% of all lock traffic. Figure 21 depicts Soo Locks Traffic from 1971 through 2006.

Figure 21 - Soo Locks Historic Traffic



Source: U.S. Army Corps of Engineers

Transportation Forecasts
Waterway traffic forecasts were not prepared as part of this Supplemental report. Waterway traffic demand forecasts were prepared for the Corps' *Great Lakes Navigation System Review, Reconnaissance Report* (GLNS 2002) and updated and expanded for the bi-national *Great Lakes St. Lawrence Seaway Study* (GLSLS 2007). The Corps' 2002 report presented bulk commodity forecasts for the GLNS that combined a forecast of U.S. waterway traffic demand and a forecast of Canadian waterway traffic demand. The primary analysis of the GLNS 2002 study was for bulk commodity moving to and from harbors, while the focus of the bi-national GLSLS study was these moves through the 15 Seaway Locks and the Soo Locks. Consequently, the GLSLS study combined forecasts that focused on Seaway traffic and Soo Locks traffic. These forecasts were available from: 1) Traffic Analysis and Forecast (TAF) Consultants for Seaway traffic and 2) The Final Limited Re-evaluation Report, Replacement Lock – Sault Ste. Marie, Michigan, Appendix B – Economic Analysis, February 2004 for Soo Locks traffic.

Both the GLNS 2002 and GLSLS 2007 reports addressed the potential for container traffic. This potential demand represented a major uncertainty in projecting future usage levels of locks, channels and harbors. The Corps' GLNS 2002 study's examination of container feasibility was framed within the context of a system capable of accommodating 35-foot draft vessels. Because this alternative was screened from further consideration during the bi-national GLSLS 2007 study, these GLNS 2002 container forecasts are not presented in this Supplemental Reconnaissance report.

Results from both the GLNS 2002 and GLSLS 2007 reports suggest there would be continued long term demand for waterway services. Examination of these two sets of forecasts also indicates little change in outlook over the intervening years for bulk commodity traffic flows.

2002 Reconnaissance Report, Great Lakes Navigation System Review Results

Total traffic demands for the GLNS, the St. Lawrence Seaway, and the aggregate GLSLS, determined in the 2002 report, are presented in Table 6, below. Total traffic demand for bulk commodities on the GLSLS is shown to increase from a level of 228M tons in 1998 to about 357M tons by year 2060, reflecting annual growth of about 0.7 percent. The St. Lawrence Seaway subsystem grows slightly faster, at about 0.8 percent per annum and annually accounts for about one quarter of the traffic on the larger system. The GLNS annually accounts for around 99 percent of traffic demand in the overall system. A detailed discussion of the industries that drive traffic demands and forecasts for individual commodities are presented in the Economics Appendix of the Corps' GLNS 2002 report.

Table 9 - GLNS 2002, Bulk Commodity Traffic Forecasts (millions of short[1] tons)

Year	GLNS	Seaway (Welland and MLO[2] Sections)	GLSLS
1998	227	61	228
2000	232	62	232
2010	255	67	255
2020	275	73	276
2030	291	80	292
2040	314	84	315
2050	335	93	336
2060	356	99	357
Annual Growth Rate	0.7%	0.8%	0.7%
NOTE: Data includes all US and Canadian traffic.			

[1] **A short ton is 2,000 pounds**
[2] **Montreal to Lake Ontario**

2007 Bi-National GLSLS Study Results

Bulk commodity forecasts for GLSLS system locks prepared by TAF Consultants and the Corps projected relatively slow growth in bulk traffic over the next four decades. Table 7 (below) summarizes the bulk traffic demand forecasts for the Seaway Locks, the Welland Locks and the Soo Locks. The Economic Appendix of the bi-national GLSLS 2007 report contains commodity specific forecasts. As noted earlier, because this study focused on lock infrastructure, no forecasts of intra-lakes traffic were prepared. Traffic demands are in metric tons. Transit (vessel trip) forecasts for bulk commodities were also prepared; however, these grew at the same rate as tonnage demands and are not shown here, though they are presented in the bi-national GLSLS 2007 Economics Appendix.

Table 10 - GLSLS 2007, Lock Forecasts (millions of metric[1] tons)

Year	Seaway Locks	Welland Locks	Soo Locks
Historic			
1960	18.4	26.5	82.9
1970	46.4	57.1	90.8
1980	49.5	59.6	87.4
1990	36.7	39.4	79.8
2000	35.4	36.6	82.0
Future			
2010	32.3	34.3	89.5
2020	37.6	36.2	91.8
2030	39.5	40.1	94.0
2040	40.8	41.3	102.3
2050	42.1	42.4	107.3
Forecast Ave. Annual Growth Rates	0.70%	0.54%	0.44%

1 Metric tons (tonnes) were used due to the bi-national nature of the study. A metric ton is approximately 2,204 pounds.

Emerging Cargo Movements

The bi-national GLSLS study investigated the potential for neo-bulk goods and containers to move on the GLSLS system without altering the current dimensions of the channels or locks. This work looked at alternative vessel fleets that might favorably alter the prospects for container movement on the existing system.

The current report summarizes the *Great Lakes – St. Lawrence Seaway New Cargoes/ New Vessels Market Assessment Report* prepared by Transportation Economics and Management Systems, Inc (TEMS) and RAND Corporation, dated January 2007. This report was prepared under a contract with the Maritime Administration, U.S. Department of Transportation to assess opportunities for growth from emerging neo-bulk and new container traffic through the Seaway and into the Great Lakes. This report focused on three areas of investigation:

- An evaluation of the economic significance and growth of industrial sectors and markets in the GLSLS region as a basis for projecting the transportation needs of this region's evolving economy;

- Market investigations and forecasts of emerging and potential cargo movements through 2050, focusing on potential growth in neo-bulk and containerized trade, and

- An evaluation of the ability of water options and vessel technologies to address shippers' service requirements for both container and neo-bulk traffic.

The results of the evaluation of potential container traffic are summarized by a congestion scenario for four general vessel categories: Small ship, Ship, PASCAT (Partial Air Cushion

Support Catamaran), and COB (container-on-barge). The TEMS and RAND Corporation study indicates the potential for the GLSLS system to play a significant role in helping to relieve anticipated capacity shortfalls in the movement of containers to U.S. and Canadian markets.

Under very conservative assumptions about the future growth of the economy and trade and continuing difficulties in building new highway and rail capacity, this study reports that modern GLSLS-max container ships (20 knots) can be competitive with truck and rail on specific trade routes, and attract significant container traffic. In this way the system can play a role as an inter-modal reliever in helping to move containers to, from, and within the system's market areas.

The TEMS/RAND report indicates a cost-effective potential for container shipment in 2010 regardless of the level of congestion along overland routes, though congestion conditions do increase demand for waterborne carriage of containers. Though all vessel types could carry containers at a cost savings, the total savings was greatest when using small ships at volumes of less than 1,000,000 FEUs (forty-foot equivalent units) and greatest for GLSLS max vessels when volumes exceeded 1,000,000 FEUs.

In 2010 the TEMS/RAND report indicates that, in the unconstrained overland route scenario, a potential demand for 3,743 vessel transits carrying 655,000 containers – however, because GLSLS max vessels are more efficient when container volumes exceed 1,000,000, the number of vessel transits in 2030 actually declines to 2,168, though the number of containers moving increases to 1,442,000. To place these forecasts in a perspective relative to bulk commodity forecasts, traffic in the Congested Overland Scenario represents as much as 52% of Montreal-Lake Ontario transits, 46% of Welland transits, and 29% of Soo transits. The share of container traffic in the Uncongested Overland Scenario is only slightly lower than Congested Overland Scenario forecasts for 2010 and 2020, but is significantly lower in the years beyond.

5.3.2 Recreational Boating Spending in the GLNS

In 2003, the Corps prepared a report to detail the economic benefits of recreational boating in the Great Lakes basin. This report was prepared in response to Section 455(c) of the Water Resources Development Act of 1999, which directed the Secretary of the Army, in cooperation with the Great Lakes States, to submit such a report to the U.S. Congress. This report is known as the *John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating Report,* released in December 2008. The recreational boating section of the Economics Appendix to this report presents a portion of the information found in the referenced report as well.

The Supplemental economics section does not attempt to estimate NED benefits for recreation. Rather, it details regional recreational boating expenditures of boat owners that operate their watercraft on the Great Lakes. Boating in the Great Lakes is a popular recreational activity for residents of and visitors to the region, which has a significant economic impact at the local, state and regional levels. Recreational boaters spend money in two ways: 1) by purchasing and maintaining their boats, and 2) by purchasing gas, oil, food and lodging each time they take a boating trip, whether it be for a short outing of an hour or two, or a multiple day cruise.

Recreational Boating

Michigan, with its considerable coastline, leads the Great Lakes states with over a quarter million recreational boats operated on the Lakes, followed distantly by Wisconsin at roughly 141,000. Three states, Minnesota, New York and Ohio exhibit relatively similar numbers while Pennsylvania has the least amount of boats operated on the Lakes, roughly 12,000. Table 11 presents the estimated number of boats operated on the Great Lakes in 2003. Because the economic impacts generated by boats in the Great Lakes vary according to length and whether they are stored at a marina or not, the estimates are categorized by state of registration, length and marina storage.

Table 11 - Estimated Boats Operated on the Great Lakes (from Table 33, John Glenn Great Lakes Basin Program Recreational Boating Report, December, 2008)

	IL	IN	MI	MN	NY	OH	PA	WI	
Boats not in Marinas									
Under 16’	20,866	15,585	99,343	17,314	28,583	24,179	5,222	55,400	**266,492**
16-20’	26,503	23,669	88,217	55,391	28,548	22,207	3,077	61,047	**308,659**
21-27’	5,562	10,305	29,181	11,180	13,390	4,881	826	16,292	**91,617**
28-40’	999	1,103	3,778	1,070	1,095	788	192	1,575	**10,600**
Over 40’	124	376	255	306	332	190	17	259	**1,859**
Boats in Marinas									
Under 20’	472	218	3,143	232	3,337	6,249	1,149	852	**15,652**
21-27’	4,373	1,758	23,660	428	7,631	18,475	1,202	3,625	**61,152**
28-40’	3,424	673	13,666	238	3,533	5,543	321	1,437	**28,835**
Over 40’	1,000	248	2,441	65	283	374	27	302	**4,740**
Total	**63,323**	**53,935**	**263,684**	**86,224**	**86,732**	**82,886**	**12,033**	**140,789**	**789,606**

Recreational Boating Expenditures

With some disaggregation, total boat spending by State of registration can be derived. State totals are shown in Table 9 below**.** These totals represent expenditures by boats registered in Great Lake bordering counties, only.

Table 12 - Total Recreational Boat Spending on the Great Lakes by State [1] (in millions of 2008 dollars)

	IL	IN	MI	MN	NY	OH	PA	WI
Boats not in Marinas								
Under 16’	$51.8	$38.7	$246.4	$43.0	$70.9	$60.0	$13.2	$137.4
16-20’	$105.5	$94.2	$351.1	$220.5	$113.6	$88.4	$13.4	$243.0
21-27’	$46.8	$86.5	$245.1	$93.8	$112.5	$40.9	$10.3	$136.9
28-40’	$14.1	$15.7	$53.3	$15.4	$15.4	$11.2	$3.1	$22.4
Over 40’	$3.1	$9.7	$6.6	$7.9	$8.5	$4.9	$0.5	$6.7
Boats in Marinas								
Under 20’	$3.1	$1.4	$20.5	$1.6	$21.8	$40.8	$3.8	$5.6
21-27’	$50.3	$20.3	$272.0	$4.9	$87.7	$212.5	$7.9	$41.7
28-40’	$60.0	$11.9	$239.6	$4.2	$62.0	$97.2	$4.9	$25.2
Over 40’	$28.7	$7.2	$70.0	$1.9	$8.0	$10.6	$0.7	$8.6
Total	**$363.4**	**$285.6**	**$1,504.6**	**$393.2**	**$500.4**	**$566.5**	**$57.8**	**$627.5**
Percentage of Total Spending	8.5%	6.6%	35.0%	9.1%	11.6%	13.2%	1.4%	14.6%

[1] p. 25-26. Stynes, Daniel J., Tsung Chiung Wu, and Edward M. Mahoney, 1998. *1994 Michigan Boating Survey. Clean Vessel Act/Michigan Boating Study, 1994-95, Report II.* East Lansing, MI: Michigan Agricultural Experiment Station, Michigan State University.

Michigan boaters lead the other seven states in recreational boating expenditures on the Great Lakes, which should not be surprising, given the length of Michigan’s Great Lakes coastline. Also not surprising is the relatively small percentages of spending represented by Pennsylvania boaters as Pennsylvania has one of the smallest Great Lakes coast lines.

This analysis has detailed the impact on Great Lakes recreational industries generated by recreational boating in the GLNS. Approximately $5.4 billion annually is spent by boaters on the Great Lakes. These impacts are regional and should not be confused with NED benefits. However, it is evident that these economic impacts are significant to the local economies of the eight Great Lakes states and that the recreational boating industry can be greatly affected, positively or negatively, by infrastructure expenditure allocations in the GLNS.

Externalities – Accidents and Emissions

An externality exists when one individual's actions affect the well-being of another individual in ways that do not involve compensation. A “negative externality" results when part of the cost of producing a good or service is born by a firm or household other than the producer or purchaser. A "positive externality" results when part of the benefit of producing or consuming a good or service accrues to a firm or household other than that which produces or purchases it. Shipping on the Great Lakes results in lower overland traffic, reducing the amount of land-based accidents, noise, vibration and air pollution from engines that would occur if the traffic was moved via land-based transportation alternatives.

Closure of the GLNS to shipping and re-routing to all-land movements would result in significant increases in rail and truck collisions and in pollutant emissions. The total annual cost associated with increases in collisions is estimated at $271.9 million in 2008 dollars. Increases in pollutant emissions, including PM-10 (particulate matter – 10 micrometers or less) were determined by calculating the mode specific mileages traveled under two specific scenarios – the current route including the mileage traveled through the Great Lakes and an alternative routing consisting solely of land transportation. These mileages were then converted to fuel consumption, total and MSA (Metropolitan Statistical Area) specific emissions, concentrations, exposure and health impacts. Overall, this initial analysis shows transportation of the existing tonnages through the GLNS yields measurable benefits in terms of reduced human exposure to PM-10. When compared with the all-land routings Great Lakes navigation leads to $355.9 million (in 2008 dollars) in annual health savings (from *Valuing the Air Quality Impacts of Modal Choice: More Evidence from the Ohio River Basin.* Marshall University, 2001).

These externalities represent substantial impacts to human health that are currently avoided through the continued maintenance of the GLNS. Thus, the total value of these externality costs avoided is $627.7 million.

5.3.3 Vessel Fleet and Operating Costs

U.S. Fleet-Vessel Type, Size

There were 117 U.S. and Canadian commercial vessels operating on the GLNS in 2005 compared to 185 in 1990 and 302 in 1980.

An examination of the data on the composition of the United States fleet in 1980 and 2005 indicates the drastic decline of bulk carriers during the 1990s was primarily responsible for the decline in the United States fleet. The decline in bulk carriers was due to the age of the bulk carriers, as well as the need for vessels that did not require shore side equipment to unload the vessel cargo. U.S. bulk freighters were either scrapped or converted to self unloaders. The resulting ships were made more efficient by not being tied to the availability of shore side unloading equipment.

Canadian Fleet-Vessel Type, Size

Canadian bulk carriers are more modern than their American counterparts having been largely constructed after the opening of the Seaway in 1959. Thus, in the 1980s, the Canadian fleet of bulk carriers was more efficient than the United States fleet. Further, the bulk freighters were engaged in the Canadian grain traffic from Thunder Bay on Lake Superior to deep-water ports on the St. Lawrence such as Montreal. Grain storage facilities were located at these deep-water ports, which could unload these bulk carriers and transfer their cargoes to deep draft ocean going vessels. On the return haul, the downbound grain vessel returned with an upbound load of iron ore from the iron ore ports on the north shore of the St. Lawrence River. Table 10 below presents the GL Fleet carrying capacity for 1980 – 2001. Increases in carrying capacity indicate that the vessels removed from the fleet were smaller sized vessels, with lower than average carrying capacities. A number of Canadian and U.S. vessels were actually converted from bulkers to self unloaders, and lengthened in the process. This resulted in an increase in the average size of vessels in the fleet between 1980 and 2001.

The data also indicates that the average capacity per trip of U.S. self-unloaders increased more than their Canadian counterparts. The U.S. self-unloading fleets carrying capacity increased by 49% (from 27,951 to 41,736 tons per trip) while the Canadian self-unloading fleet increased its average trip capacity by 29% (from 25,397 to 32,930 tons per trip).

Table 13 - Great Lakes Fleet Carrying Capacity in Tons or Barrels, 1980-2001

	1980	**1990**	**2001**
Bulk Carriers (1)			
United States	1,380,790	147,050	105,056
Canada	1,721,110	1,301,245	995,154
Subtotal	3,101,900	1,448,295	1,100,210
Self Unloaders (1)			
United States	1,621,185	1,893,275	2,045,075
Canada	888,895	986,475	1,251,342
Subtotal	2,510,080	2,879,750	3,296,417
Total Fleet (1)	5,611,980	4,328,045	4,396,627
Tankers (2)			
United States	401,335	168,500	205,500
Canada	2,036,224	1,781,101	988,710
Subtotal	2,437,559	2,049,601	1,194,210
Average Trip Capacity			
Bulk Carriers (1)			
United States	17,702	21,007	26,289
Canada	20,248	23,659	26,188
Subtotal	19,030	23,360	26,195
Self Unloaders (1)			
United States	27,951	34,423	41,736
Canada	25,397	28,185	32,930
Subtotal	26,990	31,997	37,890
Tankers (2)			
United States	28,667	44,750	51,375
Canada	63,632	65,967	70,622
Subtotal	52,990	62,109	66,345

Notes: (1) Capacity of bulk carriers and self-unloaders are in short (2,000 lbs.) tons.
(2) Capacity of tankers is in barrels. Source: Greenwood's Guide to Great Lakes Shipping, 1980, 1990 & 2001.

Projected Fleet

There has been a major restructuring of the U.S/Canadian fleet in the last 25 years. The overall fleet has declined from 302 vessels in 1980 to 117 in 2005. However, the total carrying capacity of bulkers and self unloaders has only declined by 22%. The average carrying capacity of bulkers and freighters has actually increased by 59% and 40% respectively from 1980 to 2001. The types and sizes of vessels found in the 2005 fleet are considered to be representative of the type and sizes of vessel that will be used to move bulk commodities on the GLNS for the foreseeable future. Consequently, the projected fleet is assumed to be the same as the 2005 fleet.

Vessel Operating Costs

Table 14 (on the next page) presents the vessel operating costs for 2005 along with the index used to adjust the values to 2008. The derivation of the index is described in section 8 of the economic appendix.

Table 14 - Update of Fixed and Variable Vessel Costs from 2005 to 2008 Prices

Great Lakes Vessel Classes	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10
Great Lakes Vessel Costs									
Daily Variable Operating Costs									
Wages									
2005 Wages	$10,236	$10,236	$10,236	$10,385	$10,559	$10,735	$11,193	$11,697	$11,697
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	101.34%	104.00%	113.56%	113.56%
2008 Wages	$10,236	$10,236	$10,236	$10,385	$10,559	$10,879	$11,641	$13,283	$13,283
Subsistence									
2005 Subsistence	$300	$300	$300	$300	$300	$350	$350	$350	$350
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2008 Subsistence	$300	$300	$300	$300	$300	$350	$350	$350	$350
Stores, Supplies & Equip									
2005 Stores, Supplies, Equip	$374	$450	$561	$594	$671	$722	$858	$951	$951
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2008 Stores, Supplies, Equip	$374	$450	$561	$594	$671	$722	$858	$951	$951
Insurance									
2005 Insurance	$960	$1,003	$1,047	$1,194	$1,379	$1,647	$2,113	$2,603	$2,603
Update Factor	100.00%	100.00%	100.00%	100.00%	102.75%	104.79%	106.71%	106.71%	106.71%
2008 Insurance	$960	$1,003	$1,047	$1,194	$1,417	$1,726	$2,255	$2,778	$2,778
Maintenance & Repair									
2005 Maintenance & Repair	$1,624	$1,859	$1,868	$1,972	$2,102	$2,284	$2,470	$2,581	$2,581
Update Factor	225.68%	225.68%	225.68%	212.85%	202.74%	194.57%	187.83%	174.27%	174.27%
2008 Maintenance & Repair	$3,666	$4,196	$4,216	$4,197	$4,262	$4,444	$4,639	$4,498	$4,498
Fuel									
2005 Fuel	$1,543	$2,348	$2,996	$3,364	$3,624	$4,092	$4,760	$5,212	$5,212
Update Factor	395.02%	393.00%	391.38%	347.13%	206.41%	204.99%	236.88%	285.95%	291.77%
2008 Fuel	$6,095	$9,228	$11,726	$11,676	$7,480	$8,389	$11,277	$14,903	$15,207
Other	395.02%	393.00%	391.38%	347.13%	206.41%	204.99%	236.88%	285.95%	291.77%
2005 Other	$918	$1,009	$1,101	$1,120	$1,143	$1,178	$1,215	$1,241	$1,241
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2008 Other	$918	$1,009	$1,101	$1,120	$1,143	$1,178	$1,215	$1,241	$1,241
Fixed Costs									
Construction Costs									
2005 Construction Costs	$40,484,395	$44,982,661	$49,480,927	$54,338,946	$60,393,266	$68,838,216	$83,230,971	$97,924,966	$97,924,966
Update Factor	119.76%	119.76%	119.76%	123.11%	126.12%	128.84%	131.32%	131.25%	131.25%
2008 Construction Costs	$48,483,434	$53,870,482	$59,257,531	$66,897,369	$76,170,058	$88,694,689	$109,295,167	$128,526,275	$128,526,275

Value of Dredging/Maintaining the Great Lakes Navigation System

The cost associated with waterborne transportation at Federal commercial deep draft harbors on the Great Lakes is highly sensitive to the available channel depths. The carrying capacity of Great Lakes vessels is a function of vessel dimension, the density of the commodity carried and the available vessel draft. Available channel depth changes are the result of three primary elements.

The most significant element is the continuous seasonal and annual fluctuation of lake water levels within the system, affecting large numbers of harbors simultaneously. The second element is the shoaling that results from sediment transport from sources upstream of Federal harbors. Another source of shoal material results from the littoral transport of sand and gravel along the lake coasts into Federal channels. Lake storms often contribute to this latter process. Shoaling in Federal channels reduces the available depth for commercial vessels that call there, restricting the maximum allowable tonnage on a transit. As shoal material fills in navigation channels, the vertical column of water available to a vessel using the channel may restrict the vessel from maximizing the amount of tonnage the vessel can carry, hence raising the cost per ton for the movement. The third element influencing channel depth changes is man's intervention through maintenance dredging and by authorizing new, deeper channel depths. The majority of Federal commercial deep draft harbors on the Great Lakes require periodic harbor maintenance dredging.

A new model was developed, Great Lake Levels System Analysis of Navigation Depths (GL-SAND), to determine the economic value of maintaining (dredging) varying depths at authorized Federal navigation channels. The model's purpose is to combine the features of two previous models while also enhancing the capabilities provided by both of these models.

Previous Economic Models

The primary NED benefit associated with harbor improvement plans that consider increased channel depths is transportation cost savings (TCS). The TCS benefit is now being used to help prioritize maintenance dredging work packages for the Great Lakes navigation operations and maintenance (O&M) budget. The Great Lake Level Analysis of Port Operation and Maintenance (GLLAPOM) model was developed to assess the TCS benefit associated with maintaining various harbor depths up to the authorized depth. The Great Lake Levels Analysis for System Transportation (GLLAST) model was developed to assess the TCS benefit for proposed harbor improvements under the GLNS Reconnaissance Study. A new model, the Great Lakes System Analysis of Navigation Depths (GL-SAND), incorporated the best features of these two predecessor models and did so within a system framework. The impetus for this effort was the refinement of Great Lakes transportation cost modeling to support future O&M budget economic metric requirements.

GLLAST Model

The Great Lake Levels Analysis for System Transportation (GLLAST) was a modified version of a costing model used in the 1980s to determine shipping cost effects of proposed lake level control alternatives. In the GLLAST model, the number of trips required to move all commodities was the sole factor that affected transportation cost.

This model used a set of input data that described the types and amounts of commodities shipped between Great Lakes ports, the dates that the movement began and ended, the types and costs of the boats that transported the commodities, the depths of the ports and connecting channels that the boats moved through, and monthly historic lake levels.

Calculations were made on a movement-by-movement basis. For example, if it took 25 vessel trips to move a given annual commodity tonnage from Port A to Port B, the time required to make each of the 25 movements is calculated separately. This way the seasonal variations in lake levels and vessel load line limits were included in the analysis. The impact of yearly lake level variation was analyzed by running the model several times, each time with a different set of monthly historic lake levels. The average transportation costs were computed based on the transportation costs associated with each of the set of historic years of average monthly water levels.

GLLAPOM Model

The next model, Great Lake Level Analysis of Port Operation and Maintenance (GLLAPOM), used a similar logic and input data to provide the array of transportation costs increases associated with unmitigated harbor shoaling. The incremental benefits of dredging were determined in this model.

A TCS benefit can be determined for dredging Federally-maintained channels to their authorized (and alternative) depths. These transportation cost savings are determined by simulating the shipping costs associated with the most recent representative annual waterborne shipments at varying hypothetical constrained port channel depths. GLLAPOM simulates each vessel movement for a given historical shipment list at a port of interest and determines the maximum tonnage the vessel can carry given water column constraints. Decreases in available water column lead to light loading and the need to make more round trips to carry a given annual cargo tonnage. This inefficiency results in higher transportation costs.

GLLAPOM can be used in making point estimates of net benefits (benefits minus costs), though shoaling rates and dredging costs are needed. Ultimately, it can be used in optimizing channel maintenance depths. This framework provides for consistently applied data and tools throughout the Great Lakes system of channels and harbors, an important feature when prioritizing investments throughout the entire system though the focus is still port-centric. The GLLAPOM model's decremental approach allows for an incremental estimation of benefits, which can be compared to an incremental estimate of dredging costs necessary to reclaim these benefits. Some of the limitations of this model include:

1) assumption of the same vessel on a particular route with no ability to shift to a lower cost vessel,
2) the number of commodities analyzed is limited,
3) detailed foreign vessel movements are not evaluated,
4) non-specific port characteristics are used,
5) issues in dealing with multiple origin or destination ports for a single movement and
6) there are limited pairings of port to port distances.

GL-SAND Model

The existing models, GLLAPOM (that measures the impacts associated with constrained harbor depths as a result of shoaling), and GLLAST (used to measure the benefits associated with harbor channel improvements), have the aforementioned limitations, which resulted in the following proposed model improvements:

- incorporate an expanded list of bulk commodities modeled;
- combine detailed Canadian shipment list (from Piers) with US domestic shipment list;
- have ability to analyze movements at dock level detail (not just port level);
- incorporate risk analysis for data variability and uncertainty;
- have ability to analyze at GL system level (not just port level);
- have ability to analyze for both depth improvement and shoaling scenarios;
- have ability to enable vessel swapping option to adapt to hypothetical changes in depth to allow for greater economic efficiency;
- have ability to analyze movements that have multiple origin and/or destination ports or docks;
- expand vessel list to include Canadian Lakers (vessel operating characteristics, etc.)
- have ability to analyze and compare alternative mode rate savings and emissions impacts.

The Great Lakes System Analysis of Navigation Depths (GL-SAND) model was developed to address these proposed enhancements. The impetus for this effort was the refinement of Great Lakes transportation cost modeling to support future O&M budget economic metric requirements. The idea being that the model should allow for the best practicable measurement of economic metrics to assist in the prioritization of proposed O&M budget dredging work packages for projects at Great Lakes ports.

GL-SAND uses the alternative mode rates for the selected Origin-Destination-Commodity (ODC) combinations to calculate the rate savings benefit for individual Great Lakes ports and channels. The benefit calculation compares the all-land route transportation cost for the each ODC with each corresponding respective water cost. The land portion of the water route transportation cost was added to the transportation cost for water portion to derive the total cost of moving the commodity from its true origin to its final destination. The Rate Savings benefit is calculated by summing all the individual rate savings benefits for each ODC for that port. The rate savings benefits for an individual ODC is calculated as the total tons for the ODC multiplied by the difference in all-land transit cost per ton and the water route cost per ton for that ODC. The estimated rate savings benefit for each Great Lakes Federal commercial port and channel is presented in Table 15 below.

Table 15 - GL-SAND Modeled Rate Savings Benefit by Port and Channel

Port Name	Tons Modeled (2005)	Rate Savings Benefit	Port Name	Tons Modeled (2005)	Rate Savings Benefit
Alpena Harbor, MI	3,243,534	$83,845,642	Manitowoc Harbor	208,576	$16,096,349
Ashland Harbor	98,460	$4,032,219	Marquette Harbor	1,077,218	$17,591,886
Ashtabula Harbor, OH	9,298,577	$166,317,410	Menominee Harbor, MI & Wi	24,112	$0
Buffalo Port, NY	1,092,613	$34,921,276	Milwaukee Harbor, WI	2,950,612	$72,975,706
Burns Harbor, IN	7,945,830	$76,852,623	Monroe Harbor	1,407,242	$4,616,206
Calumet Harbor and River, IL & IN	6,309,052	$129,711,785	Muskegon Harbor	2,032,953	$80,688,800
Charlevoix Harbor	749,414	$50,382,889	Ogdensburg Harbor, NY	174,095	$4,849,837
Cheboygan Harbor, MI	25,346	$0	Ontonagon Harbor	228,629	$8,476,162
Chicago Port, IL	6,309,052	$129,711,785	Oswego Harbor, NY	371,201	$10,084,221
Cleveland Harbor, OH	12,508,505	$223,125,327	Presque Isle Harbor	10,940,784	$125,467,844
Conneaut Harbor, OH	7,243,225	$153,104,753	Rochester Harbor, NY	129,535	$5,294,134
Detroit Port, MI	4,955,553	$55,110,309	Rouge Riv (Dearborn), MI	10,104,703	$160,387,964
Duluth Harbor, MN	20,458,312	$391,588,418	Saginaw River, MI	1,374,766	$19,278,417
Dunkirk Harbor, NY	143,957	$676,662	Sandusky Harbor, OH	3,550,574	$56,000,827
Erie Harbor, PA	885,757	$30,335,030	St. Joseph Harbor, MI	530,615	$14,008,579
Fairport Harbor, OH	2,390,784	$43,154,806	Superior, MN	19,265,211	$183,723,626
Grand Haven Harbor	597,958	$10,189,889	Toledo Harbor, OH	9,304,155	$267,653,793
Green Bay Harbor, WI	2,624,313	$57,288,860	Two Harbors, MN	10,958,982	$86,268,194
Harbor Beach Harbor, MI	209,507	$4,152,428	Waukegan Harbor, IL	640,352	$13,325,680
Holland Harbor, MI	536,229	$15,259,688	Detroit River Channel	62,246,601	$1,193,731,044
Huron Harbor, OH	1,011,458	$24,144,967	Channels in Lake St. Clair	58,583,137	$1,148,905,375
Indiana Harbor, IN	10,969,022	$80,819,831	St. Clair River	68,536,986	$1,257,007,565
Lorain Harbor, OH	2,995,181	$32,382,696	Straits of Mackinac	96,204,692	$1,553,705,995
Ludington Harbor, MI	187,785	$4,391,918	St. Marys River	73,282,800	$1,005,319,780
Manistee Harbor, MI	243,143	$4,146,159	Sault St. Marie (Soo Locks)	66,635,908	$868,540,041

A new analytical component added to the GL-SAND model allows for the assessment of emissions and safety by comparing water movements and the next least costly alternative mode of transportation. Comparative mileage data and ton-mileage data between modes was obtained from the model. Details of the analysis are discussed in the economics appendix of this report.

Ideally, in those instances where transportation cost savings are limited due to constraints on the existing fleet that historically served that port, the model should allow for a vessel to be swapped to correspond with a proposed port deepening alternatives that would benefit by increased efficiency. Total GLNS transportation cost for the commodities modeled amount to over $3.5 billion. This is based on close to 144.6 million tons for 975 unique Origin – Destination movements of the 35 commodities modeled.

A number of screening procedures were developed to identify harbors that have potential for deepening. The first screening was by tonnage, including all ports that ship or receive over 1 million tons annually. The second consideration was to identify the difference between the depths at the origin and the destination ports.

328 origin-destination pairs were evaluated with respect to port improvements. The commodity, tons moved, the depth at the origin port, the depth at the destination port and the difference in depth between the origin and destination port was identified for each of these origin-destination pairs.

Compared to GLLAPOM model, the GL-SAND model can also provide the rate savings benefit for each harbor as well as the emission and safety impacts for each harbor or channel based on alternative mode comparisons. In addition, GL-SAND, having expanded commodity capability, provides a more accurate reflection of impacts. Ports like Cleveland that have significant intraport movements and varying controlling depths are now analyzed properly using GL-SAND.

Summary of Modeling Work

In summary, the impetus for the development of a new model, the GL-SAND, was the refinement of Great Lakes transportation cost modeling to support future O&M in the prioritization of dredging work. The previous models, GLLAPOM and GLLAST, presented many limitations that are addressed in the GL-SAND model.

Transportation Rates and System Savings

Transportation rates were derived for the principal origin-destination-commodity movements throughout the Great Lakes. The Tennessee Valley Authority (TVA) was contracted to measure the rate savings attributable to Great Lakes and St Lawrence Seaway navigation and to measure the transportation cost effect of alternative short term unplanned navigation structure closures. TVA conducted a study that provided a full range of transportation rates and supplemental costs for 857 waterborne commodity movements made in 2002 that, in total or in part, were routed on the Great Lakes and St Lawrence Seaway.

The 857 movements accounted for all moves that exceeded 20,000 net tons annually, representing over 40 individual commodities. Rates estimated for both the existing waterway route and the alternative route are comprised of the cost of loading at origin, charge to transfer point, transfer charge, line haul (overland or waterway) charge, handling at waterway destination, charge ex waterway, and cost of unloading at destination. All computations reflect those rates and fees that were in effect as of December 2004.

This rate information, especially the alternative rate and accessorial charges, is used as input to the current GL-SAND application. This necessitated updating rate estimates reported by TVA in 2005 dollars to current 2008 dollars. The method for doing this is described in section 9 of the attached Economic Appendix. With this updated price level, it was also possible to estimate GLNS benefits for U.S. traffic as shown in Figure 22 on the next page.

Great Lakes
Rate Savings Benefits

Commodity Group	(Oct 08) $FY09 Savings per ton	CY 2006 Tonnage	Rate Savings Benefit*
Wheat	$24.02	1,636,000	$39,298,492
Maize	$32.17	1,875,000	$60,326,942
Soybeans	$30.60	1,161,000	$35,531,916
Other grains and seeds	$39.48	2,066,000	$81,570,722
Limestone	$21.78	30,908,000	$673,091,214
Other Minerals	$26.78	7,239,000	$193,848,497
Ores (including iron ore)	$12.89	58,848,000	$758,635,652
Coal	$18.05	44,896,000	$810,365,445
Petroleum Products	$27.43	5,067,000	$139,012,440
Cement	$46.00	7,151,000	$328,946,909
Miscellaneous	$42.73	12,166,000	$519,808,956
	Total	173,013,000	**$3,640,437,183**

* CY 2006 Great Lakes Waterborne Commerce; Oct 08 price level

Figure 22 - U.S. Rate Savings only for the U.S. portion of the GLNS
SPT = Savings per Ton; CY = Calendar Year. Numbers are rounded.

5.4 Providing a Low-Cost, Low-Emission Mode of Transportation

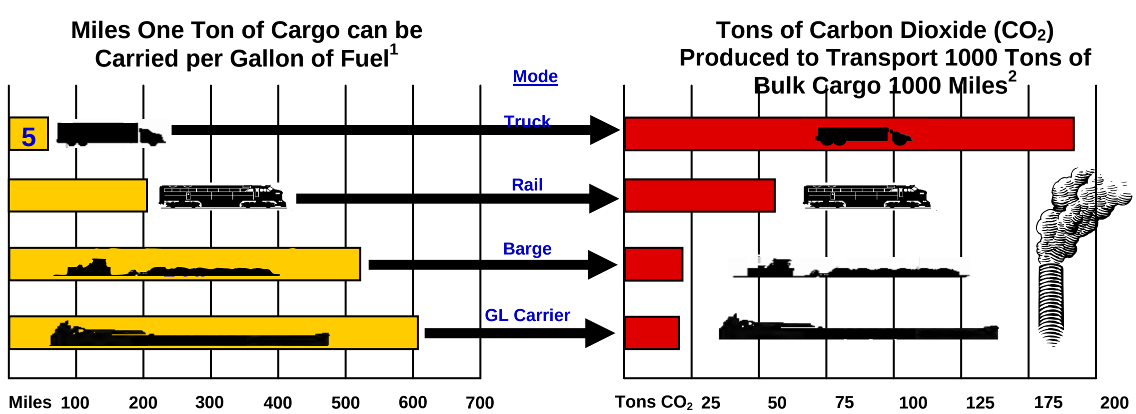
Figure 23 – Great Lakes Self-Unloader.

The GLNS also plays an important role in preserving our nation's fuel for transportation purposes. The fuel economy of maritime transportation is significantly higher than any form of ground transportation. For example, a Great Lakes carrier travels 607 miles on one gallon of fuel per ton of cargo. In contrast, a truck travels 59 miles on one gallon of fuel per ton of cargo and a freight train travels 202 miles on one gallon of fuel per ton of cargo. In one delivery, a 1000-foot Great Lakes carrier supplies 70,000 tons of cargo. It would take nearly 3,000 semi truckloads to haul the same load (from the USDOT Maritime Administration and Minnesota Department of Transportation). The trucking mode of transportation not only is much less fuel efficient, it creates significant wear-and-tear on the nation's infrastructure and increases congestion on already clogged transportation arteries.

The amount of carbon dioxide emissions is also significantly lower in maritime transportation as compared to ground transportation, as shown in the figure below. A cargo of 1,000 tons transported by Great Lakes carrier produces 90 percent less carbon dioxide as compared to the same cargo transported by truck and 70 percent less than the same cargo transported by rail.

The GLNS offers a fuel-efficient, low carbon producing, and low-cost option of transportation for millions of tons of bulk material that is vital to this country's industrial strength.

Figure 24 – Relative Efficiency of Waterborne Commerce



1. Source: USDOT Maritime Administration and Minnesota Department of Transportation
2. Assumes US DOE Fuel and Energy Emission Coefficient of 22.38 lbs of CO_2 per gallon (No.1,2,4 Fuel Oils and Diesel)

5.5 Current Environmental Conditions

The ecosystem of the Great Lakes Basin is vulnerable to a variety of stressors. Residential settlement, urban growth, industrial activities, tourism and recreation as well as navigation have all had an impact on the region's environment.

When the GLNS was originally completed, environmental protection was not a high public priority and environmental impacts were poorly understood. Over time, however, it became clear that the construction, operation and maintenance of the GLSLS had a number of significant effects on the ecology of the Great Lakes and St. Lawrence River basin.

Management of Great Lakes water levels has led to altered local ecologies, drying out some coastal wetlands and inundating other normally dry coastal plains. Dredging of navigational channels causes turbidity in the water while posing the challenge of how to dispose of dredged material with a minimal impact on the environment. Ship engines burn a lower grade fuel that contributes to air pollution. Ship wakes have eroded shorelines, and vessels were coated with special anti-fouling paint that released some toxins into the water. Current day practices are more environmentally-sensitive, though not all negative environmental impacts can be eliminated from GLNS commerce.

Furthermore, many of these effects added to larger environmental impacts caused by industrial, commercial and residential development in the region. Some, however, were unique to navigation through the system. Perhaps the most important of these was the introduction of non-indigenous invasive species (NIS) via the ballast water of vessels. An example of such a species is the zebra mussel. Having few natural predators in the region, this species proliferated rapidly with significant negative effects on native ecology. Recognition of these various impacts within the broader context of a greater appreciation of the environment, has led to a general commitment to protection.

As a result, ships' speeds are now controlled to reduce wakes in narrow channels and toxic paints have been phased out. To reduce air pollution, vessel operators are exploring fuel alternatives and scrubbing technologies. Finally, controls have been introduced on ballast water: vessels are now required to drain any ballast originating elsewhere prior to entering the Great Lakes system. Such actions are reducing the effects of commercial navigation. Activities such as ongoing maintenance of infrastructure or dredging and the placement of dredged material will continue to affect the region's environment, but their impact can be minimized through effective application of environmental assessments, remedial actions, sound environmental management strategies and best practices.

Overall, the environmental health of the Great Lakes has improved since the Cuyahoga River caught fire on June 22, 1969; future improvements are needed but are uncertain and may even be beyond our ability to control. Several credible reports have been issued recently on the future of the Great Lakes. These reports include a report on Great Lakes shipping, world trade and aquatic invasive species by the Transportation Research Board in 2007, a market assessment of new cargoes and vessels for the Great Lakes by the Department of Transportation (2007), a Brookings Institute assessment of the benefits and costs of implementing the Great Lakes Regional Collaboration, and an EPA annual report on the State of the Great Lakes. The most focused review of environmental issues as they relate to navigation appears in the Environmental Appendix to the 2007 bi-national GLSLS study. Much of what follows has its origins in that document.

The environmental problems of the Great Lakes were caused by development that peaked before broad national environmental legislation like the National Environmental Policy Act (1969), Clean Water Act (1972) and Endangered Species Act (1973) were enacted. The principal environmental issues for the Great Lakes are invasive species, pollution (air as well as point and non-point water pollution), and loss of wetland services. Efforts to reduce these impacts are ongoing.

Improvements in invasive species would require both treatment of the current effects of invasives already lodged in the Great Lakes as well as the reduction in future invasives. The most likely future is that invasives will continue to be a big problem because not enough will be spent to reduce the current problem, while the measures taken to reduce the risk of new invasions are not expected to be 100% effective.

Pollution from the land surrounding the Great Lakes has been greatly reduced since the 1960's when three foot diameter pipes jutting out of the sheet pile banks spewed untreated chemical waste directly into rivers, but the pollutants have not been cleaned out of the Great Lakes.

The principal concerns are from persistent organic compounds such as Dichloro-Diphenyl-Trichloroethane (DDT), dioxin and polychlorinated biphenyls (PCBs) which are no longer entering the lakes but have not been completely removed. The lakes can still be polluted from combined sewer overflows in which heavy rains flood systems handling both street drainage and wastewater, forcing wastewater into the lakes before it can be treated. Overland runoff – rain washing gas and oil off roads into the lakes, or agricultural pesticides and fertilizers into the lakes, is also a problem.

The State of the Lakes Ecosystem Conference (SOLEC) in October 2008 had a mixed opinion of the state of biologic components of the Great Lakes ecosystems. Native species at the base of the food web (such as zooplankton) are in decline in some of the Great Lakes, and native preyfish have declined in all lakes except Lake Superior. Lake Trout are reproducing naturally in Lake Superior and Lake Huron, but not in the other lakes to any degree. Walleye harvests have increased, although they have not reached preferred levels. Habitat loss and degradation are still the main threat to wetland birds and amphibians.

Human Health
SOLEC reports that the current status is mixed and the future is hard to assess. Levels of PCBs in the fish anglers catch continue to decline, but there are still advisories for dioxin, PCBs, toxaphene (an insecticide), and mercury in Lakes Superior and Huron; PCBs, mercury, dioxin, chlordane, and DDT in Lake Michigan; PCBs, dioxin, mercury and mirex in Lakes Erie and Ontario; as well as toxaphene in Lake Erie. Progress is being made to reduce air pollution; beaches are better assessed and more frequently monitored for pathogens, and treated drinking water quality continues to be assessed as good. Although commercial navigation was not directly responsible for most pollution, its availability supported industrial development, and dredging of contaminated sediments created exposure pathways. The connection between these problems and navigation is mostly past and not as important now as the connection with invasive species. In the past, highly contaminated sediments were dredged from navigation channels to provide adequate depth and until the late 1960s, were placed in the open lake. Since then all contaminated sediments are placed in confined disposal areas built for that purpose.

Wetlands
The rate of habitat loss and degradation has slowed considerably during the past decade with the implementation of more comprehensive habitat protection programs and policies. Incremental losses still occur, however, in locations experiencing increased development pressure and water level regulation. Beach erosion control and navigation structures interrupt shoreline sediment transport, starving beaches and increasing shoreline erosion offsite. Monitoring programs that identify and follow wetlands, such as Great Lakes Coastal Wetlands Consortium have been established.

A number of near-future stresses may have significant negative repercussions on the ecological integrity of coastal wetlands. These include reduced species diversity and increases in tolerant species densities. For example, common reed, purple loosestrife, reed-canary grass, phragmites and hybrid-cattail - all NIS - have invaded the emergent wetland habitats. These invasive species cause impairments because many grow as monocultures that create non-desirable environments for native species, reducing habitat complexity and biodiversity, and resulting in less nutrition for the native wildlife. They are also more vulnerable to disease and other pests, as well as disturbance from fire and storms that would result in catastrophic loss of cover for all species.

Coastal Zones and Aquatic Habitat
Coastal habitats have been degraded or eliminated due to development, shoreline hardening and establishment of local populations of non-native invasive species. This trend continues at a slower rate. In addition to providing habitat and feeding areas for many species of birds, amphibians and fish, coastal wetlands also serve as a refuge for native mussels and fish that are threatened by non-native invasive species.

Nutrients

The open water phosphorus concentrations have decreased in Lake Michigan, Lake Erie and Lake Ontario. In every Lake, however, high concentrations are still measured locally. These high concentrations give rise to increased phytoplankton abundances and eventually to outbreaks of potentially toxic cyanobacterial blooms and eventually mass growth of macroalga. Lake Erie shows signs once again of eutrophication whereas the efforts on nutrient reduction seemed successful during the 1980s and the first half of the 1990s.

Fish Community

The overwhelming desire of stakeholders throughout the Great Lakes to have a recreational fishery made up of naturalized and exotic salmonids has been the driving force of fish management in recent decades. Consequently, the current fish communities are largely composed of a mix of exotic species that have no evolutionary sympatry (i.e., they have not evolved together and thus lack fine-tuned interactions and adaptations between species and trophic levels). Efforts are being made to re-establish historic populations at various sites around the lakes.

Non-Indigenous Invasive Species (NIS)

Some 180 NIS have been introduced into the Great Lakes St. Lawrence River drainage basin during the past two centuries. The present rate of detection of new NIS in the Great Lakes is about one every 8 months. Of the species for which date and place of introduction is known, most (83 %) were first reported in the Great Lakes and 17 % were first reported in the St. Lawrence River. These data are based on organisms that have been identified. Since it takes up to 20 years before a new NIS is identified, there are more NIS present in the Great Lakes than mentioned above and the introduction rate might be higher than the detection rate.

Some NIS threats exist from intentional introductions through aquaculture, live fish markets, sport fishing, pet trade, bait fishes and garden plants. Accidental Introductions occur through such mechanisms as ballast water exchange by ships or transfer between basins (e.g., Mississippi and Great Lakes Basins). Of these introduction mechanisms, ballast water exchange seems to be the most common and the transfer from the Mississippi and Great Lakes Basins for Asian Carp species is presently seen as one of the major threats to the ecosystem.

High population density, high-volume transport of goods, and the degradation of native ecosystems have also made the Great Lakes region vulnerable to invasions from terrestrial non-native species. The emerald ash borer, for example, is a tree-killing beetle that has killed more than 15 million trees in the state of Michigan alone as of 2005. This beetle probably arrived in the United States on solid wood packing material carried in cargo ships or airplanes originating from its native Asia.

Measures to control invasives entry on ship started in 1989 and include exchange of ballast water before entering the lakes. Canada and the U.S. both regulate shipborne invasives, but the regulations consider cost and practicality, and have created controversy. According to a

2007 report of the Transportation Research Board (Special Report 291), new invasives continue to appear despite the regulations.

Contaminants in the Water Column

SOLEC 2008 reports that the status of waterborne contaminants is mixed but the trend is improving. For Example, contaminant uptake has been measured in gull eggs since 1974, and those levels have declined by over 90% over that time period. Concentrations of 12 of the "old" contaminants (e.g., metals, polycyclic aromatic hydrocarbons and pesticides) in the water column have declined during the last decade and the concentrations are now below the Canadian Environmental Water Quality Guidelines for the Protection of Aquatic Life in the Niagara River and St. Lawrence River. Other toxins in the water column, such as PCBs, dieldrin, hexachlorobenzene and mirex also showed declines in their concentrations. Locally, however, there are still elevated concentrations that are of concern. Generally, the contamination in the Upper Lakes is less severe than in the Lower Lakes.

Not all contaminant concentrations have declined, such as concentrations of fire-retardant brominated diphenyl ethers (BDEs), and identifiable problem areas still exist as indicated by the EPA's list of "Areas of Concern" in the Great Lakes. Also, there are new chemical contaminants like pharmaceuticals that are emerging concerns; the concentrations of "new" contaminants continue to increase. Furthermore, there are new studies that present data on the impact of chronic, life-long environmental exposure to endocrine disruptors such as xenooestrogen. While these chemicals are only present in low concentrations, the studies show that these compounds pass through the food chain and impair reproductive function in male fish. These so-called emerging substances are not yet regulated and their use grows every year.

Contaminated Sediments

Contaminants may also affect lake and river sediments which in turn, can affect overall water quality. The decreasing concentrations of PCBs and heavy metals in the water column, for example, have led to a decrease in concentrations of these contaminants in surface sediments. However, deeper sediment still maintains high levels of legacy pollutants that may become exposed during dredging operations. Erosion and deposition, brought about by changes to flow patterns associated with river channeling and flow controls and in some circumstances by ship wakes, has also affected sediments. There are both direct and indirect effects on water quality attributable to navigation. Indirect contributions include the development of port facilities, the resulting discharge of contaminants from construction and maintenance activities, and industrial and population growth resulting from port availability.

Direct contributions occur with dredging and channel maintenance activities, ship passage impacts, waste disposal, accidental or incidental discharges of contaminants, and cargo sweeping activities. Ship passage impacts include bottom scouring and prop wash, both of which contribute to increased turbidity and a re-suspension of sediments and trapped contaminants in the water column. Dredging and channel maintenance activities can also release contaminants into the water column. Inappropriate waste disposal and the incidental release of petroleum products or bilge water also contribute to degraded water quality. The activity of cargo sweeping in ports may lead to elevated nutrient levels resulting from incidental discharge of dry cargo residue, such as wood chips, coke, potash, limestone, iron ore, foundry sand, salt, fertilizer, and grain.

5.6 Projecting Ecosystem Conditions and Trends

The bi-national GLSLS Environmental Team Report (Environmental Appendix to the 2007 bi-national GLSLS study) used a set of valued ecosystem components (VECs) and a set of activities that could stress these VECs to look at ecosystem conditions and trends as they relate to navigation.

Table 16 - Valued Ecosystem Components

VEC Groups	VECs	VEC Descriptions
Air	Air quality	NOx, SOx, CO_2, CO, dust & other particulates.
Terrestrial Ecosystems	Soil & ground water	Contaminants.
	Vegetation	Limited to nearshore upland vegetation.
	Fauna	Terrestrial fauna excluding aquatic birds and shorebirds.
	Special features	Islands.
Aquatic Ecosystems	Water & substrate	Water quality, water quantity, and substrate.
	Flora / wetlands	Wetlands and phytoplankton.
	Aquatic fauna	Zooplankton, benthic invertebrates, fish, and semi-aquatic species (e.g., amphibians, reptiles, waterfowl, shorebirds, etc.).

The report looked at how these VECs have changed over time and what role Great Lakes commercial navigation has played in these changes. There is no doubt that human development within the Great Lakes St. Lawrence Basin has dramatically altered, and indeed, degraded the original natural ecosystems. What exists now is different from what originally existed; however, the natural systems have evolved – adapting to the human induced stressors. The resulting environmental condition still represents a significant and valuable ecosystem that is a major supporter of the ecological web of eastern North America.

The current ecosystem in the GLSL System has been altered but is still very valuable.

A system as large as the GLNS, carrying the volumes of traffic that it does, inevitably has an impact on the surrounding environment. Yet navigation is only one of the factors influencing the evolution of the regional environment. To understand what factors have contributed to the decline in quality of the environment, a series of stressors were selected and evaluated against each of the VECs. A stressor is an agent, condition, or other stimulus that causes stress to an organism or a system and can change the condition of a VEC. Only stressors that affect VECs that are also likely to be influenced by navigation related activities were considered.

Stressors were grouped into three main categories: Global (climate change), Non-navigation related, and Navigation related. The sensitivity of the system to each stressor was evaluated by the GLSLS environmental study team considering the area and temporal extent of the stress and the degree to which the effects can be reversed through management actions. Stressors with a local effect were considered less critical than those with regional or system-wide effects. Similarly, stressors with effects that are of a short duration were judged less critical than those with medium or long-term effects. Finally, stressors were examined to determine their reversibility. Those negative effects that were judged to have a high potential to be reversed by management actions were of less concern than stressors with effects that were more difficult to reverse. This approach provided a snapshot of the potential cumulative effects of the key stresses on the system.

Evaluation of key stressors and how they impact ecological functions in the region is important to projecting the future of the identified VECs. The Environmental Appendix of the 2007 GLSLS study report provides a view of what may be expected in the future without major changes in the navigation system by looking at expected stressors and their importance to the identified VECs. The following array summarizes the sensitivity ranking and aggregate ranking used in Table 17 on the next page.

Areal Extent	Temporal Extent	Reversibility
1 – Local	1 – Short (months)	1 – High degree
2 – Regional	2 – Medium (years)	2 – Medium degree
3 – System wide	3 – Long (decades)	3 – Low degree

Aggregate Rank	
High	8-9
Medium	5-7
Low	3-4

Table 17 - Stressor Sensitivity Analysis

Sensitivity Rating Key

Areal Extent	Temporal Extent	Reversibility
1 – Local	1 – Short	1 – High
2 – Regional	2 – Medium	2 - Medium
3 – System	3 – Long	3 - Low

Class of Stressor		Stressor	Areal Extent	Temporal Extent	Reversibility	Sensitivity Rating						
						Low		Medium			High	
						3	4	5	6	7	8	9
Global	Climate Change		3	3	3							9
Non-navigation related	Development and Land Use	Water withdrawal & diversions	3	3	3							9
		Introduction & transmittal of NIS	3	3	3							9
		Air emissions	3	3	2						8	
		Industrial / municipal effluent	2	3	2					7		
		Solid waste disposal	1	3	3					7		
		Landscape fragmentation	2	3	2					7		
		Runoff	2	2	2				6			
		Shoreline alteration / hardening	1	3	2				6			
		Noise & vibration	1	3	2				6			
		Erosion and sedimentation	1	2	2			5				
	Water Based Recreation and Tourism	Introduction & transmittal of NIS	3	3	3							9
		Shoreline alteration / hardening	1	2	2			5				
		Waste disposal / pollution	1	2	1		4					
		Erosion and sediment re-suspension	1	2	1		4					
		Wildlife conflicts	1	1	1	3						
Navigation related	Channel and Port Maintenance	Channel modification	1	3	3					7		
		Dredged material placement	1	3	2				6			
		Shoreline alteration / hardening	1	3	2				6			
		Maintenance dredging	1	2	2			5				
	Water Management	Water management for all purposes	3	3	2						8	
	Land Based Support Activities	Infrastructure development	1	3	3					7		
		Facility maintenance	1	3	2				6			
		Uncontrolled releases	1	2	2			5				
	Ship Operations	Introduction & transmittal of NIS	3	3	3							9
		Ship's air emission	2	3	2					7		
		Biocides (Antifouling)	1	3	2				6			
		Accidents / spills	2	2	2				6			
		Noise & vibration	1	1	3			5				
		Waste disposal	1	2	2			5				
		Prop wash, surge and wake	1	2	2			5				
		Cargo sweeping	1	2	1		4					
		Groundings / anchoring	1	1	1	3						
		Wildlife encounters	1	1	1	3						
	Ice Breaking		2	2	2				6			

5.7 Global and Non-Navigation Related Stresses

Eighty-three percent of the global and non-navigation related stressors are in the high to medium category with the most influential being: Climate change; Water withdrawal and diversions; Introduction and transmittal of NIS (through both development and recreation); and Air emissions.

Most non-navigation related stressors will act synergistically or cumulatively with other stressors affecting aquatic ecosystems. For example, the impact of urban air emissions will be compounded by emissions from ships hotelling in ports although the contribution of ships' emissions to the overall problem of air quality is relatively minor (and the use of waterborne commerce rather than other modes of transportation may reduce transportation related emissions). Similarly, while introduction of NIS intentionally or accidentally through recreational fishing, aquariums or the horticulture industry is a serious problem, the current perspective is that for the aquatic system, NIS introduction through ballast water discharge is probably the most important stressor.

Global Climate Change

Because water levels and temperature are so critical to ecological processes in the Great Lakes St. Lawrence Basin, discussion of the effects of global climate change is important to any consideration of environmental conditions. While no one can be absolutely certain as to the state of the lakes come mid-century, most scientists that have studied regional and global climate agree that global warming, spurred by increases in atmospheric carbon dioxide, is a bellwether of a changing global climate. If uniform global warming does occur at an accelerated rate, the likelihood of reduced runoff due to evapotranspiration and less basin-wide rainfall, along with greater evaporation of lake water (especially during the winter season), becomes more plausible. This would translate to lower lake levels basin-wide to varying degrees on each lake.

While global environmental change suggests a large-scale, single phenomenon, it is actually due to the effects of many forms of disturbances of different types, modes of action, and ecological outcomes. The following are some predicted impacts of global climate changes.

Water level rise or fall in the Great Lakes and the St. Lawrence River, depending on the scenario, will mainly affect wetlands and coastal/riverine habitats. Any permanent lowering of water levels on the lakes and rivers in the Basin may reduce the size, complexity, and accessibility of some wetlands. In other places, it may result in the opposite: deeper areas may become shallow enough to support the development of wetlands. Depending on the topography of the region, this may result in an increase or a decrease of the total wetland surface and quality.

Increased air and water temperature may reduce the available habitat for species that have their southern limit in the Great Lakes Basin. Conversely, species that have their northern limit in the Basin may see increased habitat availability. Higher water temperatures reduce the solubility of oxygen in the water column, and will increase the metabolic activity of many aquatic organisms typical of temperate regions.

Higher air and water temperatures may also delay ice formation and ice break up may happen earlier throughout the Great Lakes St. Lawrence River Basin. Reduced ice cover increases heat loss and evaporation. Less ice may impair species that need ice such as burbot and Atlantic tomcod, or mammalian species that rely on ice-cover for winter travel and dispersal.

Regardless of the climate scenario that would cause such conditions, there would be dramatic ecological and systemic impacts caused by any drastically lower Great Lakes water levels, especially if they occur in a relatively short period of time. The magnitude, nature, and timeframe of these changes will dictate the evolution of the ecosystem and the impacts to the biotic system of the Great Lakes-St. Lawrence System.

Non-Navigation Related Stressors

The four stressors that scored the highest (8 or 9) in the non-navigation group include water withdrawal and diversions, non-indigenous invasive species (NIS), and air emissions.

Water withdrawals or diversions would primarily affect the ecosystem by changing water levels. The impacts of these changes have been discussed in the previous section. Secondary impacts could result from connecting previously unconnected watersheds and introducing new species.

NIS introduction from non-navigation sources are a serious concern in both the transport of goods and in recreational activities. Terrestrial and wetland species are often introduced via air or overland transportation. Sometimes these species may be incidental to the cargo being hauled or may be intentionally shipped. For example the emerald ash borer is thought to have entered the U.S. with some air cargo. Other species like purple loosestrife have been brought in as landscape or water garden specimens and found success in the wild. One of the most feared potential invasive species to the Great Lakes is the Asian carp that were introduced to North America to aid in catfish farming operations but have escaped and are now moving close to the Great Lakes watershed through manmade connections to the Mississippi drainage basin. The high score given to the recreation and tourism reflects the threat posed by the transport of aquatic NIS when boats are moved from one area to another.

Air emissions from non-navigation sources were also identified as stressor of concern. These releases impact air quality in terms of human health, distribution of contaminants, and greenhouse gasses that affect climate change. Most releases result from industrial activities (including power generation) and transportation. Ground transportation (rail, truck and car) is responsible for the majority of transportation related emissions.

Navigation Related Stressors

As expected, most interactions of navigation related stressors are with the aquatic ecosystem; 11% of the stressors rank in the high category; and 83% of the stressors rank in the high to medium category. The 5 stressors of greatest concern (those with scores of 7 or more) are: Channel modification; Water management; Infrastructure development; Introduction and transfer of NIS; and Ships’ air emissions.

While these stressors are of greatest concern from an overall perspective, other stressors have serious implications at local or regional levels and their impact should be addressed at the appropriate scale.

Channel and Port Maintenance

Channel Modification, Dredging and Dredged Material Placement Impacts related to dredging activities include:

- turbidity, reduced light penetration, and increased suspended particles;
- re-suspension of contaminated bottom materials and release of toxic materials, nutrients, gasses and oxygen-consuming substances;
- floating scum and debris;
- impacts on fish and fish spawning habitat;
- removal of important benthic organisms;
- increased water velocity that acts as an impediment to movement of organisms;
- altered water flow in wetlands and loss of submergent wetland habitat; and
- decreased water velocities in areas outside of the navigation channel with associated sedimentation, plant and algal growth and potential eutrophication and anoxic events where fertilizer loads are high.

The placement of dredged material brings its own suite of impacts depending on the method of placement. Terrestrial placement can result in odor, dust, and reduced air quality. Ground and surface water quality also may be affected. Placement in wetlands is of particular concern. Effects could include animal disturbance or displacement, changes to surface water quality, discharge of fine particulate matter, sedimentation, burial of organisms, release of toxic substances, loss of productive habitat, and spread of invasive species. There may be some beneficial effects, particularly where highly altered sites such as abandoned quarries are used. Here new habitats could be created through beneficial use of dredged material.

Open water and in-water confined placement have their own impacts including altered currents and water flow, siltation, increased turbidity, releases of toxic materials, burial or displacement of organisms, loss of spawning or rearing habitat, and spread of NIS. It should be noted that the most severe impacts are associated with new channels or enlarging existing channels. The impacts of maintenance dredging are far less significant.

Water Management

Management of water flows and levels for navigation and power production have certainly had the most dramatic effect on the St. Lawrence River and have had lesser effects on the Great Lakes. The most dramatic impact occurred when the St. Lawrence Seaway was completed and flooding of the International Section of the St. Lawrence and the Soulanges Rapids resulted in the loss of spawning and wetlands habitat. The reduction of seasonal water level fluctuations for power production, navigation and other factors (such as in the case of Lake Superior, Lake Ontario and Lake St. Francis), continues to have a significant effect on shoreline wetlands.

Flooding and drying cycles are important for perpetuating wetland diversity and the habitats of wetland dependent species.

Land Based Support Activities

There are a variety of impacts that relate to infrastructure development, facility maintenance, and uncontrolled releases. The construction of the major ports, numerous minor harbors and countless marinas and launching facilities has had major individual and cumulative impacts. These include:

- loss of or serious modifications to terrestrial and aquatic habitats important to breeding, spawning and rearing;
- loss of staging areas for migratory species;
- hardening and other alterations to shorelines that affect coastal processes;
- release of nutrient, toxic and noxious substances into local air and watersheds as a result of construction and operations; and
- noise, traffic, and other social impacts to local communities.

Water flow patterns that have been permanently altered because of land development can drastically affect the local aquatic environment through changes in water quantity and water quality. Routine repair and maintenance activities perpetuate many of these impacts. Expansion or replacement of inter-modal connections has generated construction-related impacts and long-term impacts such as habitat fragmentation and removal. Shoreline hardening and modifications can destroy riparian communities and alter near shore aquatic habitats. Air quality suffers from industrial and transportation related emissions, dust and other particulate matter. Soil and groundwater contamination can result from uncontrolled releases such as from bulk storage. Both terrestrial and aquatic fauna can be displaced or disturbed and habitat destroyed.

Ship Operations

Ship operations have both direct and indirect impacts. Examples include:

- larval or adult fish propeller entrainment;
- physical impacts to plants or shorelines due to passing vessels (wake and wash);
- crushing/scraping of bottom-dwelling aquatic organisms;
- increases in river current velocity, return currents, or drawdown;
- pressure changes and shear stresses associated with the propeller jet as well as shear stresses on the bed sediments beneath the vessel and extending to the channel borders and backwaters;
- impacts of vessels in turning basins or fleeting areas where, for example, turning propellers or dragging anchors might mechanically disrupt sediments.
- suspended sediment effects on plant growth and mussel physiology;
- sediment deposition into backwaters and secondary channels;
- reduction or loss of spawning or over-wintering habitat through sedimentation;

- the effects of velocity changes on the movement of organisms;
- disturbance induced population declines; and
- effects of shifting commerce between waterborne and land-based modes.

Regardless of whether they are direct or secondary impacts, ship operation has been a stressor. In the St. Marys River, for example, wetland and spawning habitat loss, shoreline erosion and habitat degradation have resulted from increased current speed, wave action, erosion, and turbidity, partially caused by vessel passage. Traffic by large vessels has affected the survival of lake herring eggs due to excessive wakes and turbulence. Shearing stresses on the bed sediments can result in loss of benthic organisms and re-suspension of contaminants.

Ship operations have had impacts on shoreline and channel erosion and corresponding loss or damage to coastal wetlands. Water pollution has resulted from incorrect disposal of sewage and solid waste and from accidental and deliberate release of fuel, oils, hydraulic fluids, and bilge waste. Ships in port have exacerbated already poor air quality in many port cities by releasing high concentrations of Sulphur Dioxide (SOx), Nitrogen Oxide (NOx), and Carbon Dioxide ($CO_{2)}$ from “hotelling” practices and the burning of poorer quality fuel. The use of antifouling paints has resulted in the release of TBT with particularly high concentrations found in harbors. Cargo sweeping, the act of flushing decks and cargo holds before and after loading, has resulted in the introduction of a wide variety of materials.

Habitat disturbance results from heavy wake action and propeller motion causing hydrodynamic disturbances. Nesting waterfowl are particularly sensitive to ship wake. Noise has a known effect on wildlife and marine mammals but little is known about the effects of noise on other aquatic organisms. Noise has a disturbing or displacing effect on nesting birds, and vibrations, while poorly understood, are known to affect mollusks and other benthic organisms. Fish displacement or heightened activity in winter months can be harmful. Accidents and spills, while relatively infrequent, can have a long term and spatially extended impact.

The introduction of NIS is perhaps the single largest ecological impact of the development of the Seaway. The total number of non-native aquatic species established (meaning reproducing) in the Great Lakes system is at least 183 (M. Hoff, pers. comm.) during the past two centuries. NIS threats exist from intentional introductions to the region through aquaculture, live fish markets, sport fishing, pet trade, bait fish, and garden plants, as well as from accidental introductions through such mechanisms as ballast water discharge by ships or transfer between basins (e.g., Mississippi and Great Lakes Basins). Approximately 75% of the invasive species introduced into the Great Lakes since 1970 are attributed to ship ballast water discharges. The number of ships carrying ballast bound for the Great Lakes have declined throughout the 1980s and 1990s, and vessels that declare no ballast on board (NOBOB) now account for approximately 90% of the inbound traffic of the Great Lakes. There is evidence that the total abundance of taxa arriving in the Great Lakes is orders of magnitude lower for both NOBOB ships and ships carrying exchanged ballast water (saltwater) than for those ships that did not exchange ballast water.

Ice Breaking

Ice cover plays a major role in the physical and biological processes of northern freshwater systems. The ice that forms in early winter protects the near shore zones of the rivers and lakes. The shores would otherwise be severely eroded by waves generated by violent winter winds. The opposite occurs at the end of winter; drifting ice during break-up transports sedimentary material and erodes near shore zones and shallow areas. Ice cover also provides an important pathway for wildlife movement across water bodies. Ice breaking can upset these important processes and can directly affect mammals by blocking their movements across the ice. Ice breaking activities can also increase propeller wash and drawdown and surge waves, dislodge or destroy aquatic vegetation and benthic organisms and disturb or induce abnormal activity in resting fish. The activity can alter migratory waterfowl habitats and their use by over-wintering birds.

5.8 Expected Future Conditions of VECs (Without Project or Baseline Condition)

Air Quality

As industrial growth continues in the Basin, emissions may also grow despite improvements in emission controls. Although overall emissions in the Basin may increase, most transportation-related emissions are expected to decrease. Environment Canada predicts the following changes in the transportation sector's and marine sector's contribution to specific emissions to the year 2015 over 1990 levels (Environment Canada 2005; 2006):

Transportation Sector	Marine Sector
• Total particulates – 49% decrease	Total particulates – 3% decrease
• SOx – 73% decrease	SOx – 9% decrease
• NOx – 52% decrease	NOx – 3% decrease
• VOC – 63% decrease	VOC – 11% decrease
• CO – 48% decrease	CO – 3% decrease
• NH_3 – 120% increase	NH_3 – 18% increase

The rate of decrease in emissions is anticipated to be significantly less for the marine sector than the overall transportation sector. Marine transportation represents almost 40% of SOx emissions, mainly due to the relatively poor quality of marine fuel compared to fuels for other modes of transportation. Marine emissions are derived from emissions while under power and emissions during hotelling. Rising air temperatures resulting from the effects of climate change will exacerbate poor air quality regardless of the source of pollutants.

5.8.1 Terrestrial VECs

Soil and Ground Water

Soil and ground water quality throughout the Basin will continue to deteriorate as further development pressures build although the rate of deterioration will slow because of the greater attention paid to the management of environmental impacts. A general warming trend and shifting precipitation patterns resulting from climate change will put greater pressures on ground water supplies.

Vegetation

The deterioration of nearshore upland vegetation will slow as environmental management systems and impact mitigation measures improve. Non-native invasive species will continue to colonize disturbed areas and will likely further dominate the landscape. Increasing air temperatures will extend northern and southern ranges northward.

Fauna

Terrestrial habitats will continue to be pressured by development and resulting fragmentation resulting in further loss of viable wildlife populations, changes in species numbers and assemblages, and reduction in breeding and rearing success. Intensification of land use will continue to produce noise and other disturbances resulting in displacement or elimination of many native wildlife species. Increasing air temperatures will extend northern and southern ranges northward. Reduction in ice cover may impair species that rely on ice for travel and dispersal.

Special Features – Islands

Islands will continue to provide important habitats for fish and wildlife populations. Nesting colonial birds and migratory species will continue to rely on islands. Future development pressure will have an impact on these populations. Island ecosystems, particularly in narrow channel areas, are vulnerable to the effects of noise and erosion from passing vessels. If there are increases in vessel transits, or increased winter navigation and/or supporting ice breaking activities, increased impact on these ecosystems can be anticipated. Impacts from rare spills and regular leakage of petroleum products will continue to contribute to the degradation of island ecosystems.

5.8.2 Aquatic VECs

Water and Substrate

Water quality will likely continue to improve as standards of treatment and level of regulation increase. If there are increases in ship traffic and facility infrastructure, then these improvements may be dampened or reversed. Negative impacts on water quality will often be relatively short lived and localized in nature. Compared to urban, industrial, and agricultural contributions to water quality degradation, impacts from navigation are relatively minor and localized.

Table 16 is a compilation of the range of potential future water level declines in the Great Lakes over the next 50 years under four future climate scenarios. If such declines occur, they are likely to be the single greatest challenge facing future GLNS management. It is not possible to develop a meaningful estimate of the potential decline of Lake Ontario's water level because the existing plan for regulation of the Lake's outflow can not accommodate the change in water supply to the Lake that would occur.

Table 18 - Potential Water Level Declines over the next 50 years.

Water Body	Decline from "Base Case"	
	Centimeters	Inches
Lake Superior	11-36	4-14
Lake Huron and Lake Michigan	26-112	10-44
Lake St. Clair	20-96	8-38
Lake Erie	14-81	5-32

From the November 2007 *GLSLS Study Environmental Team Report*

While global environmental change suggests a large-scale, single phenomenon, it is actually due to the effects of many forms of disturbances of different types, modes of action, and ecological outcomes. The following are some expected impacts of global climate changes.

- The different climate change scenarios predict a reduction of the net water supply to the Great Lakes Basin and the St. Lawrence River by 4 to 24%. While water levels will likely trend lower, there will continue to be greater cyclical fluctuations around this trend. This could also lead to longer drought periods, more storms, and more severe weather events. Changes in water level will probably be greatest in Lake Michigan – Lake Huron, where the water level may decrease by 26–112 cm (10–44 in), and least in Lake Superior where the decrease may be 11–36 cm (4–14 in). Though not necessarily linked with climate change, water levels variability in Lake Ontario could have a dramatic impact downstream. If the outflow of Lake Ontario was modified to cause a rapid 2 cm (0.79 in) increase or decrease in Lake Ontario's level, the change in outflow would cause a 30-centimetre (11.8 in) change in Lac St. Lawrence and a 23-centimetre (9.0 in) change in Lac St. Louis for a few days (International Lake Ontario - St. Lawrence River Study 2005).

- Sea level rise in the Atlantic Ocean and the Gulf of St. Lawrence would result in an increase of the water level in the St. Lawrence riverine estuary.

- Increasing air temperature would transfer part of the thermal energy to the water resulting in higher water temperatures which, in turn, would reduce the solubility of oxygen in the water column.

- Impacts related to declining water levels can be especially severe on the commercial navigation community. Lower water levels will necessitate reduced draft which, in turn, means lower tonnage. This drives up per-unit costs for raw materials which, in turn, increase prices on finished products. If water levels decline significantly, some infrastructure will lose effectiveness or become damaged. Seawalls may collapse; municipal water intakes will become more vulnerable to drawing in contaminated water as they are closer to the water's surface; docks may become too high for convenient access by vessels; and harbors may become inaccessible to deeper draft watercraft. Recreational use of shallow (non-dredged) marinas would decrease.

Substrate quality is likely to show improvement in the future as pollution control efforts continue and less contaminated sediments cover older sediments. Site specific clean-up efforts will also result in improvements at select locations.

Flora and Wetlands

Algal blooms including toxic cyanobacteria blooms are likely to increase in shallow, low flow areas because of higher temperatures, nutrient loads, and low water levels. Phytoplankton communities will continue to be affected by changes in nutrient concentrations and NIS. Wetlands have already been seriously reduced and degraded throughout the system. The effects of future incremental impacts will ripple through the rest of the biotic and nutrient systems. Wetland volume will likely continue to be pressured although wetland protection policies have slowed the rate of loss. Diversity is likely to decrease because of increased nutrients and the spread of NIS. Water level changes in the Great Lakes and the St. Lawrence River, would mainly affect wetlands and coastal/riverine habitats (see wetlands). Depending on the topography of the region, this may result in an increase or a decrease of the total wetland surface and quality.

Aquatic Fauna

Increased water temperatures would increase the metabolic activity of many aquatic organisms typical of temperate regions. This mechanism, combined with the lower oxygen content of the water, may lead to increased occurrence and intensities of hypoxia events.

Aquatic organisms will continue to be affected heavily by navigation and non-navigation related activities. Reduced ice cover increases evaporation. Less ice may impair species that need ice such as burbot and Atlantic tomcod.

While the full range of navigation related activities will negatively affect aquatic organisms, the introduction of NIS, and the effects of erosion and shipping activities in narrow channels and harbors will have the most dramatic effects. Aquatic organisms may be increasingly affected if ship traffic increases. NIS already introduced will continue to spread and will continue to alter the aquatic community structure and function. Continued operation of the system will undoubtedly lead to additional introductions.

Ecological changes can be generalized to include:

- significant changes in shoreline communities;
- increased water temperature particularly in Lake St. Clair;
- flourishing aquatic plants; and
- a negative shift in fisheries in shallow lakes.

There would be dramatic ecological and systemic impacts caused by drastically lower Great Lakes water levels, especially if these occur in a relatively short period of time.

5.9 Conclusion

A series of VEC Summary Sheets summarizing past trends, potential future impacts, navigation contributions, and mitigation options for key VECs most likely to be influenced by navigation are found in Attachment 1 to Chapter 8 of the Environmental Appendix to the bi-national 2007 GLSLS study report.

The GLSLS is quite vulnerable to the stressors identified and significant management adjustments are likely to be needed to result in appreciable gains in environmental quality. Organizational and governance frameworks appear to be adequate for the management and control of navigation related activities that have a negative impact on the environment. However, urgent efforts are needed in the areas of research and development of new technologies. New and innovative protection measures are needed to guard against further ecological deterioration from navigation related stressors. Environmental management systems are needed in many areas. Rigorous monitoring of shipping practices and enforcement of regulations will be an important part of any future impact reduction strategy.

Impacts related to planned works such as maintenance of infrastructure, maintenance dredging, and disposal of dredged material will continue. Water level issues will likely result in pressure for more dredging and suitable dredged disposal sites will become increasingly scarce. Maintenance of infrastructure occurs in disturbed areas and often in confined areas such as locks. Impacts associated with this type of work will continue but are expected to be minimal.

Environmental trends, such as wetland loss, may be exacerbated by climate change effects. Shallow and narrow channel areas will feel the impact of lower water levels more intensely. Impacts related to vessel passage will continue, with the severity of impacts directly related to traffic volumes, and vessel speed and size. Management of ballast water and the control of the introduction and transmittal of NIS will continue to be a major focus of attention. As technological solutions are found, the rate of introductions is likely to decrease although transmittal concerns will remain. More rigorous control of practices leading to pollution from liquid and solid discharges from vessels will be required. Greater control will be needed on air emissions.

The evaluation of whether to promote waterborne transport must not be limited to a simple projection of potential impacts. These impacts must be balanced against those resulting from alternative modes of transportation. Despite the list of continuing negative impacts Great Lakes navigation may cause, when compared to overland transport of goods, the GLNS may provide a means of minimizing the overall environmental impacts of moving goods in the region.

6. Plan Formulation

Plan formulation is the process of combining various management measures into comprehensive water and related land resources alternative plans of action that meet the goals defined in the study authorization. The study objective is to formulate alternative plans that respond to national, regional and local objectives and resolve identified problems, meet commercial navigation needs and facilitate opportunities.

National and Regional Objectives

The national or Federal objective of water and related land resources planning is to contribute to national economic development (NED) consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal Planning requirements. Contributions to NED include increases in the net value of the national output of goods and services, expressed in monetary units.

The Corps has added a second national objective - Ecosystem Restoration - in response to legislation and administrative policy. This objective is to contribute to the nation's ecosystems through ecosystem restoration, with contributions measured by changes in the amounts and values of habitat.

Public Interest and Stakeholder Engagement

The public is interested in consideration of measures to satisfy recreation opportunities, minimizing water quality degradation, and making special efforts to preserve the environment of the Great Lakes basin. However, the general public is often not aware of the issues, challenges and disadvantages that face the commercial shipping industry. Thus, unless there are forums to make shippers accessible to stakeholders and the public (and vice-versa), the navigation system may not garner support when trying to push for modifications to the system to support their industry.

Environmental interests are concerned when they hear about potentially larger facilities and the prospective effects these facilities could have on the surrounding environment. However, since publication of the Corps' 2002 Reconnaissance Report, the bi-national GLSLS report study team has focused on the establishment of a "Baseline Condition" for the GLNS that assumes no expansion of the system will occur. Since that change of focus, the environmental concerns have not generally opposed the continuation of this work.

Also, navigation-induced shore erosion and flooding are major concerns of shoreline property owners. Terminal and transfer facilities are a concern of the study, since some vessels would likely require modifications of present operating procedures. Railroads and other alternate modes of transportation are interested since they could be affected by future action on the Great Lakes system. The most productive use of the GLNS is a mutual concern of both Federal and State agencies. International interest results from the international traffic moving on the Great Lakes.

A number of Federal, State and local agencies, academic institutions, and citizens groups have expressed interest in the bi-national GLSLS and concurrent Supplemental GLNS studies and participated in the development of the system analysis. Initial input was formally solicited on January 17, 2001, on the scope of the GLNS reconnaissance study. Comments were received from Government agencies and a wide variety of users, stakeholders, and other private interests concerned with the Great Lakes and St. Lawrence Seaway system. In addition, a web site http://www.lre.usace.army.mil/greatlakes/greatlakes&st-lawrenceseawaystudy/approvedreconnaissancereport/ for the GLSLS study was created to facilitate the sharing of information about the study. Further, stakeholder engagement undertaken by the St. Lawrence Economic Development Council (SODES) and the Great Lakes Commission (GLC) was designed to maximize stakeholder access to the process, and to fairly and accurately transmit stakeholder input to study management for consideration in their final products.

SODES and GLC sought to:

- Identify stakeholders with an interest in the study;
- Set up points of contact for the stakeholder engagement: SODES for Canada and the GLC for the United States;
- Issue a call for briefs to all stakeholders, along with a "GLSLS Study Background Document" prepared by the Study Management Team;
- Organize public meetings;
- Forward any information deemed important or relevant to the Study Management Team;
- Produce a final report presenting the outcome of the process and assessing its success.

The stakeholder meetings and the call for briefs sought to:

- Gather information and expertise from public and private sector stakeholders, especially as it relates to marine transportation and commercial navigation on the Great Lakes St. Lawrence Seaway system.
- Establish a forum for dialogue and information exchange on the study with interested parties from the following sectors:

    - o Marine transportation sector
    - o First Nations / Tribes
    - o Industrial groups
    - o Environmental and coastal management groups

    - o Municipalities
    - o Universities and research institutes
    - o Commercial entities
    - o Recreational boaters
    - o Other interested parties

- Solicit stakeholder comments and views on the study's objectives and work scope.
- Document and transmit the findings and results of the stakeholder meetings to the Management Team and working teams so that the information and opinions gathered can be processed by the study partners.

Approximately 500 organizations were contacted to participate in the stakeholder meetings and encouraged to submit briefs, position papers and comments on the GLSLS Study's context, objectives and work scope. The five main meetings were held as follows:

- June 3, 2004 Montreal, Quebec
- June 8, 2004 St. Catharines, Ontario
- June 15, 2004 Duluth, Minnesota
- July 6, 2004 Clayton, New York
- July 14, 2004 Chicago, Illinois

More than 400 individuals attended at least one of the public sessions. The number of participants at each meeting (presenters, observers, etc.) is:

- Montréal: 32
- St. Catharines: 18
- Duluth: 33
- Clayton: more than 300
- Chicago: 41

73 formal presentations were made at the meetings and a few dozen more individuals made comments and asked questions of the Management Team. Formal presentations numbered:

- Montréal: 6
- St. Catharines: 7
- Duluth: 9
- Clayton: 26
- Chicago: 25

The facilitators also received 32 written submissions, for a total of 105. A full description of these meetings including specific stakeholder input can be found in the SODES/GLC February, 2005 Stakeholder Engagement document for the Great Lakes St. Lawrence Seaway Study.

The bi-national Study Committee felt that the stakeholder engagement process was fair, open and allowed full opportunity for all stakeholders in the Great Lakes St. Lawrence Seaway system to provide input to the development of the major focus areas (Economic, Environmental and Engineering), and the overall content of the study. The briefs submitted and reported in the SODES February, 2005 Stakeholder Engagement document represents a wide range of interests in and relationships to the GLSLS. In submitting the information to the working groups and management, it was the intent of the stakeholder engagement facilitators to transmit this input as objectively and comprehensively as possible. Study Management stressed its serious involvement as the Study moved forward, and incorporated elements where appropriate in the final study product. Study management encourages continued access by stakeholders to the process through ongoing communication and dialogue.

The binational GLSLS study management team then produced a May 2005 *Response to the Report on Stakeholder Engagement* document that categorized stakeholder comments and concerns into broad categories of similar topics under Engineering (infrastructure), Environmental or Economic concerns. Even though worded differently, or regarding a specific area of the System, many comments and concerns had like interests that could be addressed through a specific response.

Overall, many of the overarching concerns were discussed in the *Response Report*. Responses indicated either that the concern was already in the process of being included in the bi-national study; being included or expanded because of the amount of stakeholder concern; not being addressed by the Study because the concern was beyond the scope of the current Study; or is addressed elsewhere in another study or research publication. Some comments suggested changes that could only be accomplished through legislative action.

However, many suggestions were incorporated into the Study by expanding discussion in a topic area that was not planned to be discussed, or not nearly as in depth. The study team reviewed the stakeholder questions and concerns and incorporated answers and information into the Study to address these concerns whenever possible. Two follow-up workshops with stakeholders were held in September 2005 (Quebec City and Cleveland) to discuss the May Report. Those who attended expressed satisfaction in the Response Report and continued support for the study.

6.1 Problems and Opportunities

Continuing growth in international trade, regional population, economic activity, and highway and rail traffic will eventually increase congestion in the bi-national transportation network that serves the Great Lakes and St. Lawrence basin. With additional capacity available, the GLNS can help to relieve some of the pressures on landside corridors by expanding into container service and short sea shipping to provide new intermodal services, particularly around road and rail bottlenecks. By addressing the stated preferences of the shipping industry and deploying the right kinds of new vessels, companies operating on the GLNS can improve their intermodal competitiveness and make significant new contributions to regional transportation needs in the near future.

6.1.1 Problems

Understanding the diverse problems, needs and existing conditions associated with the Great Lakes commercial navigation system and the economic, social and institutional systems that interact with it establishes a guide to the formulation of alternatives that address these problems and needs. **While many of the problems and needs listed below vary in intensity according to geographic areas, there are two primary issues that form the basis for problem analysis in this study. These are the needs that arise from the commercial fleet's desire for economic optimization; and the potential impacts on the existing environmental, social and institutional systems that could result from those modifications necessary to meet the demands of the commercial fleet.**

The problems and needs of the various components of the system, which were identified during the development of the 2002 Reconnaissance Report, and refined during the development of the bi-national study, are summarized by major navigational feature.

Commercial Navigation Problems

a. Capital investment required to transform vessels or build new.
b. Vessel maintenance costs.
c. Backlog of shoal material/shallow channels/low lake levels
d. Safeguards to avoid spills of oil and other hazardous substances.
e. Navigation during fog, high winds, and ice congested channels.
f. Vessel traffic and speed control.
g. Historic and cultural resources impacted by or influencing navigation.
h. Potential disruption of fish and wildlife habitat.
i. Conduit for Invasive Species;
j. Potential for increased shoreline damage.
k. Lack of sites for dredge material placement.
l. Potential bottom scouring and resuspension.
m. Potential recreational boating effects and associated recreation activities in the channels.
n. Potential social effects on channel residents.
o. Potential damage to shore structures.
p. Deterioration of navigational infrastructure.

Harbor Problems

a. Ramifications of vessel size in relation to vessel handling and control;
b. Operation of loading and unloading facilities;
c. Capital investment of others needed to handle new vessel types or sizes;
d. Potential shore erosion and shore structure damage;

e. Water quality, vessel waste discharge and turbidity;
f. Safeguards to avoid spills of oil and other hazardous substances;
g. Interfacing new vessel types with other transportation modes;
h. Inadequate channel and turning basin depth;
i. Potential bottom scouring and resuspension of sediments;
j. Potential disruption of fish and wildlife habitat;
k. Potential air pollution;
l. First costs and the operation/maintenance costs of the modifications;
m. Potential effects on littoral transport, both on lakes and rivers.

Lock Problems

a. Relationship between existing and potential new vessel types and existing facilities;
b. Capital investment requirements for necessary facilities to support and handle new vessel types;
c. Traffic control and service requirements;
d. Effects and constraints of additional locks.
e. Maintenance costs.
f. Safeguards to avoid disruption of service from accidents in critical areas.
g. Potential social effects of modified or new lockage systems;
h. Potential economic impacts resulting from lock modification;
i Potential disruption of fish and wildlife habitat;
j. Requirements and contingency plans to handle hazardous material transport;
K. Lock crew safety;
l. Potential effects on employment;
m. Water quality, vessel waste discharge and turbidity;
n. Potential effects on recreational boating and associated activities;
o Potential air pollution;
p. Navigation during fog and high winds;
q. Lock wall icing and lock approach ice congestion;
r. Periods of low water levels.

6.1.2 Opportunities

a. To utilize newer, more energy efficient and environmentally-friendly vessels, through emerging use of containers to transport goods. Newer interlake container ships can be designed to be faster than traditional bulk carriers, and would remain more fuel-efficient in relation to land-based transportation;

b. To maximize existing vessel capacity and efficiency through optimal maintenance of connecting channels and harbors and to minimize vessel delays associated with deteriorating infrastructure;

c. To improve shipping efficiency by improving services to receiving harbors/ports within the Great Lakes St. Lawrence Seaway System.

d. To further reduce land-based traffic congestion and emissions through the employment of *short-sea shipping*;

e. To enhance aquatic and riparian habitat;

f. To assure adequate capacity in future years to continue disposal of dredged material without impacting navigation;

g. To minimize the environmental impacts of shipping goods by reducing transportation-related emissions and the introductions of invasive species.

6.2 Planning Objectives and Constraints

6.2.1 Planning Objectives

A set of planning objectives have also been developed based upon the water and related resource management problems, needs and opportunities identified for the Great Lakes region. The objectives listed below contribute to both the national and regional objectives for the economic life of the project.

(1) Contribute to the maintenance and efficient utilization of the GLNS infrastructure;

(2) Contribute to the economic efficiency of the nation by keeping transportation costs economical;

(3) Contribute to the maintenance of water levels and flows for the Great Lakes;

(4) Contribute to the quality of the Great Lakes St. Lawrence Seaway basin environment, giving particular attention to the ecosystem and water quality of the Lakes, and;

(5) Contribute to the prevention of NIS introductions.

6.2.2 Planning Constraints

Planning constraints are the technical, environmental, social, economic and institutional limitations within which the proposed alternative plans would be implemented. These include resources limitations, potential competitive use of scarce resources and legislative or regulatory restrictions. Planning constraints define the scope of alternative plans formulated. Constraints identified during the development of this study include:

(1) The limits for vessel size in terms of draft, beam, and length;

(2) The dependence of benefits of maintenance and/or improvements on the Great Lakes to that of the St. Lawrence Seaway;

(3) The ongoing reduction of available sites for dredge material placement from maintenance of channels and harbors, and the limited beneficial uses available;

(4) The legal and international aspects of enacting any modifications to the system's infrastructure.

(5) The interconnectivity and dependence of harbors on each other;

(6) The need to protect the ecosystem of the Great Lakes and St. Lawrence Seaway System.

6.3 Alternative Plans from the 2002 Corps' Reconnaissance Study

The alternatives presented in this section are the alternatives from the 2002 Corps' Reconnaissance Study of the Great Lakes Navigation System Review. They are listed to allow comparison between the plan formulation alternatives of the original reconnaissance report and this supplement.

(1). No Action (Without Project Condition)

This alternative would mean that the Corps would not participate in any additional development or adaptive management of the GLNS system, aside from continuing to address critical O&M needs of the system for the next 50 years, subject to any annual Corps budget constraints. This alternative assumes that the new Poe-sized lock at Sault Ste. Marie will continue development through construction. Further, this would not preclude Canada or other interests from making adaptive changes or conducting preemptive maintenance, as long as work in U.S. waters is approved through the Federal permitting process.

(2). Deepening the Great Lakes Connecting Channels

This alternative proposed to evaluate potential alterations to the Great Lakes Connecting Channels to include: modifications to improve existing infrastructure and modifications to the existing channels to accommodate deeper draft vessel traffic. The current maximum safe vessel draft for the navigation system is 25' 6" at Low Water Datum (LWD). Evaluation of deepening of the channel would include incremental depths from 25' 6" LWD to 35' LWD.

(3). Improvements to the St. Lawrence Seaway

This alternative proposed to evaluate potential alterations to the St. Lawrence Seaway to include: optimizing the navigation season, modifications to the existing channel to accommodate two-way traffic, modifications to the existing channels to accommodate deeper drafts, and lock expansion.

(4). Deepening Individual Ports

This alternative proposed to evaluate potential betterments to the ports and harbors within the Great Lakes system to include: modifications to improve existing infrastructure and modifications to the existing channels to accommodate deeper draft vessel traffic.

(5). Addressing Navigational Restrictions

a. Chicago Sanitary & Ship Canal

This alternative proposed to evaluate potential improvements to the waterborne trade between the Great Lakes and the Mississippi River through the Illinois Waterway. There are about 8,500 river barges that pass through the Cal-Sag Channel and the Chicago Sanitary and Ship Canal annually, en route to the several major ports, Burns Harbor and Indiana Harbor in Indiana and Calumet and Chicago Harbor in Illinois. These ports are served by barge on a year round basis and connect Inland Waterway destinations/origins providing a water mode service for Seaway commodities as well as domestic commodities. The Illinois Waterway barge traffic generally carries between 42 and 50 millions tons of cargo each year. This route has infrastructure limitations such as low bridge air draft, narrow channel and high traffic volume.

b. St. Clair River Ice Boom

This alternative proposed to evaluate potential improvements to the St. Clair River within the Great Lakes system. Navigation on the middle lakes of the Great Lakes can occur all year depending on winter conditions. Ice formation and breakup on the lakes and in the rivers can cause delays to navigation interests and flooding problems for riparian properties. One of the most problematic areas is the St. Clair River and its many channeled delta, and the jamming of large ice floes from Lake Huron. The problem could be reduced by the proper placement of an ice retaining boom across the head of the river. Ice booms have been found to be quite effective in controlling the movement of ice in the St. Marys River, in Lake Erie at the Niagara River, and in the St. Lawrence Seaway.

(6). Improved Water Level Data Access

This alternative proposed to evaluate potential improvements to water level data access within the Great Lakes system. Past, current and forecasted water level and flow data are an integral part of navigation of the Great Lakes, the connecting channels and the St. Lawrence River has been monitored extensively, resulting in a vast store of information. These data are collected, stored and disseminated by a variety of agencies in several ways. Improvements in access to these data by the navigation interests and some additional equipment installations could provide benefits to the navigation industry and improved safety to the Great Lakes, their connecting channels and the St. Lawrence River.

(7). Aids to Navigation

This alternative proposed to evaluate potential improvements to the Great Lakes system through replacing seasonal buoys with permanent beacons. Great Lakes waterways are currently marked mostly by lighted buoys which must be removed in the fall prior to the onset of ice, and reset in the spring after the thaw, even though commercial shipping extends several weeks past the fall withdrawals, and starts well before buoys can be placed in the spring. This practice increases risk to mariners and costs to shippers.

6.4 Review of Alternative Plans from the 2002 Corps' Reconnaissance Study

A "Preliminary Screening" of the alternatives was conducted in the 2002 report to evaluate whether enough benefit (Economic, Environmental and Engineering/Infrastructure) could be derived from the potential project to warrant further study (Feasibility phase). The array of alternatives that was listed in the initial Reconnaissance phase included all the above alternatives. It was concluded in the 2002 report that all of the listed alternatives justified further investigation in the feasibility phase.

6.5 Additional Corps Headquarters Input

As discussed in Section 4.2 "Headquarters Approval and Directives", Corps Headquarters in Washington, D.C. approved the GLNS Reconnaissance Report in a 13 February 2003 memorandum, but also required this Supplemental Report be prepared to specifically clarify the "Without Project Condition" and provide for additional public involvement and coordination. The Detroit District of the Corps was directed to define the current status of the GLNS including a projection of the evolution of the system for the next 50 years - without anything more than maintenance to keep the existing system functional.

6.6 Influence of the Binational Study on the Supplemental Recon

After the initiation of the Supplement, a joint Canadian/United States study (the bi-national *Great Lake St. Lawrence Seaway Study)* was begun in May 2003 following the signing of a Memorandum of Cooperation (MOC) between Transport Canada and the U.S. Department of Transportation (see section 4.4). The Corps involvement in the bi-national study took place as part of the development of this Supplemental Reconnaissance Report. The work was directed by a multi-agency Steering Committee which approved the bi-national GLSLS report in the fall of 2007.

In addition to providing an updated picture of the economic importance and physical condition of the navigation system, and how it is related to the ecosystem of the region, the study also made it clear that there was no bi-national interest in changing the physical dimensions of the locks on the St. Lawrence River and Welland Canal in the foreseeable future. Removal of this potential measure from options being investigated greatly diminished the concerns of many environmental advocate groups and significantly impacted the range of alternatives recommended for future study by the 2002 GLNS Reconnaissance Report.

The GLSLS Study concluded that the system remains an important element in the North American economy and for the system to be sustainable and optimize its contribution to the future transportation of goods; a strategy is needed to address its aging infrastructure. This includes lock systems and should include ports and their evolving linkages to other modes of transportation. Major observations presented in the GLSLS report include:

- The GLSLS has the potential to alleviate congestion on the road and rail transportation networks as well as at border crossings in the Great Lakes basin and St. Lawrence region.

- A stronger focus on shortsea shipping would allow the system to be more closely integrated with the road and rail systems, while providing shippers with a cost-effective, timely and reliable means to transport goods.

- The existing infrastructure of the system must be maintained in good operating condition in order to ensure the continued safety, efficiency, reliability and competitiveness of the system.

- The long-term health and success of the system will depend in part on its sustainability, including the further reduction of negative ecological impacts caused by commercial navigation.

Optimizing the role played by the GLNS within the transportation system of the Great Lakes Basin and St. Lawrence River region requires a holistic view of the entire system. Marine transportation must be integrated seamlessly with the other modes in terms of cost, time, frequency and reliability. To make this vision a reality, there are several aspects of modal integration that will have to be addressed. There need to be highly efficient intermodal linkages at the nodes of the system. The ports of the GLNS system must have suitable road and rail connections. They must also have the right kinds of equipment to move containers easily between vessels, rail flatcars and tractor-trailers.

Advancing the concept of marine intermodal services also requires suitable vessels adapted for different cargoes: bulk commodities versus containers or neobulk shipments. The routes traveled by the cargoes also need to reflect the potential advantages of waterborne transport. For example, shipping by vessel straight across a lake can be preferable to moving goods around its shore along congested roads. Apart from taking a faster, more direct route, it may also be the case that border procedures at the respective ports can be significantly faster than those at highly congested land crossings.

There are other factors which come into play in this area. There is a need for appropriate electronic tracking and communication to direct and monitor shipments. New technologies, improvements in traditional infrastructure, streamlined border crossing procedures and the harmonization of regulations will also be important in designing systems and managing the demands of enhanced interconnectivity across transport modes.

6.7 Specific Adaptations that Would Benefit the GLNS

Containerized Transshipment

MARAD (the Maritime Administration of the U.S. Department of Transportation) produced a January 2007 report that assesses opportunities for growth in "neobulk" (shipments which consist wholly of units of a single commodity, such as vehicles, lumber or scrap metal) and container traffic, considering the industrial future of the region, global markets and ship design. The report projects that the Gross Domestic Product of the North American region serviced by GLSLS will more than double by 2050, from $6 to $14 trillion, assuming that the region's economy will continue to diversify, with trade a more, not less important component.

The total market for containerized traffic is expected to grow from 35 to over 70 million FEUs[3] by 2050. This will be a problem, because 98% of containerized cargo now finishes its journey on a truck, and the growth in traffic will not be matched by a growth in road capacity, leading to greater congestion and longer transport times. This in turn is expected to reduce truck deliveries from 98% to 92%. Rail capacity is limited and will not be able to absorb the difference, but there is enough excess capacity in the GLSLS. At the same time, global containership traffic will be redistributed because of limitations of Pacific coast ports; about a third of the new container traffic that would have gone to west coast ports will now go through the Panama Canal or Suez Canal to east coast ports such as Halifax and Norfolk

This study did an in-depth market survey of 200 shippers in the U.S. and Canada and found that they would be willing to use water container services if they compared favorably to truck or rail in terms of time, cost and reliability. The fact that ships cannot sail on the Great Lakes during winter months was found not to be as important as had been thought, since intermodal traffic is reduced by 15-20% in the same post-Christmas time period each year.

[3] FEU is "forty foot equivalent" means containerized cargo equal to one forty-foot (40 x 8 x 8 feet) or two twenty-foot (20 x 8 x 8 feet) containers. One FEU equals about 25 metric tons or 72 cubic meters.

The question then was what exactly would the water container service alternative be, and could it meet the time, reliability and cost requirements of shippers? The report envisions three new market groups for shipping containers by the GLNS:

1. From Halifax and Montreal inland to ports like Hamilton, Ontario on Lake Ontario and Cleveland, Ohio, on Lake Erie. Expansion at Montreal is possible now; Halifax would have to wait until the change in global traffic delivers it more goods from Asia.

2 Intermodal service from the eastern half of the GLNS to the Midwest and far west, including ports such as Seattle and Vancouver using the Burlington Northern Santa Fe, Canadian National and Canadian Pacific rail lines.

3 GLNS Connector service in which Great Lakes ships would replace trucked shipments between ports.

The study looked at four types of ships that could carry this cargo (container barges, container ships designed expressly for the GLSLS, and two types of high speed freighters) and determined that container ships were best suited for these markets, initially using smaller (150-200 FEU ships that rolled the containers on and off) and later transitioning to larger, 300-400 FEU ships that relied on cranes to move containers between ship and dock[4].

The study plainly describes the critical assumptions behind its convincing case that the GLNS market could expand substantially, including the expansion of trade with Asia and the limited ability of rail, road and Pacific coast North American ports to service this demand. It is also clear about how the GLNS needs to change to realize this opportunity:

- Canadian (Halifax, Quebec, Montreal and Hamilton) ports have to collaborate with the port of Cleveland, Ohio and rail lines to establish an intermodal system, especially since the rail portion would provide all transport during the ice season when shipping stops.

- Similarly, the GLNS ports of Duluth, Thunder Bay, Detroit, Windsor, Toledo, Cleveland and Hamilton have to work with the Burlington Northern Santa Fe, Canadian National and Canadian Pacific rail lines to establish intermodal service to the west.

There is an in-depth assessment of each of the modes on all of the alternative routes, with discussions of non-port alternatives such as the “CREATE” project to decongest rail traffic around Chicago. The report does not address possible negative environmental or social impacts, or provide many specific ideas about how individual ports would collaborate with each other to increase system wide traffic.

[4] Ro/Ro and Lo/Lo are the terms used for roll on, roll off and lift on, lift off container ships.

Short Sea Shipping

The bi-national GLSLS report identifies that the system offers needed capacity to supplement roads and rail lines servicing trade between Canada and the United States. The report raises possibilities for employing "short sea shipping" on the GLNS as a way to further support regional transportation and further reduce transportation costs.

Within the Great Lakes basin and St. Lawrence River, growth in economic activity as measured by GDP and international trade means that private and commercial traffic throughout the region will expand to unprecedented levels. This will put significant pressure on transportation networks. Forecasts prepared for the U.S. Department of Transportation by the Federal Highway Administration suggest that peak-period vehicular congestion threatens to exceed the capacity of the U.S. highway system, not only in all major urban centers adjacent to the Great Lakes, but virtually everywhere in the region. Canadian growth patterns are similar and analysts believe that similar levels of congestion may develop in the Windsor-Toronto-Montreal-Quebec City corridor.

Planners have recognized the challenge and are trying to respond. The U.S. Transportation Research Board has even stated that highway capital stock is being added faster than it is wearing out. Even so, the trucking industry is keenly aware of and grappling with the effects of local and regional congestion and capacity limits:

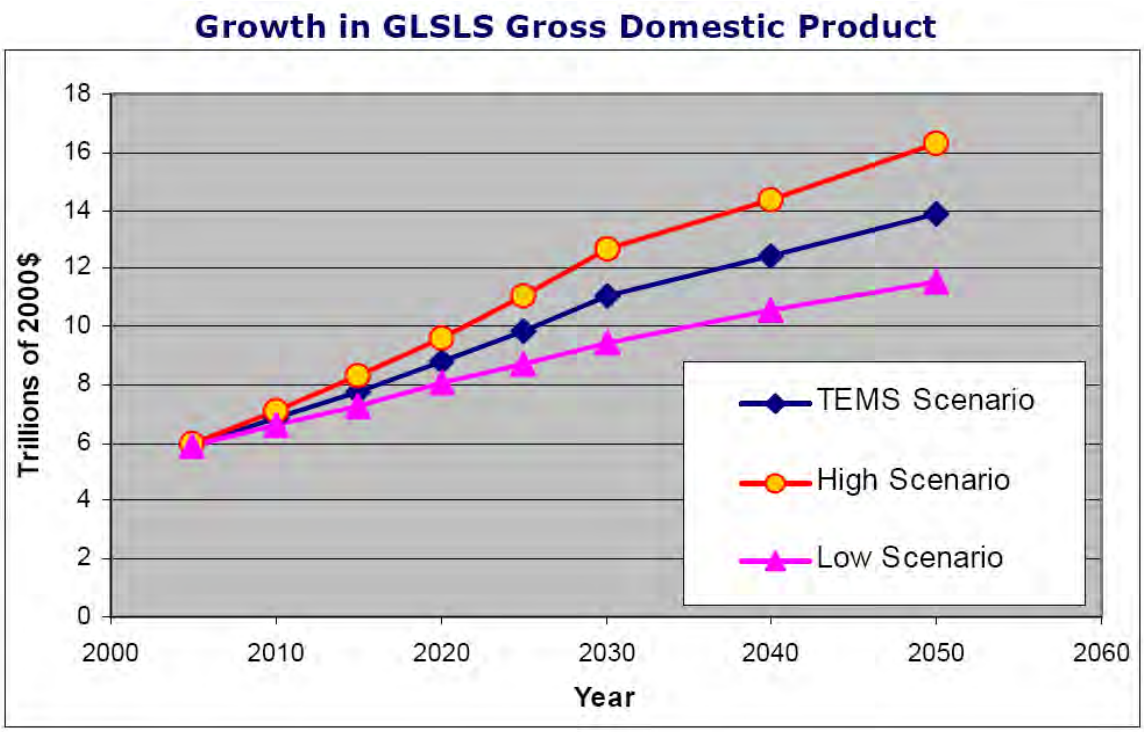
• There is a shortage of skilled drivers, especially on longer-haul routes, and the truck-driving workforce is aging.

• Trucking rates are now increasing, to factor in recent increases in driver compensation, fuel prices and insurance costs.

• More stringent security procedures at Canada-U.S. border crossings impose a disproportionate burden on the trucking industry, in terms of increased administrative costs and lower service levels to clients.

• Highway networks throughout the system are nearing capacity, thus facing increased traffic congestion.

• Some border crossings, such as Detroit-Windsor, are also nearing capacity limits. Efforts are underway to address these challenges, but it is certain that most responses will add to costs in one way or another, making the trucking industry less competitive in relation to other modes of transportation. This opens up new opportunities for both rail and water transport.



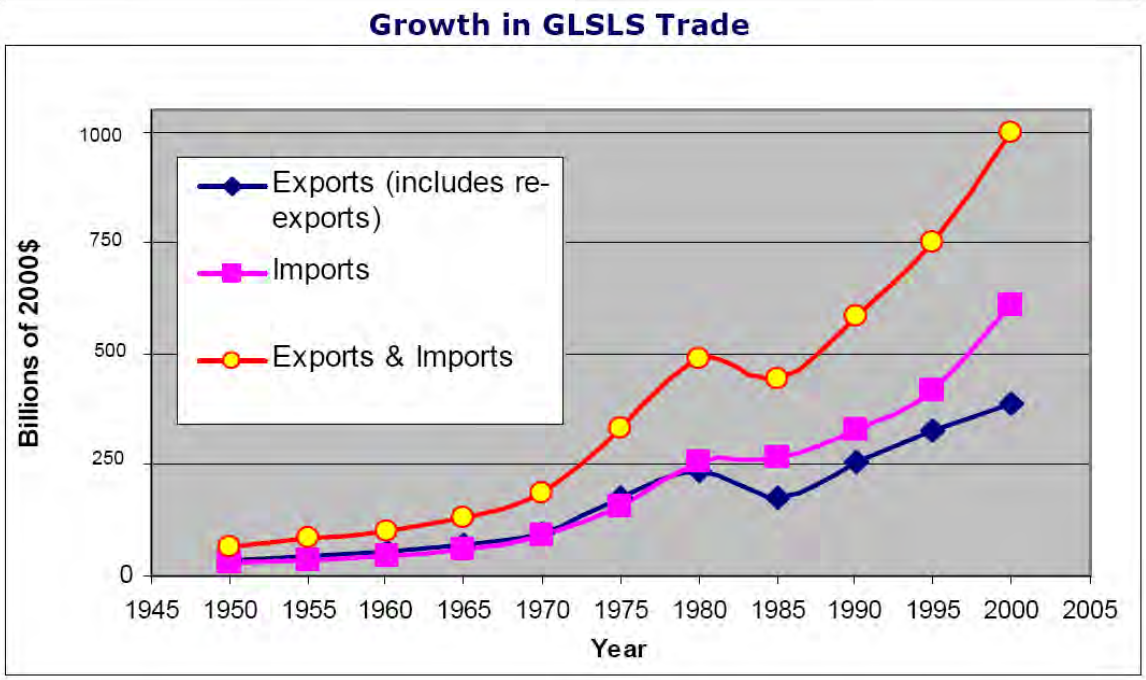


Figure 25 – Projected Growth (top) and Historic (1950 – 2002) GLSLS Trade.

One way to ease traffic congestion is shortsea shipping. Specifically, the term “short sea shipping” refers to the practice of adding a waterborne leg to an intermodal shipment that normally would travel by road or rail. The objective is to reduce travel time, avoid congested routes and reduce cost. It also holds out the promise of improving energy efficiency and lowering greenhouse gas emissions.

For example, goods that normally travel by truck through congested metropolitan areas might be rerouted across a lake, if fast and cost-effective water transport were available. Taking advantage of this opportunity would involve developing the capability of rolling the truck trailer right onto the vessel and then rolling it off on the other side so as to avoid lengthy stays in port as well as the expense of loading and unloading cargo. That requires investment in suitable roll-on, roll-off (ro-ro) vessels as well as appropriate port facilities. As congestion on the roads increases, this kind of investment may well be worth making. To fully realize the potential for short sea shipping on the Great Lakes, potential obstacles to such services such as taxes, user fees, and customs practices will have to be addressed. For example, legislation providing for exemptions to the harbor maintenance fee in the Great Lakes St. Lawrence Seaway system has been introduced into the U.S. Congress.

Improved Environmental Operations

U.S. and Canadian environmental assessment legislation provide for rigorous assessments of impacts of proposed projects and can include impact mitigation measures to be part of any approval. While this legislation provides a solid foundation for assessing environmental impacts, most ongoing operations, maintenance and repair activities envisioned in the GLSLS Study would not require further assessment under these Federal regimes, though some state or provincial assessments might apply. If the current analysis of the Great Lakes system or follow-up work should result in a recommendation to a Federal agency regarding how best to ensure the continuing viability of the GLNS, it is possible that a Environmental Assessment or Environmental Impact Statement may be required as part of the process of approving any proposed investments.

Many of the environmental pressures presently facing the system are well-known and a wide range of practices and policy initiatives are either in place or in the process of being implemented. For example:

• Speed limits have been established in narrow channel areas to reduce shoreline erosion and to improve safety of operations;

• Safety measures and draft advisories are in place to respond to water level changes and reduce the potential for grounding and bottom disturbances;

• Minimum fuel quality standards have been set to reduce ships' emissions;

• Port regulations control anchoring, waste management and other operational practices while in port;

• Anti-fouling paint using Tributyltin (TBT) has been banned in response to toxicity concerns;

• Programs have been established to monitor changes to wetlands. Not all wetlands have been catalogued, however, and improvements to the cataloguing methodology will provide more accurate estimates of wetland boundaries;

• To reduce the likelihood of introducing new NIS, ballast water management has received considerable attention, as described in detail further below.

While the preceding actions represent individual initiatives, there are also examples of comprehensive strategies aimed at promoting environmentally sustainable navigation. One of these is the Sustainable Navigation Strategy for the St. Lawrence River. This cooperative initiative involves the commercial and recreational boating industry, the governments of Canada and Quebec, environmental groups and riverside communities. It is presently the most comprehensive strategy dealing with the impacts of navigation on the system and focuses on consensus building and communications, planning, research and development. Among the issues it has addressed are dredging, adaptation to water level fluctuations, shoreline erosion, sewage and ballast water management, and the risks of hazardous product spills. Broader environmental initiatives, such as lake-wide management plans on all the Great Lakes and the St. Lawrence River Action Plan downstream, are directed at fostering environmental sustainability.

The following is a list of Environmental improvement efforts that could be explored alongside adapted navigation:

- Physical, mechanical or electrical barriers to prevent entry or exit of aquatic nuisance species at both ends of the system (Chicago Diversion and St. Lawrence River),

- Facilities for on ship or shoreside sterilization of ballast water,

- Further study of management of NOBOB (no ballast on board) vessels. Research by the Great Lakes Environmental Laboratory (GLERL) and the University of Michigan's Cooperative Institute for Limnology and Ecosystems Research (CILER) indicates that these ships may still carry invasives,

- Policy analysis to determine the effectiveness of and recommend improvements to current Canadian and U.S. Coast Guard regulations to minimize the risk of introducing new invasives (such as prohibiting saltwater vessels from entry into Great Lakes waters),

- Analysis of the costs and benefits of cleaner fuel use by ships.

Over the past 20 years, the industries that use the GLSLS and the agencies responsible for the GLSLS have taken up the role of environmental stewardship. The interagency collaboration between groups such as Environment Canada, the U.S. Fish and Wildlife Service and the regulatory and operational agencies who have oversight of the GLNS needs to be continued and further fostered. Regulations and codes of practice have been implemented to minimize many of the environmental impacts mentioned throughout this report. That said, much more needs to be done. New technologies for ballast water treatment and other NIS-related issues need to be developed and implemented.

Current initiatives, such as the Asian Carp Barrier in the Chicago Sanitary and Ship Canal and sea lamprey remediation programs, focused on dealing with NIS, should continue, as well as the development of a comprehensive plan to address the inadvertent introduction and transmittal of NIS. Ships need to use cleaner fuels and adopt emission-reducing technologies. Ship wake problems need to be assessed as an integral part of waterway management, particularly in addressing how changes in navigation and/or ship characteristics can affect the environmental impact of wakes. Through continued diligence in this area, society can capitalize on the environmental benefits offered by marine transportation within the GLSLS, while reducing the environmental impacts of navigation.

6.8 Reformulation of Alternative Plans

The reformulation of the Alternatives from the 2002 Great Lakes Navigation System Review Reconnaissance Report was necessitated for several reasons, including the determination in the bi-national GLSLS Study to not alter the dimensions of the St. Lawrence Seaway. Additional insight and information was gained by examining the condition of the Navigation System's supporting infrastructure, and economic and environmental conditions. A primary message in the bi-national GLSLS is that the system needs to maintain existing assets to remain reliable and keep the region competitive on the world market. Canada, which owns the majority of the navigation infrastructure on the St. Lawrence Seaway, participated fully in the analyses and development of the ultimate conclusions presented in the bi-national Great Lakes St. Lawrence Seaway Study.

6.9 Updated Alternative Plans

The first seven Alternative Plans remain unchanged from the June 2002 report, while Alternatives 8-11 are new plans that reflect potential measures that have developed due to changing conditions between 2002 and 2009. Each Alternative Plan will be screened as to viability for further consideration.

(1). No Action (Without Project Condition)

This alternative would continue to mean that the Corps would not participate in any additional development or adaptive management of the GLNS system, aside from continuing to address critical O&M needs of the system for the next 50 years. This would not preclude Canada or other interests from making adaptive changes or conducting preemptive maintenance, as long as work in U.S. waters is approved through the Federal permitting process.

The National Environmental Protection Act (NEPA) regulations require that a "No Action" alternative always be considered a viable alternative in any final array of plans. The "No Action" alternative is always the default plan. The Corps should become involved in a project or study only if doing something is better for society than doing nothing. As such, the planning process must convincingly establish that Federal involvement in some study or project is preferred over No Action, if a willing partner can be identified and if funding to support such work can be secured.

Because of uncertainties that exist regarding future partnering opportunities and funding levels, this Alternative will remain under consideration.

(2). Deepening the Great Lakes Connecting Channels

Connecting channel deepening is based on considering the connecting channels as constraint points in a vessel origin-destination route from port to port. Once the vessel's origin-destination route was identified, the constraint points on the route could be identified. The constraint points included Vidal Shoals (located upstream of Soo locks), the St. Marys River Little Rapids, Neebish Channel, the Straits of Mackinac, the St. Clair River, Lake St. Clair, and the Detroit River.

Lake levels began declining in late 1998 from higher than average levels due to reduced precipitation on the Great Lakes basin and minimal winter ice cover. This has been especially problematic on the Lakes Michigan-Huron basin, where levels fell nearly four feet from levels of the late 1990's. Similar declines in water levels and flows in major tributaries and in the connecting channels have forced shippers to light-load to service the lakes. Although water levels on the upper Great Lakes have been rising back closer to long-term average levels the latter part of this decade, the reduced maintenance dredging of Federal channels and harbors requires that shippers continue to light-load. Even if harbors and channels are dredged to authorized depths, the shipping industry would prefer further increasing the depth of these channels and harbors to guarantee that vessels can be fully-loaded, independent of seasonally or annually-fluctuating water levels. Also, with the possibility of potentially-significant decreases in Great Lakes water levels in the coming decades, deepening becomes an even greater desire for the commercial shipping industry.

The maximum ship draft that could be accommodated at the origin port, destination port and all the affected constraint points was determined. Potential draft is defined as the average water column available at a port or node, minus an underkeel clearance of one foot. These potential drafts were calculated from 101 years of water level data - 1900 to 2000, for all the origin ports, destination ports and constraint points. This information was compared to the fleet's maximum ship draft to determine various deepening plans.

Economic benefits for deepening connecting channels were evaluated in combination with harbors and ports and Seaway replacement locks under the five broad options described below.

Due to scheduling and funding limitations, drafts up to 30' and at 35' were evaluated for the connecting channels and ports.

> Option 1 - Includes the many combinations of improvement alternatives for the Great Lakes connecting channels and harbors (drafts up to 30 ft) combined with eventual replacement of the Seaway locks.
>
> Option 2 - Contemplates the same improvements as Option 1 above, coupled with construction of a deeper (35' draft) and larger (110'x1200' lock chambers) Welland Canal.
>
> Option 3 - Builds upon Option 2 by replacing the MLO Section of the Seaway with a deeper and larger system of locks and channels, and by extending the 35' draft system up to Detroit.
>
> Option 4 - Is the same as Option 3, except that the 35' draft now extends into Lake Michigan and Lake Huron by the deepening of the entire St. Clair-Detroit River system.
>
> Option 5 - Extends the 35' draft throughout the GLSLS system as a result of deepening the St. Marys River and lowering the sill depth of the Soo locks.

With regards to deepening the Great Lakes connecting channels to a 30' draft, the Great Lake Levels Analysis for System Transportation (GLLAST) model was run for a condition where vessels can draft to their maximum depth. The GLLAST model is a modified version of a costing model developed in the 1980's by the Buffalo District of the Corps. In the GLLAST model, the only factor that affected transportation cost was the number of trips required to move all commodities.

Using year 2000 traffic levels, it was determined that the estimated cost reduction for existing movements would be $87M annually. This estimate acts to represent the benefits of having the ability to draft 30' throughout the Great Lakes connecting channels and ports. Port deepening and channel deepening plans were developed jointly for evaluation of Option 1. All but one plan carried forward to final screening for Option 1 showed positive net benefits.

Concerning the channel deepening to 35' draft, under options 3, 4, & 5, the potential annual benefits are combined with lock replacements. The results of the combined benefits are the following; Option 3, a 35' draft channel deepening up to Detroit, a 30' draft Great Lakes connecting channels and ports in combination with seaway replacement locks ($885,000,000 annually), Option 4, a 35' draft channel up to Lake Huron and Lake Michigan and a 30' draft connecting channels and ports in combination with seaway replacement locks ($1,417,000,000 annually), and Option 5, a 35' draft channel throughout the Great Lakes and St Lawrence Seaway system in combination with seaway replacement locks ($1,510,000,000 annually).

The economic development benefits of a 35' draft system throughout were estimated using the Maritime Input-Output (MIO) model. The MIO model was created to investigate economic development benefits from increased traffic on the Great Lakes and Seaway and provides a general framework for estimating the local and regional indirect economic impact derived from regionally targeted changes in waterway infrastructure.

Based on the potential net benefits generated from this model early this decade regarding deepening the connecting channels in conjunction with associated ports and harbors, it was originally recommended that this alternative be carried forward into feasibility for further analysis. However, due to concerns about lower lake levels potentially being exacerbated by such deepening and potential social and environmental impacts, alternatives involving major dredging of the connecting channels will not be carried forward. However, minor dredging of specific locations that act as control points may be considered on a case-by-case basis.

(3). Improvements to the St. Lawrence Seaway

The economic benefits for Improvements to the St. Lawrence Seaway were evaluated in combination with harbors and ports and channel deepening under the five options listed in the preceding section *(2) Deepening the Great Lakes Connecting Channels*. Options 3, 4, & 5 include construction of a deeper (35' draft) and larger locks (110' x 1200' lock chambers) for the Welland canal section and the Montreal-Lake Ontario section of the seaway.

The original 2002 Corps' Reconnaissance Report estimated that the cost of modifying the locks and channels on the Seaway to accommodate Panamax size vessels would be in the magnitude of $10B. There would also be additional costs associated with landside infrastructure improvements and crossings. Based on the potential benefits generated in 2000 (up to $1,510,000,000 annually under a scenario that extends the 35' draft throughout the GLSLS system) for seaway modifications, compared with the potential costs of the proposed improvements, it was recommended in the 2002 Corps' Great Lakes Navigation System Review that this alternative be carried forward into feasibility for further analysis.

However, after analyzing the infrastructure of the St. Lawrence Seaway and the significant estimated costs that would be associated with the rehabilitation of the existing infrastructure, the Canadian Government does not feel that expanding the system is prudent at this time, and that both the U.S. and Canada feel that expansion of the system is not warranted at this time. Because of this, Alternative 3 will no longer be considered.

(4). Deepening Individual Ports

The benefits identified in the original 2002 Corps Reconnaissance Report for the connecting channels and ports were based on U.S. domestic traffic and a portion of U.S. foreign traffic. These benefits, along with costs are the basis of the benefit-cost analysis, which indicate whether there is Federal interest in deepening individual ports. Benefits for the ports are estimated using a vessel-costing model. Costs were estimated for deepening connecting channels and port plans. The level of detail to which the cost estimates were developed varies from port to port and also between the connecting channels. The level of detail was dependent upon availability of existing data from past studies, accessibility of recent condition surveys, and availability of existing data for non-Federal ports. Schedule and funding constraints limited the extent to which previous cost estimates could be refined based on more current data and operational conditions at each port. Where minimal or no data was readily available for a specific port, cost estimates were based on costs for ports in close proximity with similar harbor configuration. As a result, a range of cost estimates was established in order to better reflect these uncertainties. In all cases, however, the same general methodology is employed in estimating the cost of improvements at all GLNS harbors and channels.

In the 2002 report, port deepening and connecting channel deepening plans were developed jointly for the four upper Great Lakes: Superior, Michigan, Huron and Erie. A number of parameters affect the feasibility of harbor deepening. Some of these factors are: tonnage handled, origin-destination route distance, approach channel length, the existing fleet's capability to draft deeper, the destination port's draft relative to the origin port, and the connecting channel draft. Since benefits are measured as reduced transportation costs, harbors handling large tonnage with fleets that can take advantage of additional draft have the potential to generate enough benefits to justify deepening. *For example, Monroe Harbor, MI is home to Detroit Edison's Monroe electric plant. This coal-fired plant supplies a significant percentage of the power to the metropolitan Detroit area; fully loaded coal vessels have regular difficulty navigating the existing harbor under threat of grounding. During certain wind conditions and water levels, vessels will not enter the harbor until conditions improve. A short list of 26 Great Lakes harbors that could benefit from deepening is shown below.*

Figure 26
Preliminary List of Harbor Deepening Candidates

Port/Harbor	Port/Harbor	Port/Harbor
1. Superior, WI	10. Detroit, MI	20. Alpena, MI
2. Indiana Harbor, IN	11. Calumet Harbor, IL	21. Lorain, OH
3. Dearborn, MI	12. Taconite, MN	22. Cleveland, OH
4. Escanaba, MI	13. Silver Bay, MN	23. Ashtabula, OH
5. St.Clair, MI	14. Two Harbors, MN	24. Conneaut, OH
6. Duluth, MN	15. Presque Isle\Marquette, MI	25. Fairport, OH
7. Saginaw, MI	16. Gary, IN	26. Toledo, OH
8. Monroe Harbor, MI	17. Burns Harbor, IN	
9. Sandusky Harbor, OH	18. Calcite, MI	

Figure 26 – Great Lakes Harbors that Would Benefit the Most From Deepening.

As a result of the economic analysis, various ports and harbors show net positive benefits for deepening to various depths. The following table provides a list of ports/harbors which show a positive net benefit to cost ratio (BCR).

Figure 27
Summary of Economic Evaluation of Ports

Port/Harbor	BCR	Port/Harbor	BCR
Sandusky, OH 0.5’	5.7	Drummond Island, MI 2.5’	1.8
Sandusky, OH 1.0’	6.1	Indiana Harbor, IN 1.0’	6.2
Sandusky, OH 1.5’	4.3	Indiana Harbor, IN 2.0’ & Escanaba, MI 1.0’	1.8
Sandusky, OH 2.0’	3.4	Calumet Harbor, 1.0’ for coal	3.0
Sandusky, OH w/vessel change *	97.9	Presque Isle, MI 0.5’	2.4
Ashtabula, OH 0.5	0.6	Duluth-Superior, MN 0.5’	10.7
Ashtabula, OH w/vessel change *	111.3	Duluth-Superior, MN 1.0’	5.3
Fairport, OH 1.0 w/vessel change +M tons**	36.2	Two Harbors, MN 0.5’	44.6
Fairport, OH 1.0 w/vessel change *	28.8	Two Harbors, MN 0.5’ & St. Marys River 1.0’	0.9
Calcite, MI 0.5’	1.4	Six Harbors Include: Duluth 1.5’, Presque Isle 1.5’, Silver Bay 1.5’, Superior 1.5’, Taconite 1.5’, Two Harbors 1.5’ & St. Marys River 1.0’,	1.7
Calcite, MI 1.0’	1.2	St Clair Harbor, MI 5.0’	16.9
Calcite, MI 1.5’	1.5		
Calcite, MI 2.0’	1.6	Dearborn, MI (Rouge River) 0.5’	9.5
Stoneport, MI 0.5’	1.2	Dearborn, MI (Rouge River) 1.5’	9.2
Stoneport, MI 1.0’	1.1	Dearborn, MI (Rouge River) 2.5’	8.7
Stoneport, MI 1.5’	1.2	Dearborn, MI (Rouge River) 3.0’	17.0
Stoneport, MI 2.0’	1.2	Dearborn, MI (Rouge River) 6.0’	9.2

* plans allow for vessel changes in response to harbor deepening
** additional 1 M tons of limestone

Figure 27 – The Economic Summary of Select Great Lakes Ports.

Deepening individual ports or port pairs would not negatively impact water levels such as may occur with expanding the entire connecting channel system. However, some minor modification of certain reaches of an individual connecting channel may need to be modified in conjunction with the deepening of a port or port pair.

Because of the sizeable positive net benefits displayed at certain ports or port pairs, it is recommended to proceed with a feasibility study as to which ports or port-pairs would benefit the most from deepening, and if a viable cost-sharing partner could be identified.

(5). Addressing Navigational Restrictions

a. Chicago Sanitary & Ship Canal

As a result of the 2002 Corps Reconnaissance Study, four plans were developed to deal with traffic congestion that delays tows and increases safety concerns along the Lemont reach of the Chicago Sanitary and Ship Canal (CSSC). The inadequacy of fleeting areas (an area within defined boundaries used to provide barge mooring) is a major contributing factor in most instances. Low bridge clearances, specifically the Lemont-Railroad bridge, also impose time penalties and risks on commercial users. Plan CSSC 1, Quarry Site, takes advantage of an existing quarry site to provide additional fleeting. Plan CSSC 2, Three Mile Wall, proposes opening to fleeting a three mile stretch of the Cal-Sag Channel (CSC) located a few miles from the primary congestion point on the CSSC. Plan CSSC 3, Canal Widening, proposes widening a reach on the CSSC some miles distant from the Lemont-Railroad bridge, but away from the CSSC and CSC junction. The final plan is CSSC 4, Reoperation of the Lemont-Railroad Bridge. This plan would repair and replace the machinery necessary to reactivate the swing mechanism of the low-clearance, Lemont-Railroad Bridge.

All benefit estimates are based upon reducing transit times through the Lemont reach of the CSSC. It is emphasized that these benefit estimates are not comprehensive as they do not account for savings attributable to reduced damage to property and life that would likely result from the proposed improvements.

By 2002, a complete benefit-cost analysis was possible for just two of the four plans. No cost estimate is available for Plan CSSC1, Quarry Site or for Plan CSSC 3, Canal Widening. Cost estimates for Plan CSSC 2 and Plan CSSC 4, Three Mile Wall and Lemont Bridge are incomplete, as they do not include lands, easements, relocations and rights of way. This deficiency is accounted for through a fifty percent contingency. The 2002 cost estimate available for re-operation of the Lemont RR Bridge was $3,016,000. The 2002 cost estimate for mooring piers along one mile of the Three Mile Wall was $1,208,000, expanding this estimate out to the 2.8 miles of wall not yet being used increased the total cost to $3,381,000.

The annualized available 2002 cost estimates, at the discount rate of 1 0.06375, over a 50 year project life, are $225,820 for the Three Mile Wall and $201,436 for the Lemont RR bridge Available quantified 2002 benefit estimates for these two plans were $284,000 and $34,000, respectively. The resultant benefit and cost ratio for these two plans are 1.38 and 0.17, respectively. See Table 28 below.

Figure 28 Summary of Average Annual Benefits by Category Chicago Sanitary and Ship Canal Plans	
Alternative	**BCR**
CSSC 1, Quarry site	n.a
CSSC 2, Three mile wall	1.26
CSSC 3, Canal widening	n.a.
CSSC 4, Lemont RR bridge	0.17

Figure 28 – Chicago Sanitary and Ship Canal Benefits for Each Plan.

From the previous discussion, it is apparent that a least one solution for providing navigation improvements in the CSSC would produce substantial economic benefits and that those benefits would likely exceed costs. Also to be considered in any further analysis of this alternative would be the potential threat of facilitating easier passage for NIS into the Great Lakes, such as the Asian Carp, though modifications of the CSSC.

Since commercial navigation is a high priority in the Navigation Business Line in Administration budgeting, there is a strong Federal interest in conducting a feasibility study of potential Chicago Sanitary and Ship Canal navigation improvements. Also, Section 3061(D) the Water Resources Development Act of 2007 authorizes a fully Federally-funded "study of the range of options and technologies for reducing impacts of hazards that may reduce the efficacy of the Barriers"; i.e. to study additional ways to ecologically separate the Great Lakes and Mississippi River basins, to reduce or eliminate the possibility of NIS crossover.

Based on this information, there are sufficient indications that a viable and implementable plan can be developed that will meet the necessary Federal interest and environmental goals. It is recommended that this alternative proceed to the feasibility phase to determine if there is continued interest in this plan.

b. St. Clair River Ice Boom

Navigation on the middle lakes of the Great Lakes can occur all year depending on winter conditions. Ice formation and breakup on the lakes and in the rivers can cause delays to navigation interests and flooding problems for riparian properties. The St. Clair and Detroit Rivers are problematic areas with their many-channeled delta, and the jamming of large ice floes from Lakes Huron and St. Clair. The ice problems could be reduced by the proper placement of ice retaining booms across the headwaters of the rivers. Ice booms have been found to be quite effective in controlling the movement of ice in the St. Marys River, the Niagara River and in the St. Lawrence Seaway.

Previous studies conducted on the installation of ice booms at the heads of the St. Clair and Detroit Rivers provide details on the location of the booms and their costs. Problems previously identified with ice jams in the rivers include: delays to navigation due to vessels stuck in the ice in the navigation channel; scouring of the river bottom; and flooding and other damage to shore property.

The brief outline presented here relies heavily on information obtained from a report generated in March of 1995, *Analysis of Great Lakes Icebreaking Requirements, Final Report, prepared by the U.S. Department of Transportation for the U.S. Coast Guard*. This report determines Federal and user requirements, reviews icebreaker capabilities and operating costs and historical ice conditions, and presents a benefit-cost ratio for the overall icebreaking program. In the course of achieving this end, the referenced report developed a cost model for the steel industry looking at alternatives such as stock piling and alternate modes of transportation. The frequent references to the "ice season" on the Great Lakes involve the months December through March. Ice boom costs were adjusted from the 1974 Navigation Season Extension report.

A cost summary of the annual cost of ice-breaking vessels and the annual cost of the proposed ice booms is shown in the table below, in 2002 dollars. The ice booms offer an annual cost savings (net benefits) of $251,900, the difference between the vessels annual cost ($1,425,900) and the ice-boom annual cost ($1,174,000).

Figure 29 **Benefits and Cost of ice removal**	
Current Annual Cost of Ice Removal Attributable to St Clair-Detroit River System	$1,425,906
Proposed Annual Cost of Ice Booms	$1,174,000
Annual Cost Difference (Net Benefits)	$251,906

Figure 29 – The Benefit of an Ice Boom Compared to Ice Removal Through Breaking.

The direct Federal savings through decreased annual expenditures by the Coast Guard has not been exactly quantified since there has been no estimate as to the elimination of the need for icebreakers. If the need for icebreakers were eliminated, the benefit to the government would be equal to the difference in cost between the two alternatives of $250,000.

The accuracy of the cost of ice boom construction is questionable since these costs were merely adjusted to current dollars from a report completed in 1974 and technological advances could significantly affect the results. Whether updated costs would increase or decrease the final cost is uncertain. Technological advances may decrease the cost of construction by advancing our ability to produce the same product cheaper or may increase it by design improvements that increase efficiency along with costs. In addition, environmental considerations could potentially have a significant impact on the cost.

The benefits accrued to shipping are calculated from a much more recent, thorough report. Further study is required to determine the difference in the benefits between the current use of icebreakers and the possible use of ice booms. In order to make a reasonable comparison between these alternatives, it is also necessary to estimate the continued need, if any, for icebreakers after the installation of the ice booms.

This review of the available information indicates that placing ice booms in the St. Clair-Detroit River system has the potential for Federal savings. Thus, further study, including the reassessment of the desire and benefit on an ice boom, continues to be warranted for this Alternative.

(6). Improved Water Level Data Access

Real-time water level data are collected by the National Oceanic and Atmospheric Administration (NOAA) and the Corps in the U.S. and the Marine Environmental Data Service (MEDS) in Canada. The MEDS has 33 gages in place in the Canadian waters of the Great Lakes and St. Lawrence River System, while NOAA has 53 operating gages on the system and the Corps owns sixteen gages in the Great Lakes.

The inconsistency in access and presentation of these data can lead to misunderstanding of the current water level conditions throughout the system and therefore underutilization of commercial navigation capacity, or possible safety problems from grounding. Review of this information in 2009 finds that this remains an issue, although on-board access of data has improved during this decade.

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration's (NOAA) Center for Operational Oceanographic Products and Services (CO-OPS) presently operates 53 water level gauging stations, including 19 meteorological observation stations, in the Great Lakes and connecting channels. CO-OPS also operates a Physical Oceanographic Real-Time System (PORTS) at Sault Ste. Marie, Michigan. Soo Locks PORTS is available to anyone by Internet at http://tidesandcurrents.noaa.gov/slports/slports.shtml?port=sl and includes water level and meteorological station data from Point Iroquois, Southwest Pier, US Slip, Little Rapids, West Neebish Island, Neebish channel, and Detour Village. The Soo Locks PORTS Lock Masters Table is available at http://tidesandcurrents.noaa.gov/slports_lock.shtml and provides the most recent three hours of real-time 6-minute water level readouts to the lock operators, aiding lock operations.

These data are also posted to a web site accessible by Internet at www.glakesonline.nos.noaa.gov, which depicts plots of the most recent 72 hours of data to indicate trends in water level fluctuations. This web page also highlights Low Water Conditions for stations experiencing water levels below Low Water Datum (chart datum). In addition, the latest data are available through NOAA's Great Lakes Interactive Voice Response System by telephone.

Great Lakes vessels have internet access over 90% of the time via cellular or satellite delivery. Vessels mostly access water levels via internet and can utilize a cellular dial-up system, Great Lakes Online. This is a reliable system and is a good primary system for ships that have not upgraded to internet access. Lastly, Soo Traffic and Sarnia Traffic often provide specific water level information over the VHF radio if requested by a vessel.

The United States Army Corps of Engineers

The Corps installed a voice modem at the Neebish Channel (Rock Cut) gage site on the lower St. Marys River. This gage could be accessed by telephone giving the user the instantaneous water level. An advantage to this mode is the availability to anyone with a telephone, including vessel masters. The disadvantage is that the user receives only one water level reading so there is no comparison for accuracy. A voice modem system such as at Neebish Channel (Rock Cut) would cost approximately $5,000 individually (in 2002 dollars) at other gage locations and would achieve some economies of scale with multiple simultaneous installations. Annual operations costs would consist of maintaining telephone service at a cost of approximately $300 per site. Additionally, provisions would need to be made for replacement equipment, for repairs or eventual complete replacement.

Combined Water Level Data Access

The results of the study propose to coordinate one consistent access point for all water level data through working with all entities currently generating water level information, such as NOAA, MEDS, the Corps, hydropower entities, and any other data source known. This central access point involves the creation of a new web site to represent all water level data in the Great Lakes in a consistent fashion. Information would then be displayed for specific regions, regardless of the ownership of the data, providing proper credit and notations. Graphics will be consistent to show past and current information, as past trends in water level changes are important future indicators. Coordination with navigation interests is considered critical to ensure that the user's needs are being met with the web site.

The data would be available in the following formats:

- English and Metric units
- Referenced to feet/meters IGLD 1985
- Referenced to inches/cm above/below low water datum
- Tabular and graphic formats
- Detailed data for the most recent several hours
- Data for the most recent few days
- Data for the most recent month
- Historical data as available

The estimated development time for the web site, tables, and graphs is 6 months. This would necessarily include automated updating of the data and some scrutiny of errors. It is expected that the maintenance of the site would take approximately 2 hours per day. Maintenance of both the equipment and software would be required along with planning for eventual replacement. Costs to develop and run the system are displayed in Figure 30.

Figure 30 **Cost of Proposed Combined Water Level Data Access**	
Total First Cost	$ 60,000
Average Annual First Cost*	$ 5,300
Annual O & M	$ 40,000
Average Annual Cost	$ 45,300
*Based on 20-year life at an interest rate of 6-1/8%	

Figure 30 – Cost of Combined Water Level Data Access.

It may be that only certain critical water level stations would be needed and various levels of service could be implemented. Each would cost different amounts, as indicated in the NOAA and Corps sections above, and provide different data. Consultation with commercial navigation interests should be considered to determine the best options.

The benefits of a combined, common data access web site would be significant to shippers who must currently combine information from different sources in order to get complete, useful data. In addition, those involved in research and other monitoring activities would benefit. The quantification of these benefits would cost significantly more than the project itself, but are deemed sufficient in light of the tonnage moved on the Great Lakes system, 221,000,000 short tons of freight in 1998 and consistently over 200,000,000 since 2000.

This Alternative proposes to evaluate potential improvements to the water level data access within the Great Lakes system. Knowledge of past, current and forecasted water levels is an integral part of navigation on the Great Lakes, the connecting channels and the St. Lawrence River. As remains true from the Corps' 2002 report, these data are collected and disseminated by a variety of agencies in different ways. The combination of these data into a single accurate network system would improve the communication to the shippers, improve vessel loading during periods of low and high lake levels, increase safety and increase commerce, through a more reliable system. The Great Lakes shipping industry continues to be very interested in any plan to make water level data access more convenient and faster. However, even though this remains a recognized need, no funding has been made available to support the development of such a system to date.

The benefits of the proposed combined system also remain unquantified due to limited funding and scheduling, but are expected to exceed the costs by a wide margin. Therefore, direct implementation is recommended for this Alternative.

(7). Aids to Navigation

This alternative evaluates potential improvements to navigation aids in the Great Lakes system through replacing buoys, which are floating navigation aids, with permanent beacons. Lighted buoys, placed and owned by the U.S. Coast Guard, are currently the primary marker system utilized in Great Lakes waterways. They must be removed in the fall prior to the onset of ice and reset in the spring after the thaw. Commercial shipping extends several weeks past the fall withdrawals and starts well before buoys can be placed in the spring. This practice increases risk to mariners and costs to shippers. The Coast Guard envisions a system in which ice resistant permanent structures replace a considerable number of buoys. Such an aid to navigation system would be more robust by providing more reliable aids and year round service.

The table below presents the summary of the average annual benefits and costs for 29 Beacons. Benefits presented in the table below are all associated with reducing the labor, equipment and material costs necessary to operate a series of in-water navigation aids. While the benefits reflect the difference in the operational economics between buoys and permanent beacons, benefits associated with the reduced risk to buoy tending personnel and to mariners and vessels has not been estimated. Estimating safety benefits was beyond the scope of this reconnaissance study.

Figure 31
SUMMARY OF BENEFITS, COST AND BCR

Average Annual Benefits	$ 622,430
Average Annual Costs	$ 759,782
Net Benefits	-$ 137,352
BCR	0.8
(-0 @ 6.125% discount w/base year 2010)	

Figure 31 – Benefits vs. Costs of Upgrading Navigation Aids.

Albeit a safety feature and are still in use by vessel crews, it does not appear to be justifiable to replace the buoys with all-season beacons. The economic analysis above indicates a BCR of 0.8, which is below the economic justification threshold of 1.0. Simply, the costs to replace seasonal aids with permanent beacons outweigh the benefits. Further, with advances in technology such as Global Positioning Systems and remote sensing (sonar) equipment, the reliance on buoys over time may decrease. Because of the negative benefit with this alternative, it will no longer be recommended for further study.

(8). Maintain the Great Lakes Connecting Channels and Harbors

This alternative, while not involving modification to the existing system, demonstrates the importance of maintaining the Great Lakes connecting channels and harbors to their currently-authorized depths, by dredging the backlog material and maintaining Harbors of Refuge and subsistence harbors throughout the GLNS. This alternative does not suggest or imply any expansion to the existing GLNS. The importance of maintaining the connecting channels from an economic prospective is discussed in Section 5.3.1 "Summary of Economic Conditions".

Part of this alternative includes stressing the importance of proceeding with Dredged Material Management Plans (DMMPs) to plan for the beneficial use or development of placement options for material dredged from Federal channels and harbors. Priority would be given to those harbors that have the least remaining years of capacity for future placement, such as Cleveland Harbor, which has less than one year of remaining capacity. Then, DMMPs should be completed for the four CDFs that have between five and ten years of capacity (In total, 16 Great Lakes CDFs have 10 years of capacity or less remaining. Given the critical nature of the limited remaining capacity in placement sites within the Great Lakes system, it is recommended that full Federal funding be provided to conduct DMMP investigations for all Federal harbors and channels in the Great Lakes where dredged material placement capacity has become critical.

(9). Maintain the GLNS Infrastructure

Similar to Alternative 8 above, this alternative identifies the importance of also maintaining the existing Navigation System infrastructure (locks, piers, breakwaters, seawalls, etc.). This alternative proposes further analysis along the context of the Asset Renewal program with a system-wide review of coastal structures for a needs and benefits analysis. This Alternative would identify and prioritize the maintenance and repair of the existing Federal infrastructure of the GLNS (primarily breakwaters and jetties) to maintain the reliability and safety of the GLNS with minimal environmental impact.

In light of the economic and safety benefits this alternative is indicated to provide, the creation of a needs inventory, cost analysis and the prioritization of critical needs is recommended.

(10). Development of a Short-Sea Shipping System

This alternative proposes to develop an intermodal Short-Sea plan for the improved movement of goods and commodities throughout the GLNS. The plan would focus on increasing efficiency of transport by identifying underutilized rail and highway systems to shift traffic away from congested routes, and employing Great Lakes shipping to bypass over utilized corridors in the eastern U.S. and Canada. Ideally, this would help to increase transportation efficiency and safety, while benefiting the environment through lower greenhouse gas emissions. Particular attention would be focused on the opportunity to link major highways or rail lines on opposite sides of each lake.

Part of this alternative would involve the investigation of developing a bi-national transfer port to facilitate the transfer of goods from ocean carriers to interlake or land-based carriers. Such a port could reduce the threat of NIS introductions and potential threats to homeland security by reducing the number of foreign vessels that obtain access to the Great Lakes. Such a port could also increase the efficiency of customs operations. It could also capitalize on the use of more efficient trans-ocean vessels to move goods to the east coast, potentially reducing costs.

As this alternative appears beneficial for economic, environmental and homeland security reasons, this alternative is recommended for bi-national feasibility study.

(11). Review of U.S. GLNS Activities to Reduce Environmental Impacts

This alternative would initiate a review of the U.S. Federal navigation program, structures and activities, in order to improve efficiency and reduce the impacts of GLNS operations. The fall 2007 binational GLSLS Study stresses that the environmental sustainability of the Great Lakes needs to be balanced with the economic and infrastructure viability of the navigation system.

The ecosystem of the GLNS is vulnerable to a variety of stressors. Management of, or adjustments to, navigational stressors are an important part of any plan to achieve appreciable gains to overall environmental quality. As the requirements of GLNS operations and maintenance involve some stressors to the Great Lakes-St. Lawrence ecosystems, these must be managed effectively.

There have been considerable resources devoted to research and planning but, with the exception of some specific areas related to non-indigenous invasive species, there have been few initiatives that have seen "on-the-ground" changes. There will be a continuation of impacts related to planned works, such as maintenance of infrastructure, maintenance dredging and placement of dredged material, but such impacts can be minimized through effective application of environmental assessments, remedial actions, sound environmental management strategies and best practices.

The sustainable navigation strategy that exists for the St. Lawrence River could be extended to the Great Lakes basin, and further study under this alternative would facilitate such an investigation. Because of this and the importance of balancing environmental sensitivities with navigation in the Great Lakes, this Alternative is recommended for further bi-national investigation.

6.10 Alternatives Recommended for Further Consideration and Implementation

A "screening" of the reformulated alternatives evaluates whether there is Federal interest (Economic, Environmental and Engineering/Infrastructure) in further study through the execution of a Feasibility phase. The new array of Alternatives recommended for further investigation or implementation that is expanded from the initial Reconnaissance phase is less expansion-focused, and still includes the non-structural alternatives. The Alternatives recommended for further consideration or implementation are:

(1) No Action (Without Project Condition)
(4) Deepening Individual Ports
(5) Addressing Navigational Restrictions
(6) Improved Water Level Data Access
(8) Maintain the Great Lakes Connecting Channels and Harbors
(9) Maintain the GLNS Infrastructure
(10) Development of a Short-Sea Shipping System
(11) Review of GLNS Activities to Reduce Environmental Impacts

These recommendations can be split into 3 categories:

Alternatives 4, 5 and 6	Non-Structural or Site Specific U.S. Improvements
Alternatives 8 and 9	Optimization of the System through Operations and Maintenance
Alternatives 10 and 11	Bi-national efforts.

7. Federal Interest and Federal Cost Sharing of Feasibility Studies

The Federal interest in navigation developed early in the 19th century, long before other purposes such as Flood Damage Reduction (Flood Risk Management), because navigation tends to be interstate, have high first costs and widespread benefits. In the case of Great Lakes navigation, there is an obvious international dimension as well, so there is a strong Federal interest. The connections between Great Lakes shipping and the environment are many and complex and the future of Great Lakes navigation decisions or indecisions will have environmental consequences. The most important environmental issues tend to be interstate (air and water pollution) and international (invasive species), further strengthening the position that the Federal government should be involved in commercial navigation.

Since WRDA 1986, the law has been, before the feasibility phase begins, to identify a viable Federal project that could meet the *Principles and Guidelines* economic and environmental policies; that could be built under Corps authorities, and for which there is a bona fide non-Federal partner willing to invest in half the feasibility study costs and a sizable minority of project costs.

In recent years, though, Congress has selectively funded studies at 100% Federal cost if there were regional or international issues beyond the geographic scope of one state. The Great Lakes Habitat Initiative (page 16) was one of five regional studies funded completely through the Corps in 2006.

Setting aside authority and funding issues, the design of the future GLNS will require initiative, innovation and flexibility. Short sea shipping, for example, may require harbor development in both Canada and the United States, as well as investments in new ships in the private sector. Regulatory hurdles in one country can delay the inception of service and benefits in both countries.

The potential benefits go beyond the traditional reduction of shipping costs; there could be a reduction in greenhouse gases, traffic accidents and road and rail congestion delays. The provision of more effective transportation could provide the same sort of regional foundation that bulk shipping did for the steel and auto industry in the 20th century. On the other hand, progress on “unrelated” regional projects such as the “CREATE” project to decongest rail traffic around Chicago could diminish potential benefits by reducing rail congestion, and improvements on navigation systems outside the Great Lakes may create robust systems capable of attracting the same cargo from the Great Lakes systems, reducing the benefits from Great Lakes improvements.

8. Study Cost-Sharing Requirements

Currently, there is no identified non-Federal sponsor for either a system-wide feasibility study of the GLNS or for any single location under any alternative recommended for further (feasibility) study. However, depending on the progression of further study under each of the alternatives recommended to be carried forward, local sponsors would need to be identified as cost-sharing partners for any additional study and then cost-sharing partners for any potential implementation phase. It is anticipated potential sponsors may be identified during the public review of this document – those wishing to implement alternatives they deem would be beneficial to their particular location. Some potential sponsors have shown interest in possible future project participation, but neither the potential sponsor groups nor the Federal government have entered formal discussions regarding specific GLNS projects. Discussions of specific projects will be initiated with potential sponsors during the public review period for this Supplemental Reconnaissance study.

If smaller-scale feasibility studies of individual locations within the GLNS are identified, local or regional U.S. government or non-profit sponsors could potentially become study cost-share partners. However, in order for the Canadian Government or any other Canadian entity to participate as a sponsor, legislative action would be required. The Canadian Government is aware of the cost sharing requirements for potential project implementation.

A Letter of Intent (LoI) will be required from the non-Federal sponsor stating a willingness to pursue the feasibility study and to share in its cost, and to display an understanding of the cost sharing requirement for project construction. With regard to feasibility studies for individual ports, while no formal non-Federal sponsor has been identified to date, ports such as Green Bay (WI) and Monroe (MI) have expressed interest in participating is such a study.

9. Feasibility Phase Assumptions

There are a certain number of assumptions that are necessary to conduct any type of planning study. They generally tend to simplify the analysis, and help the analyst focus in on the problem being studied. Several assumptions have been incorporated into the plan formulation process. The assumptions concern the existing commercial navigation system and include:

· Traffic forecasts have been developed on a system wide basis.

· Current two-way traffic patterns in the St. Marys River and the St. Marys Falls Canal would be maintained.

· Any modifications would be designed to maintain existing water level profiles and flows.

· The costs and benefits included in the analysis are only U.S. costs and benefits.

· The navigation season remains the same.

· Non-Federal actions within the authority and abilities of port authorities, state and local agencies, and the waterborne transportation industry which increase the efficiency of the existing system would be maximized. These actions include continued use of the most efficient vessels in the existing and future fleet, light loading when necessary, tug assistance when necessary, planning shipments with seasonal fluctuations in lake levels, and utilizing alternative transportation modes and transshipment facilities when necessary.

· Sufficient commodity reserves and/or production capacities exist throughout the period of analysis at the projected tonnage levels.

· Improvements in technology would be incorporated to the maximum extent possible in mining, grain production, and transshipment and vessel operations.

· National defense. The Great Lakes system has served the nation during periods of military conflict in the past, and would be expected to do so again in the future if the need arose. It is assumed that this importance will be considered as part of the justification of any proposed project as part of the GLNS.

10. Feasibility Phase Milestones

With timely and consistent appropriations, the feasibility phases could begin in early 2011 and finish in 2013. The second phase is developing and executing any project cooperation agreements, if applicable.

Table 19 – Estimated Feasibility-Phase Milestones.

Feasibility Milestones	***Duration***
Execute Feasibility Cost-Share Agreement (FCSA), if applicable.	3 months
Planning & Detailed Planning Report and Planning Design and Analysis (PDA).	36 months
Project Cooperation Agreement (PCA) Execution, if applicable.	1 month
Implement Plans	Varies

11. Views of Other Resources Agencies

A number of Federal, State and local agencies were contacted for coordination during the preparation of the draft and final 2002 Corps' Great Lakes Navigation System Review Reconnaissance Report. The U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, Environment Canada, Transport Canada, the Canadian Department of Fisheries and Oceans, U.S. and Canadian riparian Tribes and other local interests were notified of the study. At one point, 1,700 notices were sent out to all U.S. and Canadian agencies and stakeholders that the report was available for review and comment. Several agencies and stakeholders responded with comments and made suggestions regarding the Reconnaissance report; most were interested in continued coordination should any feasibility studies be developed for specific actions or locations.

During the development of the binational GLSLS report, U.S. and Canadian agency coordination was essential to properly and thoroughly evaluate the entire Great Lakes St. Lawrence Seaway System. The agencies involved in this collaboration are presented in Section 2 *Study Purpose and Scope,* Section 4.4 *Memorandum of Cooperation (M.O.C.) Between Transport Canada and the U.S. D.O.T.* and Section 6 *Plan Formulation*. Binational team meetings of the working groups occurred several time a year in order to review report progress, make unified decisions, discuss issues and collaboratively plan next steps.

Since a significant amount of content included in this Supplemental Report also appears in the binational GLSLS report (by design), this information was largely developed using a collaborative, multi-agency approach. However, this Supplemental Reconnaissance report will also be submitted for agency and stakeholder review in 2009.

12. Potential Issues Affecting Initiation of Feasibility Phase

As discussed in Section 8, there is no mechanism for the Canadian Government or any other Canadian entity to participate as a project sponsor. However, several options exist to develop or continue regional partnerships to implement regional initiatives, such as those that were established for the binational GLSLS study. *Further, any regional initiatives would need to be in concert with the overarching goals of the GLSLS and GLNS, such as initiatives that support environmental and economic sustainability of the entire system.*

Another important consideration is the possible need for legislation (and follow-up appropriation) to fund the initial and any follow-up feasibility or implementation phases directing either Federal/non-Federal cost-share or at full Federal expense.

13. Conclusions

GLNS is a Benefit to the Nation

In general, the analysis of the current situation of the GLNS concluded that the system remains an important element in the North American economy, with a transportation rate savings of approximately $3.6 billion (U.S. only) per year (not including the St. Lawrence Seaway). Its ongoing value and future prospects certainly justify the costs of maintaining its infrastructure. Moreover, future operation and maintenance of the system can be performed in a manner that minimizes environmental impacts.

Optimizing Existing Infrastructure

It is clear that the marine transportation infrastructure of the GLNS involves more than just a series of locks. There are also ports and terminals, channels, bridges and tunnels, systems for control and communication, as well as interfaces to other transportation modes. Collectively, this constitutes an integrated system that needs to be optimized if it is to contribute to solving the transportation needs of the future. Further study needs to be conducted to better identify the economic benefit to the nation that Great Lakes infrastructure provides.

Each of the following elements represents a distinct set of requirements, all of which need to be managed in an integrated fashion to ensure the competitiveness of the GLNS.

Locks: Because of their age, locks need to be subjected to a maintenance schedule that deals with potential failures in a way that sustains traffic with the fewest possible interruptions and preserves overall system integrity.

Shipping channels: The normal flow of water inevitably carries silt deposits that must be removed to maintain channels at authorized depths for shipping.

Ports: Ports and terminals which are likely to support short sea shipping or to serve as nodes in multimodal networks will require appropriate loading and unloading facilities and equipment together with seamless links to other forms of surface transportation.

Bridges and tunnels: There are a number of bridges and tunnels throughout the Great Lakes that must be maintained in ways that do not impede traffic.

Control and communication: Logistics systems today depend on advanced electronic systems to monitor movements and track shipments in real time.

Vessels: In addition to the traditional bulk carriers, there will be a need for multi-purpose ships capable of loading, carrying and unloading containerized cargoes.

While all of these diverse systemic elements form part of an integrated whole, each demands its own investments, technologies and scheduling. Planning must factor in the specific requirements of each element in a way that harmonizes the components of the whole system.

It is clear that burgeoning trade, a capacity crunch, aging transportation infrastructure and increasing pressures on transportation lands in urban settings are an integral part of the marine system. The locks, ports, terminals and other infrastructure of the GLSLS are now critical components of North America's transportation gateways and, as such, they require investment and tools to respond to market forces in a timely manner if they are to continue supporting Canadian and US international and domestic trade.

Environmental Sustainability

The considerations noted above must be examined within the framework of sustainable development. In simplest terms, sustainable development means the ability to foster economic growth in a way that does not interfere with the function of the ecological system. Consequently, policy and planning must factor in the environmental implications of lock maintenance and repair, channel dredging, construction of new port facilities, or the introduction of new vessels into the system.

The ecosystem of the GLNS is vulnerable to a variety of stressors. Because many are not directly related to navigation, management of or adjustments to navigational stressors are important but would not necessarily result in appreciable gains to overall environmental quality unless they form part of an approach that is integrated with measures in other economic sectors. As the requirements of GLNS operations and maintenance involve some stressors to the Great Lakes-St. Lawrence ecosystems, these must be managed effectively.

Organizational and governance frameworks, together with accompanying policies and legislation, are likely adequate to manage and control the navigation-related activities that have a negative impact on the environment. There will be a continuation of impacts related to planned works, such as maintenance of infrastructure, maintenance dredging and placement of dredged material, but such impacts can be minimized through effective application of environmental assessments, remedial actions, sound environmental management strategies and best practices.

Yet sustainable development means more than just selecting options that have a minimal impact on the environment. At the broadest possible level, it means attempting to build upon certain environmental advantages of marine transportation over rail and trucking, as one component of an integrated transportation system that can be operated in a more environmentally-friendly manner. Transportation by water is significantly more fuel efficient than other modes and consequently could reduce the emission of greenhouse gases and other pollutants. Moreover, increased utilization of waterborne transportation could help to alleviate traffic congestion on roads, which could ultimately result in the reduction of road maintenance and repair costs.

Monitoring and Follow-up

Ultimately, the success of any recommendation depends on a commitment to implement, as well as mechanisms to monitor progress and success. Canada and the US should maintain binational strategic communication on commercial navigation in the Great Lakes system through a body consisting of representatives of responsible departments and agencies in both countries. The role of this steering committee would be to provide strategic oversight with regard to the operations of the entire navigation system. It would pursue an appropriate policy framework, promote the opportunities represented by the system to other parts of government and ensure an integrated approach to the distinct imperatives of the economy, the environment and engineering. Ultimately, the sustainability of the system depends on achieving a viable balance of these three perspectives.

To implement a recommended feasibility phase investigation of the GLNS, the joint collaboration exemplified by the bi-national study working groups should be employed in much of the subsequent work. Issue-specific working groups should be encouraged to pursue initiatives and take action on key subjects of interest and concern. Such working groups should be mandated to report regularly on the progress achieved in the areas identified as priorities.

The Corps' Reconnaissance and Supplemental GLNS Studies have identified the issues that need to be considered if the navigation system is to continue to efficiently serve North America's economy over the next fifty years. In doing so, the working groups have developed planning tools that can be used to optimize overall system operations and maintenance. The application of these tools to the development and implementation of an asset management strategy must also factor in concerns about its broader impact on the environment. To this end, Canada and the US will have to put in place mechanisms that can respond to the issues raised in the GLNS Study though appropriate strategic oversight as well as specific initiatives and activities. These can be identified in the development of a feasibility study of the GLNS.

14. Recommendations

Based on the analysis contained in this report it is concluded that there is Federal interest in proceeding with further studies of the GLNS and the implementation of (6) – Improved Water Level Data Access (because of the nature of the alternative, a study is not cost-effective). While this Supplemental Reconnaissance report is undergoing review (public and agency) additional work defining the scope of additional studies, including cost and duration, and the development of a Project Management Plan will occur. The following Alternatives regarding the GLNS are recommended for further investigation.

Non-Structural and Site-Specific Studies and Works

(4). Deepening Individual Ports - The GLNS review identifies several ports on the Great Lakes where there is a Federal interest in further studies. It is recommended that feasibility studies for these ports be conducted individually provided there is a non-Federal sponsor.

(5). Addressing Navigational Restrictions - It is recommended that a feasibility study be conducted individually for the Chicago Sanitary & Ship Canal provided there is non-Federal sponsor. Also, it is recommended that a feasibility study be conducted individually for the St Clair River Ice Boom provided there is non-Federal sponsor.

(6). Improved Water Level Data Access – It is recommended that implementation of a system occur for improved water level data access, provided there is an identified project partner.

Optimization of the System through Operations and Maintenance

(8). Maintain the Great Lakes Connecting Channels and Harbors – It is recommended that Federal funds be used to prioritize dredging of Federal channels and harbors in the Great Lakes, and, subject to the limits of Congressional funding, to carry out dredging to fully-authorized depths.

(9). Maintain the GLNS Infrastructure - It is recommended that Federal funds be used to develop a full Asset Renewal priority matrix for Great Lakes navigation infrastructure, subject to the limits of Congressional funding to carry out this work. Study specific to the quantification of the economic value that Great Lakes infrastructure contributes to the nation's economy also needs to be conducted.

Bi-national Studies

(10). Development of a Short-Sea Shipping System – It is recommended that fully Federally funded feasibility study be pursued in cooperation with Canada to build upon the foundation provided in the bi-national GLSLS study, and to determine if there is merit in the joint development of ports or other facilities that would foster development of short-sea shipping. Such a study would likely involve multiple Federal agencies and private interests; the lead agency would likely be determined during development of the study scope.

The study would examine the benefit of shipping across the Great Lakes as part of an intermodal transportation system to reduce congestion of overland transportation routes. The study should also consider the bi-national development of a North American international trade port in the Gulf of St. Lawrence to facilitate the transfer of goods to interlake-only vessels.

(11). Review of U.S. GLNS Activities to Reduce Environmental Impacts – It is recommended that a feasibility study be conducted at full-Federal expense to identify measures that could be taken to reduce the impacts of navigation on each of the connecting channels. This work should be conducted bi-nationally with Canada, using the steering committee framework established as part of the GLSLS study.

15. Commander's Endorsement

I hereby recommend further study of Alternatives 1, 4, 5, 8, 9, 10 and 11, and the implementation of Alternative 6, through the execution of a feasibility study or construction to execute the recommendations, depending on the availability of a cost-sharing partner(s) and/or Federal funding. As indicated by research conducted and recommended actions determined in this Supplemental Reconnaissance Report and the binational Great Lakes St. Lawrence Seaway Study, fall 2007, there is significant interest in ensuring the continued economic viability of the Great Lakes Navigation System while enhancing its environmental sustainability, reliability and safety.

JBD

JAMES B. DAVIS
LTC, EN
Commanding

Date 19 June 2009

Attachment 1 - Definition of Terms

An array of names and definitions are applied to the various waterway segments in the Great Lakes-St. Lawrence River Basin. Some waterway designations overlap others. What follows are the definitions that will be used in this study to describe the navigable waterways in the basin. These are based on most common usage in government reports and industry publications.

Great Lakes St. Lawrence Seaway (GLSLS) – navigable waterways from the Gulf of St. Lawrence west to the Head-of-the-Lakes. The GLSLS includes the St. Lawrence Seaway and the Great Lakes Navigation System.

Great Lakes Navigation System (GLNS) – all five of the Great Lakes and the Great Lakes connecting channels, excluding the Welland Canal; the GLNS encompasses the navigation system that is in the U.S. territory and/or maintained by the U.S. Federal Government.

Great Lakes Connecting Channels – navigable connecting channels (rivers) between the Great Lakes: the St. Marys River, the Straits of Mackinac, and the St. Clair/Detroit River system. This does not include harbor access channels that allow access to the lakes or to the main connecting channels (rivers).

St. Lawrence River – Commercially-navigable straight between Lake Ontario and the Gulf of St. Lawrence. It has two distinct reaches – the channelized, Montreal-Lake Ontario (MLO) section of the Seaway and the reach from Montreal to the Gulf. This latter stretch of river is referred to in this report as the lower St. Lawrence River.

St. Lawrence Seaway – the waters of the St. Lawrence River above Montreal, Lake Ontario, the Welland Canal, and Lake Erie as far west as Long Point. It includes the Welland Canal and the Montreal-Lake Ontario section. Data displays in this appendix conform to SLSMC and SLSDC Seaway statistical presentations, which do not include intra-Lake Ontario waterway traffic.

Welland Canal Section – eight lock canal linking lakes Erie and Ontario. This section of the St. Lawrence Seaway is the only all Canadian Great Lakes connecting channel.

Montreal-Lake Ontario (MLO) Section – seven-lock navigation channel of the St. Lawrence Seaway lying entirely within the St. Lawrence River and extending from the St. Lambert Lock to Lake Ontario beyond the Iroquois Lock.

RECONNAISSANCE REPORT **June 2002 (Revised February 2003)**

GREAT LAKES NAVIGATION SYSTEM REVIEW

Great Lakes - St. Lawrence River System

US Army Corps
of Engineers®
Great Lakes &
Ohio River Division

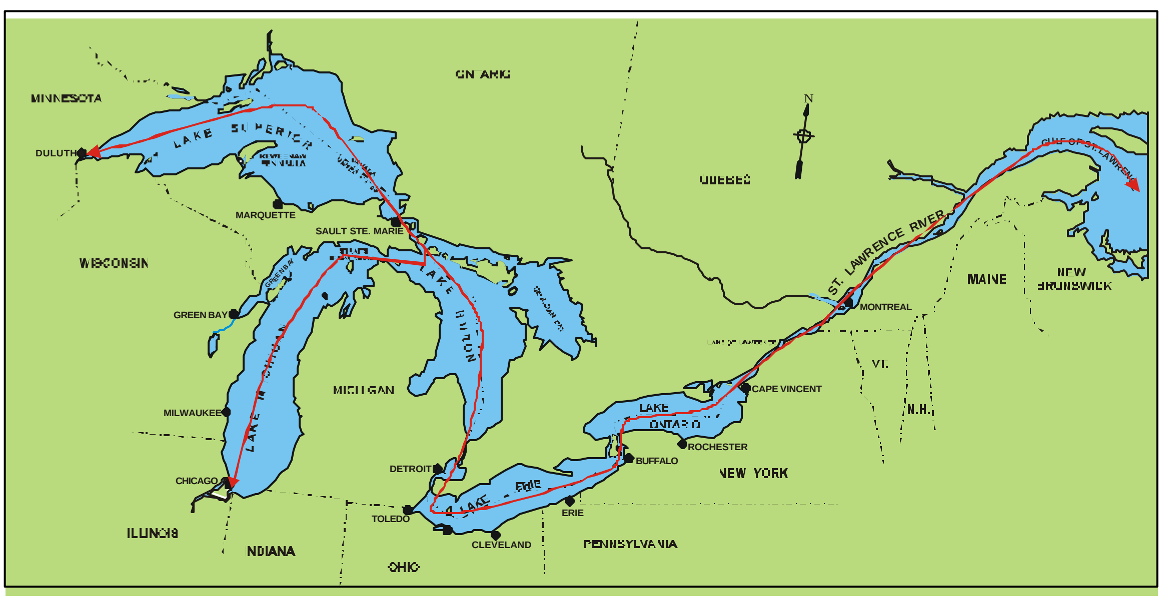
Report Summary

INTRODUCTION:

The Great Lakes/St. Lawrence River waterway corridor is unique for the scale and sophistication of its market and the extensive integration of its economy. This waterway runs alongside eight Great Lakes states and the provinces of Ontario and Quebec, home to almost 100 million people -- a third of the combined U.S.- Canadian population. The Great Lakes states, Ontario, and Quebec are by far the most manufacturing intensive regions of their respective countries. On the Canadian side, Ontario and Quebec represent over 60 percent of Canada's gross domestic product, while the Great Lakes states account for some 26 percent of the entire U.S. manufacturing base.

The waterway system extends more than 2,300 miles (3,700 kms) from the Gulf of St. Lawrence to the head of the Great Lakes at the Lake Superior ports of Duluth/Superior, Minnesota/Wisconsin and Thunder Bay, Ontario (see vicinity map on Figure 1). This direct water route to the heart of the North American continent puts Cleveland closer than Baltimore, in nautical miles, to European ports such as Liverpool and Hamburg. Over its course, from east to west, the waterway leads from the deepwater of the Gulf of St. Lawrence to Montreal, where the river is canalized in order to provide a 26'-3" draft[1], then through Lake Ontario and the Welland Canal, and finally into Lake Erie and the upper lakes. The portion of the Great Lakes/St. Lawrence River waterway between Montreal and the head of the lakes is referred to as the Great Lakes/St. Lawrence Seaway (GL/SLS).

FIGURE 1
Great Lakes/St. Lawrence Waterway Navigation System



[1] The available draft on the Seaway has been deepened over time to 26'-3". It is important to note that the available draft is always subject to the fluctuations of water levels on the system.

The GL/SLS system combines a remarkable natural resource with one of the world's great engineering feats to form a transportation network linking the middle of North America to the global marketplace. From a geographic perspective alone, the Great Lakes/St Lawrence Seaway system is unique in the world. The Great Lakes cover 95,170 square miles of water surface, about 61,000 in the U.S. and 34,000 in Canada, and defines a 10,000-mile coastline, which is longer than the entire U.S. Atlantic seaboard. The GL/SLS system was completed in 1959 with the opening of seven locks in the St. Lawrence River, complementing the 8 locks of the Welland Canal, thereby fulfilling a dream dating back to the 1700s to link the Great Lakes and Atlantic Ocean by a deep-draft channel. The development of the St. Lawrence Seaway coincided with and contributed to the emergence of the North American heartland as the world's preeminent center of agricultural and industrial production. See Attachment 1, Definition of terms, on page 46 for clarification of waterway segments.

The GL/SLS system has an enormous impact on the North American economy. It generates $3 billion annually and up to 17,000 jobs in Canada, and adds another $2 billion and some 50,000 jobs to the U.S. economy. For individual ports in the system, GL/SLS trade has been a catalyst for billions of dollars in capital investment and industrial growth. The base economies of many GL/SLS ports, and the entire Midwest, were defined by cost effective access to raw materials provided by the waterway. The GL/SLS has provided U.S. and Canadian farmers of the Great Plains an economical route to the world market for roughly 14 million metric tons a year of wheat, corn, soybeans and other products[2].

Maritime commerce on the GL/SLS involves two general trade communities: traffic moved on the Seaway, much of which is overseas import/export trade, and interlake domestic trades contained within the Great Lakes. The two universes are largely distinct, though they do both service the steel industry. Lakers hauling iron ore and "salties" specializing in steel both service the Great Lakes' steel industry.

The GL/SLS system is a true multi-modal system. Seamless movements of goods and commodities flow from ship to rail and truck and from rail and truck to ship in well-synchronized trade patterns. Some of the most successful GL/SLS trades rely on multimodal connections, such as low-sulfur coal railed to Great Lakes loading ports from Wyoming and Montana for shipment by self-unloading vessels throughout the Lakes and grain railed from the Canadian Prairie Provinces to Thunder Bay for direct export by ocean freighters.

It is no coincidence that the major rail and highway hubs of the mid-continent - such as Chicago, Toronto, Detroit and Toledo - are major GL/SLS ports as well. More than 40 provincial and interstate highways and nearly 30 rail lines link the 65 major and regional ports of the system with consumers and industries all over North America

The vessels, waterways, and ports of the GL/SLS system provide consistently safe and reliable service, while still keeping transportation costs competitive for the industrial and agricultural heart of North America. Studies also indicate that marine transport uses less fuel and has lower emissions

[2] "2001/02 Great Lakes/St. Lawrence Seaway System Directory". Published in cooperation with the St. Lawrence Seaway Management Corporation and the St Lawrence Seaway Development Corporation.

than either rail or truck for equivalent cargoes and distances. The large cargo capacity relative to engine size and the operating characteristics of Great Lakes and Seaway vessels make them models of fuel efficiency. A laker, for instance, uses about one gallon of fuel per one ton of iron ore per round trip. A 1993 study by the Great Lakes Commission found that vessel transportation on the GL/SLS system uses considerably less fuel, produces fewer emissions, and is less prone to pollution causing spills than if the same cargoes were transported by either truck or rail.

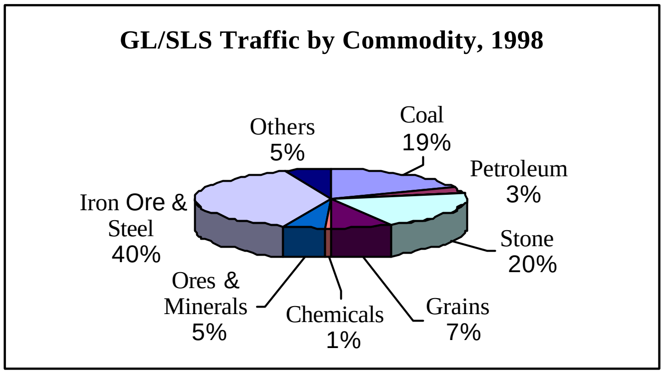
VESSEL AND TRAFFIC PROFILES AND PROJECTIONS

a. The Vessel Fleet. Vessel fleets are a critical consideration in planning future investments on any waterway. The Great Lakes/St. Lawrence Seaway (GL/SLS) is unique in the world in that it has three distinct fleets operating in its waters: 1) an intra-laker fleet, 2) a laker/Seaway fleet, and 3) a laker/Seaway oceangoing fleet of "salties". Each fleet is compatible with the traffic and market the fleet is designed to serve. The intra-laker fleet, a U.S. fleet, is dominated by the Class X thousand footers and the smaller Class VIIIs that shuttle between ore and coal docks on Lake Superior and power plants and steel mills on the upper lakes. The laker/seaway fleet, primarily a Canadian fleet, is dominated by the Seaway compatible Class VII vessel making complementary moves of grain from Lake Superior to grain elevators on the lower St. Lawrence and iron ore from the lower St. Lawrence to steel mills on Lake Ontario and the upper lakes. The oceangoing fleet of "salties" is dominated by tramp operators bringing commodities such as steel slab from overseas origins into the lakes, taking-on light loads of grain in Lake Superior before moving back to the lower St. Lawrence where they are topped-off with grain before continuing on to overseas destinations. The practice of light loading is required due to limitations on available draft on the Great Lakes Connecting Channels and St Lawrence Seaway.

While 70% of the world's fleet can transit the 80' x 766' locks and the 26'-3" channel of the Seaway, these vessels represent only 13 percent of world vessel capacity and 5 percent of the world container vessel capacity (See Appendix A- Economic Analysis, Section 5, Table 5-2 for details). The standardization of vessel loads in pallets, big bags, barge carriers, roll-on/roll-off and, most importantly, containers, and the coincidental investment in port infrastructure to handle these standard loads has allowed vessel owners to build bigger ships without increasing time-in-port for loading and unloading. These technical advances support the rapid growth of intercontinental trade. Ever larger ships are being built, indicating that the percentage of the world fleet that is Seaway capable will continue to decline in the foreseeable future. However, a deeper, wider Seaway could accommodate 34 percent (in terms of capacity) of the world fleet and, most importantly, 27 percent of the world container fleet in terms of gross ton capacity.

b. Overview of Commerce on the GL/SLS. As shown in Figure 2, the movement of iron ore and steel, coal and stone dominates GL/SLS traffic. All four commodities support the steel industry in part or in whole, though shipments of coal are primarily to electric utilities. The agriculture industry is also an important waterway user, shipping grains from Lake Superior ports through the St. Lawrence Seaway to ports along the lower St. Lawrence River (mostly for eventual shipment overseas) or directly to overseas destinations.

FIGURE 2



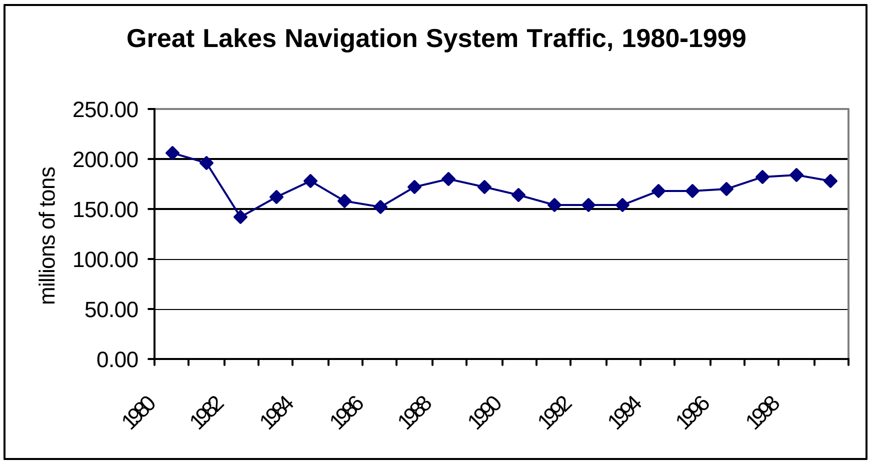
Traffic data for the GL/SLS was constructed from separate Canadian and U.S. sources as no comprehensive data base exists. In 1998, the single year for which a data base was built, 222.0 million tons of traffic moved on the GL/SLS. The U.S. component of the GL/SLS trade is dominated by waterborne trade between U.S. ports (127.6 million tons), making it the largest origin-destination flow. The next three largest flows are traffic from the U.S. to Canada (32.4 million tons), from Canada to Canada (26.1 million tons), and from Canada to the U.S. (20.5 million tons). The overseas trade is relatively small, 9.4 million tons enter the GL/SLS as imports, and 6.0 million tons leave the GL/SLS as exports from Canada and the U.S. to overseas destinations.

The movement of iron ore from U.S. ports on Lake Superior to steel mills along Lake Michigan, the Detroit River, Lake Erie and Lake Ontario is the largest commodity flow (60.4 million tons). The second and fourth largest flows are aggregates moving from U.S. ports on Lake Huron and Lake Erie, primarily to iron ore processing mills on Lake Superior, to steel mills, and to construction material yards in major metropolitan areas. Downbound flows of coal are the third largest commodity flow; Powder River Basin coals moving from Lake Superior to lakeside electric utility plant in both the U.S. and Canada dominate this flow. The fifth largest flow is Quebec/Labrador iron ores moving up the St. Lawrence River to steel mills primarily on lakes Ontario and Erie.

There are two distinct components to the GL/SLS: the Great Lakes Navigation System (GLNS) and the St. Lawrence Seaway. Each is discussed separately in subsequent paragraphs.

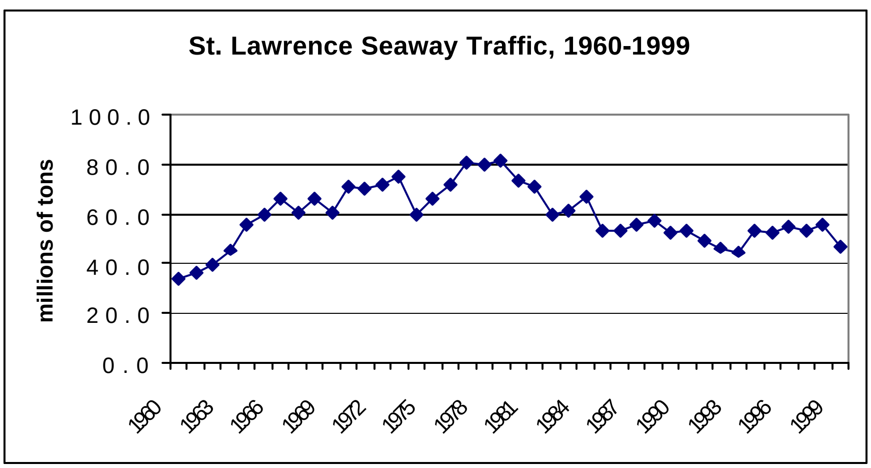
1.) <u>Great Lakes Navigation System</u>. The GLNS comprises the upper four Great Lakes and their navigable connecting channels – the St. Marys River, the Straits of Mackinac, and the St. Clair/Detroit River System. In the past 20 years, the most dramatic change in GLNS traffic occurred between 1980 and 1982. Traffic declined by 64 million tons in this two year period; the drop coinciding with a recession induced downsizing of the U.S. steel industry, primarily affecting integrated mills on Lake Erie and in the Ohio and Monongahela River valleys. Some recovery occurred over the next two years, but the GLNS has not reached the 200 million ton traffic level since 1980 (see Figure 3).

FIGURE 3



2.) St. Lawrence Seaway. The St. Lawrence Seaway is the second major component of the GL/SLS. The Seaway connects the upper four Great Lakes with the deepwater channel of the lower St. Lawrence River and from there on to the Atlantic Ocean. Traffic on the Seaway grew rapidly its first 7 years and continued to grow, with some interruptions, up until 1980 (see Figure 4). This 20-year period of growth was followed by fairly sharp decline with traffic falling from a high of 82 million tons in 1979 to 53 million tons in 1985. Grain exports through the Seaway weakened as the former Soviet Union withdrew from the world grain market, Western Europe became more agriculturally self-sufficient, and rail subsidies favored the movement of Canadian grains to developing west coast ports servicing the rapidly growing Asian market. Iron ore moving from Canadian mines in Quebec and Labrador to U.S. steel mills declined as that industry retrenched and focused on U.S. sources for ore. Seaway traffic stabilized in the 1990s.

FIGURE 4



c. Projected Traffic Demands. There are two components to the total traffic demand projections developed for the reconnaissance study -- demands based upon the existing fleet, waterway system and traffic, and demands associated with a less constrained system. Total traffic demand projections associated with the existing system are presented in Table 1. These demands are shown to increase from a level of 232 million tons in 2000 to about 356 million tons by year

2060, reflecting annual growth of about 0.7 percent. The St. Lawrence Seaway subsystem grows slightly faster, at about 0.8 percent per annum, and annually accounts for about one quarter of the traffic on the larger system. The GLNS grows at a rate of about 0.7 percent. Nearly all Seaway traffic moves on the GLNS, explaining why GLNS traffic accounts for 99 percent of GL/SLS traffic.

TABLE 1
Traffic Demand Forecasts, Great Lakes and St. Lawrence Seaway, 1998-2060
(millions of tons)

Year	Great Lakes Navigation System	St. Lawrence Seaway	Great Lakes/ St. Lawrence Seaway [1]
1998	227	61	228
2000	232	62	232
2010	255	67	255
2020	275	73	276
2030	291	80	292
2040	314	87	315
2050	335	93	336
2060	356	99	357
Annual Growth			
1998-60	0.7%	0.8%	0.7%

NOTE: Data includes both U.S. and Canadian traffic.
(1) Due to overlapping traffic, the Great Lakes/St. Lawrence Seaway totals are not the sum of the Great Lakes Navigation System & St. Lawrence Seaway traffic.
See Appendix A-Economic Analysis, Section 4 for details.

The second component of system traffic demands is potential shift of mode traffic demand. This traffic, resulting from increased system dimensions, is additional to the existing traffic. Two transportation studies were used to indicate additional traffic demand. A transportation-cost analysis for an improved Seaway identified potential bulk Seaway traffic, and a container transportation-savings analysis indicated the potential for container traffic on the GL/SLS. The container analysis shows some potential for existing-overland East Coast-Great Lakes container traffic to divert to the Seaway. Additional bulk traffic demands are mostly for export grain. Table 2 displays the additional traffic demand forecasts.

TABLE 2
Additional Traffic Demand Forecasts,
35' Great Lakes/St. Lawrence Seaway

	2010	2020	2030	Annual % Change 2000 - 2030
Additional Traffic				
Containers (in TEUs) *	2,227,999	2,965,300	3,946,594	2.9%
Bulk (in millions of tons)	6.54	7.01	7.52	0.7%

* Twenty Ton Equivalent Units
See Appendix A- Economic Analysis, Section 4, page 23, Section 6, page 8 and Attachment 4 for details.

PLAN FORMULATION

The Army Corps of Engineers, as the Federal government's largest water resources development and management agency, began its water resources (civil works) program in 1824. At that time, Congress appropriated funds for improving navigation. Since then, the Corps has been involved in improving navigation in rivers and harbors, reducing flood damage, and restoring degrading ecosystems. The Federal interest in navigation improvements stems from the Commerce Clause of the Constitution. The primary objective of navigation improvements is to assist in the development, safety, and reliability of waterborne commerce. Navigation in the nation's ports and inland waterways is an essential component of our national transportation system.

This reconnaissance analysis was prepared as an initial response to Section 456 of the Water Resources Development Act (WRDA) of 1999, which authorized the Great Lakes Navigation System Review. The full text of the Act is as follows:

> *"In consultation with the St Lawrence Seaway Development Corporation, the secretary shall review the Great Lakes Connecting Channels and Harbors Report dated March 1985 to determine the feasibility of undertaking any modification of the recommendations made in the report to improve commercial navigation on the Great Lakes navigation system, including locks, dams, harbors, ports channels, and other related features."*

a. Planning Process. A civil works project evolves from an idea about how to solve a problem and to formulate a solution that reflects both national and local interests. A project typically involves five phases: (1) reconnaissance, (2) feasibility, (3) pre-construction engineering and design, (4) construction, and (5) operation and maintenance. The primary purpose of the reconnaissance phase (first phase) is to determine if there is federal interest in proceeding with the feasibility phase.

The Great Lakes Navigation System reconnaissance study was initiated on Jan 15, 2001. It is a multi-district study, which includes team members from Chicago, Buffalo, Huntington, Louisville, and Detroit districts, with Detroit as the lead district. Four study teams were organized for the study: plan formulation, engineering, environmental, and economics.

To identify problems, opportunities, and potential improvements to the navigation system, a survey was conducted which included international, federal, public and private stakeholders of the Great Lakes/St. Lawrence Seaway (GL/SLS) navigation system. Problems, opportunities and potential improvements to the St. Lawrence Seaway portion of the navigation system were identified through coordination with both the Saint Lawrence Seaway Development Corporation (U.S.) and the St. Lawrence Seaway Management Corporation (Canada). Primary concerns among stakeholders were the limitations on vessel drafts and restrictive channel and port depths, narrow channels (applicable specifically to the Chicago Sanitary and Ship Canal), restrictive lock sizes and channel depths on the St. Lawrence Seaway, and the future reliability of lock structures on the Welland Canal and Montreal-Lake Ontario (MLO) section of the Seaway. Alternatives were then formulated using input from surveys and discussions with stakeholders. For the purposes of determining a

Federal interest in further studies, alternatives were developed incorporating the following elements:

* Deepening the Great Lakes connecting channels - potential channel and port modifications to improve vessel traffic, primarily deepening the channels.

* Improvements to the St. Lawrence Seaway[3] - replacing the existing locks with larger and deeper chambers and providing channels compatible with the larger lock dimensions.

* Deepening individual ports - improvements to the ports and harbors within the Great Lakes system. These improvements would include modifications to existing infrastructure and channels to accommodate deeper draft vessel traffic.

The alternatives identified based on these surveys do not represent the full range of alternatives to be evaluated. A more extensive process of problems identification and formulation and evaluation of alternatives would be completed during the feasibility phase of the study.

b. Without-project Conditions. The future without-project condition for the Great Lakes Navigation System (GLNS) assumes completion of authorized improvements at the Soo Locks, while maintaining the status quo elsewhere on the U.S. portion of the GLNS. The Soo Locks consist of four parallel locks, located on the St. Marys River, at Sault Ste. Marie, Michigan and the improvements include replacing the Davis and Sabin locks with one combined lock. On the U.S. portion of the GLNS a minimum draft of 25’6” LWD at all locks and connecting channels is maintained over the next 70 years. On the Seaway, a 26’3” draft is maintained. The aging Seaway locks are first maintained through normal operation and maintenance (O&M), then limited rehabilitation, and ultimately major rehabilitations. Each successively more aggressive approach to maintenance is phased in as the condition of Seaway locks deteriorates, requiring longer closures, which through time begin to occur during the navigation season, sometimes without advance notice to shippers. The single lock configuration in most locations makes the reliability of the overall system an even greater concern than it might be for dual-lock systems. The consequences of a major lock failure likely would cause traffic disruptions of the entire waterway.

The locks on the Welland Canal are at least seventy years old, while the locks on the Montreal/Lake Ontario (MLO) portion are forty-four years old. Maintaining the locks will likely result in repairs that address immediate concerns, however, these repairs may not be sufficient in scope to deal with the underlying structural problems. A comprehensive program with major expenses in lock rehabilitation will have to be initiated to keep the locks functional. Before a decision is made to make investments of this magnitude, an analysis should be completed to determine if it makes economic sense to rehabilitate the locks versus building new locks. Ultimately, the locks may face closure if a wide-ranging program to rebuild or repair the locks is not initiated.

With respect to the individual ports and harbors, the future without-project condition will be to maintain the existing project depths in the channels through ordinary operations and maintenance.

[3] "The St. Lawrence Seaway includes the waters of the St. Lawrence River above Montreal, Lake Ontario, the Welland Canal, and Lake Erie as far west as Long Point " from United States Coast Pilot 6 (31st Edition).

c. With-Project Conditions. Five broad options were developed for evaluation during the reconnaissance phase (see Table 3). Each option has three components. The first component being the U.S. portion of the GLNS, the second the Welland Canal Section of the Seaway, and the third is the MLO Section of the Seaway.

Option 1 - Includes the many combinations of improvement alternatives for the Great Lakes connecting channels and harbors combined with eventual replacement of the Seaway locks at current dimensions.

Option 2 - Contemplates the same improvements as Option 1 above, coupled with construction of a deeper (35' draft) and larger (110'x1200' lock chambers) Welland Canal.

Option 3 - Builds upon Option 2 by replacing the MLO Section of the Seaway with a deeper and larger system of locks and channels, and by extending the 35' draft system up to Detroit.

Option 4 - Is the same as Option 3, except that the 35' draft now extends into Lake Michigan and Lake Huron by the deepening of the entire St.Clair/Detroit River system.

Option 5 - Extends the 35' draft throughout the GL/SLS system as a result of deepening the St. Marys River and lowering the sill depth of the Soo locks.

TABLE 3
With-Project Conditions

Alternative	**U.S. GLNS Connecting Channels & Ports**	**Welland Canal Section—Seaway**	**MLO Section--Seaway**
Option 1	Deepen up to 30' draft	WOPC	WOPC
Option 2	Deepen up to 30' draft	Replacement of Locks 110'x1200', draft 35'	WOPC
Option 3	Deepen up to 30' draft, except Detroit R. at 35'	Replacement of Locks 110'x1200', draft 35'	Replacement of Locks 110'x1200', draft 35'
Option 4	Deepen up to 35' draft, except St. Marys R. at 30'	Replacement of Locks 110'x1200', draft 35'	Replacement of Locks 110'x1200', draft 35'
Option 5	Deepen up to 35' draft all connecting channels	Replacement of Locks 110'x1200', draft 35'	Replacement of Locks 110'x1200', draft 35'

Note: WOPC is the acronym for without-project condition.

ECONOMIC ANALYSIS

a. General. Four broad waterway improvement investment options (Options 1, 3, 4, and 5) were evaluated; Option 2 was omitted from reconnaissance-level consideration due to the difficulty in developing necessary benefit information. Owing to funding and time constraints, only a limited set of cost estimates were developed for the with-project alternatives, specifically: for Option 1 port and connecting channel plans, for some Chicago Sanitary and Ship Canal plans, and for the St. Clair/Detroit River system operational plans. As is appropriate for a reconnaissance level study effort, all estimates were developed utilizing existing information to the maximum extent possible.

The majority of the alternatives proposed for consideration for the Great Lakes Connecting Channels and Harbors portion of the navigation system have been evaluated under past studies and/or analyses. The quantities and estimates included in the past studies were used as the initial basis for development of cost estimates for this study. Where appropriate, and when lacking any definitive new data, previous estimates were updated utilizing the Corps of Engineers' Civil Works Construction Cost Index System.

No cost estimates were prepared for the without-project condition for the St. Lawrence Seaway or for Options 2, 3, 4, and 5, or for the 30' connecting channel plan under Option 1. Because lock reliability is a significant concern on the Seaway, a complete description and evaluation of the without-project condition alternatives is an especially important, analytically intensive effort. Nevertheless, completing the requisite engineering surveys, analyses, designs, and cost estimates for the 15-lock Seaway system is beyond the scope of this reconnaissance study.

Benefits for Option 1 connecting channels and port plans are based on U.S. domestic traffic and a portion of U.S. foreign traffic. It was not possible to model all traffic owing to systemic data deficiencies. These benefits, along with costs provided by the Engineering Team, are the basis of the benefit-cost analysis presented for Option 1 connecting channels and port plans. Benefits only are presented for the 30' connecting channel plan under Option 1 and the 35' draft alternatives described in Options 3, 4, and 5. As such, these benefits are intended as indicators of the possible presence or absence of federal interest. Finally, the benefits presented for the 30' and 35' draft alternatives assume federal and non-federal and waterside and landside infrastructure investments, and may require modification of the navigation season for the Seaway. Additional studies will be required to identify the extent to which the season may have to be lengthened to achieve viable commercial commerce.

b. Results. Specific connecting channels and port plans, Chicago Sanitary and Ship Canal plans, and St. Clair/Detroit River operational plans showed positive net benefits. In addition to these plans are the more comprehensive, system-wide alternatives. The benefits accruing to these plans are summarized in Table 4. Again, no costs were developed for these general, comprehensive alternatives.

TABLE 4
Summary of Average Annual Incremental Benefits
($ millions)

Category	Option 1	Option 2	Option 3	Option 4	Option 5
Incremental Annual Benefits					
Cost Reduction	$87	n.a.	$87	$87	$163
Shift of Mode					
Container	$0	n.a.	$293	$343	$343
Bulk Flows	$0	n.a.	$17	$17	$34
Economic Development	$0	n.a.	$400	$800	$800
Other Transportation Impacts	$0	n.a.	$88	$170	$170
Total Benefits	**$87**	n.a.	**$885**	**$1,417**	**$1,510**
Incremental Annual Costs	n.a.	n.a.	n.a.	n.a.	n.a.
Net Annual Benefits	n.a.	n.a.	n.a.	n.a.	n.a.
Benefit-Cost Ratio	n.a.	n.a.	n.a.	n.a.	n.a.

Note: n.a. indicates the value was not available. See Appendix A - Economic Appendix, Section 8 for details.

ENVIRONMENTAL CONSIDERATIONS:

The Great Lakes system is an ecological resource that continues to change as a result of human and natural forces. Global climate change has the potential to significantly influence water levels on the Great Lakes. Human inhabitation and development have resulted in changes in nutrient and contaminant loading, and the alteration of near-shore habitats. The consumptive use of resources due to over-fishing, water exportation, and mineral or energy extraction continue to be controversial issues. Introduced species, ranging from the sea lamprey and Pacific salmon to the zebra mussel and purple loosestrife, have resulted in dramatic changes in species composition and abundance, and the flow of energy through the ecosystem. As our understanding of the system grows, we anticipate that additional anthropogenic impacts can be minimized or mitigated.

The development of the Great Lakes navigation system has contributed significantly to the impacts cited above. Modification of the connecting channels has altered lake levels. Navigation system construction and related development have directly changed habitats. Industries locating in the Great Lakes due to shipping, and the resulting increase in population, have caused pollution. Opening up the system to traffic from the Atlantic Ocean has allowed the entry of a variety of invasive species. The most dramatic impacts to the ecosystem have likely already occurred, but further development of the navigation system does carry with it potential adverse effects. The environmental sustainability of the ecosystem must be considered when making decisions regarding improvements to the navigation system.

The action alternatives considered in this study share some of the same types of potential impacts. Construction activities would include building canals, locks, and water control structures, and dredging channels. Each of these activities has the potential to damage local habitat features, particularly near shore. Operation of a system that encourages use by more and larger vessels has the potential to increase aquatic habitat disruptions (through bow waves, drawdown and surge, and propeller wash) in terms of both frequency and severity. Maintenance of an enlarged system could also result in additional habitat disruptions or changes if additional maintenance dredging or disposal is required. Modification of the St. Lawrence Seaway would draw new overseas traffic that could increase the risks of introducing new exotic species. Changes in the navigation season could also potentially result in damage to restricted areas of the system.

On the positive side, improvements to the navigation system would reduce fuel consumption and atmospheric emissions related to the transportation of goods. Careful design and construction would also provide opportunities to incorporate environmentally beneficial features such as wetlands and spawning reefs which may help to restore ecological functions lost over the years. Reconstruction of locks in the St. Lawrence River may provide an opportunity for incorporating features to assist in the blockage of new aquatic nuisance species. Determining the overall significance of the proposed modifications will be a major effort requiring detailed site specific analyses of the alternatives carried into the feasibility stage, and the assessment of potential cumulative effects.

FEASIBILITY STUDY COSTS:

The total feasibility study cost is estimated to be approximately $20,000,000.

CONCLUSIONS AND RECOMMENDATIONS: Based on the reconnaissance analysis contained in this report it is concluded that there is Federal interest in proceeding with further studies of the Great Lakes and St. Lawrence Seaway Systems Study.

However, prior to initiation of the feasibility study, further information is needed. It is recommended that a supplement to the reconnaissance report, for clarification of the without project conditions and determination of the Federal interest, be undertaken. The purpose of this supplement is to provide needed information to support a Federal decision on whether to proceed with the feasibility study. This effort will include an assessment of baseline without-project conditions for the environment, engineering features and economic conditions, as well as public involvement and coordination. Should the recommendation be to proceed with further studies, this phase must also determine the scope of additional studies, including cost and duration, and develop a Project Management Plan. Since the system is a unique bi-national waterway, coordination with Canada that occurred during the development of the Reconnaissance Report, will continue during the reconnaissance phase as well as any future studies. Options for partnering with Canada in future study efforts are being investigated.

The following recommendations may be pursued independently:

(a) The GLSLS System Review identifies several ports on the Great Lakes where there is a federal interest in further studies. It is recommended that feasibility studies for these ports be conducted individually provided there is a non-Federal sponsor.

(b) It is recommended that a feasibility study be conducted individually for the Chicago Sanitary & Ship Canal provided there is non-Federal sponsor.

(c) It is recommended that a feasibility study be conducted individually for the St Clair River Ice Boom provided there is non-Federal sponsor.

(d) It is recommended that a feasibility study be conducted individually for Improved Water Level Data Access provided there is non-Federal sponsor.

(e) It is recommended that a feasibility study be conducted individually for Buoys and Beacons provided there is non-Federal sponsor.

Revised 2/3/03

RECONNAISSANCE REPORT
GREAT LAKES NAVIGATION SYSTEM REVIEW STUDY

JUNE 2002

US Army Corps of Engineers
Great Lakes &
Ohio River Division

RECONNAISSANCE REPORT
GREAT LAKES NAVIGATION SYSTEM REVIEW STUDY

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GREAT LAKES NAVIGATION SYSTEM REVIEW
RECONNAISSANCE STUDY

1. STUDY AUTHORITY

a. This reconnaissance analysis was prepared as an initial response to Section 456 of the Water Resources Development Act (WRDA) of 1999, which authorized the Great Lakes Navigation System Review. The full text of the Act is as follows:

"In consultation with the St Lawrence Seaway Development Corporation, the secretary shall review the Great Lakes Connecting Channels and Harbors Report dated March 1985 to determine the feasibility of undertaking any modification of the recommendations made in the report to improve commercial navigation on the Great Lakes navigation system, including locks, dams, harbors, ports channels, and other related features."

The *Great Lakes Connecting Channels and Harbors* study was authorized by two separate resolutions of the Senate Committee on Public Works in 1969 and 1976, the study was originally to determine the advisability of further improvements in the Great Lakes Connecting Channels and Harbors in the interest of present and prospective deep- draft commerce with particular consideration of improvements for the safe operation of vessels up to the maximum size permitted by the St. Mary's Falls Canal. The study was expanded by the 1976 resolution to also determine the advisability of providing additional lockage facilities and increased capacity at the St. Mary's Falls Canal at Sault Ste. Marie, Michigan.

The two separate resolutions of the Senate Committee on Public Works for the *Great Lakes Connecting Channels and Harbors* study read as follows:

"*Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested to review the report of the Chief of Engineers on the Great Lakes Connecting Channels, published as Senate Document Numbered 71, Eighty-Fourth Congress, and other pertinent reports, with a view to determining the advisability of further improvements in the Great Lakes Connecting Channels and Harbors in the interest of present and prospective deep-draft commerce, with particular consideration of improvements for the safe operation of vessels up to the maximum size permitted by the St. Mary's Falls Canal"*. (Sponsored by Senator Stephen M. Young of Ohio, adopted 2 June 1969.)

"Resolved by the Committee on Public Works of the United States Senate, that the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act, approved June 13, 1902, be, and is hereby requested to review the reports of the Chief of Engineers on the Great Lakes Connecting Channels, published as Senate Document Numbered 71, Eighty—fourth Congress, and other previous reports, with a view to determine the advisability of providing additional lockage facilities and increased capacity at St. Mary's Falls Canal, Michigan".
(Sponsored by Senator Hugh Scott of Pennsylvania, adopted 30 April 1976.)

b. Funds in the amount of $500,000 were appropriated each in Fiscal Year 2001 and Fiscal Year 2002 to conduct the reconnaissance phase of the study.

2. STUDY PURPOSE

The purpose of the reconnaissance study is to determine if there is a Federal interest in providing commercial navigation improvements to the Great Lakes-St. Lawrence Seaway System (GL/SLS). The system provides a shipping link between the deep water of the Atlantic Ocean and U.S. and Canadian ports located as much as 2,400 miles inland on the North American continent. Major sections of the system include five Great Lakes, 1,000 statute miles of the St Lawrence River and 400 miles of connecting channels. In that distance there are sixteen sets of locks that lift ships from sea level to an elevation of 600 feet in Lake Superior.

In response to the study authority, the reconnaissance phase was initiated on 15 January 2001. This phase of the study resulted in the finding that there is Federal interest in continuing the study into the feasibility phase and that the proposed improvements are found to be consistent with army policies. The purpose of the reconnaissance analysis is to document the basis for this finding and establish the scope of the feasibility phase.

3. LOCATION OF PROJECT, NON-FEDERAL SPONSOR AND CONGRESSIONAL DISTRICTS

a. The study area is located within the Great Lakes Basin, which includes the Great Lakes-St Lawrence Seaway System. The Great Lakes portion of the system encompasses the upper four Great Lakes and the connecting channels between Lake Superior and Lakes Michigan and Huron, and Lake Erie. The St. Lawrence Seaway portion of the system encompasses the Welland Canal, Lake Ontario and the St Lawrence River, which serves as the border between the U.S. and Canada. The Great Lakes-St Lawrence Seaway System borders the following U.S. states; Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and the following Canadian provinces; Quebec and Ontario (see Figure 1 in the Report Summary). See *Attachment 1, Definition of terms*, on page 46 for clarification of waterway segments.

b. This regional study includes eight Great Lakes states, and two Canadian provinces. No singular (state or regional) representative, or combination thereof, has been identified as a potential non-Federal sponsor to support a feasibility study of the Great Lakes/St. Lawrence Seaway System. However, the Canadian Government has indicated an interest in considering partnering in a joint U.S. – Canadian study of the Great Lakes/ St. Lawrence Seaway System, but has not officially come forward. The Canadian Government is aware of the requirements of a non-Federal sponsor. There is currently no provision in law for the Corps to partner with a foreign government in a feasibility study effort.

c. With regard to individual ports and harbors, there is interest in conducting individual feasibility studies, but potential non-Federal sponsors are waiting for a determination on whether the system wide study is to be carried forward.

d. The study area lies within the jurisdiction of the following Congressional Districts:

Illinois Congressional Districts:

Senator Richard J. Durbin, D
Senator Peter G. Fitzgerald, R

1st Bobby L. Rush (D)
2nd Jesse Jackson (D)
3rd William O. Lipinski (D)
4th Luis Gutierrez (D)
5th Rod Blagojevich (D)
6th Henry J. Hyde (R)
7th Danny K. Davis (D)
8th Philip M. Crane (R)
9th Janice D. Schakowsky (D)
10th Mark Steven Kirk (R)
16th Donald Manzullo (R)

Indiana Congressional Districts:

Senator Paul Evan Bayh, D
Senator Richard Lugar, R

1st Peter J. Visclosky (D)
3rd Tim Roemer (D)

Michigan Congressional Districts:

Senator Carl Levin, D
Senator Debbie Stabenow, D

1st Bart Stupak (D)
2nd Peter Hoekstra (R)
5th James Barcia (D)
6th Fred S. Upton (R)
10th David Bonier (D)
14th John Conyers (D)
15th Carolyn Cheeks-Kilpatrick (D)
16th John Dingell (D)

Minnesota Congressional Districts:

Senator Paul Wellstone, D
Senator Mark Dayton, D

8th James L. Oberstar (D)

New York Congressional Districts:

Senator Charles Schumer, D
Senator Hillary Rodham Clinton, D

24th John M. McHugh (R)
25th James T. Walsh (R)
29th John L. LaFalce (D)
30th Jack Quinn (R)

27th Thomas Reynolds (R)
28th Louise M. Slaughter (D)
31st Armory (Amo) Houghton (R)

Ohio Congressional Districts:

Senator Mike Dewine, R
Senator George V. Voinovich, R

5th Paul E. Gillmor (R)
9th Marcy Kaptur (D)
10th Dennis J. Kucinich (D)
11th Stephanie Tubbs Jones (D)
13th Sherrod Brown (D)
19th Steven LaTourette (R)

Pennsylvania Congressional Districts:

Senator Arlen Specter, R
Senator Rick Santorum, R

21st Phil R. English (R)

Wisconsin Congressional Districts:

Senator Russel Feingold, D
Senator Herbert Kohl, D

1st Paul Ryan (R)
4th Gerald D. Kleczka (D)
5th Thomas M. Barrett (D)
6th Thomas E. Petri (R)
7th David R. Obey (D)
8th Mark Green (R)
9th James F. Sensenbrenner (R)

4. PRIOR STUDIES, REPORTS AND EXISTING WATER PROJECTS

An extensive amount of literature from prior studies and reports has been reviewed during the development of this report. Prior studies pertaining to economic and engineering data are listed within their respective appendix. Other studies are shown below include:

a. <u>Prior Studies, Reports:</u>

The following reports are being reviewed as part of this study:

(1). *Great Lakes Connecting Channels and Harbors, Stage 2 Documentation, Volume 1 and 2 March 1982.* Determine the advisability of further improvements in the Great Lakes Connecting Channels and Harbors in the interest of deep-draft commerce. Also determine the advisability of providing additional lockage facilities and increase capacity at the St. Marys Fall Canal at Sault Ste. Marie, Michigan

(2). *Great Lakes Connecting Channels and Harbors, Final Feasibility Report and Environmental Impact Statement, September 1985, (Revised January 1988).* Determine the advisability of further improvements in the Great Lakes Connecting Channels and Harbors in the interest of deep-draft commerce. The study also will determine the advisability of providing additional lockage facilities and increase capacity at the St. Marys Fall Canal at Sault Ste. Marie, Michigan.

(3). *St. Lawrence Seaway Additional Locks Study, Preliminary Feasibility Report, July 1982*. Determine the adequacy of the existing locks and channels in the U.S. Section of the St. Lawrence Seaway.

(4). *Fox River Channel, Green Bay Harbor, Wisconsin, Reconnaissance Report, Commercial Navigation Improvements, April 1991*. Determine the feasibility of modifying the existing commercial navigation harbor at Green Bay, WI to modernize the harbor for large vessels and international trade.

(5). *Menominee Harbor and River, Michigan and Wisconsin Reconnaissance Report*, Commercial Navigation Improvements, March 1991. Determine the feasibility of implementing improvements to the existing commercial navigation harbor at Menominee, WI and MI that was authorized in 1960.

(6). *An Overview of the Commercial Navigation Industry of the United States on the Great Lakes, June 1992, IWR Report 92-R-6*

(7). *Great Lakes Harbors Study.* The Final Report by the U.S. Army Corps of Engineers, dated November 1966, together with 38 interim reports, included recommendations that 30 harbors be improved and one harbor be built to provide a 27- draft depth commensurate with the 27—foot depths provided in the connecting channels, the Welland Canal, and the St. Lawrence River. These reports contain the economic and physical data and analyses used to justify improvements made during the late 1950's and early 1960's.

(8). *Great Lakes-St. Lawrence Seaway Navigation Season Extension Study*. Several reports were prepared and completed under this study by the U. S. Army Corps of Engineers as authorized by Section 107(a) and Section 107(b) of the 1970 River and Harbor Act. They include four Demonstration Program Annual Reports, 1972—1975; a Demonstration Program Report Summary, 1976.; and a Special Status Report, July 1974. Also included are: the *Final Demonstration Program Report*, completed September 1979, which documented the results of the Demonstration Program that was conducted under a cooperative effort among several Federal agencies and non-Federal public and private interests. *The Interim Feasibility Study, (House Document 96-181)* forwarded to the Congress on 3 August 1979 by the Secretary of the Army, recommended Federal participation in an extended navigation season on the upper four Great Lakes and their connecting channels to 31 January, plus or minus two weeks, using existing operational measures; *The Final Survey Report* recommended a 12—month navigation season on the upper three Great Lakes and their connecting channels, up to a 12—month navigation season on the St. Clair River—Lake St. Clair-Detroit River system and Lake Erie, and up to a 10—month navigation season on Lake Ontario and the International Section of the St. Lawrence River. The Final Survey Report was completed in August 1979 and forwarded to the Board of Engineers for Rivers and Harbors for Washington level review in January 1980. The Board completed its review in February 1981, and forwarded the report to the Chief of Engineers. The Chief of Engineers has forwarded his report to the Secretary of the Army for subsequent coordination. The Secretary of the Army stated that the season extension is primarily an operational matter with which the Corps has adequate authority.

b. Existing Water Projects:

This study is investigating potential modifications of the following project(s):

Deepening Ports:

1. Alpena, MI
2. Ashtabula Harbor, OH
3. Buffalo Harbor, NY
4. Burns Waterway Harbor, IN
5. Calcite Harbor, MI
6. Calumet Harbor/Lake Calumet, IL & IN
7 Chicago Harbor, IL
8 Cleveland Harbor, OH
9. Conneaut Harbor, OH
10 Detroit River, MI
11 Drummond Island, MI
12. Duluth-Superior Harbor, MN/WI.
13. Escanaba Harbor, MI
14. Fairport, OH
15. Gary Harbor, IN
16. Green Bay Harbor, WI
17. Indiana Harbor, IN
18. Lorain Harbor, OH
19. Marinette-Menominee Hbr, WI/MI.
20. Milwaukee, WI
21. Monroe Harbor, MI
22. Presque Isle, MI
23. Rouge River, MI
24. Saginaw River, MI
25. Sandusky Harbor, OH
26. Saugatuck, MI
27. Sheboygan, WI
28. Silver Bay Harbor, MN
29. St Clair River, MI
30. Stoneport, MI
31. Taconite Harbor, MN
32. Toledo Harbor, OH
33. Two Harbors Harbor, MN

Screening procedures were developed to identify harbors that have potential for deepening. The first screening was by tonnage; all ports that ship or receive over 1 million tons per year. See additional discussion on page 33, *Deepening Individual Ports.* Trade between these 33 harbors, if accomplished through additional navigation system modifications, could result in benefits, which could immediately be "applied" against the system-wide costs of those modifications. System wide modifications may include the following:

Deepening Great Lakes Connecting Channels:

1. St. Marys River
2. St. Clair River
3. Channels in Lake St. Clair
4. Detroit River

Increased Capacity to the St. Lawrence Seaway:

1. Additional Lock, parallel to the Snell Lock, located near Massena, NY
2. Additional Lock, parallel to the Eisenhower Lock, located near Massena, NY

Improve Navigation Restrictions:

1. Chicago Sanitary Ship Canal
2. St. Clair River Ice Boom
3. Improved Water Level Data Access
4. Aids To Navigation

5. PLAN FORMULATION

Plan formulation is the process of combining various management measures into comprehensive water and related land resources alternative plans of action that meet the goals defined in the study authorization. The study objective is to formulate alternative plans that respond to national, regional and local objectives and resolve identified problems, meet commercial navigation needs and facilitate opportunities.

a. General:

A number of Federal, State and local agencies, academic institutions, and citizens groups have expressed interest in the reconnaissance study and participated in the development of the reconnaissance analysis. Input was formally solicited on January 17, 2001, on the scope of the GLNS reconnaissance study. Comments were received from a wide variety of users, stakeholders, Government agencies and other private interests of the Great Lakes and St. Lawrence Seaway system. In addition, a web site http://www.lre.usace.army.mil/glnav/INDEX.HTM for the GLNS reconnaissance study was created to facilitate the sharing of information about the study.

Coordination and cooperation are essential to determine whether pertinent data is already in existence; to arrange schedules for obtaining assistance and obtaining additional data without duplication; to exchange information; to discuss proposed plans and to identify areas where there may be complementary effects. The following is a list of agencies with which this study is being coordinated:

FEDERAL AGENCIES

UNITED STATES

U.S. Department of Interior
U.S. Fish and Wildlife Service
U.S. Department of Transportation
St. Lawrence Seaway Development Corporation
U.S. Coast Guard
U.S. Department of Transportation, Maritime Administration
Federal Highway Administration
U.S. Department of Agriculture
Advisory Council on Historic Preservation
U.S. Department of Commerce
National Oceanic & Atmospheric Administration
Bureau of Indian Affairs

Environmental Protection Agency
Federal Energy Regulatory Commission
U.S. Forest Service
U.S. Department of Health, Education & Welfare
Public Health Service

CANADIAN

St. Lawrence Seaway Management Corporation
Fisheries and Oceans Canada
Coast Guard, Canada
Department of Environment, Canada
Ministry of Transport, Canada
Toronto Harbor Commissioners

SOVEREIGN NATIVE AMERICAN NATIONALS AND AFFILIATED AGENCIES

Great Lakes Intertribal Council
Great Lakes Agency, Bureau of Indian Affairs
Great Lakes Indian Fish & Wildlife Commission

STATE AGENCIES

Michigan Department of Natural Resources
Michigan Department of Environmental Quality
Wisconsin Department of Transportation
Coastal Zone Management Office
Department of Agriculture
Michigan State Historic Preservation Office
Minnesota State Historical Society
New York State Department of Environmental Conservation
Minnesota Pollution Control Agency
Pennsylvania Department of Conservation and Natural Resources

REGIONAL

International Joint Commission
Great Lakes Commission
Great Lakes Fishery Commission
Ohio Rail Development Commission

LOCAL AGENCIES

Great Lakes Port Authorities
Duluth Seaway Port Authority
Detroit/Wayne County Port authority

Port of Oswego Authority
Indiana Port Commission
Port of Cleveland
Toledo-Lucas County Port Authority
Ohio Rail Development Commission
Counties whose boundaries borders the Great Lakes States & St. Lawrence Seaway
Cities whose boundaries borders the Great Lakes States & St. Lawrence Seaway

<u>ORGANIZED GROUPS</u> (Includes such interests as: recreational, business, conservation, industrial, environmental, professional, educational, utility, labor, or community.)

St. Lawrence County Environmental Management Council
Great Lakes Research Consortium
United States Great Lakes Shipping Association
Lake Carriers Association
National Wildlife Federation
Great Lakes Natural Resource Center
Save The River
Thousand Island Heritage Conservancy
Ducks Unlimited
Detroit Audubon Conservation Committee
Clinton River Watershed Council
Edison Sault Electric Company
Illinois River Carriers' Association
Chamber of Maritime Commerce
Strategies Saint-Laurent Inc.
Shipping Federation of Canada

b. <u>National and Regional Objectives:</u>

(1). The national or Federal objective of water and related land resources planning is to contribute to national economic development consistent with protecting the nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal Planning requirements. Contributions to national economic development (NED) are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation.

(2). The Corps has added a second national objective for Ecosystem Restoration in response to legislation and administrative policy. This objective is to contribute to the nation's ecosystems through ecosystem restoration, with contributions measured by changes in the amounts and values of habitat.

c. Public Concerns:

The concerned public is interested in consideration of measures required to satisfy recreation opportunities, minimizing water quality degradation, and making special efforts to preserve the environment of the Great Lakes-St Lawrence Seaway area. Environmentalists are concerned with larger facilities and the potential effects these facilities could have on the surrounding environment. Shore erosion and flooding are major concerns of shoreline property owners. Terminal and transfer facilities are also a concern of the study since larger vessels would likely require some modifications of present operating procedures. Railroads and other alternate modes of transportation are also interested since they could be influenced by future action on the Great Lakes-St. Lawrence Seaway system. The most productive use of the Great Lakes-St. Lawrence Seaway system is a mutual concern of both Federal and State agencies. International concern is also involved because of the international traffic moving on the Great Lakes.

d. Description of Existing Conditions:

A general survey of the geography, resources, development, and economy of the region tributary to the Great Lakes-St. Lawrence Seaway System provides a benchmark against which potential impacts from proposed modifications to the existing commercial navigation system can be evaluated.

The region provides a good "quality of life" through its beautiful scenery, fishing, swimming, power boating and sailing, and through agriculture, mining, manufacturing, water and power supply, and transportation. All these activities are dependent upon the water resources of the system.

(1). Physical Setting

Climate

In general, the Great Lakes experiences a continental; semi-maritime climate, largely determined by the prevailing winds from west to east and the modifying influences of the Great Lakes. The region is normally humid throughout the year, with cold winters and cool summers in the north and warm summers in the south. The average annual frost-free season is about four months at the northern extremity of the basin and about six months at the southern extremity. Mean annual surface air temperatures over the basin range from about 4^{o}C (39°F) on Lake Superior to 9°C (49°F) on Lake Erie. Average temperature for each of the lakes is lowest in February and highest in July.

The Great Lakes store great quantities of heat and tend to moderate temperatures on the adjacent land areas. Thus, the interiors of Michigan's Upper and Lower Peninsulas are colder than areas nearer the lakes at the same latitude. The Great Lakes cause an increase of average annual humidity on the order of 15 percent. Short—term local variations in surface air temperatures can be extreme. Intense cells of cold arctic air can lower temperatures as much as 28^{o}C (50^{o} F) in one day.

Geology

"The Great Lakes have attained their present form and connections as a result of a complicated series of events. Many of the basic attributes of the lakes, such as their locations, depths, and shapes, were indirectly influenced by events which occurred as much as a half-billion years ago, when the bedrock foundation of the region was laid down. The bedrock terrain, with various degrees of resistance to erosion, was sculptured by weathering and stream erosion over a period of some 180 million years. During the last million years, continental ice sheets invaded the region several times and scoured and molded the landscape.

The earliest known predecessors of the modern Great Lakes are relatively recent arrivals on the scene. They came into existence probably not more than 20,000 years ago, when the wasting margin of the last continental ice sheet retreated into the lake basins. The earliest lakes were narrow, ice-margin bodies of water which expanded as ice melted and which were compressed in area at various times when ice sheets temporarily re-advanced. The lake waters at first spilled southward over the divides of the various lake basins. During the northward retreat of the border of the continental ice sheet, the lake waters found new, lower outlets in the north, and the lakes periodically drained down to lower levels – only to be returned to higher levels when uplift of the land raised northern outlets higher than the old southern outlets. The process of uplift continues today[1]."

Topography

The Superior Highlands of northern Minnesota, Wisconsin, and Michigan, range in elevation from about 600 to approximately 2,300 feet above mean sea level. Elevations in the interior lowlands range from 700 to 1,000 feet. In most of the basin, land surface is less than 1,000 feet above mean sea level. The highest point is the headwaters area of Lake Superior with an elevation of 2,301 feet above mean sea level at Eagle Mountain in Cook County, Minnesota, and the lowest elevation within the Great Lakes is about 570 feet above mean sea level at the lowlands adjoining Lake Erie.

The St Lawrence River is located in the St Lawrence Lowlands, which forms the northern section of the St Lawrence Valley Physiographic Province. The lowland is a broad area, less than 1,000 feet in altitude, bordered on the north by the Laurention Plateau and on the south by the uplands of the Adirondack Province.

Soils and Mineral Resources

The Great Lakes basin has large areas of relatively flat land with fine—textured soils of glacial origin. Included are the Iron River and Gogebic soils in Minnesota, Wisconsin, and the Upper Peninsula of Michigan. The Rubicon, AuGres, and Roscommon soils which occupy areas in Wisconsin and much of Michigan, are level to rolling, well drained to poorly drained sands. Southern Michigan, Indiana, western Ohio, and eastern Wisconsin include soils in rolling, calcareous glacial till and sand outwash materials. The Wooster-Mahoning soils occur in rolling, acid glacial till in eastern Ohio and Pennsylvania. The Ontario and Lordstown soils occupy much of western New York. The Ontario soils are deep, calcareous glacial till and the Lordstown soils are thin, acid glacial

[1] Geology of the Great Lakes, Jack L. Hough 1958

till over sandstone and shale.

Minerals are the foundation of the heavy industry that has developed in the Great Lakes Region. Virtually all of the metallic minerals, including iron, zinc, lead, silver, and copper, are found in the northwest and extreme eastern parts of the basin. Mineral fuels including oil and gas and non-metallics including limestone, dolomite, sandstone, shales, salt, gypsum, and natural brines, are found in lower Michigan, Ohio, Illinois, Indiana, and New York. Sand, gravel, clay, marl, and peat are generally found throughout the region. Only a small amount of coal is in the area, but in adjacent regions there are many large coal-mining operations, the output of which affects the economy of the region.

Shore Use, Erosion and Sedimentation

Shorelands are the focus of development in the Great Lakes region since they offer the opportunity for waterborne commerce, water supply, and recreation. Primary factors determining the type of shoreland use and development in a given area are geographical location, accessibility, ownership, topography and historical development.

Industrial, commercial, and permanent residential uses are concentrated in urban areas along lower Lakes Michigan, Huron, and Erie. Forested shorelands are almost exclusively confined to the northern areas of Michigan, Wisconsin, and Minnesota. Large tracts of forest and wildlife preserves are located along undeveloped lakeshore areas of Michigan, Wisconsin, and Minnesota. Located along the Great Lakes shores are the largest recreational developments in the Great Lakes basin, including three national lakeshores, 67 State parks, and numerous local community recreation areas. Shore erosion is a natural occurrence along the Great Lakes shoreline. Major causes of the shore erosion on the Great Lakes include underground water seepage, frost and ice action, surface water runoff, and wave action. Wind generated wave action causes the greatest erosion damage. Wave action works directly on the beach or at the toe of bluffs eroding away clay, silt, sand, and gravel. The intensity of damage caused by wave action varies with the magnitude of the waves generated, the elevation of the undisturbed lake level, the temporary increase in that level generated by wind or barometric pressure gradient, and the erodibility and exposure of the shorelands.

Water Quality and Supply

Federal, State, and local programs exist for the purpose of maintaining or enhancing water quality in the Great Lakes basin. The Federal programs are primarily the responsibility of the United States Environmental Protection Agency established by Reorganization Plan No. 3, effective 2 December 1970 (42 United States Code, annoted, Section 4321).

The adoption of water quality standards by all of the Great Lakes States facilitates the coordinated efforts to maintain and enhance water quality. From time to time it may be necessary to modify those standards to reflect changing conditions, changing information, and changing public opinion as to what constitutes best use of water related resources.

Fishery and Other Aquatic Resources

The fishery resources of the region constitute one of the major natural resources. The more than 237 species and subspecies of fish found in the waters of the Great Lakes represent most of the important families of fresh water fish in North America. Most of these species are indigenous to the basin, having entered the lakes during the last glaciating (the Wisconsin) period. In addition, exotic species are present, having been either purposely or inadvertently introduced by man. These introductions, along with past fishery management practices, have led to significant changes in the fishery resources of the basin.

Wildlife and Other Terrestrial Resources

There are approximately 220 species of birds and 18 species of mammals in the Great Lakes basin. Upland game birds found in the basin include ring necked pheasants, ruffed grouse, quail, and turkey. Waterfowl include several species of geese and many species of ducks. Typical shore and marsh birds include bitterns, rails, herons, loons, red-winged blackbirds, gulls, and terns. Common non-game birds include hawks, owls and many species of songbirds. Endangered bird species in the basin include the least tern, piping plover, and falcon Kirtland's warbler .

(2). The Great Lakes–St Lawrence Seaway Navigation System

The Great Lakes—St. Lawrence Seaway system extends from the western end of Lake Superior to the Gulf of St. Lawrence on the Atlantic Ocean, a distance of more than 2,000 miles. The five Great Lakes (Superior, Michigan, Huron, Erie and Ontario) with their connecting channels and Lake St. Clair, have a water surface area of about 95,000 square miles. The lakes lie partly in each of the two countries of Canada and the United States except for Lake Michigan, which lies wholly within the United States. The total area of the Great Lakes basin, both land and water, above the eastern end of Lake Ontario is approximately 292,000 square miles, of which 174,000 square miles are in the United States and 122,000 square miles are in Canada. The upper four Great Lakes and the connecting channels have a controlling commercial navigation safe draft of 25'-6". Characteristics of the five Great Lakes are as follows:

TABLE 1
GREAT LAKES CHARACTERISTICS

Great Lakes	Water Surface Area (sq. miles)	Length (miles)	Breadth (miles)	Maximum Depth (feet)	Drainage Area (sq. miles)
Lake Superior	31,700	350	160	1,333	81,000
Lake Huron	23,000	206	101	752	74,800
Lake Michigan	22,300	307	118	925	67,900
Lake Erie	9,900	241	57	212	33,500
Lake Ontario	7,600	193	53	804	34,800*

*Includes water surface area and tributary land area downstream to the St. Lawrence Power Project at Cornwall.

Hydraulics & Hydrology

Lake Superior has been regulated since 1921 by means of a series of control structures including a gated dam across the St. Marys River at Sault Ste. Marie, Michigan and Ontario. Construction of the gated dam was authorized by the International Joint Commission (IJC) as a condition to approval of the water diversion for hydropower. By operation of the gates, locks, and changes in power diversions, flows specified by the adopted plan of regulation can be achieved. The present plan of regulation is known as Plan 1977-A. Basically, the plan balances the levels of Lake Superior and Lakes Michigan-Huron to maintain their levels at the same position to each other according to their long-term monthly means, while protecting the maximum on Lake Superior. The plan of regulation is designed to meet criteria specified by the IJC which requires, among other things, that the control works be operated so that the mean level of Lake Superior would be retained within its normal range of stage such that the level shall not exceed elevation 603.2 feet IGLD (1985) or fall below elevation 599.6 feet IGLD (1985), and will be done in such a manner so as not to interfere with navigation. This regulation plan affects water levels on Lakes Superior, Michigan, Huron, and to a lesser degree, downstream through Lake Erie. A discussion of the Lake Superior regulatory works is presented in the Cost Engineering Appendix of this report.

Lakes

Lake Superior is the largest of the Upper Great Lakes. Compared with the other Great Lakes, its surface is more elevated above the Atlantic Ocean, is more irregular in outline, has deeper water more fog, and less rain. The main United States commercial harbors are located at Duluth and Two Harbors, Minnesota; Superior and Ashland, Wisconsin; and Marquette and Presque Isle, Michigan. Two additional United States harbors, constructed by private interests, are located in Minnesota on the north shore of Lake Superior at Silver Bay, and at Taconite Harbor at Two Islands. Each is used for the shipment of concentrated taconite—iron ore. In addition, there is an important Canadian harbor at Thunder Bay, Ontario.

Lakes Huron and Michigan are one lake from a navigation standpoint, since the Straits of Mackinac which connects the two lakes is so broad and deep there is no perceptible flow between them and their surfaces stand at the same elevation. Major harbors on Lake Huron located in the United States are at Calcite, Stoneport, Alpena, Alabaster, Bay City, and Saginaw. Major harbors on Lake Michigan are located at Port Inland, Escanaba, Muskegon, and Grand Haven, Michigan; Green Bay and Milwaukee, Wisconsin; Chicago and Calumet Harbor, Illinois; and at Burns Waterway, Buffington, Gary, and Indiana Harbor, Indiana.

Lake Erie is the shallowest of all the Great Lakes and considerably smaller than Lakes Superior, Michigan and Huron. Major harbors on Lake Erie are located at Monroe, Michigan; Toledo, Sandusky, Huron, Lorain, Cleveland, Fairport, Ashtabula, and Conneaut, Ohio; Erie, Pennsylvania; and Buffalo, New York.

Lake Ontario is the smallest of the Great Lakes. It is connected to Lake Erie by the Welland Canal which extends for about 27 miles and provides a series of locks that overcome a difference in elevation of 326 feet. Major U.S. harbors on Lake Ontario are located at Rochester, Sodus Bay, and Oswego, New York. Major Canadian harbors are located at Hamilton and Toronto, Ontario.

Connecting Channels

St. Marys River is the outlet of Lake Superior and leaves the lake at Point Iroquois, flowing in a generally southeasterly direction through several channels to Lake Huron, a distance of from 63 to 75 miles according to the route traversed. The river drops approximately 22 feet with most of the drop (20 feet) occurring at the St. Marys Falls Canal, where four U.S. navigation locks and one Canadian lock allow for the transit of vessels. The natural control of the outflow from Lake Superior was a rock ledge at the head of the St. Marys River. This natural control has been replaced by the locks, compensating works, and powerhouses. As a result, the outflow from Lake Superior is regulated. Of particular interest in the St. Marys River are the Sugar, Lime, Neebish, and Drummond Islands which are inhabited year round. Transportation to these islands is provided by ferryboat or tug during the summer. During the winter, transportation has traditionally been over the ice or by ferry boat through an established open water vessel track.

The St. Clair River—Lake St. Clair-Detroit River System connects Lake Huron and Lake Erie. The system on Lake Erie is approximately 89 miles long and has a relatively uniform water surface profile with a fall of 8 feet from Lake Huron to Lake Erie. The St. Clair River has a length of *about* 39 miles. Lake St. Clair, extending between the mouth of the St. Clair River and the head of the Detroit River (a distance of about 18 miles) occupies a shallow basin having an average depth of about 10 feet, with low, marshy shores. The shallow depth requires a dredged commercial navigation channel 27.5 feet deep and 800 feet wide throughout its length. The Detroit River extends about 32 miles to Lake Erie. Major harbors located along the system are at Sarnia and Windsor, Ontario, and at Detroit, Michigan. There are no commercial harbors on Lake St. Clair.

The Welland Canal connects Lake Erie and Lake Ontario. The system is approximately 27 miles long and is somewhat restricted by structures, but has no level and flow problems because it can be totally controlled by locking operations. The Welland Canal is crossed by 12 bridges, four railroads and eight highways. The lift bridges are considered bottlenecks to the vessel traffic. Two road tunnels and one railroad tunnel cross under the canal. Navigation is also restricted in some areas because of one-way traffic. Major harbors located in the vicinity of the Welland Canal include Toledo, Lorain, Cleveland, Ashtabula, and Conneaut, Ohio, Erie, Pennsylvania and Port of Buffalo, New York, and Hamilton, Ontario.

The St. Lawrence River connects Lake Ontario and the Atlantic Ocean. The system is approximately 189 miles long and is somewhat restricted by structures, and water level flow problems. There are 17 bridges across the St Lawrence River. The minimum clearance is 120 feet and minimum width is 80 feet. Tidal variations from Quebec seaward are quite large, up to 8 feet; however at Montreal and upstream the variation is only 6 inches.

The physical characteristics of the connecting channels are summarized below:

TABLE 2 GREAT LAKES-ST LAWRENCE SEAWAY CONNECTING CHANNELS CHARACTERISTICS				
Connecting Channel	Length (miles)	Width (feet)	Depth (Feet)	Fall (feet)
St. Marys River	63	300—1500	27-30	23
Straits of Mackinac	0.80	1250	30	0
St. Clair River	40	700—1400	27-30	5
Lake St. Clair	18	700— 800	27.5	0
Detroit River	31	300—1200	27.5—29.5	3
Welland Canal	27	192-350	26	326
St Lawrence River	189	225-600	26	226

The connecting channels are unregulated (free flow) except for the St. Marys River and St. Lawrence River, which is controlled by a series of improvements. Although compensating dikes were constructed on the Lower Detroit River to partially offset (hydraulically) the lowering of the water levels (due to past authorized navigational improvements in 1912, 1936, and 1962), the Detroit River is not considered regulated.

Locks

Locks in the Great Lakes-St. Lawrence Seaway system are located in the St. Marys River, Welland Canal and St. Lawrence River. In the St. Marys River at Sault Ste. Marie, Michigan and Ontario, four parallel locks on the U.S. side, and one on the Canadian side are operational. The principal features of the locks in the St. Marys River are shown in Table 3 as follows.

TABLE 3 PRINCIPAL FEATURES OF THE SAINT MARYS FALLS CANAL LOCKS					
Principal Features	Lock				
	MacArthur	Poe	Davis	Sabin	Canadian
Opened to Commerce	1943	1969	1914	1919	1895
Width, feet	80	110	80	80	59
Length between mitre sill, feet	800	1200	1350	1350	900
Depth on upper mitre sill, feet	31	32	24.3	24.3	16.8
Depth on lower mitre sill, feet	31	32	23.1	23.1	16.8
Lift, feet	22	22	22	22	22

Welland Canal. The Welland Canal is located in Canada about 20 miles west of the Niagara

River, and connects Lake Erie to Lake Ontario. It is 27 miles long and contains eight locks. The principal features of the locks in the Welland Canal are shown in Table 4 below.

TABLE 4
PRINCIPAL FEATURES OF THE WELLAND CANAL LOCKS

Principal Features	All Eight Locks
	Canadian
Opened to Commerce	1932
Width, feet	80
Length between mitre sill, feet	766
Depth over mitre sill, feet	30
Lift, feet	46.5[(1)]
Note: 1. Lift for locks 1 through 7; variable lift Lock 8, normally less than 3 feet.	

St. Lawrence River Locks. There are seven locks in the portion of the St Lawrence River between Lake Ontario and Montreal Quebec. The two American locks, Snell and Eisenhower are located near Massena, New York: and the remaining five locks are Canadian, the St. Lambert and Cote Ste. Catherine locks near Montreal Quebec; the Upper and Lower Beauharnois locks in the Beauharnois Power Canal and the Iroquois lock near Iroquois, Ontario. The principal features of the locks in the St Lawrence River are shown in Table 5 below.

TABLE 5
PRINCIPAL FEATURES OF THE ST LAWRENCE RIVER LOCKS

Principal Features	Lock						
	Canadian				U.S.		Canadian
	St. Lambert	Cote Ste. Catherine	Lower Beauharnois	Upper Beauharnois	Snell	Eisenhower	Iroquis
Opened to Commerce	1959	1959	1959	1959	1959	1959	1959
Width, feet	80	80	80	80	80	80	80
Length between mitre sill, feet	766	766	766	766	766	766	766
Depth over mitre sill, feet	30	30	30	30	30	30	30
Lift, feet	22	37	42	40	49	42	6

Harbors

There are presently 63 commercial U.S. Federal harbors on the Great Lakes that received Federal assistance. The depths at these harbors range from 16 to 28 feet. In addition, there are 17 U.S. private deep-draft harbors in the Great Lakes system. Harbors in the study area are listed in Table 6.

There are 32 commercial harbors and 1 recreational harbor under review in this study. Three harbors, (Green Bay, WI Saugatuck, MI and Sheboygan, WI) sent letters requesting to be included in the study.

For detailed description of each harbor, refer to *Appendix B- Cost Engineering*.

Table 6
U. S. GREAT LAKES FEDERAL AND PRIVATE HARBORS

Federal		Private
Lake Superior	**Lake Michigan (cont'd)**	**Lake Superior**
Grand Marais, Minn.	Frankfort, Mich.	+ Taconite, Minn.
+ Two Harbors, Minn.	Charlevoix, Mich.	+ Silver Bay, Minn.
+ Duluth—Superior, Minn/Wis.		
Ashland, Wisconsin		**Lake Michigan**
Ontonagon, Mich.	**Lake Huron**	Oak Creek, Wis.
+ Presque Isle/,Marquette Mich.	+ Alpena, Mich.	Buffington, Ind.
Keweenaw Waterway, Mich.	Cheboygan, Mich.	+ Gary, Ind.
	+ Saginaw, Michigan	Port Dolomite, Mich.
Lake Michigan	Harbor Beach, Mich.	Port Inland, Mich.
+ Saugatuck, MI		+ Escanaba, Mich.
+ Menominee/Marinette, Mich/Wis.	+ St. Clair/Detroit Rivers	Petoskey Penn Dixie Harbor, Mich.
+ Green Bay, Wis.	Marysville, Mich.	
Sturgeon Bay, Wis.	Port of Detroit, Mich.	
Kewaunee, Wis.	+ Detroit River	**Lake Huron**
Two Rivers, Wis.	St. Clair	+ Calcite, Mich.
Manitowoc, Wis.	+ Rouge River	+ Stoneport, Mich.
+ Sheboygan, Wis.	+ Monroe, Mich.	Port Gypsum, Mich.
Port Washington, Wis.		Alabaster, Mich.
+ Milwaukee, Wis.	**Lake Erie**	+ Drummond Island, Mich.
Racine, Wis.	+ Toledo, Ohio	
Kenosha, Wis.	+ Sandusky, Ohio	**Lake Erie**
Waukegan, Ill.	Huron, Ohio	Marblehead, Ohio
+ Chicago, Ill.	+ Lorain, Ohio	
+ Calumet Harbor, Ind. & Ill. & Lake Calumet	+ Cleveland, Ohio	
+ Indiana Harbor, Ind.	+ Fairport, Ohio	
+ Burns Waterway, Ind.	+ Ashtabula, Ohio	
Michigan City, Ind.	+ Conneaut, Ohio	
St. Joseph, Mich.	Erie, Pa.	
South Haven, Mich.	+ Port of Buffalo, N.Y.	
Holland, Mich.		
Manistique, Mich.	**Lake Ontario**	
Gladstone, Mich.	Rochester, N.Y.	
Grand Haven, Mich.	Great Sodus Bay, N.Y.	
Muskegon, Mich.	Oswego, N.Y.	Legend + 33 harbors under review.
White Lake, Mich.	Ogdensburg, N.Y.	
Ludington, Mich.		
Manistee Harbor, Mich.		

(3). Social/Economic/Institutional Setting

The physical environment of the Great Lakes basin has exerted a strong influence over the distribution of population and types and distribution of economic activities. The single most significant resource of the basin is the five Great Lakes and connecting channels. In addition to abundant natural resources and large agricultural potential, this source of water has allowed a highly industrial and agricultural economic base to develop. The Great Lakes System comprises a navigation network between important industrial centers, agricultural production areas, and the heavily populated eastern market.

Population

The Great Lakes basin accounts for approximately 28.9% of the total U. S. population. The five largest metropolitan areas of Chicago, Detroit, Cleveland, Milwaukee, and Buffalo, account for a large portion of the regional population, which is approximately 18 million (Reference 2000 Census).

Employment and Labor Force

According to the Bureau of Economic Analysis (BEA), in the eight Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, approximately 47.2 million people were employed during 1999. Durable goods manufacturing were the second largest employment category, at over 14% of all employment in the region, it was surpassed only by services. Manufactured goods, paper, printing, foods, chemical and related products are other important products of the region. Chemical and allied products are expected to increase relative to the other sectors.

Earnings and Income

In 1999, earned income measured $1.7 trillion in the eight states bordering the Great Lakes. Historically, total personal income and per capita income within the eight state region has been higher than the national average. This can be attributed to a heavy concentration of industrial activity. Economic centers, which lead the basin in per capita income, are the metropolitan areas of Chicago, Illinois; Detroit, Michigan; Milwaukee, Wisconsin; and Rochester, New York.

Business and Industrial Activity

The Great Lakes area economy is heavily industrial, utilizing the transportation and power advantages offered by the Great Lakes-St. Lawrence River system. In addition, there is significant agricultural, mining and forestry production. Commercial fishing, historically one of the oldest activities, has declined in importance, although sport fishing has increased tremendously and is of great recreational importance to some regions.

Economic activity is greater and more intense in the United States portion of the basin. In the United States, more than one-fifth of the manufacturing employees, and capital expenditures, are within the Great Lakes basin. According to the BEA, the value of manufactured goods among the eight states was $529,995,000,000 for 1999. The region is the primary focus of the iron and steel industry in North America, accounting for over 50 percent of the U.S. production. The region also contains high proportions of other industries, including chemicals, paper, food products, machinery, transportation equipment and fabricated metal products. Mineral production is also important, particularly iron ore and limestone. The western Great Lakes area produces over two-thirds of the Nation's output of iron ore and one-twentieth of its domestic copper output and employ almost a half million persons.

Feed grains are grown in the basin both for local use in the livestock industry and for export. The basin is important for its dry bean production. "Hothouse" rhubarb, sugar beets, soft white wheat used in flour blending, and dairy farming are found throughout the region. Cash crops, such as corn, soybeans, and vegetables, dominate in the more productive southern portion. Due to the favorable climate along the lakes, one of the Nation's most important fruit and vegetable areas has developed. Forest resources continue to serve as a basis for economic development. Production of pulpwood, saw logs, veneer logs, and miscellaneous industrial timber products is substantial and is expected to increase.

Finally, the basin has a major recreation and tourist industry. The extensive sand beaches and scenic shorelines of the Great Lakes, with water related recreational opportunities, attract many users. Typical are the cottage and summer resort areas of northern Michigan; northeastern Wisconsin; Georgian Bay, Ontario; and the Thousand Islands reach of the St. Lawrence River. Major tourist attractions include the Soo Locks, Niagara Falls and the Welland Canal.

Travel and tourism in the Great Lakes basin generates many billions of dollars in expenditures and tax revenues each year. It is one of the top economic sectors in each of the Great Lakes states as well as in the province of Ontario. The U.S. Travel Data Center has calculated a total of $545 billion of travel-related expenditures in the U.S. for 2001 with a quarter of that amount attributed to the eight Great Lakes states. Coastal communities and state, provincial and national parks account for a growing share of travel activity. Economic impact is greatest during the summer travel season but for particular places "shoulder" and winter season tourism is expanding. Recreational boating reveals the strong connection between water resources and tourism and recreational activity. In 1999, 4.2 million recreational boats were registered in the Great Lakes States or one-third of the national total. Boat manufacturers and dealer payroll in the Great Lakes region coupled with retail related expenditures was $3 billion. With inclusion of Canadian boats, the Great Lakes Commission estimates that about 1.5 million boats operate on the Great Lakes each year. Boating and fishing are strongly connected and the Great Lakes Fishery Commission estimates that Great Lakes sport fishing accounts for a $4 billion impact.

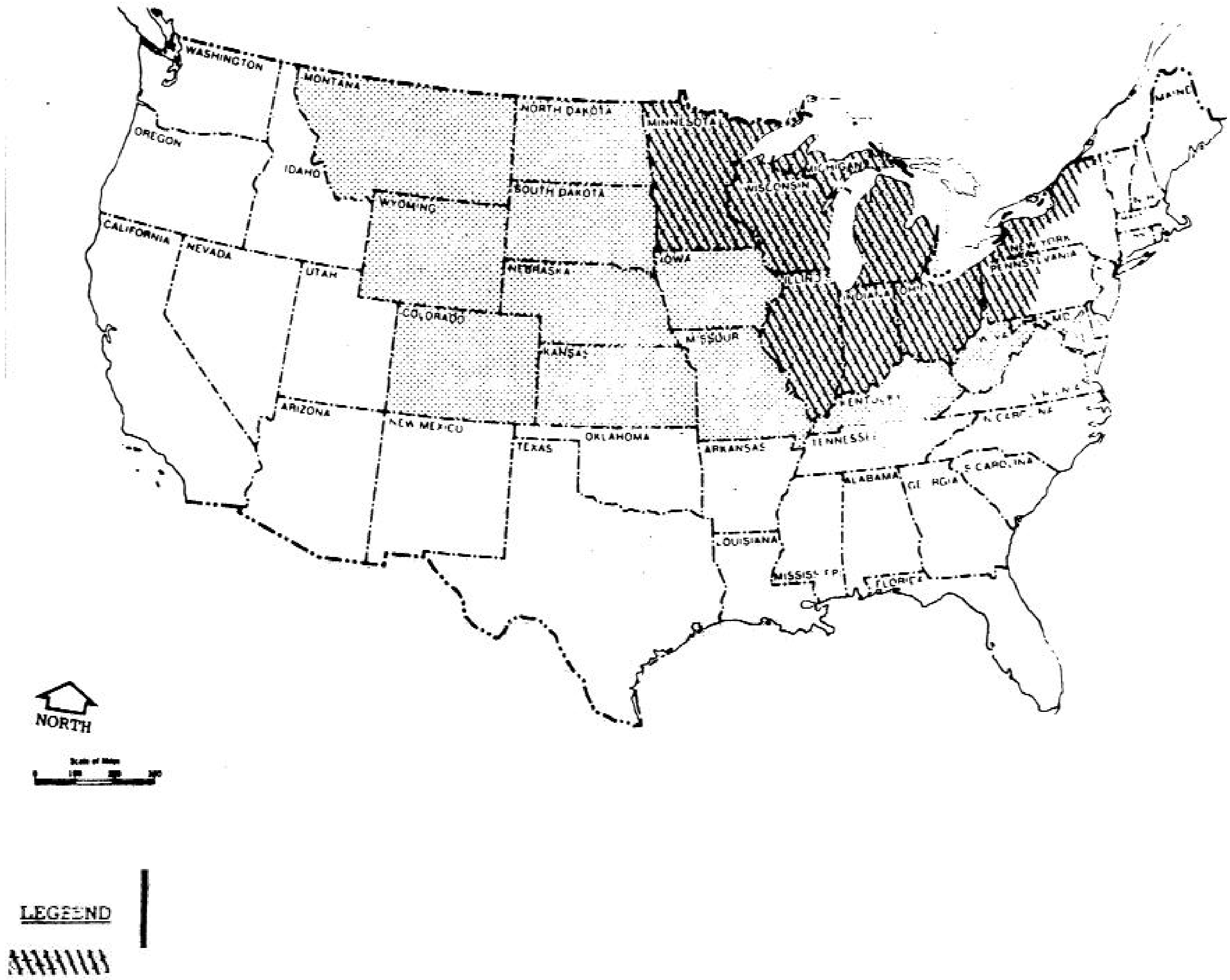
Commercial and Economic Tributary Area

The region within the United States considered to be a commercial and economic tributary to the Great Lakes for various types of commercial transportation includes the eight states bordering the Great Lakes (Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, and New York) and the eleven contiguous states (Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, Kansas, Iowa, Missouri, Kentucky, and West Virginia). The Canadian provinces of Ontario and Quebec form the entire Canadian shoreline of the Great Lakes, as well as the north shore of the St. Lawrence River. The harbors on the Great Lakes are served by commercial transportation networks (railroads, highways, airways and pipelines) which link the area with other parts of the United States and Canada. Figure 2, on page 22, is an illustration of the Great Lakes Economic Region.

Agriculture

The region is agriculturally diverse and has a comparative advantage for specific types of agricultural production. A major dairy area is located in Wisconsin. Feed grain and livestock production is important in southern Michigan, Minnesota, Wisconsin, Ohio, Illinois, and Indiana. Commercial fruits and vegetables are important in areas of Wisconsin, Michigan and Ohio. Grain and timber production contributes to the economy of the northern portions of the region.

In 1997, the eight Great Lakes states had 97.59 million acres of cropland out of 265.7 million acres total land. Thus, cropland accounted for 36.73% of the total acres in 1997. Between 1992 and 1997, Minnesota and Pennsylvania both experienced slight increases in cropland while the remainder of the Great Lakes states experienced slight declines. Irrigated farmland is not now a significant portion of the agricultural farmland, nor is it projected to be in the future. Feed and food crops predominate among the major agricultural land use categories, followed by grazed forest and woodland, other crops, pasture, and graze land.



Eight Great Lakes Border States
19 State Economically Dependent Region
GREAT LAKES ECONOMIC REGION
Figure 1

Transportation

The region occupies a location strategic to the highly industrialized and well-populated north central United States and south central Canada, and is astride the transcontinental link between the major agricultural production regions of the west and midwest and the market areas of the east.

The region is considered tributary to Great Lakes Harbors for shipment of overseas general cargo. In the United States, it includes the eight Great Lakes states and eleven additional contiguous states which generate a significant amount of the U.S. general cargo export traffic.

Recreational

The Great Lakes Basin has 17.8 million acres of public recreational areas. There is a great diversity of outstanding natural features such as forests, meadows, marshes, shorelines, islands, streams and lakes (both Great Lakes and inland). Many of these areas have exceptional scenic, wilderness, and aesthetic qualities, which make them nationally significant. Recreational resources are not evenly distributed, being mostly located in the drainages of Lake Superior, Lake Ontario, and the northern parts of Lake Michigan.

Regional Growth

Urban and developed areas, while representing only about 10% of the total land area, total over 45% of the area of the lakes coastal counties. Many rural areas in the region are affected by economic and social factors in nearby urban centers. The urban influence on agricultural land-use may be even more dramatic in the future. In the region, more than one-third of the total cropland is located within Standard Metropolitan Statistical Areas, where most future urban growth is expected.

The problems and needs of urban and developed areas are serious and growing in scope and intensity. Many of the land-use problems are associated with the change from rural to urban. Zoning conflicts, taxation problems, land value appreciation, and accelerated erosion are commonly associated with urban growth. These problems are concentrated around existing urban areas where most of the future growth is expected; large areas of the region will experience the impact of urban expansion. The southern portion of the region and along the Great Lakes will be most affected.

e. Problems and Opportunities:

(1). Identified Problems:

Understanding the diverse problems, needs and existing conditions associated with the Great Lakes/St. Lawrence Seaway commercial navigation system and the economic, social and institutional systems that interact with it establishes a guide to the formulation of alternatives that address these problems and needs. While many of the problems and needs listed below vary in intensity according to geographic areas, there are two primary issues that form the basis for problem analysis in this study. These are the needs that arise from the commercial fleet's desire for economic optimization; and the potential impacts on the existing environmental, social and institutional systems that could result from those modifications necessary to meet the demands of the commercial fleet.

The problems and needs of the various systems can best be summarized by major navigational feature.

Commercial Navigation Problems

a. Capital investment required to accommodate larger vessels.
b. Maintenance costs.
c. Vessel size and its effect on transit of channels.
d. Safeguards to avoid spills of oil and other hazardous substances.
e. Navigation during fog, high winds, and ice congested channels.
f. Vessel traffic and speed control.
g. Historic and cultural resources.
h. Potential disruption of fish and wildlife habitat.
i. Operational training of vessel pilots.
j. Potential for increased shoreline damage.
k. Availability of sites for dredge material placement.
l. Potential bottom scouring.
m. Secondary employment effects of structural and non-structural improvements for waterborne transportation.
n. Potential recreational boating effects and associated recreation activities in the channels.
o. Potential social effects on channel residents.
p. Canadian participation and responsibility and cost sharing.
q. Acceptable vessel speeds.
r. Potential damage to shore structures.

Harbor Problems

a. Ramifications of vessel size in relation to vessel handling and control.
b. Operation of loading and unloading facilities.
c. Capital investment of others needed to handle larger vessels.
d. Potential shore erosion and shore structure damage.
e. Water quality, vessel waste discharge and turbidity.
f. Safeguards to avoid spills of oil and other hazardous substances.
g. Interfacing larger vessels with other transportation modes.
h. Adequate turning basins.
i. Potential bottom scouring.
j. Potential disruption of fish and wildlife habitat.
k. Potential air pollution.
l. First costs and the operation/maintenance costs of the modifications.
m. Potential effects on littoral transport, both on lakes and rivers.

Locks Problems

a. Relationship between existing and potential vessel sizes and existing facilities.
b. Capital investment requirements for necessary facilities to support and handle larger vessels.
c. Traffic control and service requirements.
d. Effects and constraints of additional locks.
e. Maintenance costs for modifications.
f. Determination of maximum lock size.
g. Safeguards to avoid disruption of service from accidents in critical areas.
h. Need for additional locks.
i. Potential social effects of modified or new lockage systems.
j. Potential economic impacts resulting from lock modification.
k. Potential disruption of fish and wildlife habitat.
l. Requirements and contingency plans to handle hazardous material transport.
m. Lock crew safety.
n. Potential effects on employment.
o. Water quality, vessel waste discharge and turbidity.
p. Potential effects on recreational boating and associated activities,
q. Canadian participation and responsibility.
r. Potential air pollution.
s. Navigation during fog and high winds.
t. Lock wall icing and lock approach ice congestion.

(2). Opportunities:

a. To utilize larger size vessels, through increasing lock capacity. Larger ships are more efficient in relation to their size and as such are able to transport more cargo at a reduced rate per ton.

b. To maximize utilization of existing vessel capacity, through increasing channel depth. Increased channel depth would increase the ship's ability to transport more cargo at a reduced rate per ton.

c. To improve shipping efficiency by improving services to receiving harbors/ports within the Great Lakes /St. Lawrence Seaway System.

d. To minimize potential losses of cultural and historic resources in the selection of the Base Plan.

e. To enhance aquatic habitat in the selection of the Base Plan.

(3). Expected Future without Project Conditions:

The future without-project condition for the Great Lakes Navigation System (GLNS) assumes construction of a new Poe-sized lock at the current site of the Davis and Sabin locks, while maintaining the status quo elsewhere on the U.S. portion of the GLNS. The Soo Locks are defined as four parallel locks, located on the St. Marys River, at Sault Ste. Marie, Michigan. On the U.S.

portion of the GLNS a minimum draft of 25'6" LWD at all locks and connecting channels is maintained over the next 70 years. On the Seaway, a 26'3" draft is maintained. The aging Seaway locks are first maintained through normal O&M, then limited rehabilitation, and ultimately major rehabilitation. Each successively more aggressive approach to maintenance is phased in as the condition of Seaway locks deteriorates, requiring longer closures, which through time begin to occur during the navigation season, sometimes without advance notice to shippers. The single lock configuration in most locations makes the reliability of the overall system an even greater concern than it might be for dual-lock systems. The consequences of a major lock failure likely would cause traffic disruptions of the entire waterway.

The locks on the Welland Canal are at least seventy years old, while the locks on the Montreal/Lake Ontario (MLO) portion are forty-four years old. Maintaining the locks will likely result in repairs that address immediate concerns, however, these repairs may not be sufficient in scope to deal with the underlying structural problems. A comprehensive program with major expenses in lock rehabilitation will have to be initiated to keep the locks functional. Before a decision is made to make investments of this magnitude, an analysis should be completed to determine if it makes economic sense to rehabilitate the locks versus building new locks. Ultimately, the locks may face closure if a wide-ranging program to rebuild or repair the locks is not initiated.

With respect to the individual ports and harbors, the future without-project condition will be to maintain the existing project depths in the channels through ordinary operations and maintenance

f. Planning Objectives:

A set of planning objectives have also been formulated based upon the water and related resource management problems, needs and opportunities identified for the Great Lakes region. The objectives listed below contribute to both the national and regional objectives for the economic life of the project.

(1). Contribute to the development and efficient utilization of the Great Lakes/St. Lawrence Seaway commercial navigation system infrastructure;

(2). Contribute to an increase in output of goods, services and external economics of the Great Lakes/St. Lawrence Seaway system;

(3). Contribute to the maintenance of existing water levels and flows for the Great Lakes; and

(4). Contribute to the quality of the Great Lakes/St. Lawrence Seaway environment, giving particular attention to the ecosystem and water quality of the lakes.

g. Planning Constraints:

Planning constraints are the technical, environmental, social, economic and institutional limitations within which the proposed alternative plans would be implemented. These include resources limitations, potential competitive use of scarce resources and legislative or regulatory restrictions. Planning constraints define the scope of alternatives plans formulated. Constraints identified during the development of this study include:

(1). The technical limits for vessel size in terms of draft, beam, and length;

(2). The effects of larger vessels on existing port development;

(3). The dependence or independence of betterment's on the Upper Great Lakes to betterment's on the St. Lawrence River System

(4). The availability of suitable sites to provide for dredge material placement during construction and maintenance;

(5). and the legal and international aspects of enacting modifications.

h. Management Measures to Address Identified Planning Objectives:

A management measure is a feature or activity at a site, which addresses one or more of the planning objectives. In analysis of data and discussion with navigation interests, a wide variety of measures were considered, some of which were found to be infeasible due to technical, economic, or environmental constraints. Each measure was assessed and a determination made regarding whether it should be retained in the formulation of alternative plans. The description of the measures considered in this study are presented below:

(1). No Action. The Corps is required to consider the option of "No Action" as one of the alternatives in order to comply with the requirements of the National Environmental Policy Act (NEPA). No action assumes that no project would be implemented by the Federal Government or by local interests to achieve the planning objectives. No Action, which is synonymous with Without Project Condition, forms the basis from which all other plans are measured.

(2). Structural. Structural measures considered in this study include: Deepening the Great Lakes Connecting Channels, increasing capacity to the St. Lawrence Seaway, Deepening Individual Ports; and decrease Navigational Restrictions. See Section, i. Alternative Plans for a detailed description of the structural measures.

(3). Non-Structural. Non-structural measures considered in this study include: Increased Water Level Data Access, and Aids to Navigation, which would increase the operating efficiency of the navigation system. A detailed description of the non-structural measures is discussed below.

i. Alternative Plans**:**

(1). **No Action (Without project conditions)** See *Expected Future without Project Conditions* on page 25 for a detailed discussion.

(2). **Deepening the Great Lakes Connecting Channels**

This alternative proposes to evaluate potential betterments to the Great Lakes Connecting Channels to include: modifications to improve existing infrastructure and modifications to the existing channels to accommodate deeper draft vessel traffic. The current minimum, safe vessel depth for the navigation system is 25' 6" at Low Water Datum (LWD). Evaluation of deepening of the channel would include incremental depths from 25' 6" LWD to 35 feet LWD.

(3). **Improvements to the St. Lawrence Seaway**

This alternative proposes to evaluate potential betterments to the St. Lawrence Seaway to include: optimizing the navigation season, modifications to the existing channel to accommodate two way traffic, modifications to the existing channels to accommodate deeper draft, and lock expansion. The current minimum, safe vessel depth for the navigation system is 26'- 3" at Low Water Datum (LWD). Evaluation of deepening of the channel would include incremental depths from 26' – 3" LWD to 35 feet LWD.

(4). **Deepening Individual Ports**

This alternative proposes to evaluate potential betterments to the ports and harbors within the Great Lakes System to include: modifications to improve existing infrastructure and modifications to the existing channels to accommodate deeper draft vessel traffic. The current minimum, safe vessel depth for the navigation system is 25' 6" at Low Water Datum (LWD). Evaluation of deepening of the channel would include incremental depths from 25' 6" LWD to 35 feet LWD.

(5). **Navigational Restrictions**

a. **Chicago Sanitary & Ship Canal**

This alternative proposes to evaluate potential improvements to the waterborne trade between the Great Lakes and the Mississippi River through the Illinois Waterway. There are about 8,500 river barges operating through the Cal-Sag Channel and the Chicago Sanitary and Ship Canal to the several major ports, Burns Harbor and Indiana Harbor in Indiana and Calumet and Chicago Harbor in Illinois. These ports are served by barge on a year round basis and connect Inland Waterway destinations/origins providing a water mode service for Seaway commodities as well as domestic commodities. The Illinois Waterway barge traffic generally carries between 42 and 50 millions tons of cargo each year. This route has infrastructure limitations such as low bridge air draft, narrow channel and high traffic volume.

The Chicago Sanitary and Ship Canal channel from its junction with the Cal-Sag Channel (river mile 303.5) to its junction with the Des Plaines River (river mile 290) has significant barge congestion. The channel is approximately 160 feet wide through this area. Increasing the channel width would have a significant benefit to improve navigation between the Illinois Waterway and the Great Lakes.

There are also two bridges that restrict barge traffic on the Chicago Sanitary and Ship Canal. The railroad bridge in Lemont Illinois at river mile 300.5 only has a clearance of 19.1 feet. The bridge is a bascule bridge that is inoperable. The second railroad bridge in Chicago at river mile 320.4 only has a clearance of 17 feet. The bridge is also a bascule bridge that is also inoperable. Modifications to these bridges to make them operable would have significant benefits to navigation. This alternative would evaluate improvements to the infrastructure to include: modifications to the existing railroad bridges and modifications to the existing channel to accommodate traffic volume.

b. **St. Clair River Ice Boom**

This alternative proposes to evaluate potential improvements to the St. Clair River within the Great Lakes system. Navigation on the middle lakes of the Great Lakes can occur all year depending on winter conditions. Ice formation and breakup on the lakes and in the rivers can cause delays to navigation interests and flooding problems for riparian properties. One of the most problematic areas is the St. Clair River and its many channeled delta, and the jamming of large ice floes from Lake Huron. The problem could be reduced by the proper placement of an ice retaining boom across the head of the river. Ice booms have been found to be quite effective in controlling the movement of ice in the St. Marys River, in Lake Erie at the Niagara River, and in the St. Lawrence Seaway.

Previous studies have been conducted on the installation of an ice boom at the head of the St. Clair River. These studies have provided details on the location of the boom, its costs, and its benefits. Problems previously identified with ice jams in the river include: delays to navigation due to vessels stuck in the ice in the navigation channel; scouring of the river bottom; and flooding of shore property. The installation of an ice boom at the head of the St. Clair River would improve the hydraulic efficiency of the river, allowing it to pass more water during winter season, thereby providing some means to reduce water levels on the upper Great Lakes during periods of high water.

(6). **Improved Water Level Data Access**

This alternative proposes to evaluate potential improvements to the water level data access within the Great Lakes system. An integral part of navigation of the Great Lakes, their connecting channels and the St. Lawrence River is a knowledge of past, current and forecasted water levels. These data are collected and disseminated by a variety of agencies in several ways. Improvements in access to these data by the navigation interests and some additional equipment installations could provide benefits to the navigation industry and improved safety to the Great Lakes, their connecting channels and the St. Lawrence River.

Currently, real-time water level data are collected by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (USACE) in the U.S. and the Marine Environmental Data Service (MEDS) in Canada. Data are displayed at three different web sites, in different formats. Some data are available for instantaneous access by telephone to the gages directly. Some data are provided in elevation referenced to the International Great Lakes Datum of 1985 (IGLD 1985), while some data are provided as inches or centimeters above or below low water datum (LWD). Some data are provided in graphic format, showing the past three hours, the past 7 days or the past month. The inconsistency in access and presentation of these data can lead to misunderstanding of the current water level conditions throughout the system and therefore under utilization of commercial navigation capacity, or possibly safety problems from groundings.

The proposal is to work with all agencies supplying water level information to coordinate one consistent access point for all water level data. Information would be displayed for specific regions regardless of the ownership of the data, although proper credit and notations would be provided. Graphics will be consistent to show past information along with the current data, as past trends in water level changes are important future indicators. All data would be available in tabular format as well with elevations referenced to both IGLD 1985 and LWD. Other data needs and dissemination issues important to the navigation interests would be explored and incorporated if possible.

Additional equipment may also be necessary. The ability of the navigation interests to obtain real-time water level data can be important. As storms and other disturbances occur, water levels can change rapidly. Voice announcing capability at many of the gages would give the navigation interests the immediate current water level information they require during critical events. This would require the purchase of additional equipment and the installation of additional phone lines in order to provide this service while not compromising the operation of the water level gage itself. Operations and maintenance would then be required for any installations to ensure their operability and replace outdated equipment

(7). **Aids to Navigation**

This alternative proposes to evaluate potential improvements to the Great Lakes system through replacing buoys with permanent beacons. Great Lakes waterways are currently marked mostly by lighted buoys which must be removed in the fall prior to the onset of ice, and reset in the spring after the thaw, even though commercial shipping extends several weeks past the fall withdrawals, and starts well before buoys can be placed in the spring. This practice increases risk to mariners and costs to shippers. The Coast Guard envisions a system in which ice resistant structures replace a greater number of buoys. Such aids to navigation system would be more robust by providing more reliable aids and year round service. Selection of beacon placement and numbers could be determined through use of a virtual vessel simulation model. Although ice resistant structures are expensive (several hundred thousand dollars, varying with depth and bottom conditions), we believe the taxpayer would see a positive return on investment through reduced servicing costs alone.

j. Preliminary Screening of Alternative Plans**:**

Preliminary plans are comprised of one or more management measures that survived initial screening. The description and results of the evaluations of the preliminary plans that were considered in this study are now presented:

(1). No Action (Without project conditions) See *Expected Future without Project Conditions* on page 26 for a detailed discussion.

(2). Deepening the Great Lakes Connecting Channels

Connecting channel deepening is based on considering the connecting channels as constraint points in a vessel origin-destination route from port to port. Once the vessel's origin-destination route was identified, the constraint points on the route could be identified. The constraint points included Vidal Shoals (located upstream of Soo locks), the St. Marys River Little Rapids, the Straits of Mackinac, the St. Clair River, Lake St. Clair, and the Detroit River. Next, the maximum ship draft that could be accommodated at the origin port, destination port and all the affected constraint points was determined. Potential draft is defined as the average water column available at a port or node, minus an underkeel clearance of one foot. These potential drafts were calculated from 101 years of water level data - 1900 to 2000, for all the origin ports, destination ports and constraint points. This information was compared to the fleet's maximum ship draft to determine various deepening plans. Deepening plans are discussed in detail in the Economic Appendix, *SECTION 7 ALTERNATIVE FUTURE PLANS*.

For example, consider iron ore moving from a Lake Michigan port (Escanaba, draft 28.5) to a Lake Erie port (Ashtabula Harbor, draft 29.5). Ashtabula Harbor could generate iron ore benefits for potential draft deepening to 29.5 feet, however, to get to Ashtabula, vessels have to travel through the St. Clair River (draft 28.2)/Lake St. Clair/Detroit River. Deepening beyond 28.2 feet would necessitate deepening the St. Clair River (Constraint Point). Deepening beyond 28.7 feet would involve deepening the St. Clair River and Lake St. Clair.

Economic benefits for deepening connecting channels were evaluated in combination with harbors and ports and Seaway replacement locks under the five broad options described below. Due to scheduling and funding limitations, drafts up to 30' and at 35' were evaluated for the connecting channels and ports.

Option 1 - Includes the many combinations of improvement alternatives for the Great Lakes connecting channels and harbors (drafts up to 30 ft) combined with eventual replacement of the Seaway locks.

Option 2 - Contemplates the same improvements as Option 1 above, coupled with construction of a deeper (35' draft) and larger (110'x1200' lock chambers) Welland Canal.

Option 3 - Builds upon Option 2 by replacing the MLO Section of the Seaway with a deeper and larger system of locks and channels, and by extending the 35' draft system up to Detroit.

Option 4 - Is the same as Option 3, except that the 35’ draft now extends into Lake Michigan and Lake Huron by the deepening of the entire St. Clair-Detroit River system.

Option 5 - Extends the 35’ draft throughout the GLSLS system as a result of deepening the St. Marys River and lowering the sill depth of the Soo locks.

With regards to deepening the Great Lakes connecting channels to a 30’ draft, the GLLAST model was run for a condition where vessels can draft to their maximum depth. See description of option 1 on page 31. As a result of the study, using year 2000 traffic levels, it was determined that the estimated cost reduction for existing movements would be $87 million annually. This estimate acts to represent the benefits of having the ability to draft 30’ throughout the Great Lakes connecting channels and ports. The benefits for Option 1 with a 30’ draft is discussed in detail in the Economic Appendix, *SECTION 8, ECONOMIC EVALUATION FINAL ALTERNATIVE,* Section 2(d). Port deepening and channel deepening plans were developed jointly for evaluation of Option 1. All but one plan carried forward to final screening for Option 1 showed positive net benefits. The results are summarized in Table 8-2.

With regards to channel deepening to 35 ft draft, under options 3, 4, & 5, the potential annual benefits are combined with lock replacements. The results of the combined benefits are the following; Option 3, a 35 ft draft channel deepening up to Detroit, a 30 ft draft Great Lakes connecting channels and ports in combination with seaway replacement locks ($885,000,000 annually), Option 4, a 35 ft draft channel up to Lake Huron and Lake Michigan and a 30 ft draft connecting channels and ports in combination with seaway replacement locks ($1,417,000,000 annually), and Option 5, a 35’ draft channel throughout the Great Lakes and St Lawrence Seaway system in combination with seaway replacement locks ($1,510,000,000 annually).

The economic development benefits of a 35 ft draft system throughout were estimated using the Maritime Input-Output (MIO) model. See Appendix A Economic Analysis, Attachment 5 for details of the MIO model. The benefits for Options 3, 4, & 5 with a 35 ft draft are discussed in detail in the Appendix A- Economic Analysis, *SECTION 8, ECONOMIC EVALUATION FINAL ALTERNATIVE,* Sections 3, 4, & 5.

Based on the potential net benefits generated from deepening the connecting channels in conjunction with associated ports and harbors, it is therefore recommended that this alternative be carried forward into feasibility for further analysis.

(3). Improvements to the St. Lawrence Seaway

The economic benefits for Improvements to the St. Lawrence Seaway, were evaluated in combination with harbors and ports and channel deepening under the five broad options, described on page 31. Options 3, 4, & 5 include construction of a deeper (35’ draft) and larger locks (110’ x 1200’ lock chambers) for the Welland canal section and the MLO section of the seaway. See Deepening the Great Lakes Connecting Channels on page 31 for discussion of combined benefits. The benefits for Option 3, 4, & 5 with a 35 ft draft are discussed in detail in the Economic Appendix, *SECTION 8, ECONOMIC EVALUATION FINAL ALTERNATIVE,* Sections 3, 4, & 5.

No costs have been developed for the without-project condition on the St. Lawrence Seaway. Because lock reliability is a concern on the Seaway, a complete description and evaluation of the without-project condition alternatives is an especially important, analytically intensive effort. Completing the requisite engineering surveys, analyses, designs, and cost estimates for the 15-lock Seaway system (including tunnels and bridges) is beyond the scope of this reconnaissance study. The cost of modifying the locks and channels on the Seaway to accommodate Panamax size vessels may be in the magnitude of $10 billion. There would also be additional costs associated with landside infrastructure improvements and crossings.

Based on the potential benefits generated (up to $1,510,000,000 annually under option 5) for seaway modifications, compared with the potential costs of the proposed improvements, it is recommended that this alternative be carried forward into feasibility for further analysis.

(4). <u>Deepening Individual Ports</u>

Benefits for connecting channels and ports are based on U.S. domestic traffic and a portion of U.S. foreign traffic. These benefits, along with costs are the basis of the benefit-cost analysis, which indicate whether there is federal interest. Benefits for the ports are estimated using a vessel-costing model. Costs were estimated for deepening connecting channels and port plans. The level of detail to which the cost estimates were developed varies from port to port and also between the connecting channels. The level of detail was dependent upon availability of existing data from past studies, accessibility of recent condition surveys, and availability of existing data for non-Federal ports. Schedule and funding constraints limited the extent to which previous cost estimates could be refined based on more current data and operational conditions at each port. Where minimal or no data was readily available for a specific port, cost estimates were based on costs for ports in close proximity with similar harbor configuration. As a result, a range of cost estimates was established in order to better reflect these uncertainties. In all cases, however, the same general methodology is employed in estimating the cost of improvements at all GLNS harbors and channels.

Port deepening and connecting channel deepening plans were developed jointly for the four upper Great Lakes: Superior, Michigan, Huron and Erie. See Economic Appendix, *SECTION 7, ALTERNATIVE FUTURE PLANS*, for a detailed discussion of plans for each port or harbor.

A number of parameters affect the feasibility of harbor deepening. Some of these factors are: tonnage handled, origin-destination route distance, approach channel length, the existing fleet's capability to draft deeper, the destination port's draft relative to the origin port, and the connecting channel draft. Since benefits are measured as reduced transportation costs, harbors handling large tonnage with fleets that can take advantage of additional draft have the potential to generate enough benefits to justify deepening.

For example, consider iron ore moving from a Lake Superior port to a Lake Michigan port. Assume the origin port is shallower than the destination port, and there is a connecting channel constraint in the St. Marys River at Little Rapids. The deepening plan would allow the origin port to be deepened until the maximum ship draft allowed at the origin port equaled the maximum ship draft allowed at Little Rapids, assuming the vessels could utilize this additional draft.

Based upon the above criteria, a number of screening procedures were developed to identify harbors that have potential for deepening. The first screening was by tonnage, all ports that ship or receive over 1 million tons per year. These ports could be grouped by geographical area: the iron ore and coal- shipping ports of Lake Superior, the iron ore receiving and coal shipping ports located on Lake Erie, and the iron ore movements taking place between ports located on Lake Michigan. Lake Superior iron ore shipping ports include: Duluth, MN; Presque Isle, MI; Silver Bay, MN; Superior, WI; Taconite Harbor, MN; and Two Harbors, MN. Major Lake Erie ports include Toledo Harbor, Sandusky, Lorain, Cleveland, Ashtabula and Conneaut Harbor, all in Ohio. Finally, a number of ports that have large tonnages moving on the same body of water were identified: iron ore shipments from Escanaba, MI, coal shipments from Sandusky, OH and limestone shipments from various Lake Huron ports. A short list of 26 harbors was developed.

Table 7
Preliminary List of Harbor Deepening Candidates

Port/Harbor	Port/Harbor	Port/Harbor
1. Superior, WI	10. Detroit, MI	20. Alpena, MI
2. Indiana Harbor, IN	11. Calumet Harbor, IL	21. Lorain, OH
3. Dearborn, MI	12. Taconite, MN	22. Cleveland, OH
4. Escanaba, MI	13. Silver Bay, MN	23. Ashtabula, OH
5. St.Clair, MI	14. Two Harbors, MN	24. Conneaut, OH
6. Duluth, MN	15. Presque Isle\Marquette, MI	25. Fairport, OH
7. Saginaw, MI	16. Gary, IN	26. Toledo, OH
8. Monroe Harbor, MI	17. Burns Harbor, IN	
9. Sandusky Harbor, OH	18. Calcite, MI	

As a result of the economic analysis various ports and harbors show net positive benefits for deepening at various depths. The following table provides a list of ports/harbors which show a positive net benefit to cost ratio (BCR). See *SECTION 8, ECONOMIC EVALUATION FINAL ALTERNATIVE, Section 2(b)* for a detailed discussion.

Table 8 Summary of Economic Evaluation of Ports			
Port/Harbor	BCR	Port/Harbor	BCR
Sandusky, OH 0.5’	5.7	Drummond Island, MI 2.5’	1.8
Sandusky, OH 1.0’	6.1	Indiana Harbor, IN 1.0’	6.2
Sandusky, OH 1.5’	4.3	Indiana Harbor, IN 2.0’ & Escanaba, MI 1.0’	1.8
Sandusky, OH 2.0’	3.4	Calumet Harbor, 1.0’ for coal	3.0
Sandusky, OH w/vessel change *	97.9	Presque Isle, MI 0.5’	2.4
Ashtabula, OH 0.5	0.6	Duluth-Superior, MN 0.5’	10.7
Ashtabula, OH w/vessel change *	111.3	Duluth-Superior, MN 1.0’	5.3
Fairport, OH 1.0 w/vessel change +M tons**	36.2	Two Harbors, MN 0.5’	44.6
Fairport, OH 1.0 w/vessel change *	28.8	Two Harbors, MN 0.5’ & St. Marys River 1.0’	0.9
Calcite, MI 0.5’	1.4	Six Harbors Include: Duluth 1.5’, Presque Isle 1.5’, Silver Bay 1.5’, Superior 1.5’, Taconite 1.5’, Two Harbors 1.5’ & St. Marys River 1.0’,	1.7
Calcite, MI 1.0’	1.2	St Clair Harbor, MI 5.0’	16.9
Calcite, MI 1.5’	1.5		
Calcite, MI 2.0’	1.6	Dearborn, MI (Rouge River) 0.5’	9.5
Stoneport, MI 0.5’	1.2	Dearborn, MI (Rouge River) 1.5’	9.2
Stoneport, MI 1.0’	1.1	Dearborn, MI (Rouge River) 2.5’	8.7
Stoneport, MI 1.5’	1.2	Dearborn, MI (Rouge River) 3.0’	17.0
Stoneport, MI 2.0’	1.2	Dearborn, MI (Rouge River) 6.0’	9.2
* plans allow for vessel changes in response to harbor deepening ** additional 1 M tons of limestone			

Based on the potential net benefits generated (see net benefits above) it is recommended to carry all the deepening plans forward.

(5). <u>Navigational Restrictions</u>

a. Chicago Sanitary & Ship Canal

As a result of the study, four plans were developed to deal with traffic congestion that delays tows and increases safety concerns along the Lemont reach of the Chicago Sanitary and Ship Canal (CSSC). The inadequacy of fleeting areas is a major contributing factor in most instances. Low bridge clearances, specifically the Lemont-Railroad bridge, also impose time penalties and risks on commercial users. Plan CSSC 1, Quarry Site, takes advantage of an existing quarry site to provide additional fleeting. Plan CSSC 2, Three Mile Wall, proposes opening to fleeting a three mile stretch of the Cal-Sag Channel (CSC) located a few miles from the primary congestion point on the CSSC. Plan CSSC 3, Canal Widening, proposes widening a reach on the CSSC some miles distant from the Lemont-Railroad bridge, but away from the CSSC and CSC junction. The final plan is CSSC 4, Re-operation of the Lemont-Railroad Bridge. This plan would repair and replace the machinery necessary to reactivate the swing mechanism of the low-clearance, Lemont-Railroad Bridge. Each is discussed in more detail in *Appendix D- Chicago Sanitary and Ship Canal* and *Appendix A-Economic*

Analysis, Section 7 and Attachment 6.

All benefit estimates are based upon reducing transit times through the Lemont reach of the Chicago Sanitary and Ship Canal (CSSC). It is emphasized that these benefit estimates are not comprehensive as they do not account for savings attributable to reduced damage to property and life that would likely result from the proposed improvements.

A complete benefit-cost analysis was possible for just two of the four plans. No cost estimate is available for Plan CSSC1, Quarry Site or for Plan CSSC 3, Canal Widening. Cost estimates for Plan CSSC 2 and Plan CSSC 4, Three Mile Wall and Lemont Bridge are incomplete, as they do not include lands, easements, relocations and rights of way. This deficiency is accounted for through a fifty percent contingency. The cost estimate available for re-operation of the Lemont RR Bridge is $3,016,000. The cost estimate for mooring piers along one mile of the Three Mile Wall is $1,208,000, expanding this estimate out to the 2.8 miles of wall not yet being used increases the total cost to $3,381,000.

The annualized available cost estimates, at the discount rate of FY01 0.06375, over a 50 year project life, are $225,820 for the Three Mile Wall and $201,436 for the Lemont RR bridge Available quantified benefit estimates for these two plans are $284,000 and $34,000, respectively. The resultant benefit and cost ratio for these two plans are 1.38 and 0.17, respectively. See Table 9 on page 36.

Table 9
Summary of Average Annual Benefits by Category
Chicago Sanitary and Ship Canal Plans

Alternative	**BCR**
CSSC 1, Quarry site	n.a
CSSC 2, Three mile wall	1.26
CSSC 3, Canal widening	n.a.
CSSC 4, Lemont RR bridge	0.17

Based on the discussion on the previous page, it is apparent that a least one solution for providing navigation improvements in the CSSC would produce substantial economic benefits and that those benefits would likely exceed costs. Since navigation is a high priority in Administration budgeting, there is a strong Federal interest in conducting a feasibility study of the Chicago Sanitary and Ship Canal navigation improvements.

Based on this analysis, there are sufficient indications that a viable and implementable plan can be developed that will meet the necessary Federal interest criteria. It is recommended Chicago District proceed to the feasibility phase on the Chicago Sanitary and Ship Canal navigation improvements.

b. St. Clair River Ice Boom

Ice Booms. Navigation on the middle lakes of the Great Lakes can occur all year depending on winter conditions. Ice formation and breakup on the lakes and in the rivers can cause delays to navigation interests and flooding problems for riparian properties. The St. Clair and Detroit rivers are problematic areas with their many-channeled delta, and the jamming of large ice floes from lakes Huron and St. Clair. The ice problems could be reduced by the proper placement of ice-retaining booms across the headwaters of the rivers. Ice booms have been found to be quite effective in controlling the movement of ice in the St. Mary's River, the Niagara River and in the St. Lawrence Seaway.

Previous studies conducted on the installation of ice booms at the heads of the St. Clair and Detroit Rivers provide details on the location of the booms and their costs. Problems previously identified with ice jams in the rivers include: delays to navigation due to vessels stuck in the ice in the navigation channel; scouring of the river bottom; and flooding and other damage to shore property.

The brief outline presented here relies heavily on information obtained from a report generated in March of 1995, *Analysis of Great Lakes Icebreaking Requirements, Final Report, prepared by the U.S. Department of Transportation for the U.S. Coast Guard*. This report determines Federal and user requirements, reviews icebreaker capabilities and operating costs and historical ice conditions, and presents a benefit-cost ratio for the overall icebreaking program. In the course of achieving this end, the referenced report developed a cost model for the steel industry looking at alternatives such as stock piling and alternate modes of transportation. The frequent references to the "ice season" on the Great Lakes involve the months December through March. Ice boom costs were adjusted from the 1974 Navigation Season Extension report.

A cost summary of the annual cost of ice-breaking vessels and the annual cost of the proposed ice booms is shown in Table 10. The ice booms offer an annual cost savings (net benefits) of $251,900, the difference between the vessels annual cost ($1,425,900) and the ice-boom annual cost ($1,174,000). See *"Appendix A-Economic Analysis, Attachment 8, St Clair Ice Boom Alternative Analysis"* for a detailed discussion.

TABLE 10
Benefits and Cost of ice removal

Current Annual Cost of Ice Removal Attributable to St Clair-Detroit River System	$1,425,906
Proposed Annual Cost of Ice Booms	$1,174,000
Annual Cost Difference (Net Benefits)	$251,906

The direct Federal savings through decreased annual expenditures by the Coast Guard has not been exactly quantified since there has been no estimate as to the elimination of the need for icebreakers. If the need for icebreakers were eliminated, the benefit to the government would be equal to the difference in cost between the two alternatives of $250,000.

The accuracy of the cost of ice boom construction is questionable since these costs were merely adjusted to current dollars from a report completed in 1974 and technological advances could significantly affect the results. Whether updated costs would increase or decrease the bottom line is uncertain. Technological advances may decrease the cost of construction by advancing our ability to produce the same product cheaper or may increase it by design improvements that increase efficiency along with costs. In addition, environmental considerations could potentially have a significant impact on the cost.

The benefits accrued to shipping are calculated from a much more recent, thorough report. Further study is required to determine the difference in the benefits between the current use of icebreakers and the possible use of ice booms. In order to make a reasonable comparison between these alternatives, it is also necessary to estimate the continued need, if any, for icebreakers after the installation of the ice booms.

This review of the available information indicates that placing ice booms in the St. Clair-Detroit River system has the potential for federal savings and further study is warranted.

(6). Improved Water Level Data Access:

a). General

Real-time water level data are collected by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corps of Engineers (USACE) in the U.S. and the Marine Environmental Data Service (MEDS) in Canada. The inconsistency in access and presentation of these data can lead to misunderstanding of the current water level conditions throughout the system and therefore under utilization of commercial navigation capacity, or possible safety problems from grounding.

1) National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) has 45 gages in place on the Great Lakes and St. Lawrence River system.

NOAA has installed a Lite Physical Oceanographic Real-Time System (PORTS) at Sault Ste. Marie, Michigan at the S.W. Pier and at U.S. Slip stations. This system provides real-time 6-minute water level readouts to the lock operators, who in turn relay them to ships in the area. The Data are also posted to a web site accessible by anyone with Internet access. The web site shows plots of the last three hours of data to indicate recent trends in water level fluctuations at the site. The disadvantage is that this information is only accessible through the Internet. Proposed upgrade for a full PORTS system at Sault Ste. Marie would cost approximately $50,000 for a full range of equipment, backup systems and meteorologic sensors. Annual operations and maintenance costs would be approximately $7,000.

2) The United States Army Corps of Engineers

The Detroit District of the U.S. Army Corps of Engineers (USACE) has 16 gages in place on the Great Lakes and St. Lawrence River system.

USACE has installed a voice modem at the Rock Cut gage site on the lower St. Marys River. This gage can be accessed by telephone giving the user the instantaneous water level. An advantage to this mode is the availability to anyone with a telephone. The disadvantage is that the user receives only one water level reading so there is no comparison for accuracy. A system of this type would cost approximately $5,000 individually and would achieve some economies of scale with multiple simultaneous installations. Annual operations costs would consist of maintaining telephone service at a cost of approximately $300 per site. Additionally, provisions would need to be made for replacement equipment, for repairs or eventual complete replacement.

3) Marine Environment Data Services

The Marine Environment Data Services (MEDS) has 33 gages in place in the Canadian waters of the Great Lakes and St. Lawrence River System.

b) Combined Water level access level data

The results of the study propose to coordinate one consistent access point for all water level data through working with all entities currently generating water level information, such as NOAA, MEDS, USACE, hydropower entities, and any other data source known. This central access point involves the creation of a new web site to represent all water level data in the Great Lakes in a consistent fashion. Information would then be displayed for specific regions, regardless of the ownership of the data, providing proper credit and notations. Graphics will be consistent to show past and current information, as past trends in water level changes are important future indicators. Coordination with navigation interests is considered critical to ensure that the users needs are being met with the web site.

The data would be available in the following formats:

- English and Metric units
- Referenced to feet/meters IGLD 1985
- Referenced to inches/cm above/below low water datum
- Tabular and graphic formats
- Detailed data for the most recent several hours
- Data for the most recent few days
- Data for the most recent month
- Historical data as available

The estimated development time for the web site, tables, and graphs is 6 months. This would necessarily include automated updating of the data and some scrutiny of errors. It is expected that the maintenance of the site would take approximately 2 hours per day. Maintenance of both the equipment and software would be required along with planning for eventual replacement.

c) Costs

The estimated total first cost of the proposed web site development is approximately $60,000. The life of the project is assumed 20 years for discounting the first costs. Annual efforts to keep the site up to date would likely take about 2 hours per day, or approximately $40,000 per year. These costs are displayed in Table 11 below.

Table 11
Cost of Proposed Combined Water Level Data Access

Total First Cost	$ 60,000
Average Annual First Cost*	$ 5,300
Annual O & M	$ 40,000
Average Annual Cost	$ 45,300
*Based on 20-year life at an interest rate of 6-1/8%	

It may be that only certain critical water level stations would be needed and various levels of service could be implemented. Each would cost different amounts, as indicated in the NOAA and USACE sections above, and provide different data. Consultation with commercial navigation interests should be considered to determine the best options.

d) Benefits

The benefits of a combined, common data access web site would be significant to shippers who must currently combine information from different sources in order to get complete, useful data. In addition, those involved in research and other monitoring activities would benefit. The quantification of these benefits would cost significantly more than the project itself, but are deemed sufficient in light of the tonnage moved on the Great Lakes system, 221,000,000 short tons of freight in 1998 and consistently over 200,000,000 since 2000.

e) Summary

This alternative proposes to evaluate potential improvements to the water level data access within the Great Lakes system. Knowledge of past, current and forecasted water levels is an integral part of navigation on the Great Lakes, the connecting channels and the St. Lawrence River. These data are collected and disseminated by a variety of agencies in different ways. The combination of these data into a single accurate network system would improve the communication to the shippers, improve vessel loading during periods of low and high lake levels, increase safety and increase commerce, through a more reliable system. The benefits of the proposed combined system remain unquantified due to limited funding and scheduling, but are expected to exceed the costs by a wide margin. Therefore, further study is recommended.

(7). Aids to Navigation

Beacons. This alternative evaluates potential improvements to navigation aids in the Great Lakes system through replacing buoys, which are floating navigation aids, with permanent beacons. Lighted buoys are currently the primary marker system utilized in Great Lakes waterways. They must be removed in the fall prior to the onset of ice and reset in the spring after the thaw. Commercial shipping extends several weeks past the fall withdrawals and starts well before buoys can be placed in the spring. This practice increases risk to mariners and costs to shippers. The Coast Guard envisions a system in which ice resistant permanent structures replace a considerable number of buoys. Such an aid to navigation system would be more robust by providing more reliable aids and year round service. See Appendix A-Economic Analysis, *Section 8. ECONOMIC EVALUATION FINAL ALTERNATIVES* and Attachment 1 for a detailed discussion.

Table 12 presents the summary of the average annual benefits and costs for 29 Beacons. Benefits presented in the table below are all associated with reducing the labor, equipment and material costs necessary to operate a series of in-water navigation aids. While the benefits reflect the difference in the operational economics between buoys and permanent beacons, benefits associated with the reduced risk to buoy tending personnel and to mariners and vessels has not been estimated. Estimating safety benefits was beyond the scope of this reconnaissance study.

TABLE 12
SUMMARY OF BENEFITS, COST AND BCR

Average Annual Benefits	$ 622,430
Average Annual Costs	$ 759,782
Net Benefits	-$ 137,352
BCR	0.8
(-0 @ 6.125% discount w/base year 2010)	

Considering the available information, closeness of the BCR to unity, complexity of the study, and the limited schedule and funds, which prevented a thorough analysis of this alternative, therefore, it is recommended to carry this alternative forward for further analysis in feasibility.

k. Conclusions from Preliminary Screening.

The conclusions from the preliminary screening form the basis for the next iteration of the planning steps that will be conducted in the feasibility phase. The likely array of alternatives that will be considered in the next iteration includes all the above alternatives. The potential magnitude and type of benefits could include the following; (a) deepening connecting channels and ports up to 30 ft draft ($87, 000,000 annually), (b) seaway replacement locks in combination with a 35' draft channel up to Detroit and a 30'draft connecting channels and ports ($885,000,000 annually), (c) seaway replacement locks in combination with a 35' draft channel up to Lake Huron and Lake Michigan and a 30'draft connecting channels and ports ($1,417,000,000 annually), and (d) seaway replacement locks in combination with a 35' draft channel throughout the Great Lakes and St Lawrence Seaway system ($1,510,000,000 annually).

6. FEDERAL INTEREST

Since improved navigation is the primary output of the alternatives to be evaluated in the feasibility phase, there is a strong Federal interest in conducting the feasibility study. Based on the preliminary screening of alternatives, there appears to be potential project alternatives that would be consistent with Federal policies, costs, benefits and environmental impacts.

7. PRELIMINARY FINANCIAL ANALYSIS

Currently, there is no non-Federal sponsor for a feasibility study of the combined Great Lakes/ St Lawrence Seaway system. If the Canadian Government participates as the non-Federal sponsor, they will be responsible for 50 percent of the cost of the feasibility phase. In order for the Canadian Government to participate as a non-Federal sponsor, legislative action would be required. The Canadian Government is aware of the cost sharing requirements for potential project implementation. A letter of intent from the non-Federal sponsor is required stating a willingness to pursue the feasibility study and to share in its cost, and an understanding of the cost sharing for project construction.

With regards to feasibility studies for individual Ports, no non-Federal sponsor has come forward. They are awaiting a determination on whether the system wide study is to be carried forward.

8. SUMMARY OF FEASIBILITY STUDY ASSUMPTIONS

There are a certain number of assumptions that are necessary to conduct any type of planning study. They generally tend to simplify the analysis, and help the analyst focus in on the problem being studied. Several assumptions have been incorporated into the plan formulation process. The assumptions concern the existing commercial navigation system and include:

- Traffic forecasts have been developed on a system wide basis.
- Current two-way traffic patterns in the St. Marys River and the St. Marys Falls Canal would be maintained.
- Structural modifications would be designed to maintain existing water level profiles and flows.
- The costs and benefits included in the analysis are only U.S. costs and benefits.
- Base condition for navigation season

Table 13 Navigation Season				
	Season (months)	Open Date	Close Date	Closed Time
Soo Locks	9-1/4	15 March *	8 January *	66 days
Welland Canal	9	15 March	31 December	74 days
St. Lawrence Seaway	8-1/2	1 April	15 December	106 days
* Dates do not reflect actual operating practices.				

- Non-Federal actions within the authority and abilities of port authorities, state and local agencies, and the waterborne transportation industry which increase the efficiency of the existing system would be maximized. These actions include continued use of the most efficient vessels in the existing and future fleet, light loading when necessary, tug assistance when necessary, optimizing monthly mean lake levels, and utilizing alternative transportation modes and transshipment facilities when necessary.
- In analyzing commodity movements, sufficient mine reserves and/or production capacities exist throughout the period of analysis at the projected tonnage levels.
- Improvements in technology would be incorporated to the maximum extent possible in mining, grain production, transshipment and vessel operations.

- National defense. The Great Lakes system has served the nation during periods of military conflict in the past, and would be expected to do so again in the future if the need arose. To determine the existing Great Lakes/St Lawrence Seaway commercial navigation system's ability to respond to defense related demands, a sensitivity test would be needed to determine the locks' capability under various defense scenarios. Due to limited resources and time constraints, it was assumed that this analysis is not needed at the reconnaissance level but will be assessed during the feasibility phase.

9. FEASIBILITY PHASE MILESTONES

Typical Milestones for a Feasibility study			
Milestones	Description	Duration (mo)	Cumulative (mo)
1	Initiate Study/EIS	1	1
2	Public Workshop/Scope of Work	3	4
3	Alternative Formulation Briefing	6	10
4	Draft Feasibility Report/ Environmental Impact Statement	20	30
5	Public Meeting	1	31
6	Final Feasibility Report/ Environmental Impact Statement	28	59
7	DE Signs Report/EIS	1	60
8	Final Report/EIS to LRD	1	61
Note: The above schedule may vary based on the complexity of the study.			

10. FEASIBILITY PHASE COST ESTIMATE

Feasibility Phase Cost Estimate		
WBS #	Description	Cost
JA	Engineering & Cost Estimate	$ 3,500,000
JJ	Plan Formulation	$ 3,500,000
JB	Economic Analysis	$ 3,500,000
JD	Environmental Studies/Report	$ 3,500,000
JC	Real Estate	$ 450,000
JP	Management & Public Involvement	$ 3,500,000
JM	Washington Level Approval	$ 50,000
	Contingencies	$ 2,000,000
Total		$20,000,000

11. VIEWS OF OTHER RESOURCE AGENCIES

A number of Federal, State and local agencies, have expressed their views on the reconnaissance study. Comments received from a wide variety of users were placed on the web site http://www.lre.usace.army.mil/glnav/INDEX.HTM for sharing of information. Because of the voluminous amount of comments received, only a limited number of letters are shown as an attachment starting on page 49. See the above web site to view all the comments received.

12. POTENTIAL ISSUES AFFECTING INITIATION OF FEASIBLITY PHASE

Currently, there is no mechanism for the Canadian Government to participate as a non-Federal sponsor. Therefore legislative action would be required in order to proceed with a joint U.S. - Canada cost-shared feasibility study.

13. **CONCLUSIONS AND RECOMMENDATIONS**: Based on the reconnaissance analysis contained in this report it is concluded that there is Federal interest in proceeding with further studies of the Great Lakes and St. Lawrence Seaway Systems Study.

However, prior to initiation of the feasibility study, further information is needed. It is recommended that a supplement to the reconnaissance report, for clarification of the without project conditions and determination of the Federal interest, be undertaken. The purpose of this supplement is to provide needed information to support a Federal decision on whether to proceed with the feasibility study. This effort will include an assessment of baseline without-project conditions for the environment, engineering features and economic conditions, as well as public involvement and coordination. Should the recommendation be to proceed with further studies, this phase must also determine the scope of additional studies, including cost and duration, and develop a Project Management Plan. Since the system is a unique bi-national waterway, coordination with Canada that occurred during the development of the Reconnaissance Report, will continue during the reconnaissance phase as well as any future studies. Options for partnering with Canada in future study efforts are being investigated.

The following recommendations may be pursued independently:

(a) The GLSLS System Review identifies several ports on the Great Lakes where there is a federal interest in further studies. It is recommended that feasibility studies for these ports be conducted individually provided there is a non-Federal sponsor.

(b) It is recommended that a feasibility study be conducted individually for the Chicago Sanitary & Ship Canal provided there is non-Federal sponsor.

(c) It is recommended that a feasibility study be conducted individually for the St Clair River Ice Boom provided there is non-Federal sponsor.

(d) It is recommended that a feasibility study be conducted individually for Improved Water Level Data Access provided there is non-Federal sponsor.

Revised 2/3/03

(e) It is recommended that a feasibility study be conducted individually for Buoys and Beacons provided there is non-Federal sponsor.

Revised Date 2/3/03 THOMAS H. MAGNESS
LTC, EN
Commanding

Note: Original signed, 25 June 2002 by RICHARD J. POLO, JR., LTC(P)

Attachment 1 - Definition of Terms

An array of names and definitions are applied to the various waterway segments in the Great Lakes-St. Lawrence River Basin. Some waterway designations overlap others. What follows are the definitions that will be used in this study to describe the navigable waterways in the basin. These are based on most common usage in government reports and industry publications.

Great Lakes/St. Lawrence Waterway (GL/SLW) – navigable waterways from the Gulf of St. Lawrence to the Head-of-the-Lakes.

Great Lakes/St. Lawrence Seaway (GL/SLS) – navigable waterways from Montreal west to the Head-of-the-Lakes. GL/SLS includes the St. Lawrence Seaway and the Great Lakes Navigation System.

Great Lakes Navigation System (GLNS) – all five of the Great Lakes and the Great Lakes connecting channels.

Great Lakes Connecting Channels (GLCC) – navigable connecting channels between the Great Lakes: the St. Marys River, the Straits of Mackinac, the St. Clair/Detroit River system and the Welland Canal. This does not include shallow draft channels that connect with the lakes.

St. Lawrence River – navigable straight between Lake Ontario and the Gulf of St. Lawrence. It has two distinct reaches – the canalized, 26’3” draft Montreal-Lake Ontario (MLO) section of the Seaway and the minimum 35’ draft reach from Montreal to the Gulf.[2] This later stretch of river is referred to in this report as the lower St. Lawrence River.

St. Lawrence Seaway – the waters of the St. Lawrence River above Montreal, Lake Ontario, the Welland Canal, and Lake Erie as far west as Long Point. It includes the Welland Canal and the Montreal-Lake Ontario section. Data displays in this appendix conform to SLSMC and SLSDC Seaway statistical presentations, which do not include intra-Lake Ontario waterway traffic.

Welland Canal Section – eight lock canal linking lakes Erie and Ontario. This section of the St. Lawrence Seaway is the only all Canadian Great Lakes connecting channel.

Montreal-Lake Ontario (MLO) Section – seven-lock canalized section of the St. Lawrence Seaway lying entirely within the St. Lawrence River and extending from the St. Lambert Lock to Lake Ontario beyond the Iroquois Lock.

[2] The 26’3” draft presently allowed in the Seaway is not available all of the time because of variable water levels.

Attachment 2 - Agency Letters

Lake Carriers' Association

GEORGE J. RYAN
PRESIDENT
Direct Dial: 216-861-0590
E-Mail: ryan@lcaships.com
Website: www.lcaships.com

February 21, 2001

Mr. Scott Parker
Chief – Programs & Project Management Division
U.S. Army Corps of Engineers
477 Michigan Avenue
Detroit, MI 48226

Dear Scott:

The Great Lakes Navigation System Study is of great importance to our industry. This study will set the course for infrastructure improvements needed by the Great Lakes region over the next 50 years.

The attached statement is Lake Carriers' Association's vision for the Great Lakes transportation system. Please include these thoughts in your preparation of the Study outline.

We look forward to working with the U.S. Army Corps of Engineers and other agencies as you continue this long-term effort.

Sincerely,

George J. Ryan
President

GJR:cal
Attachment
ryan\coe\navigation-study\010221-1-parker

cc w/att.: Daniel E. Steiner – U.S. Army Corps of Engineers-Great Lakes & Ohio River Division
Members – LCA Advisory Committee
Members – LCA Navigation Committee
Steve Fisher – American Great Lakes Ports
Donald N. Morrison – Canadian Shipowners Association
Raymond Johnston – Chamber of Maritime Commerce
Davis Helberg – Duluth Seaway Port Authority

Lake Carriers' Association

Prepared for U.S. Army Corps of Engineers
As Preliminary Advice in Preparing the Plan for the Great Lakes Navigation Study

February 21, 2001

VISION FOR THE GREAT LAKES TRANSPORTATION SYSTEM

SUMMARY

1. **Increase Project Depth of Connecting Channels and Major Ports to a minimum of 30 feet.**
2. **Maintenance Dredging must take into consideration the expected reduction of water levels below datum.**
3. **Improvement of the major channels in the St. Marys River to permit two-way traffic for deep draft vessels in the West Neebish Channel or, if that is not feasible, dredge Middle Neebish Channel to a uniform width to allow deep-draft vessels to transit at system-wide project depth.**
4. **Port and Channel Infrastructure Needs Analysis to be completed to determine what size channels, depths, turning basins, and anchorages are needed based on current and projected traffic.**
5. **Confined Disposal Facility (CDF) Maintenance and Construction to be established to meet the needs of the new system dimensions.**
6. **Replacement Lock at Sault Ste. Marie, Michigan, to be appropriated at soon as possible.**
7. **Great Lakes System of Water Level Gauge Information Communication to be created to provide real-time water level data to Captains.**
8. **Navigation Systems onboard ships using electronic charts, satellite navigation and communication, and an Automated Information System (AIS).**
9. **Restore Full Federal Funding for Operation and Maintenance Dredging (O&M).**
10. **Length of navigation season must be re-evaluated to determine if current lock opening period from March 25 – January 15 can be lengthened given possible changed environmental conditions.**

BACKGROUND

Every interest group has a unique vision for the Great Lakes. Those groups/interests include agricultural, recreational, electric power generators, transportation, and many others. Within the transportation sector, there will be different visions held by the domestic and interlake trade carriers and those involved in deep-sea trade through the St. Lawrence Seaway. The goals of each are at times in harmony and at times in conflict.

Transportation interests' vision is rooted in the need to meet the legitimate demands of the industries they serve. In the Great Lakes region, the primary industries are steel, construction, power generation, and agriculture. American and Canadian industries are faced with stiff international competition and must continue to reduce costs through capital investment in new technology and economies of scale. Both of these factors are evident in the operation of vessels in the U.S.-Flag domestic trade. Super-sized newer vessels and modernized older vessels can carry 125 million tons of raw materials annually to fuel the Great Lakes region's economy. Unfortunately, the infrastructure of the Great Lakes transportation system is based upon size constraints of the 1930s for the St. Lawrence Seaway and the 1950s for the Great Lakes ports and connecting channels.

1. **Increase Project Depth of Connecting Channels and Major Ports**

The dimensions of the primary infrastructure, the locks, connecting channels, and major ports, are major constraints on the Great Lakes water transportation system and the ability of carriers to meet the needs of the industries served in the 21st Century. The size of many ports and some channels limit the use of the more efficient 1,000-foot long vessels. The width of the upbound channel in the St. Marys River limits the use of the super-sized vessels in a full-load condition. However, the primary limiting dimension in the system is the depth of water in a channel or lock. The project depth, authorized in the 1950s for the Great Lakes system, is 25.5 feet at mean low water datum (also known as chart datum). Often, the Lakes water levels are several feet above chart datum and, thus, loading to as much as 28.5 feet has taken place in the domestic trade of iron ore and coal through the St. Marys River. This fact proves that industry can effectively utilize existing vessels at the deeper draft and that the shippers, primarily steel mills and coal-fired utilities, benefit from larger loads. Nevertheless, there are times when the water level falls below datum and drafts are severely limited to authorized project depth or less. We are faced with these low waters now and for the foreseeable future.

The Great Lakes system needs to have a reliable, greater depth suitable to meet the needs of the 21st Century where worldwide competition demands more cost effective transportation. The target depth should be a Great Lakes system capable of handling ships with a draft of 30 feet or greater at all times in all connecting channels and major ports — regardless of water level fluctuations. The major constraint factor to be considered should be the safe transit over the sill of the Poe Lock and the new lock to be constructed.

2. **Maintenance Dredging**

While no one can accurately predict future water levels, given a worldwide warming trend, certain changes in water levels are expected to occur. On the oceans, as the polar ice melts, there will be higher water levels impacting coastlines. In the Great Lakes, with lower winter snow loads, less ice cover, and warmer air, there will be higher evaporation rates and reduced supply of water from spring thaws. The result will be lower water levels. Because of the precipitous, large drop in the water levels, the U.S. Army Corps of Engineers is unable to adequately maintain the commercial and recreational harbors in the Great Lakes to the Congressionally authorized depths.

Every inch of lost draft reduces the efficiency of waterborne commerce. The largest vessels, the 1,000-foot-long supercarriers, forfeit 270 tons of cargo for each 1-inch reduction in loaded draft. An ocean-going vessel in the Seaway trade loses 100 tons of cargo for each 1-inch reduction in loaded draft.

Congress should pass sufficient appropriations so as the Corps can carry out the authorized dredging of commercial harbors, taking into consideration the expected water levels below datum.

3. **Improvement of the Major Channels in the St. Marys River**
From 1870 through 1956, Congress authorized the various channels and locks in the St. Marys River. For a number of reasons, there are two one-way channels around Neebish Island. The east side, known as Middle Neebish Channel, is the upbound channel; although, with tight traffic control, good seamanship and reduced draft requirements, it can be navigated by a downbound vessel in a one-way traffic scheme. The west side, known as the West Neebish Channel, is the deep-draft downbound channel. Neither channel is wide enough for two-way traffic. **Our vision is to have a two-way traffic channel in the West Neebish Channel.** This would require a major dredging project from Nine Mile Point in Lake Nicolet to the Lake Munuscong Junction Buoy. The cost of annually maintaining the channels by the Corps of Engineers and the U.S. Coast Guard on both sides of Neebish Island could be significantly reduced if there was one two-way channel. For example, there are over 60 floating aids to navigation and a number of fixed aids in the 17 plus statute miles of Middle Neebish Channel — these could be eliminated. **Alternatively, if the benefit/cost analysis is not favorable, then the Middle Neebish Channel could be designed to be a safe downbound channel by removal of the 21-foot channel on the east side of courses 5 through 9. The entire channel should be dredged to the newly authorized system depth.**

4. **Port and Channel Infrastructure Needs Analysis**
A comprehensive analysis of the existing and expected trade through each Great Lakes port must be made to determine if the channel design and turning basins are sized correctly for the commerce expected over the next decades. There may be many ports that could benefit from wider and deeper channels while there are several ports that have lost the potential for significant growth and, therefore, may not need the maintenance of two-way traffic channels or channels with the currently authorized width and depth.

5. **Confined Disposal Facilities (CDF) Maintenance and Construction.**
In the 1970's, the Federal Government built 26 CDFs in the Great Lakes to hold dredged sediments from Great Lakes ports and waterways. Some of these sediments contained polluted material. The capacities of these CDFs are not infinite, so plans must be made to create new CDFs in order to receive the polluted material from normal maintenance dredging and from the clean up of the hot spots in areas of special concern where remedial action plans are in effect. **More CDFs must be authorized and built to handle the recommended project depth. Studies must be made to determine which of this dredged material can be used for land creation or open lake disposal.**

6. **Replacement Lock at Sault Ste. Marie, Michigan**
Complete plans and specifications for the new lock at Sault Ste. Marie, Michigan, capable of handling the Poe-class vessels that now represent approximately 70 percent of U.S.-Flag carrying capacity on the Great Lakes. Provide Federal share of appropriations for construction when the Great Lakes Commission has finalized the sponsorship agreement with the Governors of the Great Lakes States. **Consider construction appropriations for FY02.**

7. **Great Lakes System of Water Level Gauge Information Communication**
The Great Lakes water levels are in a dynamic state. While these waters are not as seriously impacted by tides as on ocean coasts, there are significant fluctuations caused by annual cyclical changes of water supply, unpredictable changes caused by wind and barometric action, and longer-term changes caused by drought or wet periods. For the safety and productivity of shipping in the domestic trade where turnaround times between load and discharge ports range between a matter of hours to three days, the knowledge of water levels in the area to be navigated is a great asset to the Captain of the ship. There is no system-wide manner to obtain this data in useable format and communicate it to the Captain on the ship in real-time. **U.S. and Canadian Government agencies responsible for water level measurements must put together a real-time water level communications system.**

8. **Navigation Systems Onboard Ships Using Electronic Charts, Satellite Navigation and Communication, and an Automated Information System (AIS)**
While not the direct responsibility of the U.S. Army Corps of Engineers, the Corps and the U.S. Coast Guard must take into consideration in channel design and aids to navigation installation the changed technology that will be onboard all vessels by the time the new infrastructure is in place. When the Corps carries out channel surveys in the future, the results of those surveys can be conveyed to the electronic chart suppliers and to the Captains through the AIS. The dimensions of the channels can be designed with tolerances that not only take into consideration the weather, wind, current, and other local and environmental conditions, but also the expectation of more accurate navigation.

9. **Restore Full Federal Funding for Operation and Maintenance Dredging (O&M)**
From the founding of our nation until 1987, the Federal Government funded O&M dredging of the nation's waterways from general revenues. A Harbor Maintenance Tax (HMT) was instituted in 1987 to recover 40 percent of O&M costs in the deep-draft waterways (the HMT has never been assessed on the inland waterways). When the HMT was tripled in 1991 to recoup over 100 percent of deep-draft O&M, legal challenges began that eventually led to the Supreme Court voiding the tax on exports. Legal challenges continue and, as a result, the past Administration proposed a substitute Harbor Services User Fee (HSUF) that would expand collections to include the Federal Government's share of new construction projects. In total, the HSUF would have added $1 billion a year to the nation's freight bill. The current Harbor Maintenance Trust Fund contains a surplus of $1.668 billion because of excess collections over expenditures. Even with revenues reduced by the exclusion of taxes from exports, and with revenues now coming primarily from imports, the fund continues to build a surplus. The role of waterborne commerce in our nation's economic well-being and national security demands a return to full Federal funding. Domestic waterborne commerce routinely tops 1 billion tons a year. Ninety-eight percent of our imports and exports move across the oceans in vessels. There is hardly a job or industry in this country that is not dependent on an efficient system of ports and waterways. Furthermore, a recent GAO study has determined that 11 Federal agencies already assess 124 taxes on waterborne commerce that annually generate more than $21 billion for the Federal treasury. **Maintenance of our channels can be funded through a cash transfer of revenue raised through import duties, just as the Department of Agriculture funds its marketing programs.**

10 Length of Navigation Season Must Be Re-Evaluated To Determine if Current Lock Opening Period From March 25-January 15 Can Be Lengthened Given Possible Changed Environmental Conditions

The agreement between the State of Michigan and various Federal agencies regarding the period of opening of the Locks at Sault Ste. Marie was based, in part, upon concern for environmental conditions related to ice cover and the break-up of the ice on the fisheries and the shoreline. A recent assessment completed by the Environmental Protection Agency, *Preparing for a Changing Climate, Great Lakes Overview, October 2000*, indicates that we may be in a warming trend that will result in higher average temperatures throughout the region, lower water levels, and reduced ice cover. Since this study must review all technological data impacting on the navigation system, these environmental changes must be carefully reviewed. Should there be a period of low water, tonnage will have to be shipped either over a longer period of time using the existing fleet or there will be a need to invest capital in the construction of new vessels. While ship construction may appear to be good for the economy, in the long run, it will add costs to the steel industry that is fighting for its survival against subsidized foreign imports. A preferred option is to optimize existing vessels. The study should determine the circumstances under which a longer period of lock opening could take place. It is essential to maintain fixed open and close dates so as supply decisions can be made with certainty. While the fixed closing date could be extended, it may also be possible to allow for continued vessel operations until some later date following the fixed closing date based on environmental conditions at Sault Ste. Marie. The season extension primarily should be at the end of the season when navigation can more readily continue while ice is forming, rather than at the opening of the season when heavy ice conditions may exist.

ryan/coe/lca vision/010221

Minnesota Pollution Control Agency

February 9, 2001

Mr. Terry Long
Attn: CELRE-PM-PL
Department of the Army
Detroit District, Corps of Engineers
Box 1027
Detroit, MI 48231-1027

RE: MPCA Comments Regarding the Proposed Study to Review the Great Lakes Navigation System

Dear Mr. Long:

The Minnesota Pollution Control Agency (MPCA) staff appreciate the opportunity to provide comments on the scoping of work regarding the proposal to study the Great Lakes Navigation System. The MPCA is authorized under Section 401 of the Clean Water Act (33 USC 1251 et seq.) and Minnesota Statutes Chapters 115 and 116 to evaluate projects that have the potential to impact waters of the state.

While some of the following issues identified by MPCA staff are not a direct responsibility of the Corps, these topics do and will play some type of role in the decisions of the Corps and in Great Lakes shipping:

- <u>Areas of Concern</u> - Most of the designated harbors in the Great Lakes also have significant environmental impairments and have been designated Areas of Concern. This issue should be a factor in any future studies and decisions of the Corps of Engineers in the Great Lakes region.

- <u>Dredging</u> - If dredging is a potential outcome of this study, the Corps of Engineers should also consider the direct and indirect impacts of dredging, including management of dredged material (reuse and disposal options and restrictions).

- <u>Source Reduction of Sediments</u> - More focus should be placed on source reduction (i.e., keeping the soil on the land) as a means to reduce the volume and frequency of dredging needed to maintain shipping channels.

- <u>De-Authorization of Federal Channels</u> - If a potential outcome of this study requires Congressional action, the Corps should consider requesting de-authorization of those federal navigation channels that have not been actively maintained. For the Duluth-Superior harbor, this would include the Minnesota Channel Western Section and 21st Avenue West Channel.

- Spill Containment/Prevention at Docks and Refueling Stations - Any increase and/or expansion of shipping operations should also consider prevention and minimization of environmental impacts from fueling.

  Ship Wastewater Treatment Facilities - The current on-vessel wastewater systems are largely outdated, inadequate and unmonitored. In addition to improving the currently used technology, an option worth further consideration is to improve the systems or replace with holding tanks and utilize ship-to-shore wastewater disposal.

- Expansion of the "no discharge zone" in Lake Superior - The discharge of bilge and greywater from vessels goes largely unregulated. The study should consider expansion of the "no discharge zone" bilge and greywater to include the whole of Lake Superior.

- Exotic Species - One method of introduction and spread of exotic species in the Great Lakes has been through shipping activities. The study should consider exotic species, including their movement, impacts, and legal approaches and technologies to contend with the problem.

- Viability of Expanding the Shipping Infrastructure on the Great Lakes - There have been discussions regarding expanding the locks in order to accommodate larger vessels, in part to compete with coastal harbors. Careful consideration should be given to these types of proposals to determine if the benefit outweighs the cost and if there are other alternatives, such as shipment by rail.

- Water Diversions - There have been past proposals to divert water from the Great Lakes for use in other areas of the U.S. and Canada. The study should consider the status of such proposals and the potential impacts that this activity would have on commerce and the environment of the Great Lakes.

  Global Warming - Global warming may result in drastic changes to the environment. How will global warming impact commerce and the environment of the Great Lakes?

- Environmental Impact of Outcomes of the Study - All environmental impacts of projects should be considered during and be a part of the decision-making process. For example, if one outcome is to widen and/or deepen federal navigation channels, then consideration should be given to the disposal/reuse management of the dredged material. This would include the likelihood that dredging beyond current channel dimensions may result in re-introduction of contaminated sediments and pose a disposal issue for those sediments.

Thank you again for the opportunity to provide input on this effort. If you have any questions regarding this letter, please contact me at (218) 723-4744.

Sincerely,

Pat Carey

Patrick Carey
Supervisor, Community & Area-Wide Programs Unit
North District, Duluth Office

PC:kt

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Division of Environmental Permits, Region 6
Dulles State Office Building, 317 Washington Street, Watertown, New York 13601-3787
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Website: www.dec.state.ny.us

John P. Cahill
Commissioner

February 7, 2001

Detroit District - Corps of Engineers
ATTN: CELRE-PM-PL Mr. Terry Long
P.O. Box 1027
Detroit, Michigan 48231-1027

RE: Great Lakes Navigation System (GLNS)

Dear Mr. Long:

This office of the Department of Environmental Conservation would like to take this opportunity to comment on the new study, the Great Lakes Navigation System (GLNS) Review. The jurisdictional boundaries of this office include Eastern Lake Ontario and the St. Lawrence River, and therefore, factors that impact upon these waterways are of obvious concern to this office as well as to the general public.

Issues that are of significant concern include the following:

1. The water level management of Lake Ontario and the St. Lawrence River has severely impacted and will continue to cause problems to the wetland systems located along these waterways and to the numerous small islands and shoal areas that are scattered throughout the system.

2. Dredging of any navigation channels that would include straightening, widening or deepening of existing channels or the creation of new channels.

3. Any navigation that occurs when an ice cover has formed on the St. Lawrence River and the increased environmental damage and damage to shoreline structures.

4. The potential environmental impacts associated with increased shipping, particularly on the St. Lawrence River section, including the higher potential for spills, increased impacts from ship wakes, and the potential for greater conflict between recreational versus commerical users.

5. The introduction and spread of contaminants throughout the system.

6. The water quality of the Great Lakes-St. Lawrence system and the potential of degradation of the water quality for recreational, industrial and consumptive usage.

During this entire planning and study process this office has a significant concern to stay in the information loop and requests that copies of any research proposals, summary or final reports, or recommendations generated during the GLNS Review process be forwarded to this office. From our perspective, it would be helpful to be informed early in the process to allow for a thorough review of items by appropriate staff.

Thank you for providing this office the opportunity to comment on the GLNS Review and to become involved in the process.

Sincerely,

Lawrence D. Gunn

Lawrence D. Gunn
Environmental Analyst 1
Region 6

LDG:dli

cc: Sandy LeBarron, Regional Director, Region 6 DEC
Albert Schiavone, DEC
Dennis Faulknham, DEC
Leonard Ollivett, DEC
Brian Fenlon, DEC

STATE OF MICHIGAN

JOHN ENGLER, Governor
DEPARTMENT OF ENVIRONMENTAL QUALITY
"Better Service for a Better Environment"
HOLLISTER BUILDING, PO BOX 30473, LANSING MI 48909-7973
INTERNET: www.deq.state.mi.us
RUSSELL J. HARDING, Director

February 5, 2001

Detroit District, Corps of Engineers
P.O. Box 1027
Detroit, MI 48231-1027

Attention: CELRE-PM-PL/Mr. Terry Long

Dear Mr. Long:

SUBJECT: Great Lakes Navigation System (GLNS) Review

This letter responds to the January 18, 2001, communication from Wayne Schloop, Project Manager, Planning, Programs and Project Management, soliciting comment on the scope of the Great Lakes Navigation System (GLNS) Review authorized by Congress.

In light of Mr. Schloop's statement that "the ultimate aim of the study is to produce an efficient and modern environmentally sound navigation system on the Great Lakes," we strongly recommend that the prevention of further introduction of aquatic nuisance species into, or the export of same out of, the Great Lakes–St. Lawrence Basin be made a part of the GLNS.

The Great Lakes are infested by roughly 160 aquatic nuisance species such as the sea lamprey, zebra mussel, Eurasian ruffe and the spiny water flea at a cost of, literally, billions of dollars. These exotic species threaten a $4 billion sport fishery in the region. Unfortunately, the latest research forecasts the introduction of another 17 such aliens from the Ponto-Caspian Basin alone.

Several topics for possible review are:

1 barriers - physical, mechanical or electrical - preventing entry or exit of aquatic nuisance species at both ends of the system, including the Chicago Diversion;

2. facilities for shoreside sterilization of ballast water and NOBOB vessels generally;

3. the needs of the U.S. Coast Guard in enforcing current and future laws and regulations; and

4. any other ideas from other interested parties such as the U.S. Fish and Wildlife Service, the Great Lakes Aquatic Nuisance Species Panel, and the Great Lakes Fishery commission.

Thank you for your interest.

Sincerely,

G. Tracy Mehan, III
Director
Office of the Great Lakes
517-335-4056 / fax: 517-335-4053
e-mail: mehang@state.mi.us

cc: Mr. Russell J. Harding, Director, MDEQ

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5100 Port Road
Jeffersonville, Indiana 47130
FTZ #170
(812) 283-9662

Indiana's International Port
/Burns Harbor at Portage
6625 S. Boundary Drive
Portage, Indiana 46368
FTZ #152
(219) 787-8636

Southwind Maritime Centre
1700 Bluff Road
Mount Vernon, Indiana 47620
FTZ #177
(812) 838-4382

January 30, 2001

Mr. Wayne Schoop
Programs & Project Management Division
USACE – Detroit District
PO Box 1027
Detroit, MI 48231-1027

Re: Great Lakes Navigation Study

Dear Mr. Schoop:

The Indiana Port Commission, along with several port authorities in the Great Lakes states, has the unique ability to transport waterborne commerce through both the Great Lakes Navigation System and the Inland Waterway System. These unparalleled navigation systems in the heart of the North American Continent provide a vital logistics link for shippers of domestic and international cargo. Indiana's farmers and manufacturers enjoy substantial cost savings because of the existence of these waterways, as well as the societal environmental benefits derived from the movement of bulk tonnage by water rather than by road or rail.

Indiana's International Port moves substantial bulk tonnage through its Burns Harbor, Indiana facility on Lake Michigan. In recent years the port has moved increasing amounts of general cargo, primarily steel products. In both the bulk and general cargo trade, the vessel departs the port at Seaway Mean Summer Draft (26' 3") rather than at full-vessel draft. The vessels are generally topped off once they are in deeper water east of Montreal. This situation costs both the shippers and consignees valuable time and money through delays and multiple vessel stops. Increasing the channel draft in the Great Lakes Navigation System from 26' 3" to between 30' and 35' would add substantial cost incentives for shippers utilizing our port.

Vessel safety has become an increasing concern, especially with the low water levels of the Great Lakes during the past several navigation seasons. Indiana's International Port experienced three groundings during the 1999 / 2000 shipping season. Due to vessel safety concerns the Commission performed emergency dredging within the harbor in the spring of 2000. The primary delay involved with the emergency dredging project was due to the difficulty of securing U.S. Army Corps of Engineers permits. If feasible, the Navigation Study should review the permitting process necessary for accomplishing emergency dredging.

During the past two decades, the size of almost all ocean-going vessels has increased significantly. Vessels transiting the Great Lakes/St. Lawrence Seaway, however, have been restricted because of unchanging lock dimensions. The Great Lakes Navigation Study needs to evaluate the locks of the St. Lawrence Seaway and identify what System changes would be most beneficial to shippers and the Great Lakes maritime community while maintaining a reasonable cost for lock rehabilitation or replacement.

The Indiana Port Commission considers the Great Lakes Navigation Study a timely and most important Corps of Engineers project. We stand ready to assist in any way possible with your effort.

Regards,

William D. Friedman
Executive Director

DETROIT/WAYNE COUNTY PORT AUTHORITY
MICHIGAN'S INTERMODAL GATEWAY

November 29, 2000

Mr. Daniel E. Steiner
Chief, Planning and Policy Division
U.S. Army Corps of Engineers
Great Lakes & Ohio River Division
John Weld Peck Federal Office Building
550 Main Street, Room 10-008
Cincinnati, Ohio 45202

Dear Mr. Steiner:

On behalf of the American Great Lakes Ports, I would like to express our sincere interest and extend our assistance in developing justification and direction for the Great Lakes Navigation Study authorized through the Water Resource Development Act (WRDA) for 1999. This comprehensive planning initiative is vitally important for both American and Canadian Great Lakes ports in order to ensure the competitiveness of our region within the global marketplace.

This initial reconnaissance study would help determine the needs and opportunities for growth within the Great Lakes/Saint Lawrence Seaway System by prioritizing critical areas of concern. The many stakeholders utilizing this system are depending on this study to identify the strengths of our current system, as well as the problems, weaknesses and threats. It is important to include a broad definition of economic benefits to be realized from navigational improvements in the benefit cost analysis of this study.

The Great Lakes/Saint Lawrence Seaway System is home to almost one-half of both the American and Canadian population. The region has the five largest steel producing states in the country, accounting for approximately 70% of total U.S. production. Further, almost one-half of the Fortune 500 Industrial Companies are headquartered here.

Since 1959, the Saint Lawrence Seaway has provided a global link between the world marketplace and the industrial and agricultural heartland of North America. The 2,000-mile long seaway system is responsible for annual commerce exceeding 200 million net tons. Responsible for carrying this cargo are 75 U.S. lakers, 90 Canadian lakers, nearly 1,000 saltwater vessels, and about 50,000 barges connected to the rivers that feed this system. Fanning outward from this major international artery are 40 provincial and interstate highways, nearly 30 rail lines which in turn link 15 major ports and 50 regional ports with consumers, products and industries all over North America.

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Agricultural products, primarily grain for export, comprise nearly 40% of the Great Lakes/Saint Lawrence Seaway trade. Another 40% of this trade consists of mining products including iron ore, coal, coke, salt and stone. Iron and steel products equate to the highest value goods traded due to their labor-intensive handling requirements. It has been estimated that for every imported metric ton of steel, $250 in economic impact is created for the community in the form of personal income, taxes and related business revenue. In total, it has been estimated that over 45,000 U.S. jobs and more then $2 billion in personal income are directly generated by the shipping of commodities and manufactured products on the Great Lakes.

The environmental efficiency of Great Lakes shipping cannot be matched. A 1993 study by the Great Lakes Commission of eleven trade routes on the Great Lakes showed that by utilizing ships, we save 14 million gallons of fuel and reduce emissions by more than 4,300 tons. It is a fact that a single 1,000-foot ship carries the equivalent of six 100-car unit trains. Efficiency like this requires attention, consistent study and federal involvement and appropriation. Without such attention, we will be cheating ourselves of one of our richest and most ecologically sensitive resources. Railroads would have to more then double their fuel efficiency to equal that of the Seaway System.

The study went on to report that a vessel-to-rail shift for the eleven cargo flows would statistically result in thirty-six more rail crossing accidents, fourteen more derailments and one train collision. The commodities that trucks might carry statistically would produce 141 more truck/car accidents on the roads and highways, one quarter of which would have the potential for fatalities or serious injuries.

Furthermore, with the passenger cruise industry emerging once again on the Great Lakes, the safety of the system becomes an even greater priority. It is estimated that in 2001, Great Lakes ports can expect to service over 6,000 passengers and an estimated 10,000 by 2002. Because this industry is continuing to grow, it is vitally important that our federal government take preventative steps early in reducing the possibilities of accidents and navigational problems that might threaten the safety of passengers. Such precautions will reduce liability, as well as increased costs that might be associated with future emergency navigation improvements.

Despite the substantiating environmental and economic factors, most of the seaway infrastructure dates back to design principles of the 1930's. Harbors, locks, channels and turning basins were designed with ships from this era in mind. What was a unique and incredibly modern transportation system then, has turned into an aged and outdated system that doesn't cater to a developing and mobile fleet of ships. A 1996 study by the Saint Lawrence Seaway Development Corporation found that only 40 percent of the world fleet could transit the Seaway locks. This percentage has diminished over time, falling to a mere 30 percent of the world fleet according to some recent estimates. In addition, even if a 105-

foot by 1000-foot vessel could transit the locks, it wouldn't necessarily fit into channels and harbors of many regional ports, reducing the efficiency of the Great Lakes/Saint Lawrence Seaway system.

The shipping industry we are all trying to serve and provide appropriate infrastructure for is a "mobile" industry. Vessels are not required to operate on the Great Lakes/St. Lawrence Seaway system. If it becomes cheaper and more efficient to carry cargo and serve the deep-water ports of the East Coast, then they will do this. If it becomes easier to navigate and serve ports that can feed the Midwestern ports by rail, they will do this as well.

The Great Lakes Navigation Study provides a useful tool for responsible planning to address the system's shortcomings. Issues concerning upgrade and maintenance of the Great Lakes / Saint Lawrence Seaway system are of vital importance if we are going to ensure the viability and strength the Midwest provides our nation. This study is needed to bring the St. Lawrence Seaway System up to the same competitive level that our other U.S. and Canadian transportation systems enjoy. Our organization would like to make a variety of recommendations as you prepare to begin work.

First, the American Great Lakes Ports Association asks that a primary focus of the Great Lakes Navigation Study be the maintenance and modernization of the St. Lawrence Seaway itself and related improvement to connecting channels and ports throughout the system. The feasibility, costs and benefits of an expansion of the Seaway locks - in width, depth and length - to accommodate larger vessels should be analyzed. Specifically, we are asking for expansion and/or replacement of the existing 15 Seaway locks.

Second, we support the proposal of the Lake Carriers' Association to examine the feasibility of deepening connecting channels and ports to a depth of at least 29.5 feet. Although the width of channels and locks presents problems of its own, the primary limiting dimension in the system is the depth of water in a channel or lock. Industry has proven in times of higher water levels (above low water datum) that they can effectively use their vessels at deeper drafts and that shippers benefit from these larger loads. As water levels have returned to historic levels, shippers are forced to load their vessels much lighter, erasing economies of scale and creating safety concerns where shallows spots emerge throughout the system. Maintaining adequate channel and harbor drafts become more crucial when you consider for every one-inch of reduction in depth, a 1,000 foot freighter forfeits approximately 270 tons of cargo. This loss of cargo must be made up with more trips, which creates greater fuel consumption and increased cost incurred by both the shipper and customer, thus becoming inefficient for everyone.

Third, sediment build-up on channel and river bottoms adds new problems, many of which could be reduced with proper planning and erosion control techniques. A study of the Cuyahoga River in Cleveland found that 54 percent of sediment build-up was from upland erosion. Lake Erie and the Detroit River Livingston Channel also demonstrate the need to increase channel depth. To identify where this is occurring, more research and studies need to be completed that include funding options through various engineering techniques. By controlling this problem early, we can avoid high-cost maintenance in the future.

Finally, we strongly urge the Corps of Engineers to invite the Government of Canada and the Canadian maritime industry to fully participate in the Great Lakes Navigation Study as an equal partner. The Great Lakes / St. Lawrence Seaway System is a binational waterway. Much of the infrastructure is in Canadian territory. If this study is to be of future use, it cannot be seen as an "American study." Canadian participation and buy-in will help to ensure that both governments respond to the study's recommendations. We are happy to work with the Corps to facilitate communication with Canadian stakeholders and policymakers.

Over 30 million people rely on the Great Lakes/St. Lawrence Seaway system, either recreationally or commercially. The vital importance of this system should directly correlate to the amount of federal involvement and funding set aside to ensure its viability and strength as we enter this new century. Channel and harbor deepening projects and lock dimension improvements top the list of priorities for commercial shipping interests. The time is now for all stakeholders dependent on this vital transportation system to plan ahead for much needed improvements, or we will be faced with monumental infrastructure problems down the road that cannot meet tomorrow's challenges.

Sincerely,

John Jamian
Chairman
American Great Lakes Ports

U.S. Department of Transportation
Maritime Administration
Great Lakes Region

August 25, 2000

Daniel E. Steiner, P.E.
Chief, Planning Division and Navigation Account Manager
U.S. Army Corps of Engineers
Great Lakes and Ohio River Division
P. O. Box 1159
Cincinnati, Ohio 45201-1159

Dear Mr. Steiner,

As way of introduction, Craig Middlebrook, Deputy Administrator, St. Lawrence Seaway Development Corporation, phoned recently to tell me about the Corps sponsored Great Lakes Navigation System Review project. This is a very timely project since the Department of Transportation has been holding Maritime Transportation System (MTS) review meetings around the country. During the early phases of MTS, the U.S. Coast Guard Ninth District initiated the Great Lakes Waterway Management Forum as the regional version of National MTS. This "Forum" membership is made up of U.S. and Canadian government and marine industry representatives with sole purpose of improving the Great Lakes waterways for all users - recreational as well as commercial. I am sure that the "Forum" members would like to help you with your new project.

The Maritime Administration (MARAD), Great Lakes Region staff – all three of us – are willing and able to provide technical assistance to you during your study project. MARAD's role is to promote waterborne commerce – U.S. shipbuilding – and U.S. maritime employee training – in domestic and international trade. The enclosed MARAD Annual Report describes our ship financing programs, national defense, and promotional activities. Our region responsibility includes monitoring and assisting the maritime industry in the Great Lakes as well as on the Ohio, Missouri, Upper Mississippi River and Illinois Waterway. A number of Great Lakes vessel operators are our customers through the Title XI Ship Financing and Capital Asset Fund Programs.

Recent DOT Listening and Dialogue Sessions with other Federal agencies and the maritime industry seem to run on a strong theme for the urgent need to improve the infrastructure of the American waterways. The general perception of the maritime industry is that the Nation is loosing ground in the maintenance and support for waterway improvements. This includes, specifically, dredging harbors and disposing of sediment, and the updating of connecting channels and locks to meet the needs of today's vessels as well as the potential benefit for larger vessels in the future.

The vessel efficiency issue is difficult to fully understand by those that are not directly involved in day to day operations. But, briefly, all vessels are designed to carry as much revenue producing cargo as possible and operate 24 hours a day – 7 days a week – and every day that the waterway is open. In some cases, there are vessels operating year-round within certain portions of the Great Lakes and Inland Waterways. In other cases, large vessels operate during shorter seasons due to their trade patterns in the Upper Lakes or through the Seaway. In every case, these vessels rely on the most efficient use of the waterways full dimensions – length – beam and depth. Some operators fine-tune their vessel loading to daily weather conditions and water level reports at loading and discharge ports. If winds are blowing water into a distant discharge port – they may load on a few more revenue producing tons. Other operators, such as those operating in the Seaway, are somewhat restricted by a longer-range draft forecast and limits set by the U.S. and Canadian Seaway authorities. The most efficient vessel operation is finely tuned to the maximum use of the waterways. Anything less – is unacceptable.

The general perception from the maritime representatives at DOT meetings is – the U.S. is failing to keep up with the waterway demand. According to the An Assessment of the U.S. Marine Transportation System – a Report to Congress – September 1999 - global maritime trade is predicted to grow 3.5 percent annually

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through year 2020. Vessel operators are expressing concern about existing water capability – let alone any increasing demand on existing waterway infrastructure.

This issue is even more important in the existing trade throughout the Great Lakes region. Many Great Lakes harbors have project depths of less than connecting channels or lock depth. This historical design criteria restrains efficient vessel operation and commercial development. We recommend studying those commercial harbors that have project depths of less than Seaway or SOO Lock depth to determine their present commercial needs. Perhaps a limited number of ports can be selected for a case study. Two ports that come to mind are Green Bay, WI and Waukegan, IL. Both ports have impressive growth potential if they only had deeper harbors. According to the SLSDC, their goal is to achieve a 27 foot draft in the in the next few years. In addition, the Lake Carriers Association recently expressed interest in achieving a 29.5 foot draft throughout the Upper Lakes. Certainly, there is maritime industry support for improved waterways.

We recommend that you consider a review of the world and regional vessel fleet dimensions as it relates to the projection for future harbor and lock design. The recent increased allowable vessel size through the Seaway has created new vessel construction and reconstruction of existing vessels. Canadian vessel owners have converted several Seaway vessels to fit the modern dimensions of 740' LOA 78' Beam and 26' 3" draft. These "wider" vessels can carry substantially more due to their new "cubic" capacity. In addition, recent new vessel buildings by ocean vessel owners have increased carrying capacity by building shorter but wider ocean vessels capable of transiting the 78' locks. This improvement in vessel efficiency and shipyard activity was accomplished by a review of the existing locks and without any new construction cost. The review of proposed Second Lock at Sault Ste. Marie, Mi. should also include the same concept, or perhaps, a larger "Son of POE Lock" and its impact on the Upper Lakes shipbuilding industry. There is a general rule-of-thumb that "a larger lock will create larger and more efficient vessels". This analysis may also contribute to an improved cost-benefit ratio for the proposed Second Lock if you consider new shipbuilding and improved cargo carrying capacity impact on the Great Lakes region.

One of our "unfinished projects" is the review of waterborne trade through the Chicago connection via the Illinois Waterway and Lake Michigan. According to COE statistics, there are about 8,500 river barges operating through the Chicago waterways to just two major port in Indiana – Burns Harbor and Indiana Harbor. These two ports are served by barge on a year-round basis and connect Inland Waterway destinations/origins providing a water mode service for Seaway commodities as well as domestic commodities. The Illinois Waterway barge traffic generally carries between 42 to 50 millions tons of cargo each year. Recently, the U.S. Coast Guard has published regulations for barges to transit beyond Chicago into Lake Michigan as far as Muskegon, Michigan and Milwaukee, Wisconsin. While this expanded operating capability has been slow developing, the traffic between Chicago and Northern Indiana ports continues to be strong and growing in importance. This route also has its share of infrastructure limitations such as low bridge air draft, narrow channel, and high traffic volume. We recommend that this waterway connection be included in your study effort.

These are just a few of the ideas that we may be able to help you investigate in your study project. Please feel free to contact us at any time if you have any questions. We look forward to providing technical assistance to you and your staff.

Yours truly,

Al Ames

Al Ames
Region Director

Cc: Craig Middlebrook – SLSDC
Bonnie M. Green – MARAD
RADM James D. Hull – USCG Ninth District

Enclosed:
The Great Lakes – A Waterways Management Challenge
MTS – Report to Congress –September 1999
MARAD Annual Report - 1999
Domestic Shipping
MARAD Great Lakes Region

U.S. Department
of Transportation

THE ADMINISTRATOR
Room 5424
400 Seventh Street, S.W.
(202) 366-0118

August 24, 2000

**Saint Lawrence
Seaway Development
Corporation**

Mr. Daniel E. Steiner, P.E.
Chief, Planning Division and
Navigation Account Manager
U.S. Army Corps of Engineers
Great Lakes and Ohio River Division
P.O. Box 1159
Cincinnati, OH 45201-1159

Dear ~~Mr. Steiner~~, Dan

Thank you for stopping by the office last month. I appreciate your willingness to travel to Washington and to bring key staff from your Chicago and Buffalo offices to meet with my staff. I understand that the meeting was productive. All of us at the Saint Lawrence Seaway Development Corporation (SLSDC) are excited about working with you on this important project.

At the meeting, you requested our comments to your initial scope of study document. We have reviewed the document and have prepared the enclosed comments. Please let us know if you need more information or clarification on any of the points we have raised here. I hope this same spirit of cooperation on the initial scope of work will follow throughout all aspects of the actual study. I would be happy to designate a team of SLSDC employees at your ready for consultation, expertise, facilitation, and a reality check.

We have outlined seven points for consideration, with our chief concern being that the study include a fresh examination of expanding the Seaway's locks. Accurately assessing the feasibility of lock expansion for the entire Seaway System, including both Canadian and U.S. locks, is essential to assessing the long-term competitiveness of the System. The SLSDC can play a crucial role in facilitating the involvement of the Canadian St. Lawrence Seaway Management Corporation (SLSMC) in this study. Indeed, as I believe you are aware, my Canadian counterpart, Guy Véronneau, has stated that while he is eager to participate in this study, Canadian participation is contingent on their ability to work directly through the SLSDC in consulting with your agency. To that end, we will have to establish a procedure for communicating between the SLSMC and your agency through the SLSDC. I am confident that we can arrange a procedure, just as we have done with the U.S. Coast Guard and the SLSMC, that is efficient, yet sensitive to the requirements of each agency. It would be useful to arrange a meeting, when you feel it is appropriate, between you and your staff and the appropriate Canadian representatives. I would propose that the meeting be held at or near our facilities in

Mr. Daniel E. Steiner, P.E.
August 24, 2000
Page Two

Massena, NY (which is adjacent to the SLSMC's headquarters in Cornwall, ON). If you agree, I will make arrangements for such a meeting on a date that you request.

As you and I have discussed, another area where we may be of assistance is in providing you with contacts among U.S. Great Lakes/Seaway stakeholders. I know you have already established contacts with some of the key port directors when you met last month in Washington with members of the Association of American Great Lakes' Ports. From that group, Davis Helberg, Executive Director of the Duluth Seaway Port Authority, John Jamian, Executive Director of the Detroit/Wayne County Port Authority (and current president of the American Great Lakes Ports Association), James Hartung, President of the Toledo-Lucas County Port Authority, and Gary Failor, Executive Director of the Cleveland-Cuyahoga Port Authority are individuals you should certainly be in contact with. I would also suggest contacting RADM James Hull, Commander of the USCG's Ninth District, as well as the Maritime Administration's Great Lakes Regional Director, Alpha Ames. We also can provide you with names of helpful individuals from the maritime industry should you so desire. Please let me know how extensive a list of potential contacts you would like. For now, I have enclosed the addresses and phone numbers of the individuals I've mentioned here. We would be happy to facilitate or arrange for meetings with these individuals.

Finally, I want to take this opportunity to invite you formally to our stakeholder meeting in Cleveland on October 18. We hold two such meetings a year with port and industry representatives from all over the Great Lakes, from both the U.S. and Canada. We would be honored to have you be part of the agenda to make a presentation to the group. This would, I believe, be an excellent opportunity for you to meet with and solicit input from some of the major stakeholders in the region. The meeting will be held from 10am to 3pm at the Marriott Residence Inn in downtown Cleveland. Please let me know if you can attend and how much time you would like on the agenda.

I look forward to hearing from you.

Sincerely,

Albert S. Jacquez

Encl.

The Seaway of the 21st Century

Comments of the
Saint Lawrence Seaway Development Corporation
on the scope of the
U.S. Army Corps of Engineers' Reconnaissance Study of Possible
Great Lakes/Seaway Infrastructure Improvements

August 24, 2000

The Saint Lawrence Seaway Development Corporation has been heavily involved in a binational effort to define and promote a strategic plan for the Great Lakes/St. Lawrence Seaway System (System). Under the auspices of the "Waterways Strategic Issues Forum", we have cooperated with the St. Lawrence Seaway Management Corporation (our Canadian counterpart) and various industry representatives to investigate ways to "make the Great Lakes St. Lawrence Waterway the most competitive, technologically advanced, environmentally responsible water transportation system in the world." Some of the elements of this competitive vision can be addressed in the short term, such as controlling costs, strengthening binational cooperation, and investigating new export markets. However, one issue that must be addressed when considering the long term competitiveness of the System is the feasibility of lock expansion to allow for the use of larger, more cost effective vessels. We strongly feel that this reconnaissance study must affirm that the issue of expanding the Seaway locks deserves a fresh look.

The trend in marine transportation is toward larger, more efficient vessels. Currently, the Seaway can only accommodate 40 percent of the world fleet. Ships calling at North America's Gulf and West Coast ports are able to load cargoes of 80,000 to 100,000 tons, whereas the maximum Seaway-draft cargoes are around 25,000 tons. While it is unrealistic to ever think of 100,000 ton cargoes transiting the Seaway, if the locks were modified to accommodate class X vessels, the maximum cargoes would increase dramatically to the vicinity of 60,000 tons. This increase in capacity would decrease the cost per ton by 25 percent based on the vessel utilization savings figures calculated in the 1987 report.

Inspired by the Water Resources and Development Act of 1999, which authorizes the U.S. Army Corps of Engineers in consultation with the SLSDC to examine the feasibility of navigation improvements in the System, we have reviewed the 1987 additional locks study. At the conclusion of the 1987 final feasibility study, the Corps determined that increasing the capacity of the U.S. locks was not economically feasible at that time. In our review, we have identified various issues that we would like to address in the current study reconnaissance phase.

First, we believe that the Corps should closely examine the economic models used in the previous study to determine whether the prior methodology led to an understatement of the true economic benefits to be gained by lock expansion. For instance, we have identified several factors that may have led to underestimating the extent of the "vessel utilization savings" to be gained by using larger ships. First, the vessel utilization savings were calculated based on a maximum draft of 26'. Even at the time of the study, the draft was 26'3", and we are looking into increasing the draft to 26'6" in the near future (possibly as early as the 2001 Navigation

Season), with a final goal of 27'. Each inch of increased draft translates into additional cargo capacity of 100 metric tons for Seaway size vessels, or up to 270 additional metric tons for Class X Poe-sized vessels that are 1000 feet long. Therefore, any future study should calculate vessel utilization savings for drafts of at least 27'.

In addition, the 1987 study focused on grain and iron ore only when computing the projected vessel utilization savings. While "iron ore in, grain out" is a traditional pattern for Seaway cargo, these cargoes only account for 2/3 of the total tonnage shipped through the Seaway. Any study that does not include vessel utilization savings for this other 1/3 of cargo will understate the benefits relative to the cost of the project.

Also, when calculating the vessel utilization savings, the 1987 study estimated future traffic levels for the years 2000-2050 using 1978 levels as a baseline, then making adjustments based on long term commodity forecasts for grain and iron ore. However, the report seems to consider these future traffic levels as independent of any increases made to the capacities of the locks. In other words, those traffic levels will occur whether the locks are expanded or not. However, if increasing the size of the locks decreases the cost per ton of cargo, either more cargo will be attracted to the System, or the cost of alternative transportation will fall from the competitive pressure of lower Seaway costs. Either alternative represents an increase in transportation savings that were not reflected in the 1987 report, and should be considered in an updated study.

We would also suggest, at this early phase, to be as open as possible to different options for increasing lock capacity. Perhaps it might be feasible to increase only one dimension (only length, width or draft). While the transportation savings may be lower for such an option, the decreased cost might lead to a positive benefit/cost ratio.

The 1987 study defined the relevant benefit to transportation improvements, including lock expansion, as U.S. transportation savings. Is it possible to expand this definition of benefit? One obvious concern is the exclusion of Canadian cost and benefits in the analysis. Since only 2 of the 15 locks on the Seaway are within U.S. control, any expansion of capacity on the U.S. side would be of limited value without a corresponding expansion of the Canadian locks. We cannot overemphasize our desire to see that any future study examines costs and benefits on a System-wide basis. We have informed our Canadian counterparts of the upcoming study, and they have expressed their willingness to provide assistance. We will do anything in our power to facilitate binational cooperation in such a study, and we recommend that securing Canadian input in the reconnaissance phase be made a top priority.

In addition, we understand that the current economic protocol followed by the Corps for navigation studies narrowly restricts the benefits used in the benefit/cost analysis to transportation benefits, such as vessel delay savings and vessel utilization savings. Can changes be made to this protocol to allow for the measurement of other economic benefits accruing to the Great Lakes area due to increased use of the Seaway? According to the 1987 study,

> Assuming similar System-wide improvement capabilities, preliminary studies indicated that significant Great Lakes regional benefits could be realized [from

increased lock capacity]. Increased capacity would facilitate waterborne commercial, industrial, and agricultural transportation needs through increased capacity for shipment of future commodity flows resulting from continued growth within the region and increased use of the System. Some associated employment and income, and community developmental benefits might also be expected which would help to stabilize and/or promote continued community and regional socioeconomic growth.

At this early phase, we believe it might be useful to at least discuss a mechanism for quantifying these benefits for inclusion in the benefit/cost ratio.

Historically, the Seaway has played an important role as a conduit for exports from and imports to the nation's heartland. Not only is the Seaway a very cost competitive route for trade between the U.S. and Europe, North Africa and the Mediterranean, it also serves as an important source of extra capacity when surges in commodity movements overwhelm the capacity of rail and barge alternatives. However, the movement toward larger vessels threatens to erode the long term competitiveness of the Seaway as a viable mode of transportation. Faced with similar evidence of the growing dimensions of the world fleet, even the Panama Canal is looking at the option of lock expansion. The 1989 Interim Report on International Fleet Compatibility prepared by the Corps argues that "[c]onstruction of major lock and channel systems are unique in history...Decisions to size locks are almost irreversible." (p. 16, Interim Report) However, it may be time to reexamine this view. We believe that the current reconnaissance study will indeed identify a federal interest in reexamining the feasibility of lock expansion.

Attachment 2 - Agency Letters

Lake Carriers' Association

GEORGE J. RYAN
PRESIDENT
Direct Dial: *216-861-0590*
E-Mail: *ryan@lcaships.com*
Website: www.lcaships.com

February 21, 2001

Mr. Scott Parker
Chief – Programs & Project Management Division
U.S. Army Corps of Engineers
477 Michigan Avenue
Detroit, MI 48226

Dear Scott:

The Great Lakes Navigation System Study is of great importance to our industry. This study will set the course for infrastructure improvements needed by the Great Lakes region over the next 50 years.

The attached statement is Lake Carriers' Association's vision for the Great Lakes transportation system. Please include these thoughts in your preparation of the Study outline.

We look forward to working with the U.S. Army Corps of Engineers and other agencies as you continue this long-term effort.

Sincerely,

George J. Ryan

George J. Ryan
President

GJR:cal
Attachment
ryan\coe\navigation-study\010221-1-parker

cc w/att.: Daniel E. Steiner – U.S. Army Corps of Engineers-Great Lakes & Ohio River Division
Members – LCA Advisory Committee
Members – LCA Navigation Committee
Steve Fisher – American Great Lakes Ports
Donald N. Morrison – Canadian Shipowners Association
Raymond Johnston – Chamber of Maritime Commerce
Davis Helberg – Duluth Seaway Port Authority

Lake Carriers' Association

Prepared for U.S. Army Corps of Engineers
As Preliminary Advice in Preparing the Plan for the Great Lakes Navigation Study

February 21, 2001

VISION FOR THE GREAT LAKES TRANSPORTATION SYSTEM

SUMMARY

1. **Increase Project Depth of Connecting Channels and Major Ports to a minimum of 30 feet.**
2. **Maintenance Dredging must take into consideration the expected reduction of water levels below datum.**
3. **Improvement of the major channels in the St. Marys River to permit two-way traffic for deep draft vessels in the West Neebish Channel or, if that is not feasible, dredge Middle Neebish Channel to a uniform width to allow deep-draft vessels to transit at system-wide project depth.**
4. **Port and Channel Infrastructure Needs Analysis to be completed to determine what size channels, depths, turning basins, and anchorages are needed based on current and projected traffic.**
5. **Confined Disposal Facility (CDF) Maintenance and Construction to be established to meet the needs of the new system dimensions.**
6. **Replacement Lock at Sault Ste. Marie, Michigan, to be appropriated at soon as possible.**
7. **Great Lakes System of Water Level Gauge Information Communication to be created to provide real-time water level data to Captains.**
8. **Navigation Systems onboard ships using electronic charts, satellite navigation and communication, and an Automated Information System (AIS).**
9. **Restore Full Federal Funding for Operation and Maintenance Dredging (O&M).**
10. **Length of navigation season must be re-evaluated to determine if current lock opening period from March 25 – January 15 can be lengthened given possible changed environmental conditions.**

BACKGROUND

Every interest group has a unique vision for the Great Lakes. Those groups/interests include agricultural, recreational, electric power generators, transportation, and many others. Within the transportation sector, there will be different visions held by the domestic and interlake trade carriers and those involved in deep-sea trade through the St. Lawrence Seaway. The goals of each are at times in harmony and at times in conflict.

Transportation interests' vision is rooted in the need to meet the legitimate demands of the industries they serve. In the Great Lakes region, the primary industries are steel, construction, power generation, and agriculture. American and Canadian industries are faced with stiff international competition and must continue to reduce costs through capital investment in new technology and economies of scale. Both of these factors are evident in the operation of vessels in the U.S.-Flag domestic trade. Super-sized newer vessels and modernized older vessels can carry 125 million tons of raw materials annually to fuel the Great Lakes region's economy. Unfortunately, the infrastructure of the Great Lakes transportation system is based upon size constraints of the 1930s for the St. Lawrence Seaway and the 1950s for the Great Lakes ports and connecting channels.

1. **Increase Project Depth of Connecting Channels and Major Ports**

The dimensions of the primary infrastructure, the locks, connecting channels, and major ports, are major constraints on the Great Lakes water transportation system and the ability of carriers to meet the needs of the industries served in the 21st Century. The size of many ports and some channels limit the use of the more efficient 1,000-foot long vessels. The width of the upbound channel in the St. Marys River limits the use of the super-sized vessels in a full-load condition. However, the primary limiting dimension in the system is the depth of water in a channel or lock. The project depth, authorized in the 1950s for the Great Lakes system, is 25.5 feet at mean low water datum (also known as chart datum). Often, the Lakes water levels are several feet above chart datum and, thus, loading to as much as 28.5 feet has taken place in the domestic trade of iron ore and coal through the St. Marys River. This fact proves that industry can effectively utilize existing vessels at the deeper draft and that the shippers, primarily steel mills and coal-fired utilities, benefit from larger loads. Nevertheless, there are times when the water level falls below datum and drafts are severely limited to authorized project depth or less. We are faced with these low waters now and for the foreseeable future.

The Great Lakes system needs to have a reliable, greater depth suitable to meet the needs of the 21st Century where worldwide competition demands more cost effective transportation. The target depth should be a Great Lakes system capable of handling ships with a draft of 30 feet or greater at all times in all connecting channels and major ports — regardless of water level fluctuations. The major constraint factor to be considered should be the safe transit over the sill of the Poe Lock and the new lock to be constructed.

2. **Maintenance Dredging**

While no one can accurately predict future water levels, given a worldwide warming trend, certain changes in water levels are expected to occur. On the oceans, as the polar ice melts, there will be higher water levels impacting coastlines. In the Great Lakes, with lower winter snow loads, less ice cover, and warmer air, there will be higher evaporation rates and reduced supply of water from spring thaws. The result will be lower water levels. Because of the precipitous, large drop in the water levels, the U.S. Army Corps of Engineers is unable to adequately maintain the commercial and recreational harbors in the Great Lakes to the Congressionally authorized depths.

Every inch of lost draft reduces the efficiency of waterborne commerce. The largest vessels, the 1,000-foot-long supercarriers, forfeit 270 tons of cargo for each 1-inch reduction in loaded draft. An ocean-going vessel in the Seaway trade loses 100 tons of cargo for each 1-inch reduction in loaded draft.

Congress should pass sufficient appropriations so as the Corps can carry out the authorized dredging of commercial harbors, taking into consideration the expected water levels below datum.

3. **Improvement of the Major Channels in the St. Marys River**
From 1870 through 1956, Congress authorized the various channels and locks in the St. Marys River. For a number of reasons, there are two one-way channels around Neebish Island. The east side, known as Middle Neebish Channel, is the upbound channel; although, with tight traffic control, good seamanship and reduced draft requirements, it can be navigated by a downbound vessel in a one-way traffic scheme. The west side, known as the West Neebish Channel, is the deep-draft downbound channel. Neither channel is wide enough for two-way traffic. **Our vision is to have a two-way traffic channel in the West Neebish Channel.** This would require a major dredging project from Nine Mile Point in Lake Nicolet to the Lake Munuscong Junction Buoy. The cost of annually maintaining the channels by the Corps of Engineers and the U.S. Coast Guard on both sides of Neebish Island could be significantly reduced if there was one two-way channel. For example, there are over 60 floating aids to navigation and a number of fixed aids in the 17 plus statute miles of Middle Neebish Channel — these could be eliminated. **Alternatively, if the benefit/cost analysis is not favorable, then the Middle Neebish Channel could be designed to be a safe downbound channel by removal of the 21-foot channel on the east side of courses 5 through 9. The entire channel should be dredged to the newly authorized system depth.**

4. **Port and Channel Infrastructure Needs Analysis**
A comprehensive analysis of the existing and expected trade through each Great Lakes port must be made to determine if the channel design and turning basins are sized correctly for the commerce expected over the next decades. There may be many ports that could benefit from wider and deeper channels while there are several ports that have lost the potential for significant growth and, therefore, may not need the maintenance of two-way traffic channels or channels with the currently authorized width and depth.

5. **Confined Disposal Facilities (CDF) Maintenance and Construction.**
In the 1970's, the Federal Government built 26 CDFs in the Great Lakes to hold dredged sediments from Great Lakes ports and waterways. Some of these sediments contained polluted material. The capacities of these CDFs are not infinite, so plans must be made to create new CDFs in order to receive the polluted material from normal maintenance dredging and from the clean up of the hot spots in areas of special concern where remedial action plans are in effect. **More CDFs must be authorized and built to handle the recommended project depth. Studies must be made to determine which of this dredged material can be used for land creation or open lake disposal.**

6. **Replacement Lock at Sault Ste. Marie, Michigan**
Complete plans and specifications for the new lock at Sault Ste. Marie, Michigan, capable of handling the Poe-class vessels that now represent approximately 70 percent of U.S.-Flag carrying capacity on the Great Lakes. Provide Federal share of appropriations for construction when the Great Lakes Commission has finalized the sponsorship agreement with the Governors of the Great Lakes States. **Consider construction appropriations for FY02.**

7. **Great Lakes System of Water Level Gauge Information Communication**
The Great Lakes water levels are in a dynamic state. While these waters are not as seriously impacted by tides as on ocean coasts, there are significant fluctuations caused by annual cyclical changes of water supply, unpredictable changes caused by wind and barometric action, and longer-term changes caused by drought or wet periods. For the safety and productivity of shipping in the domestic trade where turnaround times between load and discharge ports range between a matter of hours to three days, the knowledge of water levels in the area to be navigated is a great asset to the Captain of the ship. There is no system-wide manner to obtain this data in useable format and communicate it to the Captain on the ship in real-time. **U.S. and Canadian Government agencies responsible for water level measurements must put together a real-time water level communications system.**

8. **Navigation Systems Onboard Ships Using Electronic Charts, Satellite Navigation and Communication, and an Automated Information System (AIS)**
While not the direct responsibility of the U.S. Army Corps of Engineers, the Corps and the U.S. Coast Guard must take into consideration in channel design and aids to navigation installation the changed technology that will be onboard all vessels by the time the new infrastructure is in place. When the Corps carries out channel surveys in the future, the results of those surveys can be conveyed to the electronic chart suppliers and to the Captains through the AIS. The dimensions of the channels can be designed with tolerances that not only take into consideration the weather, wind, current, and other local and environmental conditions, but also the expectation of more accurate navigation.

9. **Restore Full Federal Funding for Operation and Maintenance Dredging (O&M)**
From the founding of our nation until 1987, the Federal Government funded O&M dredging of the nation's waterways from general revenues. A Harbor Maintenance Tax (HMT) was instituted in 1987 to recover 40 percent of O&M costs in the deep-draft waterways (the HMT has never been assessed on the inland waterways). When the HMT was tripled in 1991 to recoup over 100 percent of deep-draft O&M, legal challenges began that eventually led to the Supreme Court voiding the tax on exports. Legal challenges continue and, as a result, the past Administration proposed a substitute Harbor Services User Fee (HSUF) that would expand collections to include the Federal Government's share of new construction projects. In total, the HSUF would have added $1 billion a year to the nation's freight bill. The current Harbor Maintenance Trust Fund contains a surplus of $1.668 billion because of excess collections over expenditures. Even with revenues reduced by the exclusion of taxes from exports, and with revenues now coming primarily from imports, the fund continues to build a surplus. The role of waterborne commerce in our nation's economic well-being and national security demands a return to full Federal funding. Domestic waterborne commerce routinely tops 1 billion tons a year. Ninety-eight percent of our imports and exports move across the oceans in vessels. There is hardly a job or industry in this country that is not dependent on an efficient system of ports and waterways. Furthermore, a recent GAO study has determined that 11 Federal agencies already assess 124 taxes on waterborne commerce that annually generate more than $21 billion for the Federal treasury. **Maintenance of our channels can be funded through a cash transfer of revenue raised through import duties, just as the Department of Agriculture funds its marketing programs.**

**10 Length of Navigation Season Must Be Re-Evaluated
To Determine if Current Lock Opening Period From March 25-January 15
Can Be Lengthened Given Possible Changed Environmental Conditions**

The agreement between the State of Michigan and various Federal agencies regarding the period of opening of the Locks at Sault Ste. Marie was based, in part, upon concern for environmental conditions related to ice cover and the break-up of the ice on the fisheries and the shoreline. A recent assessment completed by the Environmental Protection Agency, *Preparing for a Changing Climate, Great Lakes Overview, October 2000*, indicates that we may be in a warming trend that will result in higher average temperatures throughout the region, lower water levels, and reduced ice cover. Since this study must review all technological data impacting on the navigation system, these environmental changes must be carefully reviewed. Should there be a period of low water, tonnage will have to be shipped either over a longer period of time using the existing fleet or there will be a need to invest capital in the construction of new vessels. While ship construction may appear to be good for the economy, in the long run, it will add costs to the steel industry that is fighting for its survival against subsidized foreign imports. A preferred option is to optimize existing vessels. The study should determine the circumstances under which a longer period of lock opening could take place. It is essential to maintain fixed open and close dates so as supply decisions can be made with certainty. While the fixed closing date could be extended, it may also be possible to allow for continued vessel operations until some later date following the fixed closing date based on environmental conditions at Sault Ste. Marie. The season extension primarily should be at the end of the season when navigation can more readily continue while ice is forming, rather than at the opening of the season when heavy ice conditions may exist.

ryan/coe/lca vision/010221

Minnesota Pollution Control Agency

February 9, 2001

Mr. Terry Long
Attn: CELRE-PM-PL
Department of the Army
Detroit District, Corps of Engineers
Box 1027
Detroit, MI 48231-1027

RE: MPCA Comments Regarding the Proposed Study to Review the Great Lakes Navigation System

Dear Mr. Long:

The Minnesota Pollution Control Agency (MPCA) staff appreciate the opportunity to provide comments on the scoping of work regarding the proposal to study the Great Lakes Navigation System. The MPCA is authorized under Section 401 of the Clean Water Act (33 USC 1251 et seq.) and Minnesota Statutes Chapters 115 and 116 to evaluate projects that have the potential to impact waters of the state.

While some of the following issues identified by MPCA staff are not a direct responsibility of the Corps, these topics do and will play some type of role in the decisions of the Corps and in Great Lakes shipping:

- <u>Areas of Concern</u> - Most of the designated harbors in the Great Lakes also have significant environmental impairments and have been designated Areas of Concern. This issue should be a factor in any future studies and decisions of the Corps of Engineers in the Great Lakes region.

- <u>Dredging</u> - If dredging is a potential outcome of this study, the Corps of Engineers should also consider the direct and indirect impacts of dredging, including management of dredged material (reuse and disposal options and restrictions).

- <u>Source Reduction of Sediments</u> - More focus should be placed on source reduction (i.e., keeping the soil on the land) as a means to reduce the volume and frequency of dredging needed to maintain shipping channels.

- <u>De-Authorization of Federal Channels</u> - If a potential outcome of this study requires Congressional action, the Corps should consider requesting de-authorization of those federal navigation channels that have not been actively maintained. For the Duluth-Superior harbor, this would include the Minnesota Channel Western Section and 21st Avenue West Channel.

- Spill Containment/Prevention at Docks and Refueling Stations - Any increase and/or expansion of shipping operations should also consider prevention and minimization of environmental impacts from fueling.

  Ship Wastewater Treatment Facilities - The current on-vessel wastewater systems are largely outdated, inadequate and unmonitored. In addition to improving the currently used technology, an option worth further consideration is to improve the systems or replace with holding tanks and utilize ship-to-shore wastewater disposal.

- Expansion of the "no discharge zone" in Lake Superior - The discharge of bilge and greywater from vessels goes largely unregulated. The study should consider expansion of the "no discharge zone" bilge and greywater to include the whole of Lake Superior.

- Exotic Species - One method of introduction and spread of exotic species in the Great Lakes has been through shipping activities. The study should consider exotic species, including their movement, impacts, and legal approaches and technologies to contend with the problem.

- Viability of Expanding the Shipping Infrastructure on the Great Lakes - There have been discussions regarding expanding the locks in order to accommodate larger vessels, in part to compete with coastal harbors. Careful consideration should be given to these types of proposals to determine if the benefit outweighs the cost and if there are other alternatives, such as shipment by rail.

- Water Diversions - There have been past proposals to divert water from the Great Lakes for use in other areas of the U.S. and Canada. The study should consider the status of such proposals and the potential impacts that this activity would have on commerce and the environment of the Great Lakes.

  Global Warming - Global warming may result in drastic changes to the environment. How will global warming impact commerce and the environment of the Great Lakes?

- Environmental Impact of Outcomes of the Study - All environmental impacts of projects should be considered during and be a part of the decision-making process. For example, if one outcome is to widen and/or deepen federal navigation channels, then consideration should be given to the disposal/reuse management of the dredged material. This would include the likelihood that dredging beyond current channel dimensions may result in re-introduction of contaminated sediments and pose a disposal issue for those sediments.

Thank you again for the opportunity to provide input on this effort. If you have any questions regarding this letter, please contact me at (218) 723-4744.

Sincerely,

Pat Carey

Patrick Carey
Supervisor, Community & Area-Wide Programs Unit
North District, Duluth Office

PC:kt

New York State Department of Environmental Conservation
Division of Environmental Permits, Region 6
Dulles State Office Building, 317 Washington Street, Watertown, New York 13601-3787
Phone: (315) 785-2245 • **FAX:** (315) 785-2242
Website: www.dec.state.ny.us

John P. Cahill
Commissioner

February 7, 2001

Detroit District - Corps of Engineers
ATTN: CELRE-PM-PL Mr. Terry Long
P.O. Box 1027
Detroit, Michigan 48231-1027

RE: Great Lakes Navigation System (GLNS)

Dear Mr. Long:

This office of the Department of Environmental Conservation would like to take this opportunity to comment on the new study, the Great Lakes Navigation System (GLNS) Review. The jurisdictional boundaries of this office include Eastern Lake Ontario and the St. Lawrence River, and therefore, factors that impact upon these waterways are of obvious concern to this office as well as to the general public.

Issues that are of significant concern include the following:

1. The water level management of Lake Ontario and the St. Lawrence River has severely impacted and will continue to cause problems to the wetland systems located along these waterways and to the numerous small islands and shoal areas that are scattered throughout the system.

2. Dredging of any navigation channels that would include straightening, widening or deepening of existing channels or the creation of new channels.

3. Any navigation that occurs when an ice cover has formed on the St. Lawrence River and the increased environmental damage and damage to shoreline structures.

4. The potential environmental impacts associated with increased shipping, particularly on the St. Lawrence River section, including the higher potential for spills, increased impacts from ship wakes, and the potential for greater conflict between recreational versus commerical users.

5. The introduction and spread of contaminants throughout the system.

6. The water quality of the Great Lakes-St. Lawrence system and the potential of degradation of the water quality for recreational, industrial and consumptive usage.

During this entire planning and study process this office has a significant concern to stay in the information loop and requests that copies of any research proposals, summary or final reports, or recommendations generated during the GLNS Review process be forwarded to this office. From our perspective, it would be helpful to be informed early in the process to allow for a thorough review of items by appropriate staff.

Thank you for providing this office the opportunity to comment on the GLNS Review and to become involved in the process.

Sincerely,

Lawrence D. Gunn

Lawrence D. Gunn
Environmental Analyst 1
Region 6

LDG:dli

cc: Sandy LeBarron, Regional Director, Region 6 DEC
Albert Schiavone, DEC
Dennis Faulknham, DEC
Leonard Ollivett, DEC
Brian Fenlon, DEC

STATE OF MICHIGAN

JOHN ENGLER, Governor

DEPARTMENT OF ENVIRONMENTAL QUALITY

"Better Service for a Better Environment"

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RUSSELL J. HARDING, Director

February 5, 2001

Detroit District, Corps of Engineers
P.O. Box 1027
Detroit, MI 48231-1027

Attention: CELRE-PM-PL/Mr. Terry Long

Dear Mr. Long:

SUBJECT: Great Lakes Navigation System (GLNS) Review

This letter responds to the January 18, 2001, communication from Wayne Schloop, Project Manager, Planning, Programs and Project Management, soliciting comment on the scope of the Great Lakes Navigation System (GLNS) Review authorized by Congress.

In light of Mr. Schloop's statement that "the ultimate aim of the study is to produce an efficient and modern environmentally sound navigation system on the Great Lakes," we strongly recommend that the prevention of further introduction of aquatic nuisance species into, or the export of same out of, the Great Lakes–St. Lawrence Basin be made a part of the GLNS.

The Great Lakes are infested by roughly 160 aquatic nuisance species such as the sea lamprey, zebra mussel, Eurasian ruffe and the spiny water flea at a cost of, literally, billions of dollars. These exotic species threaten a $4 billion sport fishery in the region. Unfortunately, the latest research forecasts the introduction of another 17 such aliens from the Ponto-Caspian Basin alone.

Several topics for possible review are:

1 barriers - physical, mechanical or electrical - preventing entry or exit of aquatic nuisance species at both ends of the system, including the Chicago Diversion;

2. facilities for shoreside sterilization of ballast water and NOBOB vessels generally;

3. the needs of the U.S. Coast Guard in enforcing current and future laws and regulations; and

4. any other ideas from other interested parties such as the U.S. Fish and Wildlife Service, the Great Lakes Aquatic Nuisance Species Panel, and the Great Lakes Fishery commission.

Thank you for your interest.

Sincerely,

G. Tracy Mehan

G. Tracy Mehan, III
Director
Office of the Great Lakes
517-335-4056 / fax: 517-335-4053
e-mail: mehang@state.mi.us

cc: Mr. Russell J. Harding, Director, MDEQ

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(219) 787-8636

Southwind Maritime Centre
1700 Bluff Road
Mount Vernon, Indiana 47620
FTZ #177
(812) 838-4382

January 30, 2001

Mr. Wayne Schoop
Programs & Project Management Division
USACE – Detroit District
PO Box 1027
Detroit, MI 48231-1027

Re: Great Lakes Navigation Study

Dear Mr. Schoop:

The Indiana Port Commission, along with several port authorities in the Great Lakes states, has the unique ability to transport waterborne commerce through both the Great Lakes Navigation System and the Inland Waterway System. These unparalleled navigation systems in the heart of the North American Continent provide a vital logistics link for shippers of domestic and international cargo. Indiana's farmers and manufacturers enjoy substantial cost savings because of the existence of these waterways, as well as the societal environmental benefits derived from the movement of bulk tonnage by water rather than by road or rail.

Indiana's International Port moves substantial bulk tonnage through its Burns Harbor, Indiana facility on Lake Michigan. In recent years the port has moved increasing amounts of general cargo, primarily steel products. In both the bulk and general cargo trade, the vessel departs the port at Seaway Mean Summer Draft (26' 3") rather than at full-vessel draft. The vessels are generally topped off once they are in deeper water east of Montreal. This situation costs both the shippers and consignees valuable time and money through delays and multiple vessel stops. Increasing the channel draft in the Great Lakes Navigation System from 26' 3" to between 30' and 35' would add substantial cost incentives for shippers utilizing our port.

Vessel safety has become an increasing concern, especially with the low water levels of the Great Lakes during the past several navigation seasons. Indiana's International Port experienced three groundings during the 1999 / 2000 shipping season. Due to vessel safety concerns the Commission performed emergency dredging within the harbor in the spring of 2000. The primary delay involved with the emergency dredging project was due to the difficulty of securing U.S. Army Corps of Engineers permits. If feasible, the Navigation Study should review the permitting process necessary for accomplishing emergency dredging.

During the past two decades, the size of almost all ocean-going vessels has increased significantly. Vessels transiting the Great Lakes/St. Lawrence Seaway, however, have been restricted because of unchanging lock dimensions. The Great Lakes Navigation Study needs to evaluate the locks of the St. Lawrence Seaway and identify what System changes would be most beneficial to shippers and the Great Lakes maritime community while maintaining a reasonable cost for lock rehabilitation or replacement.

The Indiana Port Commission considers the Great Lakes Navigation Study a timely and most important Corps of Engineers project. We stand ready to assist in any way possible with your effort.

Regards,

William D. Friedman
Executive Director

DETROIT/WAYNE COUNTY PORT AUTHORITY
MICHIGAN'S INTERMODAL GATEWAY

November 29, 2000

Mr. Daniel E. Steiner
Chief, Planning and Policy Division
U.S. Army Corps of Engineers
Great Lakes & Ohio River Division
John Weld Peck Federal Office Building
550 Main Street, Room 10-008
Cincinnati, Ohio 45202

Dear Mr. Steiner:

On behalf of the American Great Lakes Ports, I would like to express our sincere interest and extend our assistance in developing justification and direction for the Great Lakes Navigation Study authorized through the Water Resource Development Act (WRDA) for 1999. This comprehensive planning initiative is vitally important for both American and Canadian Great Lakes ports in order to ensure the competitiveness of our region within the global marketplace.

This initial reconnaissance study would help determine the needs and opportunities for growth within the Great Lakes/Saint Lawrence Seaway System by prioritizing critical areas of concern. The many stakeholders utilizing this system are depending on this study to identify the strengths of our current system, as well as the problems, weaknesses and threats. It is important to include a broad definition of economic benefits to be realized from navigational improvements in the benefit cost analysis of this study.

The Great Lakes/Saint Lawrence Seaway System is home to almost one-half of both the American and Canadian population. The region has the five largest steel producing states in the country, accounting for approximately 70% of total U.S. production. Further, almost one-half of the Fortune 500 Industrial Companies are headquartered here.

Since 1959, the Saint Lawrence Seaway has provided a global link between the world marketplace and the industrial and agricultural heartland of North America. The 2,000-mile long seaway system is responsible for annual commerce exceeding 200 million net tons. Responsible for carrying this cargo are 75 U.S. lakers, 90 Canadian lakers, nearly 1,000 saltwater vessels, and about 50,000 barges connected to the rivers that feed this system. Fanning outward from this major international artery are 40 provincial and interstate highways, nearly 30 rail lines which in turn link 15 major ports and 50 regional ports with consumers, products and industries all over North America.

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Agricultural products, primarily grain for export, comprise nearly 40% of the Great Lakes/Saint Lawrence Seaway trade. Another 40% of this trade consists of mining products including iron ore, coal, coke, salt and stone. Iron and steel products equate to the highest value goods traded due to their labor-intensive handling requirements. It has been estimated that for every imported metric ton of steel, $250 in economic impact is created for the community in the form of personal income, taxes and related business revenue. In total, it has been estimated that over 45,000 U.S. jobs and more then $2 billion in personal income are directly generated by the shipping of commodities and manufactured products on the Great Lakes.

The environmental efficiency of Great Lakes shipping cannot be matched. A 1993 study by the Great Lakes Commission of eleven trade routes on the Great Lakes showed that by utilizing ships, we save 14 million gallons of fuel and reduce emissions by more than 4,300 tons. It is a fact that a single 1,000-foot ship carries the equivalent of six 100-car unit trains. Efficiency like this requires attention, consistent study and federal involvement and appropriation. Without such attention, we will be cheating ourselves of one of our richest and most ecologically sensitive resources. Railroads would have to more then double their fuel efficiency to equal that of the Seaway System.

The study went on to report that a vessel-to-rail shift for the eleven cargo flows would statistically result in thirty-six more rail crossing accidents, fourteen more derailments and one train collision. The commodities that trucks might carry statistically would produce 141 more truck/car accidents on the roads and highways, one quarter of which would have the potential for fatalities or serious injuries.

Furthermore, with the passenger cruise industry emerging once again on the Great Lakes, the safety of the system becomes an even greater priority. It is estimated that in 2001, Great Lakes ports can expect to service over 6,000 passengers and an estimated 10,000 by 2002. Because this industry is continuing to grow, it is vitally important that our federal government take preventative steps early in reducing the possibilities of accidents and navigational problems that might threaten the safety of passengers. Such precautions will reduce liability, as well as increased costs that might be associated with future emergency navigation improvements.

Despite the substantiating environmental and economic factors, most of the seaway infrastructure dates back to design principles of the 1930's. Harbors, locks, channels and turning basins were designed with ships from this era in mind. What was a unique and incredibly modern transportation system then, has turned into an aged and outdated system that doesn't cater to a developing and mobile fleet of ships. A 1996 study by the Saint Lawrence Seaway Development Corporation found that only 40 percent of the world fleet could transit the Seaway locks. This percentage has diminished over time, falling to a mere 30 percent of the world fleet according to some recent estimates. In addition, even if a 105-

foot by 1000-foot vessel could transit the locks, it wouldn't necessarily fit into channels and harbors of many regional ports, reducing the efficiency of the Great Lakes/Saint Lawrence Seaway system.

The shipping industry we are all trying to serve and provide appropriate infrastructure for is a "mobile" industry. Vessels are not required to operate on the Great Lakes/St. Lawrence Seaway system. If it becomes cheaper and more efficient to carry cargo and serve the deep-water ports of the East Coast, then they will do this. If it becomes easier to navigate and serve ports that can feed the Midwestern ports by rail, they will do this as well.

The Great Lakes Navigation Study provides a useful tool for responsible planning to address the system's shortcomings. Issues concerning upgrade and maintenance of the Great Lakes / Saint Lawrence Seaway system are of vital importance if we are going to ensure the viability and strength the Midwest provides our nation. This study is needed to bring the St. Lawrence Seaway System up to the same competitive level that our other U.S. and Canadian transportation systems enjoy. Our organization would like to make a variety of recommendations as you prepare to begin work.

First, the American Great Lakes Ports Association asks that a primary focus of the Great Lakes Navigation Study be the maintenance and modernization of the St. Lawrence Seaway itself and related improvement to connecting channels and ports throughout the system. The feasibility, costs and benefits of an expansion of the Seaway locks - in width, depth and length - to accommodate larger vessels should be analyzed. Specifically, we are asking for expansion and/or replacement of the existing 15 Seaway locks.

Second, we support the proposal of the Lake Carriers' Association to examine the feasibility of deepening connecting channels and ports to a depth of at least 29.5 feet. Although the width of channels and locks presents problems of its own, the primary limiting dimension in the system is the depth of water in a channel or lock. Industry has proven in times of higher water levels (above low water datum) that they can effectively use their vessels at deeper drafts and that shippers benefit from these larger loads. As water levels have returned to historic levels, shippers are forced to load their vessels much lighter, erasing economies of scale and creating safety concerns where shallows spots emerge throughout the system. Maintaining adequate channel and harbor drafts become more crucial when you consider for every one-inch of reduction in depth, a 1,000 foot freighter forfeits approximately 270 tons of cargo. This loss of cargo must be made up with more trips, which creates greater fuel consumption and increased cost incurred by both the shipper and customer, thus becoming inefficient for everyone.

Third, sediment build-up on channel and river bottoms adds new problems, many of which could be reduced with proper planning and erosion control techniques. A study of the Cuyahoga River in Cleveland found that 54 percent of sediment build-up was from upland erosion. Lake Erie and the Detroit River Livingston Channel also demonstrate the need to increase channel depth. To identify where this is occurring, more research and studies need to be completed that include funding options through various engineering techniques. By controlling this problem early, we can avoid high-cost maintenance in the future.

Finally, we strongly urge the Corps of Engineers to invite the Government of Canada and the Canadian maritime industry to fully participate in the Great Lakes Navigation Study as an equal partner. The Great Lakes / St. Lawrence Seaway System is a binational waterway. Much of the infrastructure is in Canadian territory. If this study is to be of future use, it cannot be seen as an "American study." Canadian participation and buy-in will help to ensure that both governments respond to the study's recommendations. We are happy to work with the Corps to facilitate communication with Canadian stakeholders and policymakers.

Over 30 million people rely on the Great Lakes/St. Lawrence Seaway system, either recreationally or commercially. The vital importance of this system should directly correlate to the amount of federal involvement and funding set aside to ensure its viability and strength as we enter this new century. Channel and harbor deepening projects and lock dimension improvements top the list of priorities for commercial shipping interests. The time is now for all stakeholders dependent on this vital transportation system to plan ahead for much needed improvements, or we will be faced with monumental infrastructure problems down the road that cannot meet tomorrow's challenges.

Sincerely,

John Jamian
Chairman
American Great Lakes Ports

U.S. Department of Transportation
Maritime Administration
Great Lakes Region

August 25, 2000

Daniel E. Steiner, P.E.
Chief, Planning Division and Navigation Account Manager
U.S. Army Corps of Engineers
Great Lakes and Ohio River Division
P. O. Box 1159
Cincinnati, Ohio 45201-1159

Dear Mr. Steiner,

As way of introduction, Craig Middlebrook, Deputy Administrator, St. Lawrence Seaway Development Corporation, phoned recently to tell me about the Corps sponsored Great Lakes Navigation System Review project. This is a very timely project since the Department of Transportation has been holding Maritime Transportation System (MTS) review meetings around the country. During the early phases of MTS, the U.S. Coast Guard Ninth District initiated the Great Lakes Waterway Management Forum as the regional version of National MTS. This "Forum" membership is made up of U.S. and Canadian government and marine industry representatives with sole purpose of improving the Great Lakes waterways for all users - recreational as well as commercial. I am sure that the "Forum" members would like to help you with your new project.

The Maritime Administration (MARAD), Great Lakes Region staff – all three of us – are willing and able to provide technical assistance to you during your study project. MARAD's role is to promote waterborne commerce – U.S. shipbuilding – and U.S. maritime employee training – in domestic and international trade. The enclosed MARAD Annual Report describes our ship financing programs, national defense, and promotional activities. Our region responsibility includes monitoring and assisting the maritime industry in the Great Lakes as well as on the Ohio, Missouri, Upper Mississippi River and Illinois Waterway. A number of Great Lakes vessel operators are our customers through the Title XI Ship Financing and Capital Asset Fund Programs.

Recent DOT Listening and Dialogue Sessions with other Federal agencies and the maritime industry seem to run on a strong theme for the urgent need to improve the infrastructure of the American waterways. The general perception of the maritime industry is that the Nation is loosing ground in the maintenance and support for waterway improvements. This includes, specifically, dredging harbors and disposing of sediment, and the updating of connecting channels and locks to meet the needs of today's vessels as well as the potential benefit for larger vessels in the future.

The vessel efficiency issue is difficult to fully understand by those that are not directly involved in day to day operations. But, briefly, all vessels are designed to carry as much revenue producing cargo as possible and operate 24 hours a day – 7 days a week – and every day that the waterway is open. In some cases, there are vessels operating year-round within certain portions of the Great Lakes and Inland Waterways. In other cases, large vessels operate during shorter seasons due to their trade patterns in the Upper Lakes or through the Seaway. In every case, these vessels rely on the most efficient use of the waterways full dimensions – length – beam and depth. Some operators fine-tune their vessel loading to daily weather conditions and water level reports at loading and discharge ports. If winds are blowing water into a distant discharge port – they may load on a few more revenue producing tons. Other operators, such as those operating in the Seaway, are somewhat restricted by a longer-range draft forecast and limits set by the U.S. and Canadian Seaway authorities. The most efficient vessel operation is finely tuned to the maximum use of the waterways. Anything less – is unacceptable.

The general perception from the maritime representatives at DOT meetings is – the U.S. is failing to keep up with the waterway demand. According to the An Assessment of the U.S. Marine Transportation System – a Report to Congress – September 1999 - global maritime trade is predicted to grow 3.5 percent annually

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through year 2020. Vessel operators are expressing concern about existing water capability – let alone any increasing demand on existing waterway infrastructure.

This issue is even more important in the existing trade throughout the Great Lakes region. Many Great Lakes harbors have project depths of less than connecting channels or lock depth. This historical design criteria restrains efficient vessel operation and commercial development. We recommend studying those commercial harbors that have project depths of less than Seaway or SOO Lock depth to determine their present commercial needs. Perhaps a limited number of ports can be selected for a case study. Two ports that come to mind are Green Bay, WI and Waukegan, IL. Both ports have impressive growth potential if they only had deeper harbors. According to the SLSDC, their goal is to achieve a 27 foot draft in the in the next few years. In addition, the Lake Carriers Association recently expressed interest in achieving a 29.5 foot draft throughout the Upper Lakes. Certainly, there is maritime industry support for improved waterways.

We recommend that you consider a review of the world and regional vessel fleet dimensions as it relates to the projection for future harbor and lock design. The recent increased allowable vessel size through the Seaway has created new vessel construction and reconstruction of existing vessels. Canadian vessel owners have converted several Seaway vessels to fit the modern dimensions of 740' LOA 78' Beam and 26' 3" draft. These "wider" vessels can carry substantially more due to their new "cubic" capacity. In addition, recent new vessel buildings by ocean vessel owners have increased carrying capacity by building shorter but wider ocean vessels capable of transiting the 78' locks. This improvement in vessel efficiency and shipyard activity was accomplished by a review of the existing locks and without any new construction cost. The review of proposed Second Lock at Sault Ste. Marie, Mi. should also include the same concept, or perhaps, a larger "Son of POE Lock" and its impact on the Upper Lakes shipbuilding industry. There is a general rule-of-thumb that "a larger lock will create larger and more efficient vessels". This analysis may also contribute to an improved cost-benefit ratio for the proposed Second Lock if you consider new shipbuilding and improved cargo carrying capacity impact on the Great Lakes region.

One of our "unfinished projects" is the review of waterborne trade through the Chicago connection via the Illinois Waterway and Lake Michigan. According to COE statistics, there are about 8,500 river barges operating through the Chicago waterways to just two major port in Indiana – Burns Harbor and Indiana Harbor. These two ports are served by barge on a year-round basis and connect Inland Waterway destinations/origins providing a water mode service for Seaway commodities as well as domestic commodities. The Illinois Waterway barge traffic generally carries between 42 to 50 millions tons of cargo each year. Recently, the U.S. Coast Guard has published regulations for barges to transit beyond Chicago into Lake Michigan as far as Muskegon, Michigan and Milwaukee, Wisconsin. While this expanded operating capability has been slow developing, the traffic between Chicago and Northern Indiana ports continues to be strong and growing in importance. This route also has its share of infrastructure limitations such as low bridge air draft, narrow channel, and high traffic volume. We recommend that this waterway connection be included in your study effort.

These are just a few of the ideas that we may be able to help you investigate in your study project. Please feel free to contact us at any time if you have any questions. We look forward to providing technical assistance to you and your staff.

Yours truly,

Al Ames

Al Ames
Region Director

Cc: Craig Middlebrook – SLSDC
Bonnie M. Green – MARAD
RADM James D. Hull – USCG Ninth District

Enclosed:
The Great Lakes – A Waterways Management Challenge
MTS – Report to Congress –September 1999
MARAD Annual Report - 1999
Domestic Shipping
MARAD Great Lakes Region

U.S. Department
of Transportation

THE ADMINISTRATOR
Room 5424
400 Seventh Street, S.W.
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Saint Lawrence
Seaway Development
Corporation

August 24, 2000

Mr. Daniel E. Steiner, P.E.
Chief, Planning Division and
Navigation Account Manager
U.S. Army Corps of Engineers
Great Lakes and Ohio River Division
P.O. Box 1159
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Dear ~~Mr. Steiner,~~ Dan

Thank you for stopping by the office last month. I appreciate your willingness to travel to Washington and to bring key staff from your Chicago and Buffalo offices to meet with my staff. I understand that the meeting was productive. All of us at the Saint Lawrence Seaway Development Corporation (SLSDC) are excited about working with you on this important project.

At the meeting, you requested our comments to your initial scope of study document. We have reviewed the document and have prepared the enclosed comments. Please let us know if you need more information or clarification on any of the points we have raised here. I hope this same spirit of cooperation on the initial scope of work will follow throughout all aspects of the actual study. I would be happy to designate a team of SLSDC employees at your ready for consultation, expertise, facilitation, and a reality check.

We have outlined seven points for consideration, with our chief concern being that the study include a fresh examination of expanding the Seaway's locks. Accurately assessing the feasibility of lock expansion for the entire Seaway System, including both Canadian and U.S. locks, is essential to assessing the long-term competitiveness of the System. The SLSDC can play a crucial role in facilitating the involvement of the Canadian St. Lawrence Seaway Management Corporation (SLSMC) in this study. Indeed, as I believe you are aware, my Canadian counterpart, Guy Véronneau, has stated that while he is eager to participate in this study, Canadian participation is contingent on their ability to work directly through the SLSDC in consulting with your agency. To that end, we will have to establish a procedure for communicating between the SLSMC and your agency through the SLSDC. I am confident that we can arrange a procedure, just as we have done with the U.S. Coast Guard and the SLSMC, that is efficient, yet sensitive to the requirements of each agency. It would be useful to arrange a meeting, when you feel it is appropriate, between you and your staff and the appropriate Canadian representatives. I would propose that the meeting be held at or near our facilities in

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Massena, NY (which is adjacent to the SLSMC's headquarters in Cornwall, ON). If you agree, I will make arrangements for such a meeting on a date that you request.

As you and I have discussed, another area where we may be of assistance is in providing you with contacts among U.S. Great Lakes/Seaway stakeholders. I know you have already established contacts with some of the key port directors when you met last month in Washington with members of the Association of American Great Lakes' Ports. From that group, Davis Helberg, Executive Director of the Duluth Seaway Port Authority, John Jamian, Executive Director of the Detroit/Wayne County Port Authority (and current president of the American Great Lakes Ports Association), James Hartung, President of the Toledo-Lucas County Port Authority, and Gary Failor, Executive Director of the Cleveland-Cuyahoga Port Authority are individuals you should certainly be in contact with. I would also suggest contacting RADM James Hull, Commander of the USCG's Ninth District, as well as the Maritime Administration's Great Lakes Regional Director, Alpha Ames. We also can provide you with names of helpful individuals from the maritime industry should you so desire. Please let me know how extensive a list of potential contacts you would like. For now, I have enclosed the addresses and phone numbers of the individuals I've mentioned here. We would be happy to facilitate or arrange for meetings with these individuals.

Finally, I want to take this opportunity to invite you formally to our stakeholder meeting in Cleveland on October 18. We hold two such meetings a year with port and industry representatives from all over the Great Lakes, from both the U.S. and Canada. We would be honored to have you be part of the agenda to make a presentation to the group. This would, I believe, be an excellent opportunity for you to meet with and solicit input from some of the major stakeholders in the region. The meeting will be held from 10am to 3pm at the Marriott Residence Inn in downtown Cleveland. Please let me know if you can attend and how much time you would like on the agenda.

I look forward to hearing from you.

Sincerely,

Albert S. Jacquez

Albert S. Jacquez

Encl.

The Seaway of the 21st Century

Comments of the
Saint Lawrence Seaway Development Corporation
on the scope of the
U.S. Army Corps of Engineers' Reconnaissance Study of Possible
Great Lakes/Seaway Infrastructure Improvements

August 24, 2000

The Saint Lawrence Seaway Development Corporation has been heavily involved in a binational effort to define and promote a strategic plan for the Great Lakes/St. Lawrence Seaway System (System). Under the auspices of the "Waterways Strategic Issues Forum", we have cooperated with the St. Lawrence Seaway Management Corporation (our Canadian counterpart) and various industry representatives to investigate ways to "make the Great Lakes St. Lawrence Waterway the most competitive, technologically advanced, environmentally responsible water transportation system in the world." Some of the elements of this competitive vision can be addressed in the short term, such as controlling costs, strengthening binational cooperation, and investigating new export markets. However, one issue that must be addressed when considering the long term competitiveness of the System is the feasibility of lock expansion to allow for the use of larger, more cost effective vessels. We strongly feel that this reconnaissance study must affirm that the issue of expanding the Seaway locks deserves a fresh look.

The trend in marine transportation is toward larger, more efficient vessels. Currently, the Seaway can only accommodate 40 percent of the world fleet. Ships calling at North America's Gulf and West Coast ports are able to load cargoes of 80,000 to 100,000 tons, whereas the maximum Seaway-draft cargoes are around 25,000 tons. While it is unrealistic to ever think of 100,000 ton cargoes transiting the Seaway, if the locks were modified to accommodate class X vessels, the maximum cargoes would increase dramatically to the vicinity of 60,000 tons. This increase in capacity would decrease the cost per ton by 25 percent based on the vessel utilization savings figures calculated in the 1987 report.

Inspired by the Water Resources and Development Act of 1999, which authorizes the U.S. Army Corps of Engineers in consultation with the SLSDC to examine the feasibility of navigation improvements in the System, we have reviewed the 1987 additional locks study. At the conclusion of the 1987 final feasibility study, the Corps determined that increasing the capacity of the U.S. locks was not economically feasible at that time. In our review, we have identified various issues that we would like to address in the current study reconnaissance phase.

First, we believe that the Corps should closely examine the economic models used in the previous study to determine whether the prior methodology led to an understatement of the true economic benefits to be gained by lock expansion. For instance, we have identified several factors that may have led to underestimating the extent of the "vessel utilization savings" to be gained by using larger ships. First, the vessel utilization savings were calculated based on a maximum draft of 26'. Even at the time of the study, the draft was 26'3", and we are looking into increasing the draft to 26'6" in the near future (possibly as early as the 2001 Navigation

Season), with a final goal of 27'. Each inch of increased draft translates into additional cargo capacity of 100 metric tons for Seaway size vessels, or up to 270 additional metric tons for Class X Poe-sized vessels that are 1000 feet long. Therefore, any future study should calculate vessel utilization savings for drafts of at least 27'.

In addition, the 1987 study focused on grain and iron ore only when computing the projected vessel utilization savings. While "iron ore in, grain out" is a traditional pattern for Seaway cargo, these cargoes only account for 2/3 of the total tonnage shipped through the Seaway. Any study that does not include vessel utilization savings for this other 1/3 of cargo will understate the benefits relative to the cost of the project.

Also, when calculating the vessel utilization savings, the 1987 study estimated future traffic levels for the years 2000-2050 using 1978 levels as a baseline, then making adjustments based on long term commodity forecasts for grain and iron ore. However, the report seems to consider these future traffic levels as independent of any increases made to the capacities of the locks. In other words, those traffic levels will occur whether the locks are expanded or not. However, if increasing the size of the locks decreases the cost per ton of cargo, either more cargo will be attracted to the System, or the cost of alternative transportation will fall from the competitive pressure of lower Seaway costs. Either alternative represents an increase in transportation savings that were not reflected in the 1987 report, and should be considered in an updated study.

We would also suggest, at this early phase, to be as open as possible to different options for increasing lock capacity. Perhaps it might be feasible to increase only one dimension (only length, width or draft). While the transportation savings may be lower for such an option, the decreased cost might lead to a positive benefit/cost ratio.

The 1987 study defined the relevant benefit to transportation improvements, including lock expansion, as U.S. transportation savings. Is it possible to expand this definition of benefit? One obvious concern is the exclusion of Canadian cost and benefits in the analysis. Since only 2 of the 15 locks on the Seaway are within U.S. control, any expansion of capacity on the U.S. side would be of limited value without a corresponding expansion of the Canadian locks. We cannot overemphasize our desire to see that any future study examines costs and benefits on a System-wide basis. We have informed our Canadian counterparts of the upcoming study, and they have expressed their willingness to provide assistance. We will do anything in our power to facilitate binational cooperation in such a study, and we recommend that securing Canadian input in the reconnaissance phase be made a top priority.

In addition, we understand that the current economic protocol followed by the Corps for navigation studies narrowly restricts the benefits used in the benefit/cost analysis to transportation benefits, such as vessel delay savings and vessel utilization savings. Can changes be made to this protocol to allow for the measurement of other economic benefits accruing to the Great Lakes area due to increased use of the Seaway? According to the 1987 study,

> Assuming similar System-wide improvement capabilities, preliminary studies indicated that significant Great Lakes regional benefits could be realized [from

increased lock capacity]. Increased capacity would facilitate waterborne commercial, industrial, and agricultural transportation needs through increased capacity for shipment of future commodity flows resulting from continued growth within the region and increased use of the System. Some associated employment and income, and community developmental benefits might also be expected which would help to stabilize and/or promote continued community and regional socioeconomic growth.

At this early phase, we believe it might be useful to at least discuss a mechanism for quantifying these benefits for inclusion in the benefit/cost ratio.

Historically, the Seaway has played an important role as a conduit for exports from and imports to the nation's heartland. Not only is the Seaway a very cost competitive route for trade between the U.S. and Europe, North Africa and the Mediterranean, it also serves as an important source of extra capacity when surges in commodity movements overwhelm the capacity of rail and barge alternatives. However, the movement toward larger vessels threatens to erode the long term competitiveness of the Seaway as a viable mode of transportation. Faced with similar evidence of the growing dimensions of the world fleet, even the Panama Canal is looking at the option of lock expansion. The 1989 Interim Report on International Fleet Compatibility prepared by the Corps argues that "[c]onstruction of major lock and channel systems are unique in history...Decisions to size locks are almost irreversible." (p. 16, Interim Report) However, it may be time to reexamine this view. We believe that the current reconnaissance study will indeed identify a federal interest in reexamining the feasibility of lock expansion.

Attachment 1 - Definition of Terms

An array of names and definitions are applied to the various waterway segments in the Great Lakes-St. Lawrence River Basin. Some waterway designations overlap others. What follows are the definitions that will be used in this study to describe the navigable waterways in the basin. These are based on most common usage in government reports and industry publications.

<u>Great Lakes/St. Lawrence Waterway (GL/SLW)</u> – navigable waterways from the Gulf of St. Lawrence to the Head-of-the-Lakes.

<u>Great Lakes/St. Lawrence Seaway (GL/SLS)</u> – navigable waterways from Montreal west to the Head-of-the-Lakes. GL/SLS includes the St. Lawrence Seaway and the Great Lakes Navigation System.

<u>Great Lakes Navigation System (GLNS)</u> – all five of the Great Lakes and the Great Lakes connecting channels.

<u>Great Lakes Connecting Channels (GLCC)</u> – navigable connecting channels between the Great Lakes: the St. Marys River, the Straits of Mackinac, the St. Clair/Detroit River system and the Welland Canal. This does not include shallow draft channels that connect with the lakes.

<u>St. Lawrence River</u> – navigable straight between Lake Ontario and the Gulf of St. Lawrence. It has two distinct reaches – the canalized, 26’3” draft Montreal-Lake Ontario (MLO) section of the Seaway and the minimum 35’ draft reach from Montreal to the Gulf.[2] This later stretch of river is referred to in this report as the lower St. Lawrence River.

<u>St. Lawrence Seaway</u> – the waters of the St. Lawrence River above Montreal, Lake Ontario, the Welland Canal, and Lake Erie as far west as Long Point. It includes the Welland Canal and the Montreal-Lake Ontario section. Data displays in this appendix conform to SLSMC and SLSDC Seaway statistical presentations, which do not include intra-Lake Ontario waterway traffic.

<u>Welland Canal Section</u> – eight lock canal linking lakes Erie and Ontario. This section of the St. Lawrence Seaway is the only all Canadian Great Lakes connecting channel.

<u>Montreal-Lake Ontario (MLO) Section</u> – seven-lock canalized section of the St. Lawrence Seaway lying entirely within the St. Lawrence River and extending from the St. Lambert Lock to Lake Ontario beyond the Iroquois Lock.

[2] The 26’3” draft presently allowed in the Seaway is not available all of the time because of variable water levels.

GREAT LAKES
ST. LAWRENCE SEAWAY STUDY

Final Report
Fall 2007

Great Lakes St. Lawrence Seaway Study

By:

Transport Canada
U.S. Army Corps of Engineers
U.S. Department of Transportation
The St. Lawrence Seaway Management Corporation
Saint Lawrence Seaway Development Corporation
Environment Canada
U.S. Fish and Wildlife Service

Credits

Publication

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This publications is also available in French under the title:

Étude des Grands lacs et la Voie maritime du Saint-Laurent
Rapport final – Octobre 2007

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TP XXXXX (10/2007)

Foreword and acknowledgements

We are pleased to present the binational report on the Great Lakes St. Lawrence Seaway Study, the result of collaborative research and analysis by seven federal departments and agencies from Canada and the United States. The report summarizes the findings of the study and sets out observations and key considerations for continuing the success of a productive, safe and reliable waterway in a cost-effective, efficient and sustainable manner.

The Great Lakes St. Lawrence Seaway system is a vital resource. As one of the world's greatest and most strategic waterways, it is also an essential part of North America's transportation infrastructure. The system enables and facilitates significant domestic and international trade for the continent's largest interior markets including the industrial, manufacturing, agricultural and natural resource sectors.

It is likely that few outside the Great Lakes basin and St. Lawrence River region appreciate the crucial role of the waterway. This resource flows directly across two provinces and eight states, situated at the axis of the world's largest binational trading relationship. Since coming into full operation in 1959, the St. Lawrence Seaway has handled more than 2.3 billion metric tons of cargo with an estimated value of $350 billion. The competitiveness, prosperity and economic progress achieved are the result of a strong partnership that provides enormous benefit to both countries.

The upcoming 50th anniversary of the opening of the St. Lawrence Seaway is a reminder that the economic vitality and efficiency of marine transportation and trade cannot be taken for granted. Waterborne movement is cost competitive, fuel efficient, safe, and possesses some environmental advantages. When integrated with rail and trucking into a multimodal transportation network, it can greatly increase capacity with minimal negative impacts on society.

For the Great Lakes St. Lawrence Seaway system to be sustainable and optimize its contribution to the future movement of goods, it needs a strategy for addressing its aging infrastructure. Principally this includes its lock systems, but it should also adopt a more holistic view of the ports it serves and their evolving linkages to other modes of transportation. Recognition of this central fact by both nations prompted this comprehensive study on future needs of the system focusing on strategic issues that encompass economic, environmental and engineering dimensions.

Study partners look to a future in which a modern waterway capitalizes on its inherent advantages to meet the projected doubling of freight traffic and trade activity in North America. An improved Great Lakes St. Lawrence Seaway system — one that is part of a more integrated transportation network and trade corridor — can serve as a complement and alternative that can accommodate rapidly growing containerized freight traffic as easily as it does bulk and general cargoes.

This binational report is a unique document. It expresses not only a common determination, but also a climate of mutual understanding, sharing and confidence among the study partners. This is a testament to the scores of individuals representing the seven participating departments and agencies who devoted their considerable time, effort and expertise to this initiative.

Thanking all who have contributed to this undertaking would be a significant task in itself and inevitably result in omission of individuals who merit deep gratitude. However, we cannot forgo honouring the study's management committee: Marc Fortin from Transport Canada and David Wright from the U.S. Army Corps of Engineers. Their commitment and determination built a culture of teamwork that has resulted in this impressive effort.

The Great Lakes St. Lawrence Seaway system is bigger than any report, or commission, charged to investigate it. It belongs to all stakeholders. It is our hope that the study will have a significant influence in creating a context for discussion and action to develop a safe, healthy and economically sound waterway for future generations. In our estimation, the study lives up to its appointed task of providing a comprehensive understanding of needs, opportunities and challenges in the next 50 years.

We look forward to sharing and discussing the work and findings of the study.

Respectfully,
The Great Lakes St. Lawrence Seaway Study's Steering Committee

Kristine Burr
Assistant Deputy Minister, Policy
Transport Canada
Steering Committee Co-Chair

Jeffrey N. Shane
Under Secretary for Policy
U.S. Department of Transportation
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Executive Summary

Geography has provided a natural highway reaching into the heart of North America. As a result, the waters of the St. Lawrence River and the Great Lakes were used from earliest times to open up the region to commerce and settlement. Eventually, the areas around the waterway evolved into the continent's industrial heartland.

Not surprisingly, human action sought to enhance what nature provided. Soon after European settlers arrived, the first efforts were made to bypass rapids, install locks and deepen channels. This work persisted for almost 200 years and culminated in the mid twentieth century with the completion of a waterway that could take ocean-going vessels through the St. Lawrence, around Niagara Falls and across the upper Great Lakes to the furthest shores of Lake Superior – a distance of some 3,700 kilometres or 2,300 miles.

That was more than half a century ago. With the passage of time, the original economic factors that drove the creation of the Great Lakes St. Lawrence Seaway (GLSLS) system underwent significant change. Moreover, the infrastructure itself began to show the inevitable effects of wear and aging.

The GLSLS Study

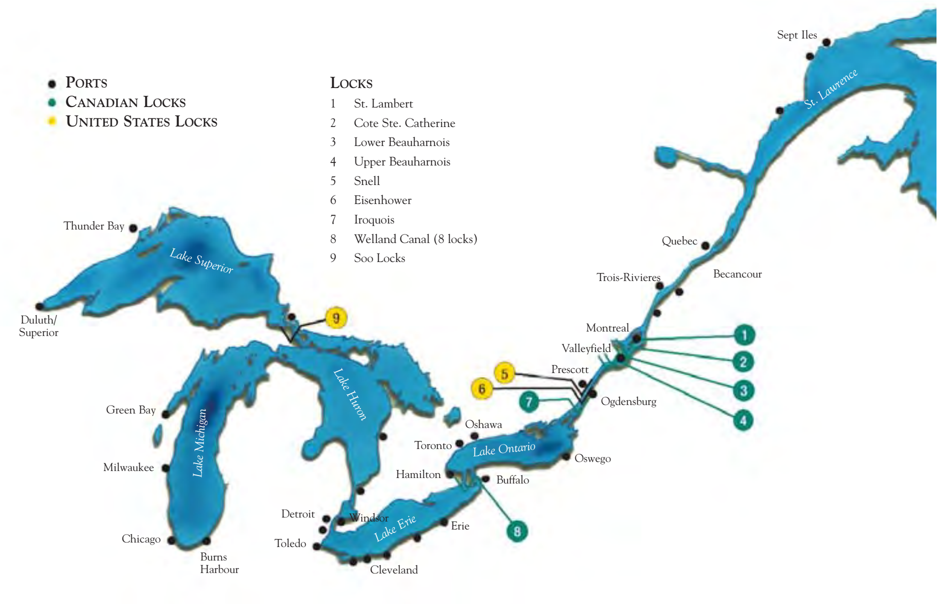
The beginning of the new millennium marked an appropriate moment to reflect on the system, its future prospects and what should be invested to keep it operational. As joint custodians of the GLSLS and its infrastructure, the governments of Canada and the United States (U.S.) entered into a Memorandum of Cooperation that formed the framework for a binational effort to address the fundamental question:

> *What is the current condition of the GLSLS system, and how best should we use and maintain the system, in its current physical configuration, in order to capitalize on the opportunities and face the challenges that will present themselves in coming years?*

Seven Canadian and U.S. federal departments and agencies were involved in a multi-year study of this issue: Transport Canada, the U.S. Department of Transportation, the U.S. Army Corps of Engineers, the Canadian St. Lawrence Seaway Management Corporation, the U.S. Saint Lawrence Seaway Development Corporation, Environment Canada and the U.S. Fish and Wildlife Service. Their representatives formed a steering committee responsible for the Study's overall strategic direction. Study tasks and analysis were overseen by a management committee consisting of one representative from Transport Canada and one from the U.S. Army Corps of Engineers.

The Study itself was carried out by subject-matter experts organized into three working groups. The Economic Working Group was tasked with investigating the current and possible future role of the GLSLS in both regional and global commercial and transportation networks. The Environmental Working Group examined the impact of navigation and its operations within the larger context of ecological conditions in the Great Lakes basin and St. Lawrence River. Finally, the Engineering Working Group examined the current physical condition of lock system infrastructure, evaluated its reliability and developed options for its future maintenance.

THE IMPORTANCE OF THE SYSTEM



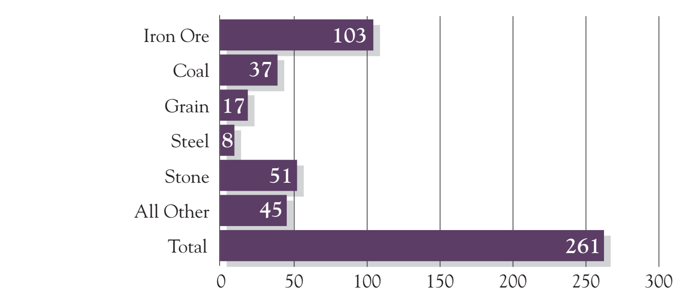
The three working groups began with a common recognition of the importance of the GLSLS system. It is located at the core of North America's industrial heartland, which contains a quarter of North America's population, and accounts for 55 percent of its manufacturing and service industries. Within this region, the waterway plays a key strategic role, carrying the iron ore and coal that are critical to the health of vital industries such as steelmaking and automotive manufacturing.

Physically, the GLSLS consists of an interconnected system of locks located at 16 different sites, four major navigational channels, more than 50 ports, several bridges, tunnels and a variety of approach roads. Within this array there are four distinct segments. The Great Lakes waterway links Lakes Superior, Michigan, Huron and Erie through locks at Sault Ste. Marie and the channels of the St. Marys, Detroit and St. Clair rivers. Key to this segment are the two operational U.S. locks, the Poe and MacArthur locks. The second segment is the Welland Canal, which consists of eight Canadian locks linking Lake Erie to Lake Ontario. The third part of the system is known as the Montreal-Lake Ontario segment, which include seven locks: the Iroquois, Upper and Lower Beauharnois, Côte Ste. Catherine and St. Lambert locks on the Canadian side of the waterway, and the Dwight D. Eisenhower and Bertrand H. Snell locks on the American side. Finally, there is the St. Lawrence ship channel, which has no locks and runs downstream from the port of Montreal to the Atlantic Ocean.

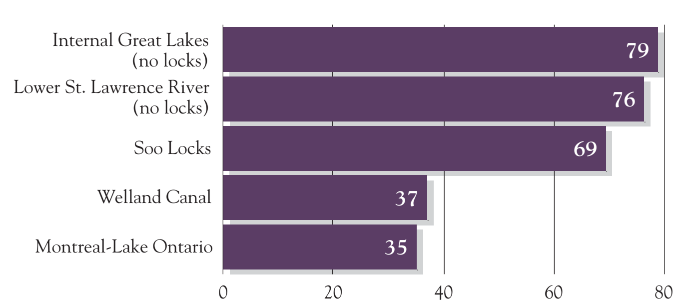
ECONOMIC ROLE

When this system was completed with the opening of the St. Lawrence Seaway in 1959, planners envisaged that it would carry grain from North America's prairies to the markets of Europe and the Soviet Union. Subsequent political and economic changes in those markets have reduced demand for North American grain, which has recently found alternative buyers in the Pacific region. While grain still moves through the GLSLS, its volumes have been overshadowed by huge shipments of iron ore, which are carried from Minnesota and Wisconsin to the smelters of Ohio. Today, the waterway transports more than 80 percent of the iron ore used in U.S. steel production. The system also carries vast quantities of coal from Montana and Wyoming to power generating stations along the shores of the Great Lakes. Other commodities shipped through the system include limestone, coke, salt, petroleum products, chemicals, processed iron and steel as well as a variety of goods carried in containers.

Average annual tonnage shipped 1995-2003
(millions of metric tons)



Average annual tonnage shipped 1995-2003
(millions of metric tons)



Between 1995 and 2003, total cargo traffic through the GLSLS averaged 261 million metric tons (Mt) annually. Of this, some 69 Mt passed through the Soo Locks, while the Welland Canal and MLO section saw about 37 Mt and 35 Mt, respectively. The balance moved between ports within the system without passing through any of its locks. Economic forecasts suggest that this traffic is likely to grow at a moderate pace over the coming half century. This expectation leads to the fundamental question of what role the GLSLS is likely to play in the future: the answer will determine how much should be invested in keeping it operational.

Environmental impacts

The economic advantages of the GLSLS have to be balanced against its costs. Those costs entail more than just the expenditures associated with operating, maintaining or repairing its infrastructure, or the costs incurred by the transportation industry in the event of unexpected component failures. There are also the impacts associated with commercial navigation to the ecology of the Great Lakes basin and St. Lawrence River.

The ecosystem of the GLSLS is vulnerable to a variety of stressors. Residential settlement, urban growth, industrial activities, tourism and recreation have all had an impact on environmental degradation. Thus navigation is by no means the only factor operating on the region's environment.

When the system was originally completed, environmental protection was not a high public priority and environmental impacts were poorly understood. Over time, however, it became clear that the construction, operation and maintenance of the GLSLS had a number of significant effects on the ecology of the basin.

Ships' wakes eroded shorelines. The management of water levels in the basin altered local ecologies, drying out some areas and inundating others. Dredging of navigational channels caused turbidity in the water while posing the challenge of how to dispose of dredged material with a minimal impact on the environment. Ship engines burned a lower grade fuel that contributed to air pollution. Vessels were also coated with special corrosion-resistant paint that released toxins into the water.

Many of these effects were part of larger environmental impacts caused by industrial, commercial and residential development in the region. Some, however, were unique to navigation through the system. Perhaps the most important of these was the introduction and transmission of aquatic non-indigenous invasive species (NIS) via the ballast water of vessels. Examples of such species include the zebra mussel. With few natural predators in the region, such species proliferate rapidly with significant negative effects on native ecology.

Environmental stressors

Class of stressor		*Stressor*
Global	**Climate change**	
Non-navigational related	**Development and land use**	Water withdrawal & diversions
		Introduction & transfer of aquatic NIS
		Air emissions
		Industrial/municipal effluent
		Solid waste disposal
		Landscape fragmentation
		Runoff
		Shoreline alteration/hardening
		Noise & vibration
		Erosion and sedimentation
	Water-based recreation and tourism	Introduction & transfer of aquatic NIS
		Shoreline alteration/hardening
		Waste disposal/pollution
		Erosion and sediment re-suspension
		Wildlife conflicts
Navigational related	**Channel & port maintenance**	Channel modification
		Dredge material placement
		Shoreline alteration/hardening
		Maintenance dredging
	Water management	Water management for all purposes
	Land-based support activities	Infrastructure development
		Facility maintenance
		Uncontrolled releases
	Ship operations	Introduction & transfer of aquatic NIS
		Ship's air emissions
		Biocides (antifouling)
		Accidents/spills
		Noise & vibration
		Waste disposal
		Prop wash, surge and wake
		Cargo sweeping
		Groundings/anchoring
		Wildlife encounters
	Ice breaking	

Recognition of these impacts within the broader context of a greater appreciation of the environment, has led to a general commitment to remediation. As a result, ships' speeds are controlled to reduce wakes in narrow channels. Toxic paints have been phased out. To reduce air pollution, vessel operators are exploring fuel alternatives and scrubbing technologies. Finally, strict controls have been introduced on ballast water. Vessels are now required to manage ballast water by exchanging at sea in order to reduce the risk of any further NIS introductions. Even loaded vessels that carry only small quantities of residual ballast are required to properly manage their residual ballast if it is to be mixed with Great Lakes waters and subsequently discharged into the lakes.

Activities such as ongoing maintenance of infrastructure or dredging and the placement of dredged material will continue to affect the region's environment, but their impact can be minimized through effective application of environmental assessments, remedial actions, sound environmental management strategies and best practices.

Generally, it seems that organizational and governance frameworks together with accompanying policies and legislation are likely adequate for the management and control of the navigation-related activities that have had a negative impact on the environment in the region. However, because most of the environmental stressors in the Great Lakes basin and St. Lawrence River are not related to navigation, action on navigational stressors may be beneficial but, on its own, is unlikely to result in significant gains to overall environmental quality.

The future of the GLSLS

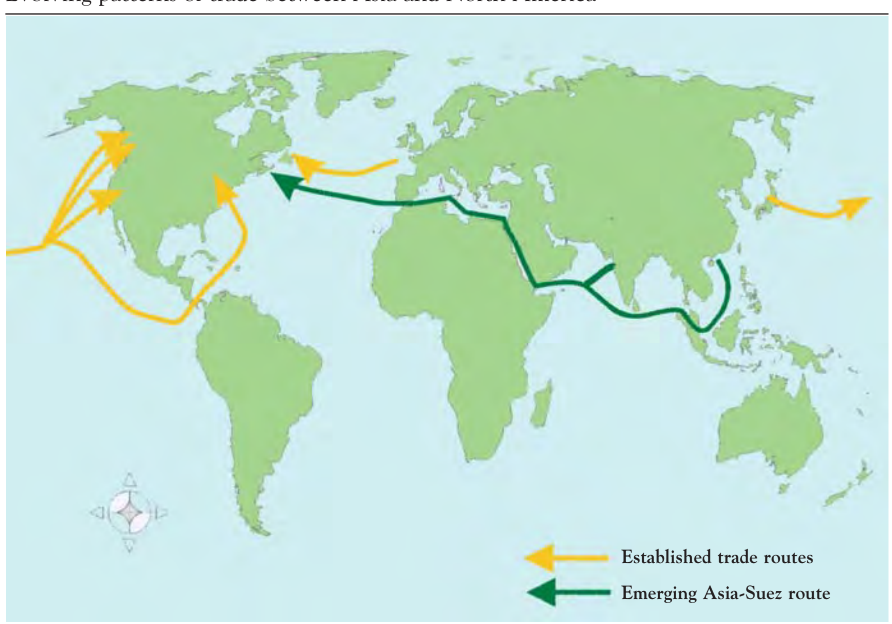
It is clear that the GLSLS offers shippers significant savings: surveys suggest that the system saves them approximately $2.7 billion a year in transportation costs. Moreover these savings are especially felt in strategic sectors such as steelmaking and energy, the competitiveness of which is vital to the health of the North American economy.

The GLSLS also offers shippers considerable spare capacity. This is becoming increasingly significant as highways and rail lines in the region experience growing congestion. Much of the huge volumes of trade passing between Canada and the U.S. is funnelled through crossings at Windsor-Detroit and Niagara Falls. The road and rail networks carrying this traffic are reaching physical limits, the challenges of which have been exacerbated by new security procedures.

The GLSLS can play an important role in relieving some of these pressures by offering complementary transportation routes through less busy ports and by moving goods directly across lakes rather than around them. Called shortsea shipping, the latter alternative would require an investment in upgraded surface links to the rest of the transportation grid, enhanced port facilities for loading and unloading containers as well as regular shipping service along the likeliest alternative routes.

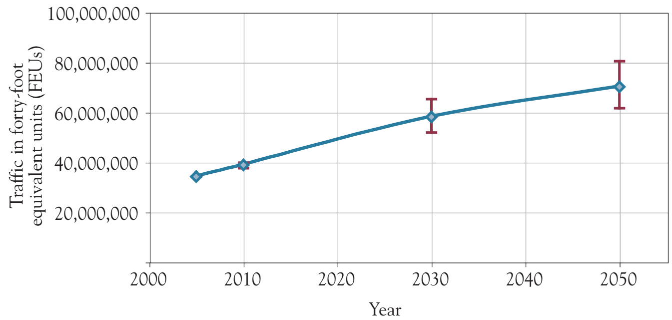
The future of the waterway should also be seen within the broader context of international trade. The advent of a global economy has been accompanied by the emergence of containerized shipping as well as by the development of new markets in Asia that has shifted the focus of international trade from the Atlantic to the Pacific. As a result, the ports of North America's West Coast are also experiencing the challenges of congestion. In response, shippers are looking

Evolving patterns of trade between Asia and North America



for alternative routes, one of which is to move containerized goods from East Asia through the Suez Canal into Europe and then continue the journey to ports along the eastern seaboard of North America. Such goods could then be transhipped onto carriers that move them through the GLSLS into the heart of North America. Given that most GLSLS shipping has traditionally focused on bulk commodities, a key determinant of success would be the ability of GLSLS vessels and ports to handle containerized cargoes. If such capabilities are ensured, waterborne traffic can be used to alleviate some of the pressures on regional congestion and global restructuring.

Forecast of market for container traffic carried by all modes in the GLSLS binational region



The GLSLS currently operates with spare capacity that could absorb traffic from other surface routes. For the marine mode to emerge as a viable complement to the movement of goods by road and rail, the system must focus on enhancing and maintaining its competitiveness.

In the shipping industry, competitiveness is determined by a combination of factors: cost, time, frequency and reliability. Clearly the cost per unit per kilometre or mile transported is a fundamental consideration and in this case, waterborne shipping enjoys a clear advantage. That is why it is used to move large volumes of bulk goods. To compete effectively with other transportation modes, waterborne shipping must also address other determinants of competitiveness such as trip times and frequency of shipments.

Perhaps the most fundamental competitive consideration, however, is reliability: shippers will not use a system in which there are frequent unplanned closures and traffic interruptions. The GLSLS offers them a high level of dependability. Historically, it has been available to vessels for 98 percent of the regular shipping season. About two-thirds of the remaining two percent was downtime attributable to weather (poor visibility, ice, wind), one quarter was caused by vessel incidents, and the balance was accounted for by all other causes, including lock failures. This high level of availability is a direct result of the investments that have been and continue to be made in ongoing system maintenance.

Current condition of the infrastructure

If the GLSLS is to remain reliable, its infrastructure will have to be maintained. The system consists of locks, shipping channels, ports, bridges, control and communications systems, as well as interfaces to other transportation modes. The navigation channels accumulate silt over time and must be dredged periodically to maintain the required depth. Locks can experience deterioration to components such as walls and gates, or mechanical failures that affect gate movement. There are also a number of bridges and tunnels spanning the locks of the Welland Canal and Montreal-Lake Ontario section of the Seaway that must be maintained in ways that do not impede road and rail traffic.

While all of these diverse systemic elements form part of an integrated whole, each demands its own investments, technologies and scheduling. Planning must factor in the specific requirements of each element in a way that harmonizes the components of the whole system.

A review of the current condition of the system was performed, with special attention devoted to the lock structures located throughout the system. The process included the development of a "criticality index" of system components that included factors such as availability of replacement parts, current condition, likelihood of failure and impact on navigation. The index provided a standardized and systematic way of evaluating the current condition of the system's infrastructure. The condition of approximately 160 components of the GLSLS was examined: the review included locks, approach walls, water-level control structures, road and railway bridges as well as tunnels. Analysis found that overall, the system has held up reasonably well. Moreover, despite differences in construction and maintenance strategies, the rankings for the sets of locks were similar from region to region. Each lock region, however, has several critical components that have been rated as high priority and in need of repair, rehabilitation and/or replacement. The majority of components are still serviceable, with several in need of major maintenance in future years .

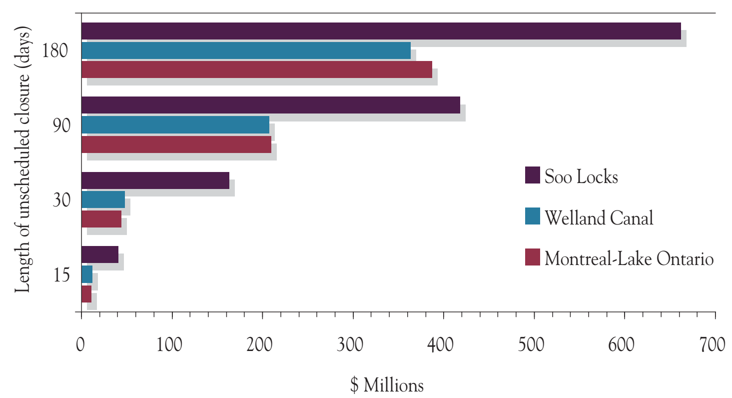
Analysis has also developed models that can be used to predict when components are likely to fail. Criticality assessments coupled with reliability data have identified and prioritized key operating components with an elevated risk of failure and significant consequences. Knowing this allows for the adoption of a maintenance strategy that anticipates problems rather than dealing with them once they have occurred.

It is possible to maintain the system by focusing on ongoing, routine maintenance, with components being replaced after they reach the limit of their useful life. Such an approach, however, does run a higher risk of unanticipated failure. A more proactive strategy, however, uses reliability data to anticipate when components are statistically likely to fail and rehabilitate or replace those components before failure occurs, thereby increasing overall system reliability.

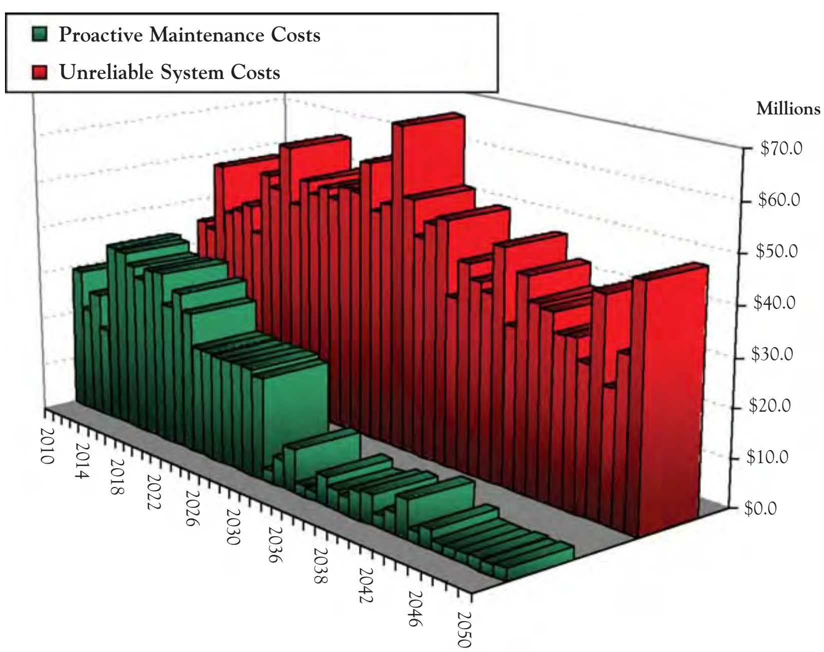
Reliability is critical because the GLSLS is essentially a series of structures that must be transited with no alternatives (except at the Welland Canal flight locks and the dual chambers at Sault Ste. Marie). As a result, closure of one of the structures in the series closes the entire system. Moreover, a closure or a sequence of closures during the navigation season can result in incomplete vessel trips from origin to destination and back.

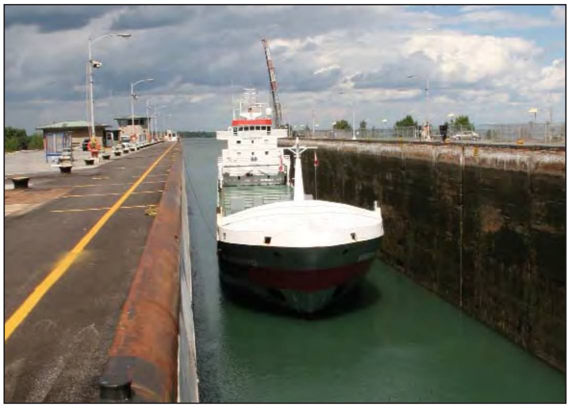
The consequences of service disruption vary by shipment and depend on the service disruption type (closure or service time increase), location of the disruption (at a single or dual lock chamber site), duration and timing (beginning, middle or end of the navigation season). Impacts from a service disruption can include not only shipment delay, but also return trips to unload a shipment for rerouting on an alternative transportation mode, vessel idling, stockpile depletion and plant shutdowns. Whatever the specifics, however, it is clear that disruptions impose significant costs on the transportation industry.

Estimated costs of unscheduled lock closure



Scheduled costs under the reliable system scenario versus expected unscheduled repair costs and transportation costs from under funding the priority components





The key, then, is to adopt a maintenance strategy that minimizes the possibilities of disruption and maximizes overall system reliability. This is shown in the adjacent graph, which compares the projected maintenance costs of addressing system components in a proactive manner with the projected impacts of system disruptions. The unreliable system costs are significantly higher and even these are considered conservative inasmuch as they assume that vessels incur no return trip and unloading costs, no vessel idling costs, no stockpile depletion costs, no plant shutdown costs, and assuming unmet tonnage flows are able to acquire alternative mode transportation (when needed) at their long-run least-costly all-overland alternative rate. The comparison shows the value of scheduling the expenditure needed to maintain system reliability in a proactive manner.

The general conclusion to be drawn from this modeling is that a proactive maintenance strategy will avoid the additional costs of unscheduled maintenance repairs and general system unreliability. Its real benefit, however, lies in avoiding the additional transportation costs associated with unanticipated failures: such failures lead to waiting and queuing; switching to more expensive alternative transportation modes during closures; and ultimately switching permanently to costlier modes if the system is perceived as unreliable. A more reliable GLSLS system with less disruptive lock events (closures, speed reductions, etc.) is likely to attract more commercial traffic, which will, in turn, make the system more cost-effective.

Observations

In general, the analysis of the current situation of the GLSLS concluded that the system remains an important element in the North American economy. Its ongoing value and future prospects certainly justify the costs of maintaining its infrastructure. Moreover, future operation and maintenance of the system can be performed in a manner that minimizes environmental impacts. Given this broad consensus, the Study developed a set of specific observations for the future of the system.

The GLSLS system is an incredibly valuable North American asset. Marine transportation on the waterway provides shippers with a safe, efficient, reliable and competitive option for the movement of goods. However, there is also unrealized potential in the system in terms of the important future contribution it could make to regional and continental transportation. The fundamental understanding of the opportunities and challenges acquired through the course of the GLSLS Study can be applied to identify priority areas and develop a balanced approach across economic, environmental and engineering factors, while addressing four strategic imperatives:

1. What role should the GLSLS system play within the highly integrated North American transportation system?
2. What transportation solutions are available to guarantee a dynamic future for the waterway?
3. What measures need to be taken to ensure the continued reliability of the system's infrastructure? and
4. How should the GLSLS system sustain its operations in a way that responds to concerns about environmental integrity?

The following sections will consider each of these strategic imperatives by summarizing the information gathered through the GLSLS Study and by presenting some observations and key considerations.

Role in North American transportation

North America is part of a global trade network that has experienced explosive growth over the past two decades. Part of this growth has a geographic dimension: East and South-east Asia have emerged as major players in international trade. Another part involves new types of cargoes, travelling primarily in containerized vessels. Both of these trends are having an impact on North America as a whole and the GLSLS system in particular.

As the volume of goods transported internationally continues to grow, bottlenecks on North America's West Coast are leading shippers to look for alternative routes through both the Panama and Suez canals. Some of this redirected traffic is finding its way into the Great Lakes basin and St. Lawrence River region. Yet the surface transportation routes in this region are already facing pressures. Both roads and railways are strained in terms of increasing congestion and tightening capacity. This is exacerbated by the fact that most of this surface traffic is funnelled through a small number of transit points, and security requirements are slowing clearance procedures at borders. Moreover, there is limited scope for the construction of additional roads or railways to alleviate such congestion.

The inescapable conclusion is that waterborne traffic could help to ease some of these pressures. The GLSLS is currently operating with spare capacity that could be used to redirect some traffic from overland routes. Moreover, redirection of traffic through the GLSLS system is directly connected with the other major trend in international trade – the move toward containerization of cargoes. Much of the traffic now entering North America consists of containerized shipping. As a result, when it arrives at a port of entry, shippers have a choice in how to move those containers inland inasmuch as ships, trucks and railway cars are now all adapted to carry containers.

In the past, container ships entering northeastern North America would either discharge cargo at the main eastern seaboard ports or carry their cargo inland as far as the Port of Montreal. Given the anticipated growth in traffic on road and rail routes in the region, there is an opportunity to move at least some portion of this containerized cargo by water through the GLSLS system.

For the GLSLS to emerge as a viable complement to the movement of goods by road and rail, the system must focus on enhancing and maintaining its competitiveness. In the shipping industry, this is determined by a combination of factors: cost, time, frequency and reliability. Clearly the cost per unit per kilometre or mile transported is a fundamental determinant of competitiveness. In this case, waterborne shipping enjoys a clear advantage. That is why it has been used to move large volumes of bulk goods. If waterborne shipping is to compete for more diverse cargo traffic, however, it must also focus on the other determinants of competitiveness. Total trip times need to be shortened. Sailing frequencies need to accommodate shipper requirements. Unplanned closures and traffic interruptions must be minimized. In fact, the GLSLS system already has a good record in these areas, but any additional improvements will enhance its overall competitiveness and strengthen its position as a viable transport alternative.

Observation:

The GLSLS system has the potential to alleviate congestion on the road and rail transportation networks as well as at border crossings in the Great Lakes Basin and St. Lawrence River region.

Key considerations:

- The GLSLS system is currently only operating at about half its potential capacity and is therefore under-utilized.
- Given projected growth in the economy and trade, all modes of transportation in both countries will be faced with increases in traffic. When integrated with rail and trucking, the region's marine mode can greatly increase the overall capacity of the transportation system while reducing highway, railway and cross-border congestion.
- A research and development agenda would help to advance the use of new technologies to improve the efficiency of marine transportation as well as strengthen its linkages to other transport modes.

Solutions for a Dynamic Future

The North American transportation system is more than just the sum of its parts: it also involves linkages between and integration of various modes and jurisdictions. Within this context, the GLSLS system cannot be thought of as a stand-alone mode restricted to one type of traditional traffic.

The GLSLS can play an important role in contributing another set of capabilities, while offering shippers greater flexibility. In order to fulfill this complementary role, policy and planning should focus on developing the waterway's shortsea shipping potential to enhance its intermodal capabilities and its ability to handle container traffic.

Optimizing the role played by the GLSLS within the transportation system of the Great Lakes basin and St. Lawrence River region requires a holistic view of the entire system. Marine transportation must be integrated seamlessly with the other modes in terms of cost, time, frequency and reliability.

To make this vision a reality, there are several aspects of modal integration that will have to be addressed. There need to be highly efficient intermodal linkages at the nodes of the system. The ports of the GLSLS system must have suitable road and rail connections. They must also have the right kinds of equipment to move containers easily between vessels, rail flatcars and tractor-trailers.

There are other factors which come into play in this area. There is a need for appropriate electronic tracking and communication to direct and monitor shipments.

New technologies, improvements in traditional infrastructure, streamlined border crossing procedures and the harmonization of regulations will also be important in designing systems and managing the demands of enhanced interconnectivity across transport modes.

Advancing the concept of marine intermodal services also requires suitable vessels adapted for different cargoes: bulk commodities versus containers or neobulk shipments. The routes travelled by the cargoes also need to reflect the potential advantages of waterborne transport. For example, shipping by vessel straight across a lake can be preferable to moving goods around its shore along congested roads. Apart from taking a faster, more direct route, it may also be the case that border procedures at the respective ports can be significantly faster than those at highly congested land crossings.

Observation:

A stronger focus on shortsea shipping would allow the GLSLS system to be more closely integrated with the road and rail transportation systems, while providing shippers with a cost-effective, timely and reliable means to transport goods.

Key considerations:

- Incentives need to be identified and promoted to encourage the use of marine transportation as a complement to the road and rail transportation modes.
- Institutional impediments that discourage the provision of shortsea shipping services need to be addressed.
- Potential opportunities to encourage the establishment of cross-lake shortsea shipping services could be identified on a pilot project basis.
- The existing Memorandum of Cooperation and Declaration on Shortsea Shipping, adopted by Canada and the U.S. in 2003 and 2006, respectively, could be used to continue to advance the North American shortsea shipping agenda.

Optimizing the existing infrastructure

It is clear that the marine transportation infrastructure of the GLSLS system involves more than just a series of locks. There are also ports and terminals, channels, bridges and tunnels, systems for control and communication, as well as interfaces to other transportation modes. Collectively, this constitutes an integrated system that needs to be optimized if it is to contribute to solving the transportation needs of the future.

Each of the following elements represents a distinct set of requirements, all of which need to be managed in an integrated fashion to ensure the competitiveness of the GLSLS system.

Locks: Because of their age, locks need to be subjected to a maintenance schedule that deals with potential failures in a way that sustains traffic with the fewest possible interruptions and preserves overall system integrity.

Shipping channels: The normal flow of water inevitably carries silt deposits that must be removed to maintain channels at authorized depths for shipping.

Ports: Ports and terminals that are likely to support shortsea shipping or to serve as nodes in multimodal networks will require appropriate loading and unloading facilities and equipment together with seamless links to other forms of surface transportation.

Bridges and tunnels: There are a number of bridges and tunnels spanning the locks and channels of the Welland Canal and Montreal-Lake Ontario section of the Seaway that must be maintained in ways that do not impede traffic.

Control and communication: Logistics systems today depend on advanced electronic systems to monitor movements and track shipments in real time.

Vessels: In addition to the traditional bulk carriers, there will be a need for ships capable of loading, carrying and unloading containerized cargoes.

While all of these diverse systemic elements form part of an integrated whole, each demands its own investments, technologies and scheduling. Planning must factor in the specific requirements of each element in a way that harmonizes the components of the whole system.

It is clear that burgeoning trade, a capacity crunch, aging transport infrastructure and increasing pressures on transportation lands in urban settings are an integral part of the marine environment. The locks, ports, terminals and other infrastructure of the GLSLS are critical components of North America's transportation gateways and, as such, they require investment and tools to respond to market forces in a timely manner if they are to continue supporting Canadian and U.S. international and domestic trade.

Observation:

The existing infrastructure of the GLSLS system must be maintained in good operating condition in order to ensure the continued safety, efficiency, reliability and competitiveness of the system.

Key considerations:

- Any GLSLS infrastructure components identified as at risk and critical to the continuing smooth operations of the system should be addressed on a priority basis.
- The existing GLSLS infrastructure requires ongoing capital investment to ensure that the system can continue to provide reliable transportation services in the future.
- Modern technology, especially in areas such as control, should be used to maintain the GLSLS system in a state that preserves its capability to respond to changing and unpredictable market conditions.
- The development of a long-term asset management strategy would help to anticipate problems with GLSLS infrastructure before they occur and avoid potential disruptions that would reduce the overall efficiency and reliability of the system.
- Investment options with respect to the system would involve numerous factors such as long-term planning, innovative funding approaches, partnerships among governments and collaboration between the public and private sectors.

Environmental sustainability

The considerations noted above must be examined within the framework of sustainable development. In simplest terms, sustainable development means the ability to foster economic growth in a way that does not cause undue damage to the environment. Consequently, policy and planning must factor in the environmental implications of lock maintenance and repair, channel dredging, construction of new port facilities, or the introduction of new vessels into the system.

The ecosystem of the GLSLS system is vulnerable to the stressors at play. Because many are not directly related to navigation, management of or adjustments to navigational stressors are important but would not necessarily result in appreciable gains to overall environmental quality unless they form part of an approach that is integrated with measures in other economic sectors.

As the requirements of GLSLS operations and maintenance involve some stressors to the Great Lakes-St. Lawrence ecosystems, these must be managed effectively. Organizational and governance frameworks, together with accompanying policies and legislation, are likely adequate to manage and control the navigation-related activities that have a negative impact on the environment.

There have been considerable resources devoted to research and planning but, with the exception of some specific areas related to non-indigenous invasive species, there have been few initiatives that have seen "on-the-ground" changes. There will be a continuation of impacts related to planned works, such as maintenance of infrastructure, maintenance dredging and placement of dredged material, but such impacts can be minimized through effective application of environmental assessments, remedial actions, sound environmental management strategies and best practices.

Yet sustainable development means more than just selecting options that have a minimal impact on the environment. At the broadest possible level, it means attempting to build upon certain environmental advantages of marine transportation over rail and trucking, as one component of an integrated transportation system that can be operated in a more environmentally friendly manner. Transportation by water is significantly more fuel efficient than other modes and consequently could reduce the emission of greenhouse gases and other pollutants. Moreover, increased utilization of waterborne transportation could help to alleviate traffic congestion on roads, which could ultimately result in the reduction of road maintenance and repair costs.

Observation:

The long-term health and success of the GLSLS system will depend in part on its sustainability, including the further reduction of negative ecological impacts caused by commercial navigation.

Key considerations:

- The GLSLS system should be managed in a way that prevents the inadvertent introduction and transmission of non-indigenous invasive species and supports the objectives of programs designed to minimize or eliminate their impact.
- The existing sustainable navigation strategy for the St. Lawrence River could be extended to the Great Lakes Basin.
- The movement and suspension of sediments caused by shipping or operations related to navigation should be managed by developing a GLSLS system-wide strategy that addresses the many challenges associated with dredged material and looks for beneficial re-use opportunities.
- Ship emissions should be minimized through the use of new fuels, new technologies or different navigational practices.
- Islands and narrow channel habitats should be protected from the impacts of vessel wakes.
- There is a need to improve our understanding of the social, technical and environmental impacts of long-term declines in water levels as related to navigation, and identify mitigation strategies.
- Improvements should be made to short- and long-term environmental monitoring of mitigation activities.

Monitoring and Follow-up

The observations and key considerations emerging from the GLSLS Study are the result of a comprehensive, multi-year research effort involving dozens of experts and specialists. Moreover, they reflect a consensus among the seven participating agencies. This is, in itself, a unique milestone in the history of the GLSLS.

The success of any initiative to build the future of the GLSLS system depends on a commitment by government and industry in both Canada and the U.S. to clear objectives and to the continuous monitoring of progress and success. Canada and the U.S. should maintain their collaborative efforts to plan the future of commercial navigation on the GLSLS system through a binational body of governmental representatives. The role of this body would be to monitor the progress achieved in the areas identified as priorities in the GLSLS study. The two countries would work in partnership to pursue an appropriate policy framework, promote the opportunities represented by the system to other parts of government and ensure an integrated approach to the distinct imperatives of the economy, the environment and engineering. Ultimately, the sustainability of the GLSLS system depends on achieving a viable balance of these three perspectives.

The understanding gained from the expertise of those who contributed to the GLSLS study can be used to inform Canadian and U.S. decision-makers. The study has identified observations and key considerations that need to be taken into account in order to optimize the operations and maintenance of the GLSLS system and ensure it continues to serve North America's economy over the next 50 years.

Chapter 1

Introduction

The Great Lakes St. Lawrence Seaway system is a vital waterway that has played a critical role in the economic evolution and prosperity of North America. The system as we know it today, however, is more than half a century old and is beginning to show the effects of age. In response, the governments of Canada and the United States undertook a joint effort to assess the system's current infrastructure condition and future commercial prospects within the broader context of regional environmental stewardship.

For more than half a century, the Great Lakes St. Lawrence Seaway (GLSLS) system has served as a vital transportation corridor for the single largest concentration of industry in the world. Straddling the Great Lakes basin, North America's industrial heartland depends on this intricate system of locks, channels, ports and open water.

Yet the waterway is facing new challenges that could not have been anticipated when the last link in the chain, the St. Lawrence Seaway, came into full operation in 1959. Changes in the economy have altered product demand and traffic patterns while the evolution of the transportation industry has affected vessel dimensions. As a result, shipping volumes have fluctuated and the system's underlying economic drivers have been transformed. Still, the GLSLS continues to fulfill a vital transport function not only for the Great Lakes and St. Lawrence regions, but also for the entire industrial core of the North American economy. Given its ongoing importance and in light of growing congestion at border crossings and on other transport modes, it is essential that the system be maintained as a safe, reliable, efficient and sustainable component of the continent's overall transportation network.

What is the current condition of the GLSLS system, and how best should we use and maintain the system, in its current physical configuration, in order to capitalize on the opportunities and face the challenges that will present themselves in coming years?

A system as large and complex as the GLSLS inevitably affects the environment around it. Generally, society has become far more aware of such environmental impacts, exacerbated as they are by the parallel pressures of population growth, urbanization and changes in lifestyle. Recent scientific research has yielded a better understanding of the cumulative effect of human action on the environment. It has also led to an enhanced appreciation of complex environments such as the Great Lakes basin and the St. Lawrence River, and has transformed the way in which such ecosystems are studied and evaluated.

The infrastructure of the GLSLS is starting to show its age. After 50 to 75 years of service, the system of locks and channels shows wear and tear from several hundred thousand vessel transits. As the system ages, the demands of maintenance grow, as do its costs.

In light of these cumulative changes, the governments of Canada and the United States (U.S.) undertook a comprehensive review of the GLSLS system. On May 1, 2003, they signed a memorandum of cooperation that provided for their collaboration in a wide-ranging study intended to address the fundamental question: *What is the current condition of the GLSLS system, and how best should we use and maintain the system, in its current physical configuration, in order to capitalize on the opportunities and face the challenges that will present themselves in coming years?*

Seven Canadian and U.S. federal departments and agencies were involved in this initiative: Transport Canada, the U.S. Department of Transportation, the U.S. Army Corps of Engineers, the Canadian St. Lawrence Seaway Management Corporation, the U.S. Saint Lawrence Seaway Development Corporation, Environment Canada and the U.S. Fish and Wildlife Service. All of them participated in a steering committee responsible for the project's overall strategic direction. Responsibility for overseeing the study tasks and analysis was vested in a management committee consisting of one representative from Transport Canada and one from the U.S. Army Corps of Engineers.

The study was carried out by subject-matter experts and representatives drawn from the seven partners and organized into three working groups: economic, engineering, and environment.

The mandate of the Economic Working Group was to consider the current economic role of the GLSLS and its likely future evolution. It was to examine the nature and directions of historical and present-day traffic flows and project the kind of traffic that might be expected over the coming half century. This was intended to estimate the future economic importance of the GLSLS as a key factor in determining the infrastructure that will be needed to support it.

Satellite view of the Great Lakes
Source: U.S. Army Corps of Engineers

Meetings with interested parties from both the public and private sectors were held initially in June and July 2004, and then again in September 2005. These sessions were instrumental in engaging stakeholders, informing them about study objectives and soliciting input concerning their concerns. Opinions were voiced, presentations were made and submissions were gathered. Not only did the meetings serve to assemble information and expertise, but they also provided a forum for the exchange of ideas, notably on important environmental issues and concerns. The input gathered at these sessions was transmitted to the management committee, to the study working groups and to all study partners for their consideration.

As a major binational undertaking, the study was mandated to conduct an extensive review of the existing infrastructure of the GLSLS in its current configuration. Despite its breadth and depth, there are issues that the study deliberately did not address. The focus was restricted to commercial navigation and excluded the navigational issues relating to recreation or tourism. In addition, the study did not consider any changes to the existing configuration of the GLSLS system such as larger locks, deeper channels, double lock systems or turning basins, nor did it review issues such as extending the navigational season and deferred any consideration of the possible impacts of long-term climate change. Finally, while the role played by commercial navigation in the introduction of aquatic non-indigenous invasive species is taken into consideration, the study did not address the specifics of possible future remedial measures such as regulations affecting the treatment of ballast water.

In evaluating the infrastructure needs of the GLSLS system as they pertain to commercial navigation, the study focused on the engineering, economic and environmental implications of those needs. This document integrates the findings from each of these three perspectives to provide a broad assessment of the current status of the GLSLS as well as an indication of opportunities and challenges in the coming years.

The Engineering Working Group was tasked with examining the current condition of the GLSLS system's physical infrastructure. It was directed to identify potential problem areas, estimate costs associated with keeping the system functional, and articulate an optimal strategy for ensuring its reliable ongoing operation.

The Environment Working Group was directed to review the current state of the environment in the Great Lakes basin and St. Lawrence River. It was to identify the most valued components of this ecosystem and determine how they had been affected by commercial navigation. Ultimately the group was to suggest ways of ensuring that the future environmental impact of commercial navigation could be minimized.

Stakeholder engagement was an important component of the study process, given its size and scope. From the outset, there was clear recognition of the need to consult with stakeholders in order to obtain their comments, determine their interests, and identify issues of concern.

This study constitutes the first comprehensive assessment of the physical state of the GLSLS. It has enhanced the understanding of the system's physical dynamics in terms of wear, material fatigue and concrete conditions. So far, despite the age of its infrastructure, the system continues to provide highly reliable service. It is, however, time to re-evaluate current practices and to define a maintenance and rehabilitation strategy that will accommodate the needs of the next 50 years.

How that maintenance strategy will be implemented depends on the future role that the waterway is expected to play and the funding decisions of both Canada and the U.S. It is clear that the system will continue to make a vital economic contribution to the region. The traffic currently moving through the system could not be transferred to road and rail without incurring congestion, inefficiencies and additional greenhouse gas emissions that would have a significantly negative impact on both economic efficiency and the environment. Traffic forecasts presented in this report show that the bulk trade presently carried through the system is likely to experience modest but steady growth.

Beyond that and within the context of the existing physical infrastructure, new opportunities are emerging from the possibility of introducing containerization into the GLSLS. However, in order to realize these opportunities, analysis shows that the *reliability* of the system must be maintained.

In order to maximize the dependability of the GLSLS, while making the most efficient and prudent use of public funds, a system-wide reliability analysis has been undertaken. Different system maintenance scenarios have been examined to evaluate their impact on reliability, their relative costs and their implications for marine freight traffic on the waterway.

Complementing the engineering perspective, the environmental component of the study compiled information necessary to determine the current condition of valued environmental resources that could potentially be affected by navigation-related activities on the system. It assessed the potential impacts of future traffic projections and different system maintenance scenarios. It then identified the kinds of management actions that are needed to minimize environmental impacts in the future.

This report summarizes the findings of the various study teams and working groups, and it synthesizes material taken from dozens of reports, studies and evaluations. It has deliberately been written in non-technical language to make the findings of the GLSLS Study accessible to the broadest possible audience of policy-makers and interested stakeholders.

The GLSLS Study has been a major, multi-year undertaking, involving more than 50 experts and authorities in a wide variety of fields. Ultimately, the understanding gained from their expertise can be used to inform Canadian and U.S. decision-makers who are developing strategies and options for ongoing system monitoring and maintenance. The analysis presented constitutes a solid foundation upon which to build a cost-effective and sustainable system-wide asset management strategy for the future.

Chapter 2

The Waterway

The Great Lakes St. Lawrence Seaway system is situated within North America's industrial heartland. Emerging in tandem with the development of that heartland, it has played and continues to play a vital role, not only in sustaining economic development throughout this region, but in supporting its international competitiveness. As an integral component of the region's overall transportation network and trade corridor, the system comprises many inter-related elements including locks, water channels, ports, ships, multimodal linkages, as well as organizations dedicated to its service and support. It is this complex interplay of diverse elements that must be addressed when forging a strategy to meet emerging challenges and ensure that marine transportation on the waterway continues its contribution to prosperity in the future.

As a major commercial artery, the Great Lakes St. Lawrence Seaway (GLSLS) constitutes an essential component of an integrated economic system that spans the basins of the Great Lakes and St. Lawrence River and extends into the surrounding hinterland. Indeed, the GLSLS system lies at the heart of what has become one of the largest and most dynamic economic hubs in the world. It serves producers and manufacturers that account for about one third of the North American economy. As a result, it is a region of high transport intensity with huge volumes of freight moving by road, rail, air, water or a combination thereof. Within this vibrant market, the GLSLS supports and strengthens regional, continental and intercontinental economic relationships by providing low-cost, waterborne, bulk transportation.

The economic importance of the GLSLS region[1]

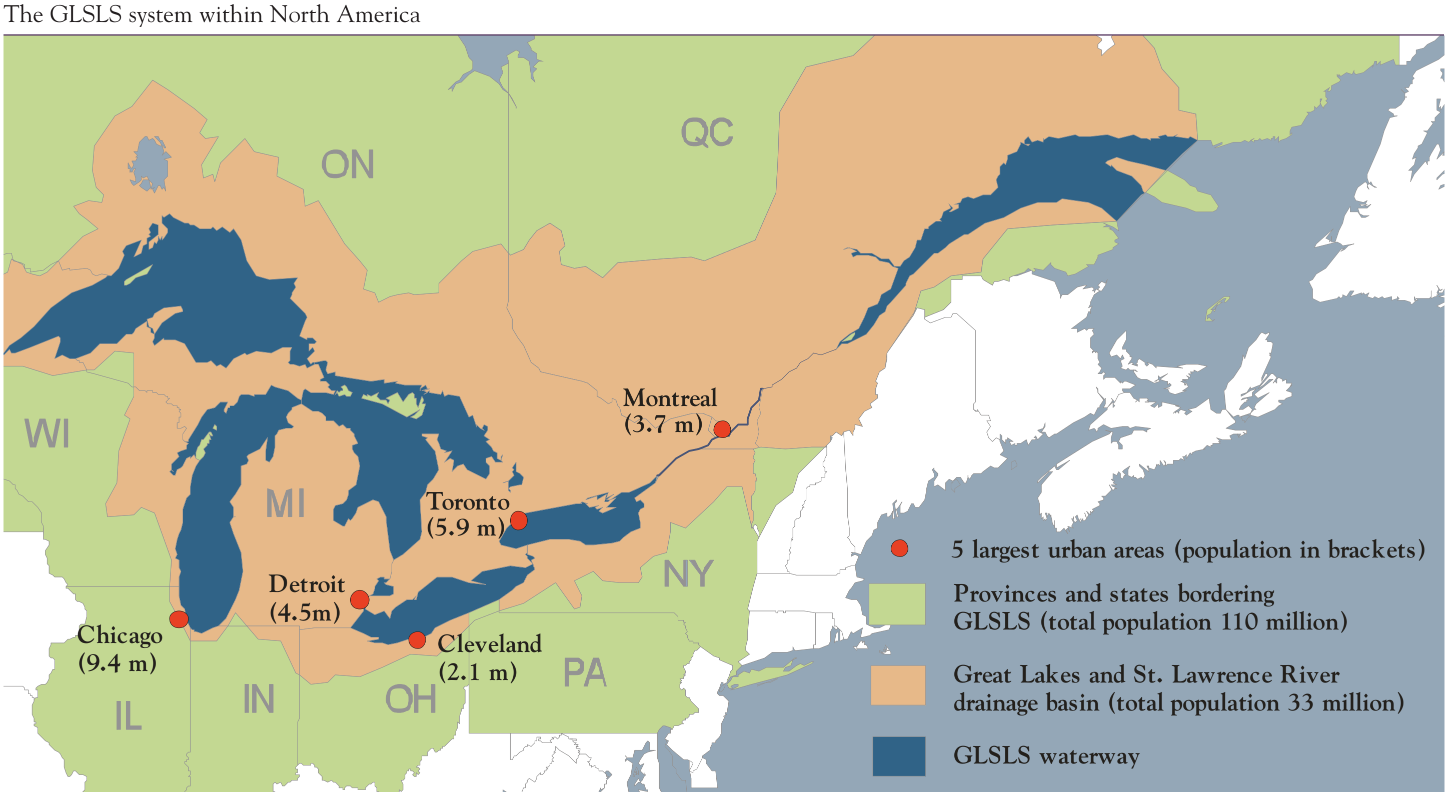
- 110 million people (one quarter of North America's population) live in the adjoining provinces and states (Ontario, Quebec, New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin and Minnesota).
- In 2006, Ontario and Quebec accounted for 58 percent of Canada's gross domestic product (GDP).
- In 2005, the eight states in the region contributed 28.5 percent to U.S. GDP.
- The combined regional GDP was $4.3 trillion in 2005.
- The region accounts for 55 percent of North America's manufacturing and services industries and about half of all North American retail sales.

System overview

The navigable waterway extends from the Atlantic Ocean at the Gulf of St. Lawrence through the St. Lawrence River and into all of the Great Lakes. It consists of channels through the St. Lawrence, Detroit, St. Clair and St. Marys rivers, which are dredged where necessary to provide adequate vessel draft. It also consists of canals and locks that allow ships to bypass the rapids and falls in these rivers. Measured from Sept-Îles, Quebec, in the Gulf of St. Lawrence to the lakehead at Duluth, Minnesota, this waterway extends a total of 3,700 kilometres (km) (2,300 miles). Its locks allow ships to be raised more than 180 metres (m) (600 feet) from sea level to the level of Lake Superior.

Figure 2.1

The GLSLS system within North America



1 Source: Statistics Canada and the U.S. Bureau of Economic Analysis.

Origins

Since humans first settled in the region, the waters of the Great Lakes basin and the St. Lawrence River have served as a transportation corridor. That corridor evolved in step with the developing needs of the Canadian and American economies. Initially, its primary function was to support internal linkages across the region. Eventually, it also came to provide North America's industrial heartland with direct access to the markets of the world.

Because the waterway presents significant changes in elevation as a result of rapids or falls, starting in the eighteenth century, canals and locks were built and re-built to circumvent these natural barriers. The culmination of this process occurred in 1959, when the Seaway was opened with locks large enough to carry freighters and ocean-going vessels efficiently throughout the system.

The original vision for the Seaway focused specifically on the grain and ore trades. By the 1950s, the ability of railways to haul bulk commodities had reached a capacity limit. Nowhere was this more evident than in an expanding grain trade. Grain from the Prairies had traditionally been hauled in small volumes by rail from the Lake Superior lakehead at Thunder Bay and Duluth or from the ports of Georgian Bay. From there, it was taken to Montreal and to other eastern ports for export or domestic use. With the world's grain trade growing, however, rail was no longer able to accommodate the rising volumes associated with this traffic.

Industrial expansion after World War II created another need for efficient regional and international shipping. This involved the movement of iron ore both from the Quebec-Labrador region into the Great Lakes basin, and from the Mesabi Range in Minnesota to mills in Indiana, Ohio and Ontario.

The need to move larger volumes of grain and iron ore cost-effectively was the impetus behind the long-planned development of the Seaway, a system of 15 locks able to support the passage of ocean-going vessels from the St. Lawrence River into Lake Erie. After four years of construction, the waterway became operational in 1959, opening up the North American industrial heartland to ocean-going shipping. The ensuing surge in traffic lasted for more than two decades and ushered in a period of rapid economic development throughout the adjacent provinces and states. Since its opening, the Seaway has moved more than 2.3 billion metric tons of cargo.

These improvements to navigation were paralleled by a similar expansion of capacity at Sault Ste. Marie, where navigation was impeded by a drop of 6.4 m (21 ft) as the St. Marys River falls from Lake Superior to the level of Lake Huron. Here, too, the original intent was to support the export of grain and agricultural products as well as ore and other raw materials. A key consideration at the time was to supply the American steel mills along the southern shores of the system with increasing amounts of iron ore and coke for smelting.

Upgrading of the Davis and Sabin locks at Sault Ste. Marie had occurred in the second decade of the twentieth century and the MacArthur Lock was opened in 1943. Development culminated, however, with the giant Poe Lock, which had been built in 1896, but which was rebuilt in the mid 1960s to handle large laker traffic up to 300 m (1,000 ft) in length; it was finally opened for navigation in 1969.

Opening of the Seaway in 1959.
Source: The St. Lawrence Seaway Management Corporation

The system today

The GLSLS system as it exists today is the culmination of centuries of systematic enhancements designed to move ships easily across a vast expanse of territory in which water falls more than 180 m (600 ft) as it flows from Lake Superior to the Atlantic Ocean. Since most of this change in elevation occurs over rapids or falls, a series of canals and locks have been built to raise and lower vessels across these natural barriers.

In addition to locks, the system depends on channels through the St. Lawrence, Detroit, St. Clair and St. Marys rivers. These are dredged where necessary to provide adequate draft for vessels moving through these passages. There is also a wide range of supporting infrastructure and services that include:

- port terminals, docks, loading facilities and port authorities;
- port services (docking, loading, unloading, etc.);
- marine navigation services, pilotage, and ice-breaking services;
- shipping companies, and shipping and logistic service providers; and
- various services associated with lock maintenance and support.

The GLSLS at a glance

Main waterways: the five Great Lakes, the St. Marys River, Lake St. Clair, the Detroit River, the St. Lawrence River and the Gulf of St. Lawrence

Waterway and port infrastructure: 6 canals, locks located at 16 different sites, serving 15 major international ports and more than 50 regional ports on both sides of the border

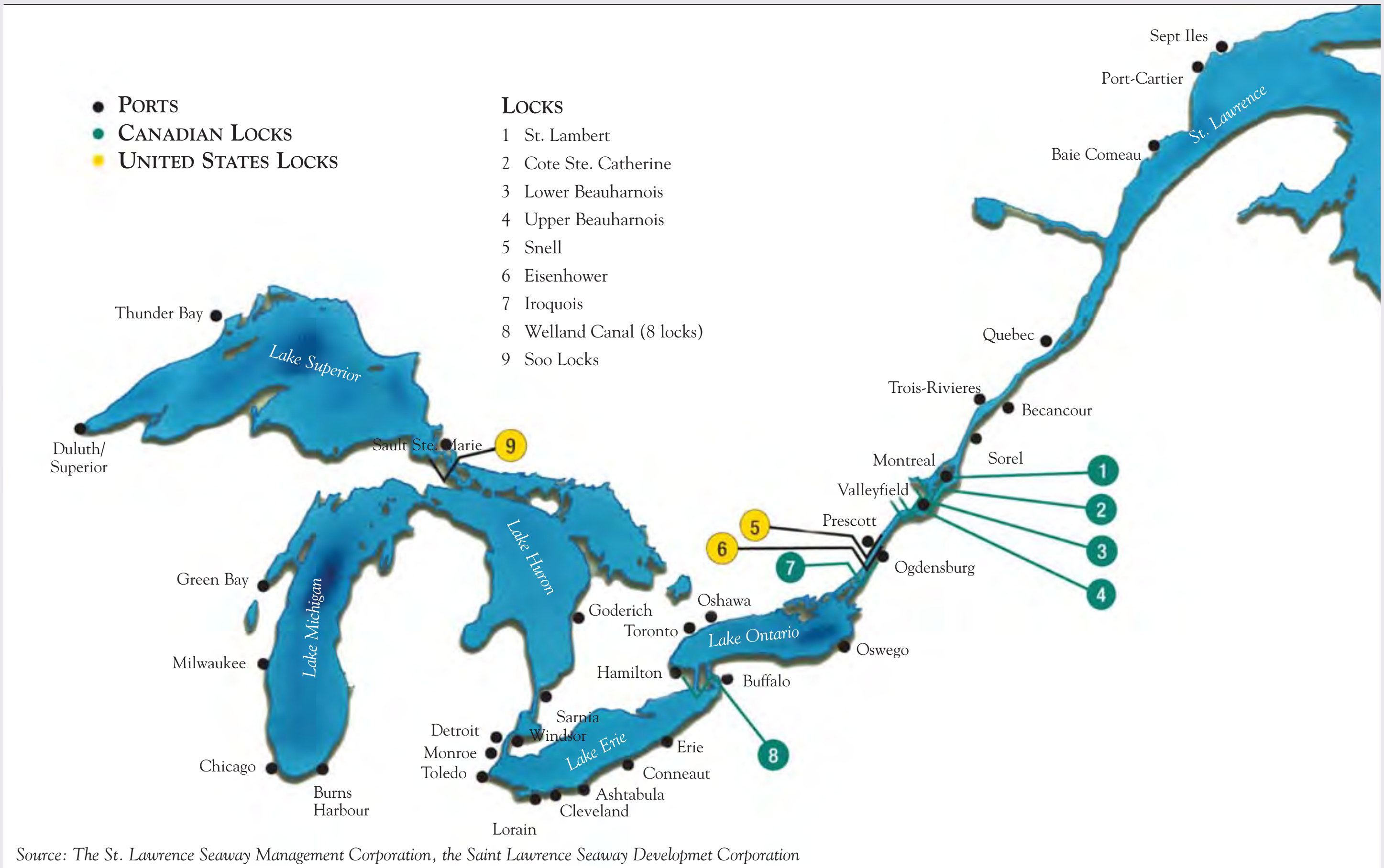
Cargo shipped through the Seaway locks since 1959: 2.3 billion metric tons valued at $350 billion

Cargo shipped through the Soo locks since 1959: 4.2 billion tons

Direct economic contribution: Every year, U.S. commercial traffic through the GLSLS system generates more than $4.3 billion in personal income, $3.4 billion in transportation-related revenue and $1.3 billion in federal, state and local taxes

Figure 2.2

Key features of the GLSLS system



Source: The St. Lawrence Seaway Management Corporation, the Saint Lawrence Seaway Developmet Corporation

Finally, the ports of the GLSLS serve as nodes in a vast multimodal transportation network that also includes more than 40 highways and 30 railway lines. As a result, the GLSLS is deeply embedded in the transportation infrastructure of the entire region.

The GLSLS system consists of four distinct sections: the Great Lakes, the Welland Canal, the Montreal-Lake Ontario section, and the St. Lawrence ship channel. Each of these is described in detail in the pages that follow.

FIGURE 2.3

Major highways and railways within the GLSLS region

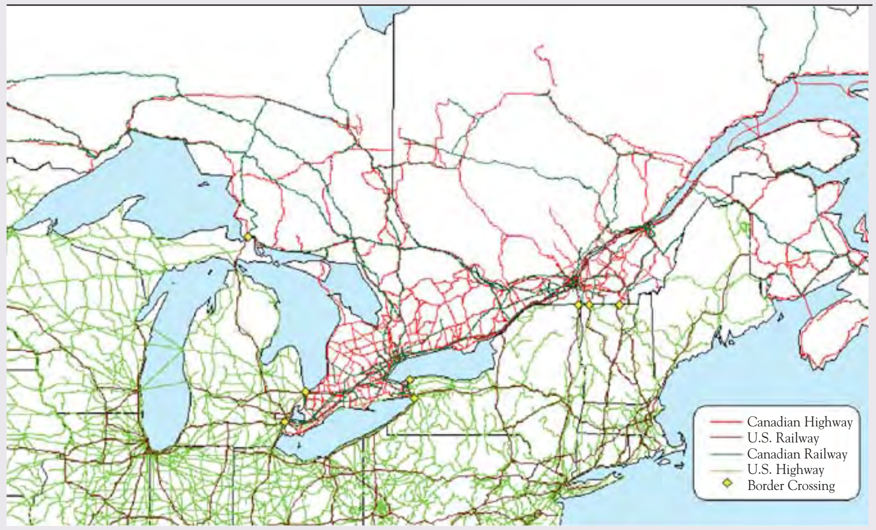
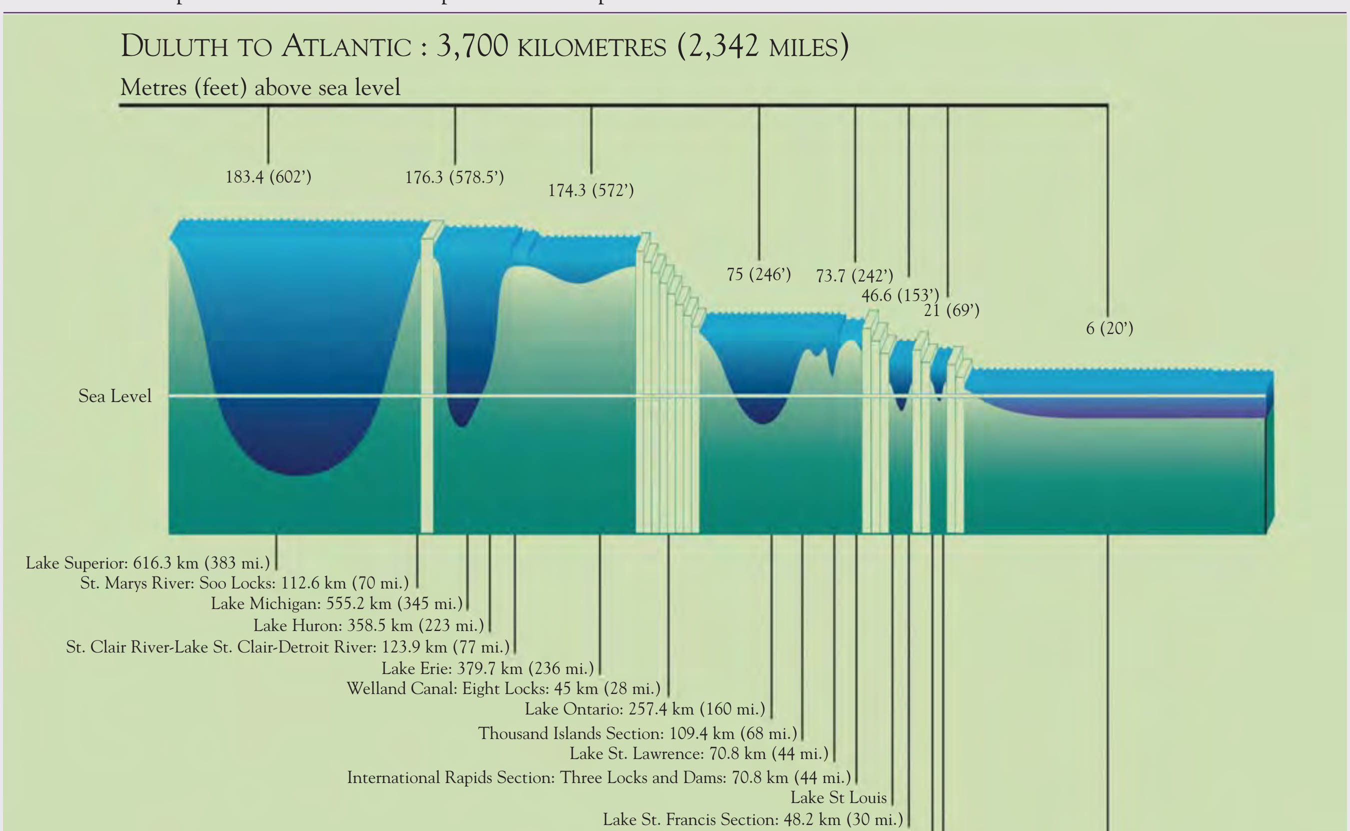


FIGURE 2.4

Schematic of the profile of the GLSLS in steps from Lake Superior to the Atlantic Ocean



Source: The St. Lawrence Seaway Management Corporation, the Saint Lawrence Seaway Development Corporation

The Great Lakes

This is the navigational system linking Lakes Superior, Michigan, Huron and Erie. It includes the connecting channels of the St. Marys River, the Straits of Mackinac, and the Detroit–St. Clair rivers system.

There are five locks at Sault Ste. Marie, though the small lock on the Canadian side is only used for recreational craft. On the American side, the Soo Locks consist of four parallel locks (Poe, MacArthur, Sabin and Davis), all of which are administered by the Great Lakes and Ohio River Division of the U.S. Army Corps of Engineers (USACE). At present, only the two largest locks, the MacArthur and the Poe, serve commercial navigation. The MacArthur Lock chamber can accommodate vessels of the "Seaway Max" class, which is 225.5 m (740 ft) long with a 23.8 m (78 ft) beam. The Poe Lock can accommodate "1,000-footer" vessels that are up to 308.9 m (1,014 ft) long with a 32 m (105 ft) beam. The draft available for shipping is nominally 7.77 m (25.5 ft), but this varies with fluctuations in lake levels.

Satellite photo of the Great Lakes
Source: SeaWiFS Project NASA/GSFC and GeoEye

Some facts

Compensating gates controlled by the International Joint Commission are used to regulate the water level in Lake Superior. The rapids just below these gates are important spawning grounds.

There are power canals and generating stations on both the Canadian and American sides of the river. This includes the Edison plant with its power canal running through Sault St. Marie, Michigan.

Lakers using the waterway serve three primary purposes: they carry iron ore and coal for domestic steel production; they transport coal for electricity generation; and they move limestone for cement production.

Because the upper lakes ships operate exclusively in freshwater, they experience less corrosion and enjoy life spans of up to 50 years as compared to 25 years for ocean-going ships.

Table 2.1

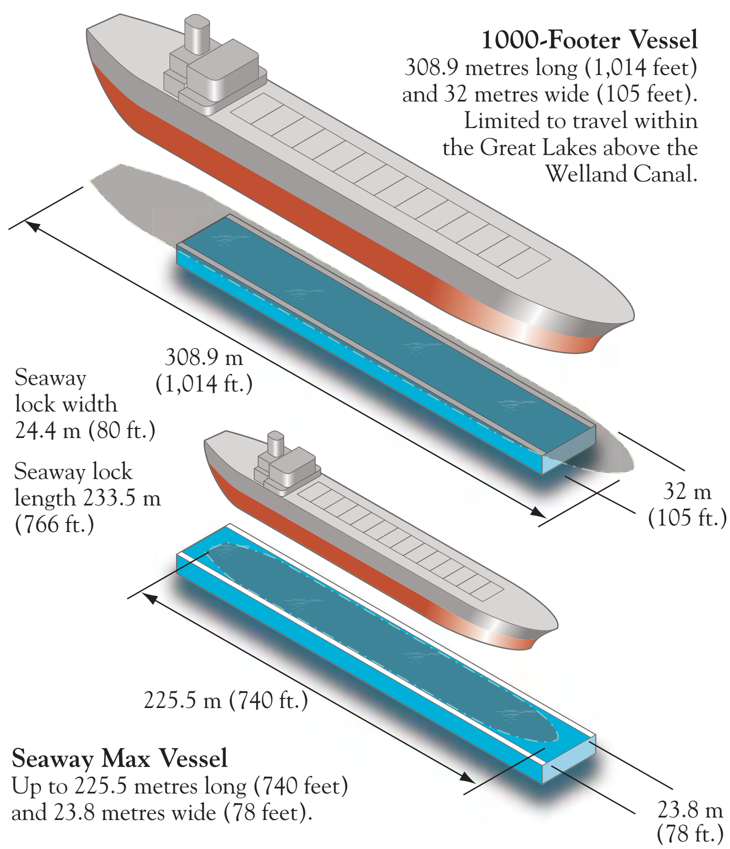
Lake characteristics

	Superior	*Michigan*	*Huron*	*Erie*	*Ontario*
Elevation in metres (ft)	182 (598)	176 (577)	176 (577)	173 (569)	74 (243)
Average depth in metres (ft)	147 (483)	85 (279)	59 (195)	19 (62)	86 (283)
Maxiumum depth in metres (ft)	406 (1,332)	282 (925)	229 (750)	64 (21)	244 (802)
Water area in km^2 (mi^2)	82,100 (31,700)	57,800 (22,300)	59,600 (23,000)	25,700 (9,910)	18,960 (7,340)
Shoreline length in km (mi)	4,385 (2,726)	2,633 (1,638)	6,157 (3,827)	1,401 (871)	1,146 (712)
Volume in km^3 (mi^3)	2,900	1,180	850	116	393

Bulk cargo vessels known as "lakers" and designed specifically for the Great Lakes dominate this waterway. The vast majority of vessels are self-unloading dry bulk carriers. Cargo is released through hatches that feed a conveyor belt running along the bottom of the ship. Bulk material is carried along the conveyor and lifted up and out onto the adjacent dock via a pivoting boom. This configuration allows vessels to unload their cargoes at a rate of up to 10,000 metric tons per hour without the need for any shoreside personnel or equipment. Among these is a fleet of 13 American "1,000-foot" lakers that are the longest ships on the GLSLS system. By far the single largest trade in the entire GLSLS system consists of the bulk cargoes of ore and coal carried by lakers from the Port of Duluth-Superior downstream as far as Lake Erie.

Aerial photo of the Soo Locks
Source: U.S. Army Corps of Engineers

Figure 2.5
Vessels of the Great Lakes



Vessels of the Great Lakes

Most U.S.-flagged domestic vessels ("Lakers") are by far the largest vessels on the Great Lakes, with some vessels over 300 meters (1,000 feet) in length. Their size prevents them from transiting the Welland Canal, and so they trade exclusively in the upper four Great Lakes.

Canadian-flagged domestic vessels ("Canadian lakers") are generally built to 'Seaway Max' dimensions, enabling them to call at ports throughout each of the five Great Lakes, the St. Lawrence River, and in some cases, ports outside the GLSLS system.

Seaway-sized transoceanic vessels ("salties") are approximately 180 meters (600 feet) long and able to enter the lakes from overseas, transit the St. Lawrence Seaway, Welland Canal, and all five Great Lakes.

The Welland Canal

The Welland Canal is one of the two components of the St. Lawrence Seaway, which connects Lake Erie and Lake Ontario to the St. Lawrence River and to the Atlantic Ocean.

The canal allows for navigation between lakes Erie and Ontario, bypassing the 99 m (326 ft) drop of the Niagara River at Niagara Falls. The Welland Canal is composed of eight Canadian locks extending over 42 km (26 miles). Its locks accommodate more than half of the change in elevation between Lake Superior and sea level. Port Colborne on Lake Erie, marks the upstream boundary of the Welland Canal with Port Weller on Lake Ontario as its downstream boundary. Its locks can accommodate the standard "Seaway Max" vessels that are 225.5 m (740 ft) long and 23.8 m (78 ft) wide. The canal's nominal draft is 8.08 m (26.6 ft).

Some facts

Navigation canals through Welland to bypass Niagara Falls have existed since 1829. This current system is the fourth of these canals.

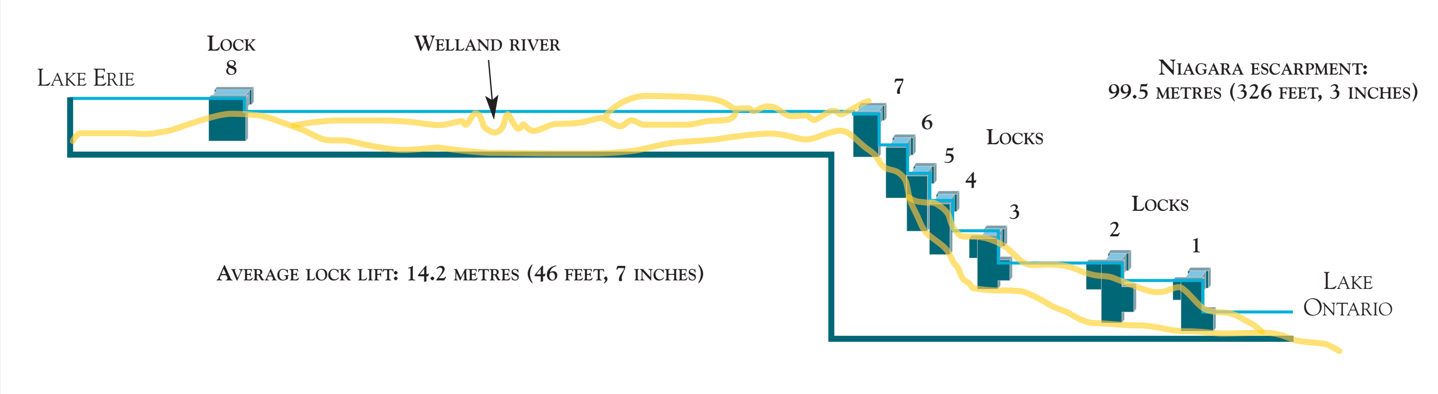
It was opened in 1932 and experienced minor modifications in the 1950s to adapt to Seaway specifications.

A siphon allows the Welland River to cross perpendicular to the canal by flowing underneath the canal in a large concrete culvert.

Twinned flight locks (Locks 4, 5, 6) climb the steepest portion of the canal. Flight locks are typically slower to navigate so they are twinned (parallel) to speed traffic. These flight locks and the Soo Locks are the only parallel locks in the GLSLS system.

One of the gates of the Welland Canal
Source: The Saint Lawrence Seaway Development Corporation

Figure 2.6
Profile of the Welland Canal



The seven lifts are located in the northern 11.6 km (7.2 miles) section of the canal, between Lake Ontario and the top of the Niagara escarpment. A 27.8 km (17.3 miles) man-made channel runs through level ground to the shallow-lift control lock at Lake Erie. Piers projecting into the lakes account for an additional 4.0 km (2.5 miles).

The Welland Canal provides more than half the lift needed between tidewater and the Lakehead.

Aerial view of the Welland Canal
Source: Thies Bogner, photographer

Closer view of the locks 4, 5 and 6 at Thorold (Welland Canal)
Source: Thies Bogner, photographer

THE MONTREAL-LAKE ONTARIO SECTION

The Montreal-Lake Ontario (MLO) section extends approximately 300 km (186 miles) along the St. Lawrence River from Lake Ontario to the Port of Montreal. Water from Lake Ontario falls a total of 74 m (243 ft) before it reaches sea level in the Gulf of St. Lawrence.

The MLO section consists of seven locks: the Iroquois, Upper and Lower Beauharnois, Côte Ste. Catherine and St. Lambert locks on the Canadian side of the waterway, and the Dwight D. Eisenhower and Bertrand H. Snell locks on the American side.

This section of the waterway carries both overseas imports and exports as well as bulk goods (ore, coal, minerals, etc.) moving within the system.

Vessel size is limited by lock geometry, which allows for a maximum vessel length of 225.5 m (740 ft) and a beam of 23.8 m (78 ft). Its nominal draft of 8.08 m (26.6 ft) is the same as that of the Welland Canal.

SOME FACTS

The Canadian Iroquois Lock is between the levels of Lake Ontario on its upstream side and Lake St. Lawrence on its downstream side. The small head difference at this lock permits the use of sector gates rather than the massive mitre gates used elsewhere in the system.

Upstream of Montreal is the Beauharnois Canal (21 km or 13 miles long). The Upper and Lower Beauharnois locks are located here beside the Beauharnois hydroelectric dam and generating station. Downstream of Beauharnois is Lake St. Louis and the City of Montreal.

The ship channel bypasses the Lachine rapids via the 22.5 km (14 miles) long Canadian South Shore Canal. There are two locks in the canal, Côte Ste-Catherine Lock at the upstream end and the St. Lambert Lock at the downstream end.

The two American locks are located between Montreal and Lake Ontario. They span the head difference controlled by the Moses-Saunders dam and generating station.

The upstream U.S. Eisenhower Lock is connected to the downstream Snell Lock by the Wiley-Dondero ship channel.

At the Eisenhower Lock, access to the Moses-Saunders generating station is obtained via a tunnel passing through the lock sill.

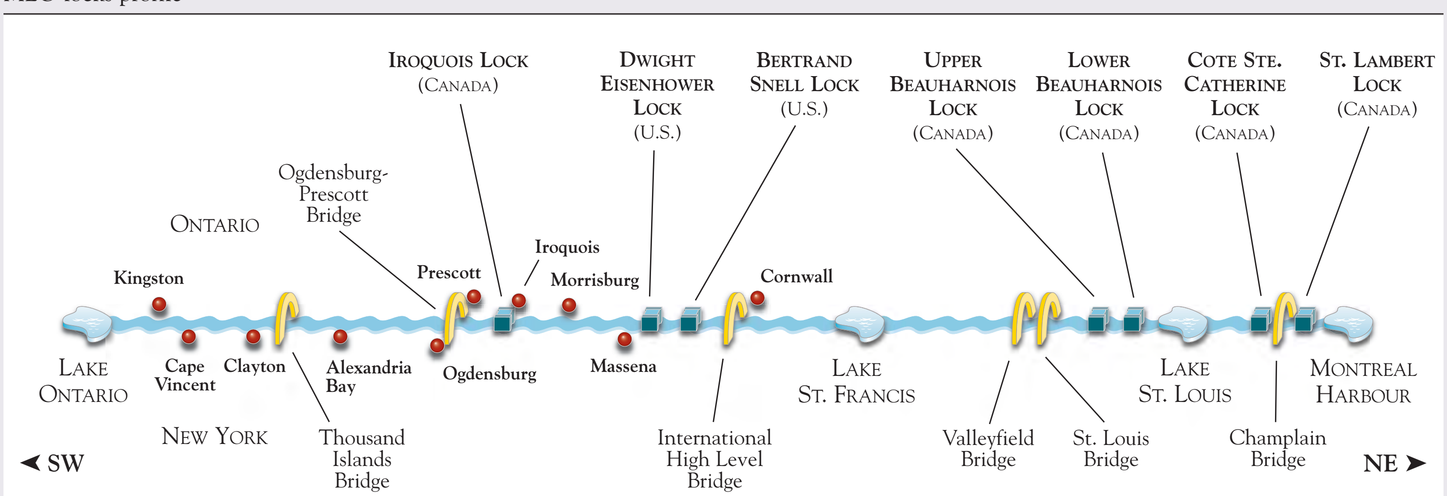
Aerial view of the Eisenhower Lock
Source: Saint Lawrence Seaway Development Corporation

The MLO section opened the North American heartland to international shipping, and vessels from all over the world now make their way to St. Lawrence and Great Lakes ports carrying the large quantities of finished products, manufactured iron and steel and general cargo imported by Canada and the United States. Return voyages can include a myriad of cargoes from the inland industrial centres.

The navigation season on the waterway extends generally from late March to late December. Since the Seaway opened in 1959, new technologies against ice formation in locks and canals have been implemented and more than 25 days have been added to the shipping season. Between the opening of the Seaway in 1959 and 2006, the Seaway carried more than 2.3 billion metric tons of cargo. The rational utilization of ships which may carry one commodity upbound (such as iron ore) and a different commodity downbound (such as grain) makes the Seaway a competitive mode of transportation for a wide variety of bulk products and project cargoes.

Aerial view of St. Lambert Lock
Source: The St. Lawrence Seaway Management Corporation

Figure 2.7
MLO locks profile



The St. Lawrence ship channel

The St. Lawrence ship channel is the navigation channel that is maintained downstream of the last lock of the GLSLS system. It runs between the Port of Montreal and the Gulf of St. Lawrence on the Atlantic Ocean. It has no locks and is open to year-round navigation.

Originally, ocean-going vessels could only reach Quebec City before their cargo had to be transshipped onto vessels with shallower drafts for passage into the interior. Most of the rapids along the channel became navigable with the advent of increasingly powerful steamboats able to navigate through them. Navigation across three particularly difficult sections (Montreal–Lachine, Pointe-des-Cascades–Coteau Landing, Cornwall–Dickinson's Landing) was made possible when canals were built there. The entire channel was systematically deepened throughout the 19th and early 20th centuries. As a result, Montreal replaced Quebec City as the leading port on the St. Lawrence River.

Some facts

The St. Lawrence ship channel has no locks and is open to year-round navigation. Icebreaking operations during winter months allow vessels to navigate from the Atlantic up to Montreal.

The majority of the commercial traffic flows includes vessels that are larger than the maximum Seaway size, like ocean-going vessels transporting containers or large bulk carriers.

The dredging performed in various points within the channel and at ports is necessary to ensure continuous safe navigation.

This natural channel is one of the most important ecosystems in Canada. The movement of ships takes them through different ecosystem components (rivers, lakes, estuary) that vary in terms of fragility.

The saltwater goes up to the eastern edge of Île d'Orléans, and this fluvial section is subject to tides.

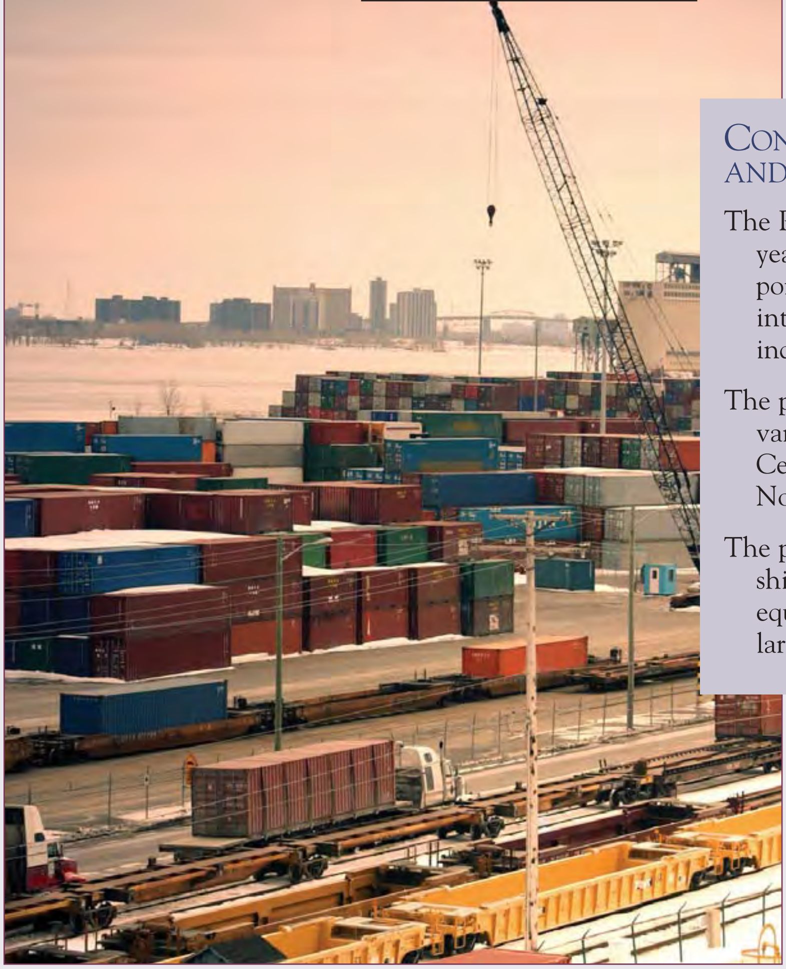
Vessel passing through the Lake Saint-Pierre, Quebec
Source: Environment Canada

Vessel arriving at the Port of Montreal, Quebec
Source: Environment Canada

Ship in ice
Source: Port of Montreal

Today, the St. Lawrence ship channel serves both shipping that is internal to GLSLS trade as well as the ocean-going traffic of vessels that are larger than the maximum Seaway size. The latter includes container ship traffic moving to and from the Port of Montreal as well as the large bulk carrier traffic (particularly oil tankers) serving the Port of Quebec. The nominal draft of the waterway from Quebec City to Montreal is 10.7 m (35.1 ft), but the navigation channel is maintained to a depth of 11.3 m (37.1 ft) to provide adequate clearance for ships.

Satellite view of the Gulf of St. Lawrence
Source: NASA, Visible Earth



Containerized cargo at the port of Montreal, Quebec
Source: Transport Canada

Container Ship Traffic Moving to and from the Port of Montreal

The Port of Montreal handles all types of cargo year-round and is a leader among the container ports serving the North Atlantic market, and the international port closest to North America's industrial heartland.

The port's containerized cargo is made up of a wide variety of products reflecting the industrial mix of Central Canada and the U.S. Midwest and Northeast.

The port typically handles ocean-going container ships with capacity up to 4,500 twenty-foot equivalent units (TEUs). These ships are too large to transit the Seaway locks.

System operation and management

Aerial view of the Beauharnois dam and power station, next to the Lower Beauharnois Lock.
Source: The St. Lawrence Seaway Management Corporation

Responsibility for management and operation of GLSLS system infrastructure rests with several government agencies and private enterprises.

The Government of Canada owns all of the fixed assets of the Canadian portion of the Seaway. The St. Lawrence Seaway Management Corporation (SLSMC), a not-for-profit entity established by Seaway users and other interested parties, has been contracted to assume responsibility for the operations and maintenance of the Canadian portion of the Seaway, including its 13 locks. To generate the revenues needed to operate and maintain the Seaway, the SLSMC is authorized to levy tolls and other charges. The agreement also provides for the SLSMC to recover additional funds from the government of Canada to eliminate operating deficits, when required.

The two American locks in the Seaway are operated and maintained by the Saint Lawrence Seaway Development Corporation (SLSDC), a wholly-owned government corporation within the U.S. Department of Transportation. The SLSDC is funded through appropriations from the Harbor Maintenance Trust Fund, which is the repository for revenues collected nationwide from harbour maintenance fees.

The Soo Locks on the upper Great Lakes are managed and operated by the U.S. Army Corps of Engineers. Its Great Lakes and Ohio River Division is based in Cincinnati and has seven districts, three of which (Detroit, Buffalo and Chicago) cover the American territory within the Great Lakes basin. Apart from management of the Soo Locks, USACE has also been given responsibility for water resource projects related to navigation, flood control, streambank and shore erosion, ecosystem restoration and protection, and the maintenance of ports and harbours.

Both the Canadian and U.S. coast guard services are active on the Seaway and in the Great Lakes. Both coast guards are responsible for buoys, lights, channel markers and sophisticated electronic positioning systems used by large commercial vessels. They also undertake some icebreaking activities on the waterway. The U.S. Coast Guard is charged with a series of enforcement and policing activities in all the coastal waters of the United States.

Non infrastructure support for the GLSLS system

Beyond the organizations with direct responsibility for the operation and maintenance of system infrastructure, there are numerous other government or private organizations that provide a variety of important services in the GLSLS system. Key services include:

- regulation of water levels by the International Joint Commission set up by Canada and the U.S.;
- customs and immigration services of both governments;
- health inspections by agencies of both governments;
- environmental protection and clean-up by a variety of government agencies;
- oversight of pilotage and navigation services by several pilotage authorities;
- oversight of shipping and carriage by several business associations; and
- economic development and business representation by organizations such as local chambers of commerce.

The number and diversity of these services reflects the significance and complexity of the system.

There are many ports in the GLSLS system, ranging from the very large to the very small. Major ports such as Montreal, Hamilton or Duluth-Superior handle millions of metric tons of traffic each year. In addition, there are smaller ports that handle significant volumes of traffic as well as ports that specialize in one or a few commodities.

The administration of the ports varies. In the U.S., ports may be administered by state authorities or by independent commercial operations. In Canada, the ports of the GLSLS system include the commercialized Canadian port authorities, local port authorities, private ports and those directly administered by government. In addition, facilities within ports may also be public or private and either specialized or able to handle a wide variety of cargoes.

GLSLS infrastructure is also governed by the seasons. In winter, ice clogs much of the waterway, closing the upper portion to navigation. Ice breaking, ice booms and other ice management activities allow for year-round shipping from the Port of Montreal out to the Atlantic Ocean. Above Montreal, in the St. Lawrence Seaway, ice breaking and other ice management activities are often required at various locations both early in the season and near its end, depending upon the severity of the winter and its related ice conditions. Generally, the Seaway from Montreal through to Lake Erie operates on a nine and a half month season, typically closing at the end of December and re-opening in March. On the upper Great Lakes, the Soo Locks generally are open for approximately ten months of the year. It is during winter closures of the GLSLS that major maintenance and rehabilitation are performed on the locks and canals.

The complex array of locks, canals, navigational channels and ports of the GLSLS system operates with a reliability of more than 98 percent. Slowdowns or closures occur less than 2 percent of the time. Approximately two-thirds of this downtime is weather-related (poor visibility, ice, wind). Vessel incidents cause one-quarter of the downtime. All other causes, including breakdowns, account for the remainder.

This high level of reliability can be attributed to the regular ongoing maintenance activities conducted throughout the system. The annual winter shutdown of navigation gives work crews an opportunity to conduct scheduled maintenance of the lock facilities. The lock systems have experienced minimal physical change over the past half-century. Inevitably, however, they are subject to the wear and tear of constant ship passages and sooner or later, components wear out and must be replaced.

Evolution

The GLSLS system achieved its current configuration with the opening of the St. Lawrence Seaway in 1959 and the re-opening of the rebuilt Poe Lock in 1969.

The assumptions underlying the development of the system at that time were relatively straightforward: traffic in the GLSLS was expected to consist of downbound grain from Canadian and American ports, and upbound iron ore moving from the Quebec-Labrador region to American and Canadian steel mills. This was the core of the original vision for the GLSLS and it remained valid for two decades of rapid economic growth. Eventually, however, this vision was supplanted because of fundamental shifts in the global economy.

The international marketplace underwent a series of dramatic transformations in the 1970s and 1980s. A revolution in agricultural productivity meant that the European Union (EU), East European and Russian demand for grain peaked in the 1970s and declined thereafter. At the same time, there was a shift in the focus of grain exports to the markets of Asia. The grain trade was also weakened by growing international conflicts over agricultural subsidies. As a result, demand for grain fell well below original expectations and the movement of grain through the GLSLS declined appreciably.

The decline in grain exports turned out to be a contributing factor in the observed decline in upbound iron ore shipments from Quebec-Labrador, since these had been used as a backhaul complement to the grain moving in the other direction. But there were other factors affecting iron ore. The regional and North American economies shifted away from primary industries and toward other forms of manufacturing as well as the service sector. That meant reduced demand for primary materials such as steel and thus not only a decline in the steel industry, but in the shipping of ore and coal needed to sustain that industry. This change was exacerbated by the dual effects of recession and restructuring, the latter spurred on by trade liberalization, which exposed regional industries to international competition.

The advent of globalization meant radical shifts in demand, markets and production. East Asia emerged as a manufacturing powerhouse, shifting the economic centre of gravity away from the Atlantic and into the Pacific. At the same time, the demands of competition drove the construction of larger oceangoing vessels that were simply too big to pass through the locks of the GLSLS system. Finally, general cargo ships were replaced by container ships that operated on tight schedules and made a limited number of calls, thus further transforming the competitive environment within which the GLSLS system operated.

Another set of fundamental changes occurred in the North American domestic transportation industry. The construction of the GLSLS system was paralleled by the development of a continental system of multilane expressways that made trucking the key element in commercial transportation and induced other transport modes to link to it. Increasingly, trucking was used when timelines were short and flexibility was critical. As the relationship between the Canadian and American economies developed in the wake of the Auto Pact, and then free trade, companies on both sides of the border used trucks to deliver key inputs “just-in-time” to subsidiaries or partners. The GLSLS system did not participate to any great extent in this intense intra-firm and intra-industry cross-border exchange of semi-finished and finished manufactured goods. But it has been indirectly affected by the growing congestion experienced along the highways that carry this traffic. Congested highways affect the operations of the GLSLS ports that link into them, but they also make the relatively uncongested GLSLS an appealing alternative for certain types of traffic.

Finally, it should be noted that in the 1960s, environmental issues did not carry the same weight that they have subsequently acquired and little was known about the potential environmental impacts of the GLSLS system. Physical changes to the waterway happened, for

Vessel being raised in a lock
Source: The St. Lawrence Seaway Management Corporation

Caption to come
Source:

the most part, some 50 to 75 years ago and the aquatic and nearshore ecosystems have largely adapted to these new conditions. Some effects, such as water level regulation, ship wakes, pollution, spill risk and non-indigenous invasive species continue to present environmental challenges. Such problems are the topics of extensive ongoing study by scientific and environmental personnel from both the U.S. and Canada. The findings of these studies are being used to develop new management strategies for the environmental challenges posed by commercial navigation.

The GLSLS system has faced numerous challenges and changes. Because it has been dominated by bulk commodity traffic, its evolution reflects the economic and geographic characteristics and trends of the iron, coal and grain trades. As a result, usage in the Seaway portion of the system increased steadily from its opening in 1959 until 1979, after which traffic began to decline. Even so, the GLSLS remains vital to several strategically significant industries in the region. For example, it remains critical for the region's steel industry, which in turn is a major driving force in the overall economy not just of the Great Lakes basin, but of North America as a whole. In addition, the GLSLS system has the capacity to carry twice the volume of its current traffic, an important potential asset for the future, given growing congestion on roads and railways in the region.

Challenges

The changes of the past half-century have presented the GLSLS with four distinct but interrelated challenges that form the basis of this study.

The first of these challenges is to determine what role the GLSLS should play within a highly integrated North American transportation system. The answer to that involves an analysis of markets and products to determine what goods can benefit the most from the transportation services offered by the GLSLS (see chapter 3). It involves an analysis of alternative modes of transportation to determine where the GLSLS enjoys a competitive advantage. And it includes a review of the continental transportation grid to determine how best the GLSLS can take advantage of multimodal linkages and opportunities (see chapter 6).

When moving goods from one point to another, marine transportation usually cannot cover the entire route from original source to final consumer. As a result, it needs to link to rail and road transport modes. The availability, efficiency and costs of such intermodal linkages determine when marine transportation is used by shippers. Increasing road and rail congestion in the Great Lakes basin presents an opportunity to off-load some traffic onto the marine sector; however, this opportunity is also constrained by the availability and efficiency of multimodal linkages.

The demographic shift toward increasing urbanization over the past 50 years has strained highway systems and there is now a widely acknowledged need to re-invest in transportation infrastructure. Left unchecked, congestion of North America's rail and highway systems may become a limiting factor in economic growth. Consequently, the ongoing operation of the GLSLS is essential to avoid transfer of its current cargo mix to already congested rail and highway networks. Moreover, the surplus capacity that exists in the GLSLS could provide significant relief to these other transportation networks.

The second challenge facing the GLSLS system is to keep up with changes in the transportation industry and the technologies that drive change in order to guarantee a dynamic future for the industry.

Four fundamental challenges

What role should the GLSLS system play within the highly integrated North American transportation system?

What transportation solutions are available to guarantee a dynamic future for the waterway?

What measures need to be taken to optimize the many different components of the system's infrastructure?

How should the GLSLS system sustain its operations in a way that responds to concerns about environmental integrity?

Over the past few decades, the railways have introduced significant improvements, especially to their container services. For example, significant enhancements have been made to "through services" from Montreal and Halifax, and new container lines are now serving ports on the U.S. East Coast, including the Port of New York/ New Jersey and the Port of Norfolk, Virginia. There is also continuous upgrading of highways in the region, though road improvements in urban areas confer little benefit on the trucking industry, since they are quickly absorbed by rapidly growing volumes of commuter traffic. Finally, coastal seaports in the U.S. are increasingly experiencing capacity constraints because they lack space and ground transportation infrastructure.

Set against these changes are new types of vessels that can enhance the competitiveness of the GLSLS system vis-à-vis other transportation modes. Faster vessels, container ships and self-unloading carriers are examples of new technological solutions that can restore the competitiveness of the GLSLS system. This issue is dealt with extensively in chapter 6 of this document.

The third challenge facing the GLSLS system is to optimize the many different components of the system's infrastructure, maintaining its operational viability in the face of the inevitable processes of wear and aging. Thousands of passages through the system's locks have left their mark on the components of the system. If the system is to continue to serve the industries of the region while providing an alternative to congestion in land-based transportation, then its components must be refurbished or replaced, ideally before they fail and interrupt traffic. The analysis of system components summarized in chapter 5 constitutes the basis of recommendations for a strategy for anticipating and mitigating such failures.

The final challenge is to sustain the operations of the GLSLS system in a way that responds to concerns about environmental integrity. Chapter 4 summarizes the key concerns about the impact of the GLSLS system on the region's environment. It is clear from this analysis that navigation is only one of the factors at play. The region in which the GLSLS system is situated is home to three-fifths of the Canadian population and one-fifth of the American population. There are also five major urban centers in the Great Lakes basin and St. Lawrence River. The diverse activities typical of these urban agglomerations have a profound effect on air, water and soil quality. As North America's industrial heartland, the region inevitably affects a variety of environmental features. Even the recreational activities that gravitate to the Great Lakes are responsible for their own set of impacts. The additional environmental stresses imposed by commercial navigation contribute to the cumulative environmental impact of human activities within the Great Lakes basin and St. Lawrence River, but they are only one of the factors at play.

The GLSLS region retains its role as a major manufacturing hub by continuing to maintain and improve its transportation infrastructure and service levels to focus on responsiveness, punctuality and reliability. It is an integral part of a major international, multimodal transportation network. In the case of many major mature industries, their goods and commodities flow from ship to rail and truck, and from rail and truck to ship in well-synchronized trade patterns. And for all industries in the region, the traffic that continues to flow through the GLSLS shows that the system continues to be a tremendous economic asset that must be renewed and maintained.

CHAPTER 3

The Economic Importance of the GLSLS

The Great Lakes St. Lawrence Seaway system continues to play a decisive role in the economic life of North America. The nature and size of the traffic passing through it remains imposing. Moreover, much of this traffic serves industries with specialized needs that make them highly dependent on the availability of cost-effective waterborne transportation. These industries are integrated into value chains stretching into virtually every sector of the North American economy, thus giving the traffic moved on the waterway a strategic significance beyond its already considerable dimensions. What is more, those volumes will experience moderate growth in coming decades, reinforcing the system's value to the North American economy.

The fate of the Great Lakes St. Lawrence Seaway (GLSLS) ultimately depends on the economic role that the system plays now and in the future. The size, significance, frequency, and nature of the traffic using the system will determine the type of maintenance strategy that is most appropriate for the needs of the GLSLS.

Recognizing this, the Economic Working Group of the GLSLS Study examined the size and nature of the traffic that has used the system since the middle of the 20th century, looking at changes in its cargo mix and direction. It then used a variety of models to project the kind of traffic that might be expected in the GLSLS over the coming half century. In developing these models, the working group examined both the internal dynamics of the system as well as foreseeable external trends likely to influence that traffic. Ultimately, the purpose of this part of the study was to define the economic significance of the GLSLS as input into the exercise of determining the infrastructure that will be needed to support that economic activity.

Evaluating significance

In evaluating the economic significance, the study considered the size and scale of the traffic that flows through the GLSLS today.

On the Canadian side, half of Canada's 20 largest ports are part of the system. On average, these ports handle approximately 55 million metric tons (Mt) or 40 percent of Canada's total domestic marine trade by volume and close to 60 Mt or 50 percent of Canada's total transborder trade by volume with the United States (U.S.). With respect to American domestic marine trade, more than 100 Mt is moved internally between ports on the system. This accounts for about 10 percent of all U.S. waterborne domestic traffic.

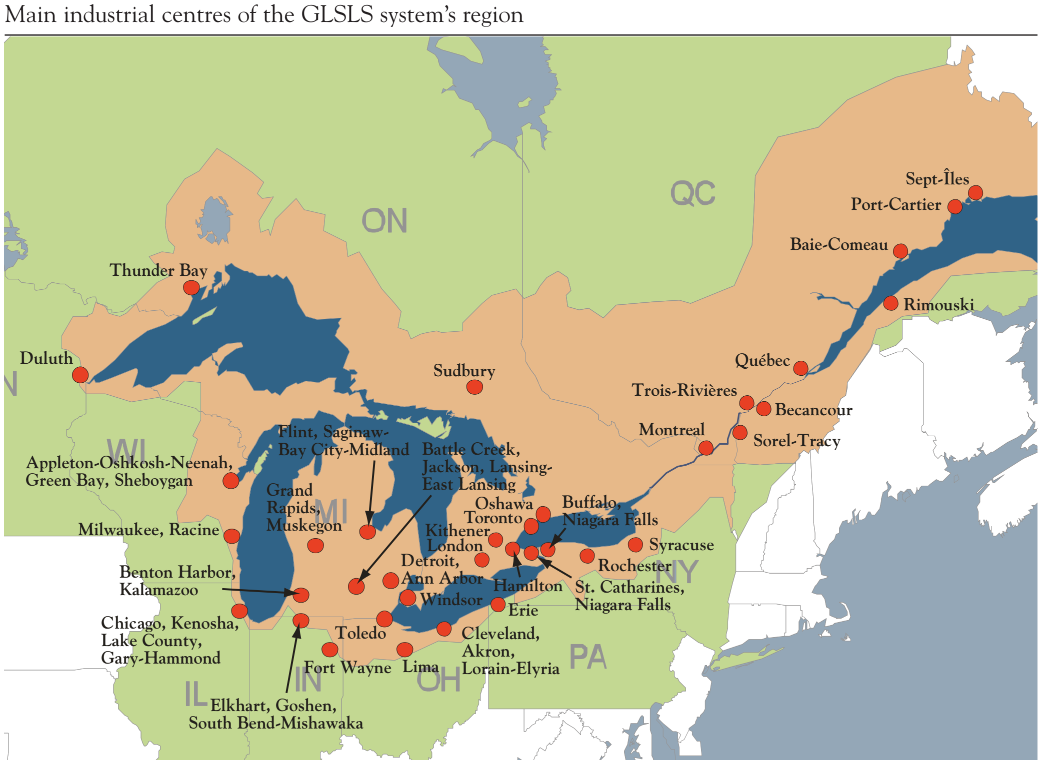
The true importance of the GLSLS, however, rests with the nature of its traffic: the prosperity of several sectors depends on the system. These include iron and steel, cement manufacturing, energy production, and agricultural exports. All of these industries depend on the availability of reliable, low-cost waterborne transportation. For example, the North American steel industry is clustered around the perimeter of the Great Lakes, as is the automotive industry that depends on it. Similarly, coal-fired electrical plants stretch along the shores of the Great Lakes, which offer a highly cost-effective way of providing them with the fuel they need.

In these cases and others, the GLSLS plays a vital role as a transportation corridor, providing industry with raw material inputs or offering a convenient and cost-effective way of exporting their outputs. In that sense, the GLSLS is the foundation of economic activity that has a multiplier effect throughout North America.

There are several ways of describing the traffic that moves through the waterway. The most fundamental of these is to look at the types of cargoes carried in the system. In addition, however, it is also possible to develop important insights by looking at the individual segments of the system or by considering origins and destinations of traffic. The study considered each of these in turn.

Figure 3.1

Main industrial centres of the GLSLS system's region



Cargoes

The commerce passing through the GLSLS today can be grouped into six broad cargo categories: grain, iron ore, coal, steel, stone and all other commodities. A separate feature of GLSLS traffic is containerized cargo (mostly concentrated at the Port of Montreal), carrying a wide variety of goods.

Grain

The possibility of strengthening North American agriculture by exporting grain internationally was a key factor driving the original construction of the St. Lawrence Seaway. To this day, grain originating on the Canadian and American prairies is moved by rail to Thunder Bay, Ontario and Duluth, Minnesota, from where it is loaded either onto lakers that move it to ports on the lower St. Lawrence for further transhipment, or onto ocean-going vessels for direct export overseas. A small portion of the grain is dropped off at various ports along the GLSLS. In recent years, grain produced in Ontario has started playing a somewhat larger role in the movement of grain through the Seaway.

FIGURE 3.2
Grain trade patterns

Historical grain traffic through the GLSLS peaked in the late 1970s and early 1980s. Subsequent market and structural changes have reoriented shipping patterns in this industry. Over 1998-2003, the GLSLS carried 12.5 Mt per year of grain, which amounted to approximately 10 percent of the combined total of all U.S. and Canadian grain exports. The GLSLS accounted for about 30 percent of Canadian grain exports, but only two percent of the total American grain exports, which overwhelmingly tend to move down the Mississippi and out through the Gulf of Mexico. Even so, the GLSLS continues to be a significant factor in maintaining North American agriculture.

Cereals Terminal in Montreal, Quebec
Source: Port of Montreal, Quebec

Determinants of grain traffic: Canadian grain traffic through the GLSLS is influenced primarily by changes in demand for grain in traditional markets in Europe, North Africa and the Middle East, Latin America, the U.S., other African countries and the former Soviet Union. Two key factors in this regard were the softening of demand for imported grain in Western Europe as a result of the European Union's common agricultural policy and the disappearance of demand for foreign grain in the former Soviet Union after 1993.

Beside these demand factors, the size of the grain movements via the waterway depends on the availability of alternative modes of transportation that offer competitive total costs and charges. In recent years, technological and legislative developments in Canadian grain transportation and handling systems have made it more cost-effective to move Canadian grain directly by rail from the Prairies to Quebec and American markets. The development of grain exports through the ports of the Pacific seaboard has also affected the proportion of Canadian grain exported via the GLSLS.

Most of the U.S. grain exported through the GLSLS is destined for Western Europe. In 1988, only 14 percent of U.S. grain exports to Europe moved through the GLSLS, but by 2004 this share had risen to 45 percent. This is, however, a larger proportion of a declining base: total American grain exports to Western Europe have declined from 12.7 Mt in 1988 to 4.9 Mt in 2004, which means that the absolute volume of American grain moving through the GLSLS has fallen. The GLSLS does play an important role as a safety valve, however. In years when the American grain transportation system reached limits on capacity, the GLSLS was able to accommodate the overflow. This has happened on several occasions, most recently in the aftermath of hurricanes Katrina and Rita in 2005.

The movement of grain through the GLSLS is influenced by broader changes in grain handling and transportation occurring at the continental level. Western Canada has experienced increasing commercialization of the statutory rail freight rate structure, closure of branch lines and country elevators, and the growth of large inland terminals. In the East, the railways have captured some of the grain traffic that lakers used to carry to the milling industries of Ontario and Quebec. This happened because the railways are able to supply smaller quantities at frequent intervals, saving millers from having to store boatload quantities of grain in elevators. The same preference for convenience is also being reflected in the increasing containerization of export grain, since millers and processors prefer to receive shipments in quantities that are easier to handle.

Rail transportation from the Prairies directly to Quebec City is a cost competitive alternative to the GLSLS, especially in the winter months when the latter is closed. However, given the large volumes of grain that move through the eastern transfer elevators, marine transportation should continue to predominate, especially since not all elevators are accessible by rail. Grain is also shipped by ocean-going vessels from Thunder Bay directly to overseas destinations at costs that are almost exactly comparable to moving the grain by rail from Brandon, Manitoba to Quebec City and then by ship. Since grain is often sold where it is available, the options of shipping direct from Thunder Bay or from a transfer elevator in the St. Lawrence River have additional advantages that are not reflected in a simple analysis of transport and handling costs.

Inputs to the iron and steel industries

The second major group of commodities passing through the GLSLS consists of inputs to the steel industry. The group includes iron ore, metalurgic coal and coke and limestone – all used in the production of steel.

Iron ore: In terms of raw tonnage, iron ore accounts for a larger proportion of GLSLS shipments than any other commodity. In 2004, about 40 percent of the tonnage carried through the GLSLS consisted of 103 Mt of iron ore from local sources.

FIGURE 3.3
Iron ore trade patterns

Ore from the Mesabi Range was shipped by laker via Duluth, Minnesota and Superior, Wisconsin and from Marquette, Michigan on Lake Superior. Most of it passed through the Soo Locks to steel mills in Illinois, Indiana, Michigan, Ohio and Ontario. In addition, ore from the Marquette Range was shipped through Escanaba, Michigan on the shores of Lake Michigan.

In 2004, the mines of the Labrador Trough in Quebec produced some 28 Mt of iron ore. Of this total, more than 11 Mt, about 40 percent, was sent upstream through the Montreal-Lake Ontario (MLO) section of the GLSLS with 5.5 Mt destined for Canadian steel mills and 6.1 Mt for the U.S. The remaining iron ore from the Labrador Trough was exported, primarily to Germany and the United Kingdom.

Metallurgical coal and coke: The major steel producers in Indiana, Illinois, Ohio and Ontario all use metallurgical coal. In addition, coke, which is derived from coal, is used in firing steel mill blast furnaces to provide the carbon and heat required to reduce iron ore to molten pig iron. Coke is also consumed to a lesser degree by the cement and aluminum industries. Most coke traffic is downbound, originating in the U.S. and moving to Canadian destinations for local consumption or for transhipment overseas. Major American ports of origin include Detroit, Duluth-Superior, Cleveland and Buffalo.
The major overseas sources of coke are European, particularly Italy and Spain. Since coke is integral to the iron and steel industry, fluctuations in coke traffic through the GLSLS follow fluctuations in the iron ore and steel industries as well as changes in the availability of Canadian domestic supplies.

Limestone: The producers of iron and steel also depend on supplies of limestone, which is used as an agent that reacts with and removes impurities during the production process. See the section below on stone for details about the position of limestone in GLSLS traffic analysis.

Iron and steel: The iron and steel passing through the GLSLS is imported from abroad and destined for Canadian and American ports on the Great Lakes. The volume of foreign, unfinished steel (e.g., slab) is overshadowed by the much larger volumes of finished steel (e.g., coil). Slab is generally destined for Hamilton and several U.S. Lakes ports including Toledo, Detroit and Burns Harbor. A small amount of American and Canadian steel moves through the Seaway for export overseas but the bulk of the region's steel production is consumed in local markets. The Seaway transports a small amount of steel passing between the U.S. and Canada, as well as steel moving within Canadian or American domestic markets. The volumes of steel shipments fluctuate in accordance with the health of the economy, which has a direct impact on American steel mills in particular.

FIGURE 3.4
Iron and steel trade patterns

Determinants of traffic: Ultimately, shipments of this commodity group depend on the demand for steel within the areas served by the GLSLS. Because these commodities constitute the core of the iron and steel industry, shipment volumes are heavily influenced by macroeconomic considerations and technological change as well as by the economic performance of the steel manufacturing and automotive industries that are the cornerstone of the entire region.

There have been several waves of restructuring in the North American steel industry over the past 20 years. This has resulted in fewer, but financially stronger, companies. Since 2004, the world economy, and China's economy in particular, have experienced strong economic growth. This has been associated with stronger demand for steel: North American steel usage has increased by almost 4 percent per annum between 1990 and 2003. As a result, world steel prices have risen. At the same time, increases in the costs of energy and raw materials have been offset by improved labour efficiency. The end result has been a more profitable industry that has the means to invest in new technologies associated with more efficient steel making as well as reduced environmental impacts. The industry is now producing new lightweight and high-strength steels, using less energy than before.

A variety of technological developments will strengthen the long-term sustainability of the industry but they also exert a decisive influence on related traffic through the GLSLS. In some cases, that influence actually diminishes traffic flows. For example, the growing use of electric arc furnace technology has made it economically feasible to reuse scrap metal more efficiently: approximately 51 percent of the iron now used to make steel comes from scrap, and this reduces overall demand for iron ore. The result is a reduction in iron ore shipments through the GLSLS.

Tending in the other direction, however are improvements in the capacity and efficiency of regional steel production as compared to international sources. These drive increases in GLSLS traffic. One example of this is offered by emerging techniques for converting ore to finished steel. Prior to the 1950s, the iron ore produced north of Lake Superior was high-grade hematite ore, typically with an iron content of 50 percent. As these deposits were depleted, production fell. In the 1950s, new techniques emerged for extracting and refining the region's abundant deposits of lower grade taconite ore, which has an iron content of 25-30 percent. The resulting marble-sized taconite pellets have an iron content of 60-65 percent. This new mining technology revitalized the production of ore from the Mesabi Range, which is now the mainstay of modern ore traffic in the GLSLS: approximately 95 percent of all ore shipped in the system is now pelletized.

New technologies are also being developed to produce iron nuggets using coal as a reduction agent in a rotary hearth furnace. If proven at the pilot-plant scale, this new technology could allow large-scale production of nuggets with an iron content of 97 percent. This could lead to significant energy savings and emission reductions in the steel making process, and could allow steel makers to use this processed ore directly in basic oxygen steel furnaces or electric arc furnaces. Such emerging technologies may serve as the foundation for a highly efficient third wave of steel making that could revitalize and sustain steel making within the Great Lakes basin.

Such technological developments will strengthen traffic through the GLSLS. Beyond technology, however, there are other drivers. For example, the imposition of American tariffs on steel imports from March 2002 to December 2003 significantly reduced the amount of foreign steel moving through the Seaway during the 2002 and 2003 navigation seasons.

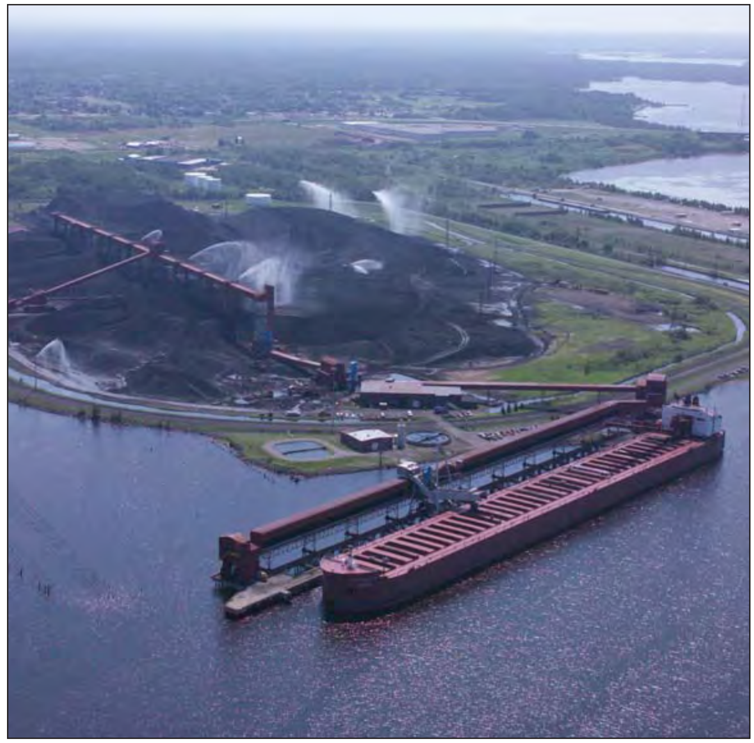
Ultimately, the volume of steel industry inputs passing through the GLSLS depends on both the competitiveness of local producers vis-à-vis international competitors, and the competitiveness of the GLSLS transportation system vis-à-vis alternative modes and routes.

In terms of industry competitiveness, local producers are holding their own. For example, Canadian producers of iron ore remain competitive as suppliers to the iron and steel industries on the shores of Lake Ontario, Lake Erie, Lake Michigan and the American eastern seaboard. Their competitiveness, however, diminishes as their distance to other markets increases. High transportation costs make them less competitive on the American Gulf Coast and in Europe. In 2004, 4 Mt of Quebec-Labrador iron ores were exported to Asia, as compared to 2.8 Mt a decade ago. This is because Asian clients are willing to offer preferential transportation rates on their vessels. However, any combination of a stronger Canadian dollar, higher freight rates on the St. Lawrence Seaway and/or higher energy costs could significantly reduce the cost-competitiveness of local iron ore producers.

The competitiveness of the GLSLS as a transportation system is reflected in factors such as locational advantages and transportation charges. The iron and steel industry arose in the Great Lakes basin because of the availability of low-cost waterborne transportation suitable for the movement of large volumes of bulk commodities. The volumes transported, however, fell in the early 1980s because of significant restructuring within the industry. Those volumes have now recovered as new technologies have come on line: they have been rising since about 2001 and are expected to continue doing so. As long as the iron and steel industry prospers in its current location, there will be an ongoing demand for transportation through the GLSLS. That is because it is unlikely that the huge volumes of iron ore or coal driving this industry can be shipped cost-effectively or expeditiously over the already congested rail or highway routes in the region.

Coal

Most of the coal passing through the GLSLS is destined not for the steel industry but for power generation. In 2004, the system carried 37.5 Mt of coal worth approximately $1.7 billion. Of this total, 94 percent was destined for power generation and only 6 percent was in the form of coke for the steel industry.



Midwest Energy terminal in Superior, Wisconsin
Photo: http://www.midwestenergy.com

> The Midwest Energy Resources Company coal transhipment facility at the port of Superior was opened in 1976 at a cost of $45 million. After completing the 1,100 mile journey from the Powder River Basin in Wyoming, trains carrying 13,200 metric tons of coal are discharged at the port facility in about 3.5 hours by the world's fastest single-car rotary unloader. The coal is then loaded aboard lakers at an average rate of 8,000 metric tons per hour.

Local power plants are especially interested in the low-sulphur coal from the Powder River Basin stretching across southeast Montana and northeast Wyoming. Coal from this region is transported by train to Superior, Wisconsin, where it is loaded aboard lakers that deliver it to electrical generating stations along the shores of the lower Great Lakes. One of the largest consumers of this coal is Michigan's Detroit Edison, which annually tranships approximately 20 Mt of coal through the port at Superior.

In addition, there is coal originating in Kentucky and West Virginia that is shipped from Chicago and from Lake Erie ports such as Ashtabula, Ohio. In fact, Ohio has emerged as the second largest transit point for coal shipments in the GLSLS. In 2004, it accounted for shipments of 20 Mt, 79 percent of which was destined for Ontario. Because it has no coal sources of its own, Ontario imports a total of about 21 Mt of coal a year

FIGURE 3.5
Coal trade patterns

(about 95 percent of all coal imported into Canada). Approximately 17 Mt of the coal imported by Ontario is consumed in power generation, 3-4 Mt is used in steel production and a small amount goes to other industries.

Determinants of coal traffic: Coal traffic through the Soo Locks and on the Upper Great Lakes has been driven by the availability of low sulphur coal from the Powder River Basin. At the port of Duluth-Superior, shipments have been growing steadily to the point that in 2005, volumes of coal (19 Mt) exceeded volumes of iron ore (17 Mt) for the first time in history. In the Seaway portion of the GLSLS system, coal shipments recovered after the closure of several Ontario nuclear generating plants increased demand for thermal coal in the late 1990s.

Coal shipments through the GLSLS have changed significantly over the past 50 years. Shipments through the MLO and Welland Canal have tended to be stable while shipments through the Soo Locks have risen significantly. The three lock systems, however do not encompass all of the coal shipped through the system traffic, since some of it moves through the lakes without passing any locks. Overall, however, the upward trend in coal shipments has been unmistakable. The system has adapted to these additional volumes by developing port facilities on Lake Superior capable of loading coal onto lakers at an average rate of 8,000 metric tons per hour.

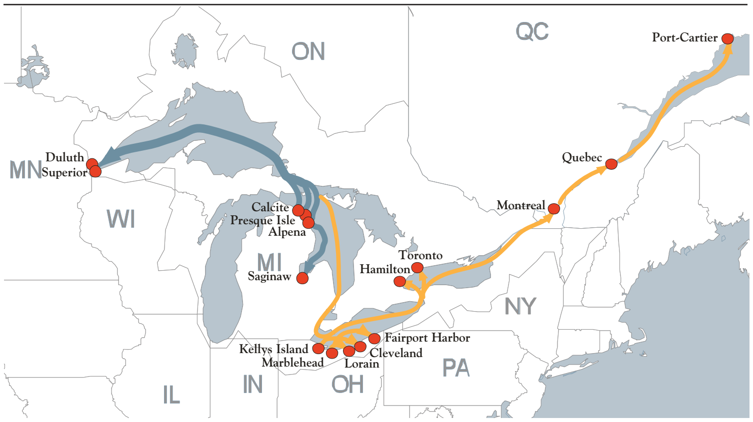
The growth of coal traffic in the GLSLS and the system's ability to accommodate additional volumes shows that it remains competitive for this commodity. It is possible to move coal by rail and continued improvement in railway efficiency, especially the deployment of higher capacity freight cars and new locomotives, has meant that direct rail transport can be less expensive than a combined rail-laker routing. The use of higher-capacity ships, however, has helped to keep this cost differential relatively small. In addition, marine transport through the GLSLS offers coal shippers the use of self-unloading lakers, a significant advantage over the need to develop facilities for unloading unit train loads of coal at the final destination.

Stone

There are two categories of stone cargo moving through the GLSLS system: limestone is used for its chemical properties in a variety of industries while other types of stone are used primarily in construction.

The market for limestone illustrates the interrelationships among the various commodities shipped through the GLSLS. Limestone has long been used in the steel industry, cement production and construction. However there is growing demand for limestone coming from coal-burning industries since it serves as an important reagent for the reduction of sulphur emissions through the use of scrubbers and fluidized bed combustion systems. As a result, growing demand for coal, coupled with more stringent emission standards for coal-burning facilities, has strengthened the demand for limestone.

FIGURE 3.6
Stone trade patterns



Most of the traffic in other types of Canadian and American stone is upbound through the Welland Canal and the Soo Locks. Downbound traffic moves from Canada and the U.S. through both sections of the Seaway to Canadian destinations. Because this stone is used in producing concrete and in highway construction, traffic volumes are affected by supply and demand factors determined by the general economic situation.

Other cargoes

The last major cargo grouping in the GLSLS consists of commodities such as petroleum products, chemicals, salt and cement. Common to them all is that consumption patterns and, therefore traffic volumes through the GLSLS, are determined by largely local demand. To take one example, the amount of salt shipped through the GLSLS in any given year is influenced by the severity of local winters and thus the need for salt on local highways.

Petroleum products: This category includes commodities such as crude oil as well as refined products such as gasoline and fuel oil. Refineries in Quebec import their crude oil requirements by tanker, while those located upstream of Montreal are generally supplied by pipelines, though this is supplemented by some imports carried on tankers. Between 1995 and 2003, traffic in petroleum products through the St. Lawrence ship channel grew by almost 20 percent to 20.6 Mt., driven largely by the increasing quantities of crude oil imported to the Saint-Romuald refinery in Quebec.

Almost all of the traffic in petroleum products between Montreal and Lake Erie originates in Canada and moves through the Seaway to Canadian and American destinations. Major Canadian ports of origin are Sarnia, Nanticoke and Montreal. Important destinations include Quebec City, Montreal, Cornwall and American coastal ports in New England. Across the border, some 60 percent of American petroleum product traffic originates in Indiana Harbor and is distributed to ports on lakes Michigan, Huron and Erie.

Chemicals: As a category, chemical products are more diverse than any other commodity group. This is mainly because they are used in a broad range of industries including automotive, metals, housing, fertilizers, plastics and glass. Chemical cargo tends to be downbound through both parts of the Seaway, moving from Canadian producers to destinations in Canada, the U.S. and overseas. Upbound flows are mainly from overseas to the U.S. as well as from Canadian and U.S. sources to other parts of Canada. Overseas cargo accounts for major variations from year to year. Major ports of origin include Sarnia and Windsor in Ontario, and Louisiana and Florida in the U.S. Major destinations include Toledo, Hamilton, Montreal, Morrisburg, Burns Harbor and Western Europe. Annual variations in Seaway chemicals traffic can be related to fluctuations in the business cycles of industries served and to the highly competitive nature of the chemical industry worldwide.

Self unloader laker vessel unloading limestone
Source: U.S. Army Corps of Engineers

Salt: The salt transported through the Seaway is mined mostly in the Goderich and Windsor areas of Ontario and shipped to several Ontario, Quebec and American destinations. Most of the salt traffic is downbound from Canadian and American origins to Canadian destinations. Salt is used to control ice on highways and to a lesser degree in the food processing industry. Annual variations reflect winter severity and growth in the demand for salt is related to the expansion and upgrading of road networks.

Cement: Cement tends to be upbound from Canada to the U.S. through the Welland Canal. Ontario dominates Canada's cement industry. Cross-border trade in cement varies considerably from year to year according to demand. Annual exports of cement to the U.S. amount to 3-4 Mt and account for about one-third of total Canadian production. Cement exports are mainly destined for the southern Great Lakes region and the northwestern Pacific region. Canada imports about 0.5 Mt of cement each year, primarily as part of cross-border regional trade. Cement traffic on the Seaway is affected by supply and demand as well as the overall economic situation.

After some years of initial growth, total traffic in these varied commodities has reached a point of stability. Some products in some segments of the system display marginal long-term growth: this is the case with salt and cement moving through the Welland Canal over the past three decades. Other products in other segments display trends moving in the opposite direction: shipments of petroleum products through the MLO section have contracted from 3.5 Mt in 1970 to only 1.4 Mt in 2004. Despite such variation, overall traffic remains stable. On both the Welland Canal and the MLO sections, annual non-grain, non-ore traffic has averaged just over 13 Mt since 1965 and traffic in individual years has not varied from that average by more than 3 Mt.

Emerging cargo movements: The bulk commodities traditionally carried through the GLSLS system have recently been augmented by new and diversified types of cargo movements. While the tonnages of these new cargoes remain relatively small, as a category, they reflect niche markets where marine transportation provides either direct, bottom-line benefits or serves as an efficiency-enhancing complement to surface transportation. The movement of aluminum ingots between Sept-Îles and Trois-Rivières is a good example of this new traffic: these shipments move from the St. Lawrence River to Great Lakes ports such as Oswego, New York and Toledo, Ohio. Forest products comprise part of the emerging marine trades along the St. Lawrence River. There is also growth in highly diversified non-traditional cargoes such as windmill parts, which are imported from overseas to inland ports like Hamilton, Ontario and Duluth, Minnesota, from where they are subsequently transhipped by truck. These emerging cargo movements reflect an interest in shortsea shipping as a means to improve utilization of existing waterway capacity and facilitate modal integration to help meet the commercial and socio-economic needs of client industries.

Containerized cargo

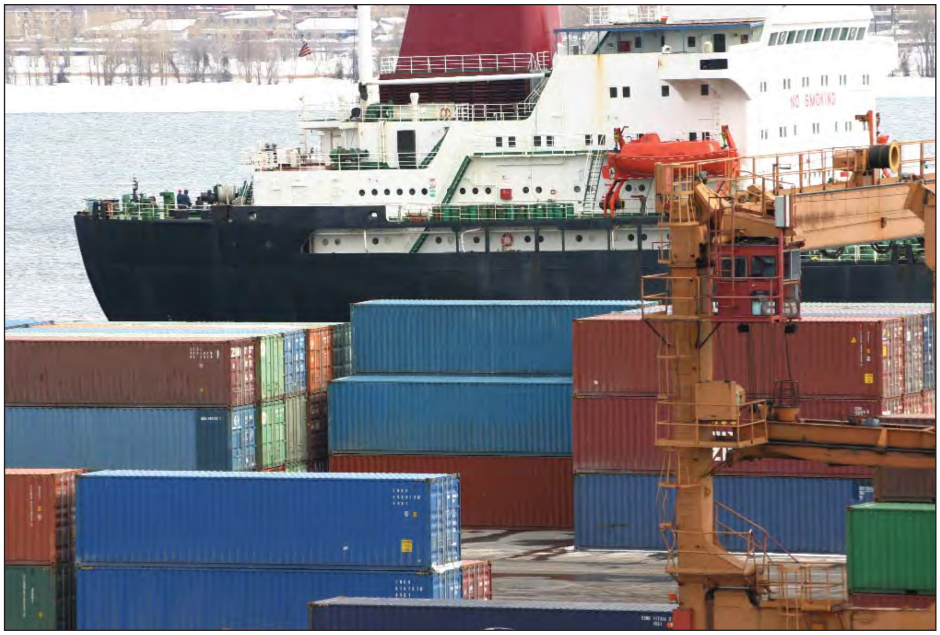
Containerized cargo in the GLSLS is mostly concentrated at the Port of Montreal. It consists of a wide variety of products reflecting the industrial mix of Central Canada and the American Midwest and Northeast. Items such as forest products, manufactured products, animal, and food and chemical products, accounted for most of the international containerized cargo passing through the Port of Montreal.

Approximately half of the port's containerized cargo traffic has its point of origin or destination in the Canadian market, mainly in Quebec and Ontario. The other half moves to or from the American market, mainly the Midwest (Illinois, Michigan, Minnesota, Wisconsin and Ohio) and the Northeast (New England and New York). Most of this containerized traffic is transhipped onto or from rail lines running inland to and from markets in Ontario and the American Midwest.

In terms of handling containerized cargo, Montreal ranks 5th among the ports of the North American Atlantic coast. Its hinterland consists of the most heavily industrialized region on the continent and huge manufacturing centres are found along the water, road and rail lines connecting to Montreal. Between 1993 and 2003, the general expansion in global trade contributed to a sharp worldwide growth in containerization. As a result, container traffic at the Port of Montreal grew from 0.57 million twenty-foot equivalent units (TEU) in 1994 to 1.11 million TEUs in 2003, an average annual growth rate of 7.6 percent.

Western Europe is by far the most important overseas market for the Port of Montreal's containerized cargo exports. In 2003, these exports totalled 4.2 Mt or 98 percent of all containerized cargo exports handled at the port. The port accounted for 34 percent of all container exports to Western Europe from the North American Atlantic coast.

Western Europe is also the most important overseas source of containerized cargo imports through the Port of Montreal. In 2003, Montreal's imports from this market totalled 4.9 Mt, or 98 percent of its total inbound containerized cargo. This accounted for 24 percent of all North American Atlantic coast imports from Western Europe.



Vessel unloading containers at the Port of Montreal
Source: Transport Canada

System segments

The three clusters of locks in the GLSLS define three distinct segments in the system: the Soo Locks sit athwart the traffic of the upper Great Lakes, the Welland Canal controls the passage of goods between the upper lakes and Lake Ontario, while the locks of the MLO section support traffic between the St. Lawrence ship channel and the Great Lakes.

It is important to remember, however, that the size of the locks determines the dimensions of the traffic. The relatively small locks of the Welland Canal and the MLO segments do not support the same scale of domestic bulk cargo traffic as do the much larger Soo Locks. Furthermore, because both the Welland Canal and the MLO section carry a significant amount of ocean going traffic, they are generally more sensitive to global economic trends.

Between 1995 and 2003, total cargo traffic through the GLSLS averaged 261 Mt annually. Of this, some 69 Mt passed through the Soo Locks, while the Welland Canal and MLO section saw about 37 Mt, and 35 Mt, respectively. Much of the traffic was internal, meaning that it was loaded and unloaded within the GLSLS system: the total tonnage handled by all of the ports of the GLSLS was about 440 Mt.

As Figure 3.7 shows, about 26 percent (76 Mt) of cargo traffic in the GLSLS originates and terminates in the lower St. Lawrence River and thus involves no lock passages. A further 27 percent is internal traffic, which originates and terminates within the Great Lakes (e.g., traffic on lakes Michigan, Huron and Erie), again without any lock passages. Taken together, the three lock systems at the Soo, Welland and MLO account for about 47 percent of total GLSLS cargo traffic, an average of about 108 Mt per year (based on 1995-2003 statistics).[1]

Another way of looking at traffic through the GLSLS is by commodity groupings. Figure 3.8 represents total average annual tonnages for the six basic cargo groups in the system in the period between 1995 and 2004. Iron ore and concentrates accounted for approximately 40 percent of total volumes and stone was second with about 20 percent. Coal accounted for 15 percent of the total, grain – 7 percent, steel – 3 percent and all other cargo for 17 percent.3 Shipments of cargo are essentially an internal trade, since the overwhelming proportion of this cargo remains within the system. By contrast, steel tends to reflect imports of various semi-finished steel products, primarily from Europe.

There is considerable variation in the traffic mix at each of the three lock systems. Traffic at the Soo Locks is dominated to an overwhelming extent by ores and ore concentrates. By contrast, traffic at the Welland Canal displays a balance among different commodity groups, while grains and ores feature prominently at the locks of the MLO.

Figure 3.7
Average annual tonnage shipped 1995-2003 (millions of metric tons)

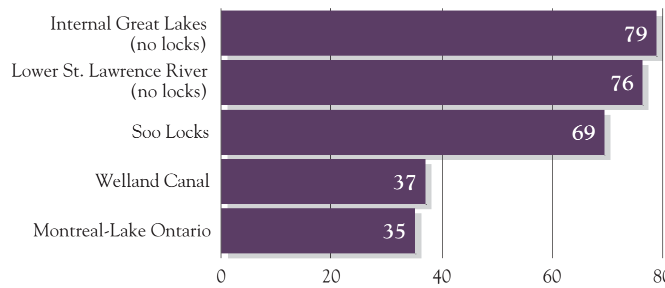
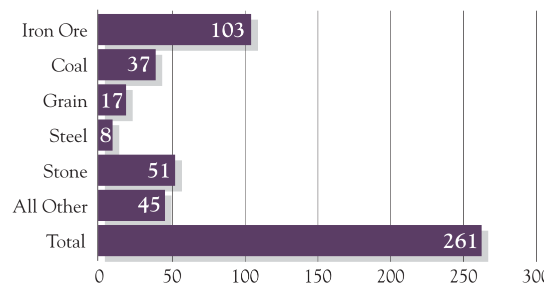


Figure 3.8
Average annual tonnage shipped 1995-2003 (millions of metric tons)



1 Note that this 108 Mt is lower than the sum of the traffic through each of these three lock systems since some of the traffic goes through more than one lock system.

It is also possible to trace a certain pattern of movement through the three lock systems of the GLSLS. The nine Mt of grain that pass through the Soo Locks on an annual basis is destined for export, so the same 9 Mt is seen passing through both the Welland Canal and MLO section of the Seaway.

A closer study of the data underlying the figure reveals that the iron ore and coal trade at the Soo Locks is downbound, inasmuch as it originates in Minnesota-Michigan and Wyoming, respectively, whereas the iron ore passing through the MLO section is upbound since it originates in the Labrador Trough.

Other determinants of traffic

The GLSLS system's primary commercial strength is that it provides low cost transportation to industries that move bulk commodities in high volumes. This has led to the establishment and growth of industries, the competitiveness of which depends on direct access to that low cost transportation capability.

There is also a stability inherent in the transportation requirements of these businesses. Primary industries such as steel mills, cement plants, and sugar and oil refineries represent significant capital investments. Once established, they are not likely to move operations elsewhere. Thus the GLSLS has a captive client base for a significant portion of its operations. Even though the sources for certain raw materials such as coal, iron ore, and coke may change from time to time, both the supply and the demand sides of the equation depend on low cost marine transport.

Set against the background of this relatively stable core business, there are other factors that affect the size and nature of the traffic that moves through the GLSLS.

Backhaul opportunities

Certain types of GLSLS traffic are affected by the availability of suitable backhaul opportunities. It is fundamental to all modes of transportation that operational efficiency is optimized when there are full loads moving in both directions during any trip. This principle can apply to seemingly unrelated cargoes. For example, when there is a growth in American imports of steel through the GLSLS to ports on Lake Erie and Lake Michigan, there is a corresponding growth in the export of American grain from Duluth in the other direction, since grain serves as a backhaul for ocean-going vessels bringing in the steel.

This relationship can also have a negative impact. As already noted, shifts in world markets and domestic production have meant that the GLSLS is no longer viewed as the main conduit for Canadian grain exports. More processing and consumption is done on the Prairies, while ports such as Vancouver and Prince Rupert on the Canadian West Coast have emerged as major grain export centres. As a result, the amount of Canadian grain available on the Great Lakes has declined over the past decade. In the absence of this backhaul opportunity, many smaller trans-oceanic vessels have become more reluctant to sail into the Great Lakes and that has resulted in a shortage of trans-oceanic capacity in the system for moving other types of cargoes.

Canadian ore remains highly popular due to its quality, price and proximity. In the past, iron ore was considered a backhaul for Canadian lakers carrying grain. With the decline in grain, however, it has emerged as a headhaul and the most important cargo in the GLSLS system. Its seasonal nature does not seem to be an impediment since, with the exception of the Dofasco steel facility at the Canadian port of Hamilton, Ontario, the dock facilities of all the regional steel mills rely on self-unloading lakers, which are not practical in winter months when the ore freezes in the vessel's hopper.

Competition

There are a variety of competitive factors that act as significant determinants of traffic in the GLSLS. Alternative routes, different modes of transportation, rates, availability, and reliability all play a role in influencing traffic flows.

The movement of grain in the GLSLS is influenced by competing alternatives. Besides the GLSLS, Canadian and American grain is moved via several other routes and modes of transportation. Rail is used to move Canadian grain to Canada's Pacific ports, to the northern port of Churchill, to the eastern export ports on the Atlantic and lower St. Lawrence and to the U.S. In the U.S., grain is transported to the Gulf of Mexico via the Mississippi barge/rail system, and by rail to Atlantic and Pacific seaboard outlets.

Another competitive factor relates to the supply of and rates charged for ocean going transportation. Because ocean-going grain carriers operate in a free market, rates rise and fall according to changes in demand for services and the supply of vessels. Thus the extent to which the GLSLS can offer grain exporters available transport and competitive rates is directly affected by the global demand for and supply of ships of an appropriate size.

There is also fierce competition among world ports for container traffic. On the supply side, shipping lines continually attempt to augment their operational efficiency by reducing costs and by attracting larger volumes of containers. They employ larger ships and they use routes that involve more efficient ports of call.

Given such competition, it is important to note that the GLSLS enjoys a decisive competitive advantage. The system has surplus capacity, and it is thus in a position to absorb additional traffic at a time when competing modes are feeling the effects of congestion and constraints on capacity. For example, Canadian railways are facing significant congestion on the rail lines from Toronto to the Detroit/Windsor gateway, while the trucking industry is becoming increasingly frustrated by traffic congestion in the Greater Toronto Area and at border crossings between Ontario and the U.S. As these pressures increase, shippers may be increasingly interested in shifting some of their cargoes to waterborne routes.

Traffic in the Greater Toronto Area
Source: Transport Canada

Technology

There are two ways in which technology affects GLSLS traffic. On the one hand, changes in technologies associated with shipping alter the cost structures and competitiveness of waterborne transportation. These effects are discussed in Chapter 6 of this document. On the other hand, technological change within the industries served by the GLSLS can alter the mix of cargoes supplying these industries.

Limestone offers an example of how technological change influences the size and direction of certain classes of shipments. Limestone quarries produce stone used in steel making, cement production and construction.

Cement companies usually own their own quarries from which they extract their raw materials. Where possible, these are located on a waterfront and as close to the cement plant as possible. In this case, demand for limestone is directly linked to the demand for cement, which is affected by the general level of public construction activity and government investment in public infrastructures.

On the other hand, the steel industry uses high-grade limestone in the production of iron ore pellets and, as a fluxing agent, in the manufacture of steel. In this case, technological changes in how steel is made could reduce the need for fluxing limestone over the longer-term.

A technological change can also affect demand for coke. It is likely that North American steel producers will eventually switch from blast furnaces to electric furnaces or to a pulverized coal injection process which does not require coke. As a result, the production and carriage of coke is likely to continue declining.

Finally, in the case of coal, concerns about the environment play a decisive role. Currently such concerns have strengthened the demand for low-sulphur coal and shipments of this through Duluth-Superior have risen rapidly. Environmental concerns about the use of fossil fuels, especially as regards the emission of carbon and other substances, make coal's longer term future dependent upon the implementation of carbon capture technologies.

Forecast based on existing traffic mix

Under current conditions and given observable trends in market demand and regional transportation patterns, the volume of traffic through the various parts of the GLSLS system should experience a slow but steady increase. Even if nothing else changes, which is to say, even if no new cargoes or shipping technologies are introduced into the GLSLS, there will still be a significant amount of economic activity that will continue to depend on the GLSLS. Thus the system will be needed to support that traffic. The following section analyzes this scenario. It should, however, be seen as a baseline. There is also the possibility of new cargos and new transportation technologies being introduced into the GLSLS, which will raise demand for its services. That possibility is explored in Chapter 6.

Forecast methodology

To confirm the assumption that there will at least be a slow but steady rise in the demand for transport services through the GLSLS, forecasts were prepared of the traffic mix expected up to 2020 at the MLO section, the

Welland Canal and the Soo Locks. Using historical data up to 2003, the forecasts focused only on the existing cargo and traffic mix and explored three potential scenarios: pessimistic, most likely and optimistic. They also incorporated assumptions about the economic conditions and other factors that are likely to affect GLSLS traffic up to 2020. The methodology used in preparing these forecasts combined both quantitative and qualitative econometric techniques directed toward the analysis of markets as well as the region and its industrial complexes. Each commodity was analyzed separately and the methodology applied was adjusted to the specific characteristics of each commodity.

First, world demand and supply for the major commodities using the GLSLS were analyzed and projected. Next, the North American balances between domestic supply and demand were estimated and the exports, imports and domestic shipments that could move via the GLSLS were segregated. The weight of the combined factors that influence the selection of the mode(s) and route(s) through which the cargo could move was applied in order to estimate the GLSLS' share of this movement. Validation and testing of the equations consisted of running a correlation of estimates with past movements. More empirical means, such as smoothing forecasting techniques were used to extend the traffic forecast from 2020 to 2050.

It should be added that this forecasting process incorporated the following assumptions:

- There will be annual growth rates of 1.1 percent for the population, 3.3 percent for the economy as a whole, and 5.9 percent for international trade. These estimates are based on World Bank global economic prospects and the International Monetary Fund's economic outlook, along with data from Global Insight and Transport Canada.
- Liberalization of trade and globalization of business will continue.
- The American economy will grow at 2.6 percent (conservative) and 3.0 percent (optimistic) with the most likely growth rate of 2.8 percent. It assumes the American industrial production index should grow between 2.8 percent and 3.8 percent. The Canadian economy is assumed to grow between 2.3 percent and 2.6 percent, and the Canadian industrial production index should increase between 2.6 percent and 3.4 percent. The exchange rate for the Canadian dollar against the American dollar should average 1.28 fluctuating between 1.27 and 1.29.[2]
- Strategic initiatives to enhance the competitive position of the GLSLS should counterbalance equivalent activities in other modes; and the system's tolls and other related costs will not be increased to levels that could negatively affect GLSLS traffic.
- Fluctuations in Great Lakes water levels will follow the trends of the past 20 years; there will be no major strikes or accidents; and there will be no major political, social or economic disruptions.

Changes in one or more of these major conditions could alter the results of this forecast. For example, emerging world trade blocs could reduce internal trade barriers while raising external ones, thereby prompting trade wars between blocs and weakening international trade. In this case, North American trade would suffer and patterns of traffic through the GLSLS would change.

Shifts between the *most likely* traffic forecast and the *pessimistic* forecast could frequently happen during the forecast period, depending on conditions prevailing at a certain point in time. The *optimistic* traffic forecast is the least likely to occur and represents the maximum traffic potential currently possible. This forecast could, however, be useful in evaluating system capacity.

Forecast results

As shown in the Figures 3.9, 3.10 and 3.11, traffic in bulk commodities through the GLSLS system is expected to increase gradually through to the year 2030 and to grow steadily for the 20 years thereafter.

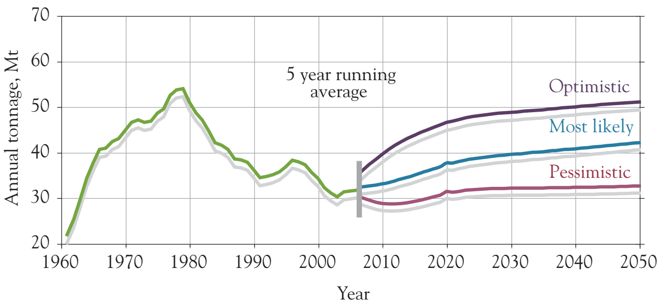
The data summarized in Figures 3.12, 3.13 and 3.14 show the forecasted shifts in the mix of existing commodities expected in the MLO section, Welland Canal and Soo Locks up to the year 2050.

Montreal-Lake Ontario section: In the case of the MLO section, the relative proportion of most cargoes should remain more or less the same over the coming decades, with the exception of steel, which is expected to experience an increase from 9.3 percent to 16 percent of total tonnage. Grain should continue to be the largest cargo category moving through the MLO section, followed by iron ore, other commodities, steel and coal. The current relative proportions of the various commodities are not expected to change appreciably.

2 At the time of printing of this report, the value of the U.S. dollar has declined relative to the Canadian dollar and many other currencies. Hence, U.S. exports to Canada (and other countries through the Seaway) will rise so long as they stay competitiely lower in price, while Canadian exports to the U.S. will decline in response to their rising cost in U.S. dollars.

FIGURE 3.9

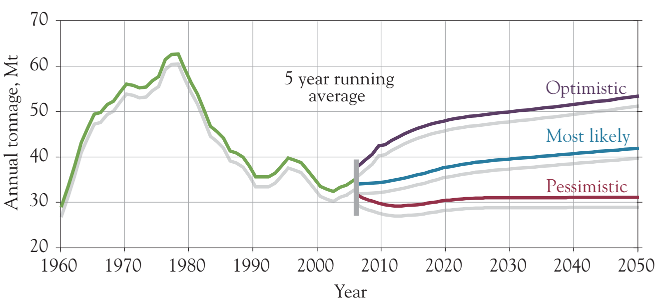
Traffic forecast for the Montreal – Lake Ontario section to 2050



Cargo traffic through the MLO section is expected to grow at average annual rates of 0.1 percent, 0.7 percent and 1.1 percent under the pessimistic, most likely and optimistic scenarios, respectively, reaching 33 Mt, 42 Mt, or 51 Mt by 2050.

FIGURE 3.10

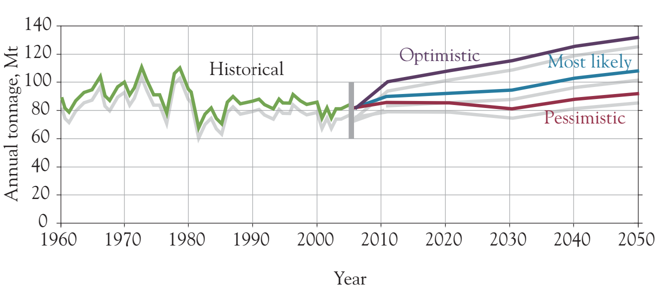
Traffic forecast for the Welland Canal to 2050



On the Welland Canal, traffic is expected to grow by 0.0 percent, 0.5 percent and 1.0 percent under the pessimistic, most likely and optimistic scenarios, respectively, to reach 32 Mt, 42 Mt or 54 Mt by 2050.

FIGURE 3.11

Traffic forecast for the Soo Locks to 2050



Traffic at the Soo Locks is more heavily influenced by domestic rather than global economic trends. It is expected to grow at an annual rate of 0.3 percent, 0.7 percent and 1.3 percent under the pessimistic, most likely and optimistic scenarios, respectively, reaching 91.4 Mt, 107.3 Mt or 131.3 Mt by the year 2050.

Welland Canal: The category of "all other" commodities is expected to assume a slightly greater prominence in the Welland Canal, moving from 34.5 percent to 38.1 percent of total tonnage by the year 2050. Similarly, steel tonnage is expected to rise from 5.6 percent to 10.6 percent, and grain from 24.5 percent to 29 percent, while coal and iron ore will become less prominent in the mix.

Soo Locks: In the case of the Soo Locks, iron ore should continue to be the largest cargo category until about 2030, after which coal traffic is expected to overtake it. This will reflect increased demand for coal-based energy as a result of increasing demand for electricity. Iron ore and coal are expected to reverse their positions at the Soo Locks by 2050. Coal will rise from 26.6 percent to 41.7 percent of total tonnage, while iron ore will fall from 52.3 percent to 36.4 percent by 2050.

It should be noted that the preceding forecasts all address the traffic that is expected to pass through the locks of the MLO, the Welland Canal, or the Soo Locks. There is also a significant volume of traffic that moves between different ports on the Great Lakes without ever passing through any one of the lock systems. It is expected that this traffic will follow the same general trends as the Soo Locks forecast, since the commodity mix and market factors influencing these cargo levels are fairly similar.

Ultimately, the GLSLS forecast, based on the existing traffic mix for the three GLSLS system locks indicates modest, but steady, growth up to 2050.

The competitiveness of the GLSLS

The trends in cargoes and tonnages summarized in this chapter reflect the interplay of complex economic forces. Within this shifting landscape, however, the competitiveness of the GLSLS system as an alternative to other modes of transportation always depends on its reliability and its relative cost.

Reliability

The cargoes shipped through the locks of the GLSLS system feed a network of industries within the central portion of the Great Lakes basin and St. Lawrence River region. The health of these industries depends, in part, on the extent to which the supply of the raw materials shipped through the GLSLS remains reliable.

Most of the locks of the GLSLS system are arranged in a series. There are only two instances (one at the Soo Locks and one in the Welland Canal) where there are parallel locks that could provide redundancy in the event that one of them fails for any reason. In the rest of the GLSLS, however, the failure of any one lock gate or wall can lead to an unscheduled closure of a large part of the system, and significant economic impacts on the industries served. In effect, a lock failure at any point along the system would create a bottleneck that would halt all traffic until it was resolved.

Given this reality, it is encouraging to note that the GLSLS system remains highly dependable. The complex array of locks, canals, navigational channels and ports of the GLSLS system operates with a reliability of more than 98 percent. Slowdowns or closures occur less than 2 percent of the time. Approximately two-thirds of this downtime is weather-related (poor visibility, ice, wind). Vessel incidents cause one-quarter of the downtime. All other causes, including lock failures, account for the remainder.

Cost

The cost of providing waterway service is a critical competitive factor. Overall marine transportation costs include the capital and operating costs of both the vessels and the system infrastructure. System infrastructure costs are accounted for in the assessment of alternative maintenance scenarios as part of the benefit-cost analysis. Vessel operating costs are imbedded in the existing transportation rate that shippers pay for waterway transportation service. The vessel operating cost, or waterway linehaul cost, is estimated using vessel costing models which use hourly vessel operating costs specific to vessel type and commodity together with estimates of transit times between specific ports of origin and destination. The ability to measure the effect of changes in transit time on transit costs is important, because the level of investment or maintenance in the system affects transit times. Less reliable systems will result in longer transit times, which in turn will result in higher vessel transportation costs.

Rate analysis and shipper survey

Vessel costs and transportation rates can be used to calculate the transportation benefits offered by the GLSLS. A comprehensive transportation rate and traffic analysis was performed using a 2002 sample of 857 shipping movements. These are origin-destination-commodity triplets, each with an annual flow exceeding 18,000 tons. The sample covered more than 40 different commodities and comprised a total of 163 Mt of shipping; representing roughly 90 percent of total tonnage through the GLSLS in 2002. The study used fourth quarter 2004 cost levels to compute economic effects on a National Economic Development (NED) basis. The freight rates computed for each movement are all-inclusive from origin to ultimate destination, including truck or rail legs to/from the water, loading, trans-loading and unloading charges,

FIGURE 3.12

Forecast by commodity for Montreal – Lake Ontario section to 2050 (most likely scenario)

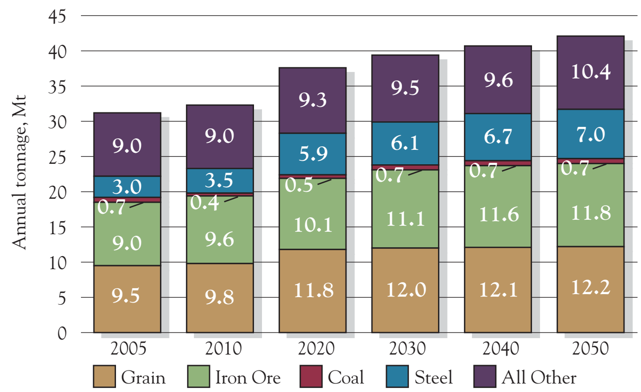


FIGURE 3.13

Forecast by commodity for Welland Canal to 2050 (most likely scenario)

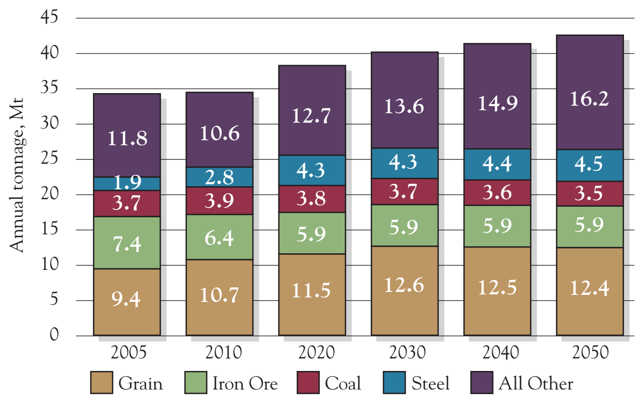
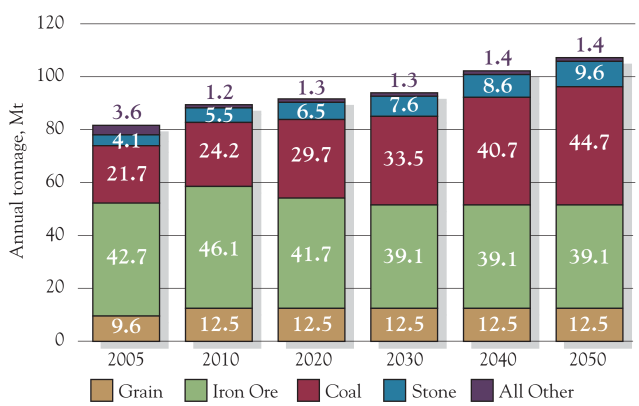


FIGURE 3.14

Forecast by commodity for Soo Locks to 2050 (most likely scenario)



and the main linehaul rate (vessel, rail or truck). The result offers a concise and reliable estimate of the transportation cost savings provided to industry by the GLSLS system. These estimates are limited, however, in that they do not account for the competitive effect that waterway rates have on overall rate structures in the region, nor do they capture any benefits associated with alleviating congestion on highways or rail at border crossings.

The study provides a breakdown of shipper cost savings for 10 different commodity groups (see Table 3.1). For some commodities, the savings represent the difference between breaking even and profitability. For example, the GLSLS offers savings of $17.37/ton for wheat. This is 12 percent of the market price of wheat, assuming typical wheat prices of $150/ton. It offers savings of $9.35/ton for iron ore. This is 23 percent of the market price of ore, assuming typical ore prices of $40/ton. Such economic advantages are large enough to be a significant factor in the economic competitiveness of the agricultural and steel sectors.

Overall, the GLSLS offers shippers an average savings of $14.80/ton in transportation and handling charges compared to the next-best, all-land transportation alternative. For the period reviewed, the GLSLS system saved shippers a total of $2.7 billion in transportation and handling charges that they would otherwise have incurred had they used other modes of transportation.

The regional breakdown of shipper savings for the system is shown in Table 3.2. This table includes the savings for traffic that passes through each lock system as well as for internal Great Lakes traffic that does not pass through any navigation structures.

Table 3.1

Transportation savings offered by the GLSLS by commodity[3]

Commodity Group	*Sample size Tons*	*Savings/ Ton*	*Total savings**
Aggregates and Slag	37,813,000	$16.03	$605,988,000
Metallic Minerals and Ores	62,395,300	$9.35	$583,464,000
Coal, Coke, Pet Coke	40,783,600	$13.36	$544,961,000
Iron, Steel and Other Metals	12,872,200	$32.49	$418,219,000
Non-metallic Minerals	8,883,600	$19.50	$173,224,000
Wheat	8,046,500	$17.37	$139,776,000
Petroleum Products	3,932,500	$18.60	$73,137,000
Other Grains and Feed Ingredients	1,819,400	$28.20	$51,330,000
Soybeans	1,691,800	$22.26	$37,667,000
Corn	1,169,300	$23.61	$27,614,000
Total	**179,407,200**	**$14.80**	**$2,655,360,000**

* in descending order of total shipper savings, numbers rounded to nearest 1,000

Table 3.2

Transportation savings offered by the GLSLS by region

Commodity Group	*Sample size Tons*	*Savings/ Ton*	*Total savings**
Soo Locks	83,921,100	$12.98	$1,089,296,000
Welland Canal	29,746,000	$20.11	$598,277,000
Montreal-Lake Ontario	26,822,000	$22.74	$609,812,000
Internal Great Lakes Traffic not transiting a lock	69,832,000	$15.37	$1,073,488,000

* numbers rounded to nearest 1,000

3 The rate analysis did not include movements in the lower St. Lawrence River, though it did factor in movements into and out of the Seaway.

Costs of unplanned closures

The rate analysis provided in the previous section also points to the economic impact of unplanned short-term closures in different parts of the system. The analysis involved interviews with shippers in the field to determine their likely responses to such closures. The cost to shipping of such closures can then be determined by comparing GLSLS costs with those of the next best available alternative.

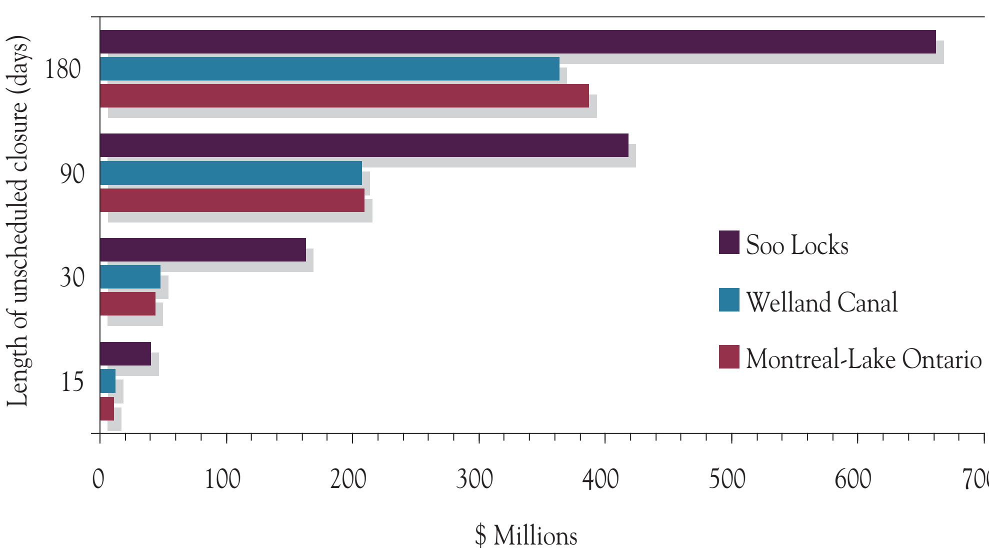
For closure lasting up to 30 days, the primary impact would likely be delays in the movement of cargoes since shippers would be more likely at this level to wait out the closure. Closures in excess of 90 days, however, resulted in a modal shift to rail or truck, or both and they could also involve shifting cargoes to different ports on the East Coast or the Gulf of Mexico. Generally, long-term closures would lead shippers to select an all-overland transportation option.

The estimated costs incurred by shippers due to the various unscheduled closure scenarios are presented in Figure 3.15. A 15-day closure could reduce the cost benefit to shippers offered by the GLSLS by $10.9 million in the MLO section, by $12.1 million at the Welland Canal, and by $41 million at the Soo Locks. A 180-day closure would cost $387 million, $363 million and $661 million respectively.

This information provides an estimate of the benefits of providing a reliable system. Saving money by implementing a more austere maintenance plan has to be balanced against the frequency of unexpected closures, which result in higher transportation costs. The trade-off between upfront investment in infrastructure and transportation savings is the heart of the economic analysis.

One important finding that can be gleaned from this closure analysis comes from analyzing the daily cost of closure. Short closures (15 days or less) cost less than the annual average daily benefit offered by the system (most shippers just wait out the closure). Long closures (90-180 days) cost the same per day as the average daily benefit (as would be expected). The response to a 30-day closure is somewhat different, because of the cost implications of a short-term re-routing. The Soo Locks, in particular, see a significant cost impact for a 30-day unscheduled closure. This is associated with the captive nature of the coal and ore trades in these locks and the difficulties involved in re-directing such massive volumes through alternative routes. The other locks in the system are not nearly as sensitive to closures, as the daily costs of closure are essentially equal to the daily net benefits offered by the system. This reduced sensitivity to closures in the lower Great Lakes reflects the relative availability of alternative transportation in the region, making shifts in modality relatively inexpensive. An important exception to this, however, is the steel industry in Canada. System closures would close the steel mills as there is no other supply option available.

FIGURE 3.15
Estimated costs of unscheduled lock closure



Conclusions

For half a century, the GLSLS system has played a vital role as a major transportation corridor serving the commerce of the Great Lakes and St. Lawrence River basins. During that time, its role has evolved to accommodate changing economic circumstances and its economic contribution remains significant on a regional and national level. Even so, the GLSLS remains focused on the delivery of bulk goods, such as iron ore and coal to domestic markets, while also participating in the downbound flow of grain for trans-Atlantic export.

The GLSLS continues to make a significant contribution to the regional economy of the Great Lakes and through it, to the economy of North America as a whole. Admittedly, there have been fluctuations in total tonnages carried through the system over the past fifty years, reflecting changes in the supply of and demand for different commodities. The past few years, however, have seen these traffic levels stabilize to about 260 Mt annually. This volume of traffic simply could not be transferred to an already overloaded land-based transportation network without severe economic impacts on the industries served. Marine transportation continues to be a viable and essential complement to the existing road and rail transportation networks in the region. Since trade volumes are expected to increase in coming years, marine transportation is likely to grow in importance.

At current traffic levels, the GLSLS system has an enormous potential asset in terms of unused capacity. With growing pressure on land-based transportation networks in the region, there is a possibility of using the GLSLS to relieve some of that pressure.

Chapter 4

Environmental Considerations

The Great Lakes basin and St. Lawrence River is a unique water resource of major significance to the environment. As the world's largest fresh water system, it supports the livelihood and activities of 10 percent of the U.S. and 25 percent of the Canadian population. This ecosystem has been degraded by many different human activities, one of which is commercial navigation. The ecological state of the region's associated lakes and rivers as well as the fish and wildlife that rely on them has a direct impact on the future vitality of the Great Lakes St. Lawrence Seaway system. The size of the system and the volume of traffic passing through it inevitably affects the surrounding environment. Yet commercial navigation is only one of the many factors influencing the environment. To preserve and maintain the region's vitality, it is critical to identify and control the most significant navigational and non-navigational environmental stressors.

An important component of the GLSLS Study is consideration of the impact of the GLSLS system on the regional environment. The Environmental Working Group was mandated to address this issue. Its primary goal was to review the current environmental conditions present in the Great Lakes basin and St. Lawrence River, highlighting in particular the impacts on the environment arising from commercial navigation. In addition, the Working Group looked at anticipated future trends that may affect key ecosystem components. Finally, it considered ways of mitigating any future negative environmental impacts associated with commercial navigation through the GLSLS system.

Within this context, the Environmental Working Group considered the environmental implications of potential changes to the volume or type of traffic passing through the system as well as any effects associated with operating or maintaining the infrastructure of the GLSLS.

Canada Goose, Kent Lake Kensington Metro Park, Michigan
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office, www.epa.gov

Overview

The Great Lakes basin and St. Lawrence River together encompass the world's largest fresh water system, supporting the livelihood and activities of approximately 33 million people living within its catchment area. This vast watershed provides drinking water, and supports domestic, municipal, industrial, recreational and transportation needs throughout the region. Its waters are used for hydroelectric power generation, waste water disposal, recreational boating, tourism, natural wetlands and a range of interdependent and unique habitats and species, as well as the commercial navigation of the GLSLS system itself. The GLSLS system, therefore, exists within this complex network of human activities and environmental relationships, all of which originate with and depend on the waters of this immense region.

Development in the region dates back several centuries since the St. Lawrence River was the first gateway into the continent for European settlers. Early economic activities included the fur trade and commercial logging. The Great Lakes and St. Lawrence River were also used for subsistence fishing which eventually evolved into an important commercial fishery. Without government-imposed catch limits, however, overfishing depleted fish stocks. Agriculture grew steadily to the point where it currently accounts for approximately 33 percent of land use in the Great Lakes basin, dominating the riparian area of the St. Lawrence River, and contributing fertilizers and herbicides into the ecosystem. The growth of cities in the region brought discharges of sewage and polluted air. About 26 million of the basin's inhabitants are now concentrated in five major metropolitan areas (Chicago, Toronto, Detroit, Montreal and Cleveland). All of these major centers and several smaller ones have well-developed industrial bases which are associated with the discharge of heavy metals, organic compounds and a variety of other pollutants. In other words, forestry, fishing, agriculture, urbanization and industrialization have each brought permanent environmental changes to the basin.

Within this broader context, there is a separate though cumulative set of environmental effects associated with commercial navigation through the GLSLS system. Some of these derived from construction activities, dredging, or the effect of ship wakes. As infrastructure and additional connecting bodies of water were created to support shipping traffic and commerce, aquatic non-indigenous invasive species (NIS) were introduced.

Many of these established themselves permanently, affecting both human activities and the basin's flora and fauna. The completion of the GLSLS system in 1959 was also accompanied by a management regime for water levels that brought additional environmental impacts.

To evaluate the environmental context within which the GLSLS waterway operates, the Environmental Working Group examined the environmental stresses affecting the key ecosystems of the region. It considered both the stresses due directly to navigation and stresses that were not related to navigation and that did not involve major socio-economic structural changes or catastrophic environmental events. It also evaluated the potential cumulative effects of all environmental stresses acting together. While navigational factors can operate separately and independently of other stressors, there are cases in which navigational and non-navigational stressors can have a synergistic or cumulative impact on the environment.

Valued ecosystem components (VECs)

To make analysis manageable given the diversity of the region's ecosystems, the Environment Working Group focused on its most important valued ecosystem components (VECs). The VEC approach is a widely used technique for focusing environmental assessments on those components that have the greatest relevance in terms of value and sensitivity to specific issues. The Canadian Environmental Assessment Agency defines a VEC as:

> *Any part of the environment that is considered important by the proponent, public, scientists and government involved in the assessment process. Importance may be determined on the basis of cultural values or scientific concern (CEAA, 1999)*[1]

Because this type of environmental assessment is driven by relevance to particular concerns, in the GLSLS Study it was used to examine the impact of commercial navigation. The Environmental Working Group organized its analysis under three categories of VECs – Air, Terrestrial Ecosystems, and Aquatic Ecosystems (see Table 4.1). It then focused specifically on the impacts on these VECs that were related to navigation.

Air quality

Air quality is significantly affected by population density, the nature of the industrial base and geographical location. For example, levels of air pollution initially were low in the upper basin, but increased in the years just before and just after 2000. In contrast, levels of air pollution have declined in airsheds around the lower basin lakes. Air quality is largely affected by urban and industrial emissions as well as long-range transportation and it varies according to weather. Studies conducted by Environment Canada have shown gradual improvement in air quality in major urban centres between 1974 and 1992. Overall emissions of greenhouse gases (GHG) increased by 24 percent during the period between 1990 and 2003. Over the same period, Gross Domestic Product (GDP) grew by 43 percent, which means that there was a reduction in the amount of GHG emitted per unit of GDP.

Table 4.1
Valued Ecosystem Components

VEC Groups	*VECs*	*VEC Descriptions*
Air	Air quality	Nitrogen oxides (NOx), sulphur oxides (SOx), CO_2 carbon monoxide (CO), dust and other particulate matter (PM)
Terrestrial Ecosystems	Soil and Ground Water	Contamination
	Vegetation	Limited to nearshore upland vegetation
	Fauna	Terrestrial fauna excluding aquatic birds and shorebirds
	Special features	Islands
Aquatic Ecosystems	Water and Substrate	Water quality, water quantity and substrate
	Flora and Wetlands	Wetlands and phytoplankton
	Aquatic fauna	Fish, benthic invertebrates, zooplankton, semi-aquatic species (e.g., amphibians, reptiles, waterfowl, shorebirds, etc.)

1 CEAA (1999) Cumulative Effects Assessment Practitioners Guide http://www.ceaa.gc.ca/013/0001/0004/index_e.htm

The transportation sector as a whole contributes 27 percent of total GHG emissions. But less than three percent of all GHG emissions come from shipping. Because each vessel can carry a very large amount of cargo, shipping remains more fuel efficient overall than rail or truck; it consumes less energy and creates fewer emissions. Even so, ships in port have a negative impact on air quality by releasing high concentrations of SOx, NOx, and PM Some of this is attributable to “hotelling” practices in which ships at port continue to run their engines to generate electrical power. Some is attributable to the burning of poor quality fuel. While the global effect of these factors is small, local impacts can be more intense. However, emissions from ships are increasingly regulated, and some progress has been made in switching ships to cleaner-burning fuel.

Terrestrial ecosystems

Soil and Ground Water: Though impacts vary throughout the basin, the quality of soil and ground water has generally fallen in response to development and industrialization. Navigation-related activities can degrade soil and ground water in two ways. First, the development and use of port infrastructure and related industrial development can contaminate soil while industrial and toxic materials can similarly affect water. Second, the terrestrial placement of dredged material can affect both soil and ground water quality, depending on the character of the material deposited and the condition of the site prior to disposal. For example, if sediments are highly polluted, toxic materials can find their way through the soil and ground water into the food web.

Vegetation: Agriculture is often practiced close to the water’s edge, thus altering natural vegetative cover. Urban and industrial development inevitably affects nearshore upland vegetation. In addition, both native and non-indigenous invasive species have colonized disturbed areas and now dominate the landscape. In terms of navigation, nearshore vegetation and habitats have been changed and even eliminated as a result of efforts to alter shorelines or harden them as part of port development or erosion control. The placement of dredged material has also modified natural areas. Finally, air emissions including contributions from ships have had some localized impacts.

Fauna: Habitat destruction and fragmentation caused by both urban and industrial development have reduced breeding areas, viable wildlife populations, and species numbers. Noise and other disturbances have resulted in displacement or elimination of many native wildlife species. In places, port development and maintenance have eliminated viable mammal, reptile and bird populations. In areas of dredge disposal, different habitats have been created that, in some areas, helped the recovery of bird populations, and in others, attracted birds into contaminated areas. Ice breaking, to keep channels open, has disrupted animal movements across ice and affected predator-prey relationships.

Islands: Because of their unique habitats and intact ecosystems, islands are considered special features of the Great Lakes and St. Lawrence River and deserve special attention. Islands provide unique wildlife and fish habitat, recreational opportunities, and locations for navigational aids. There is a tendency toward endemic species and a frequent lack of mammalian predators on islands. Biodiversity is relatively high due to edge-effect; the presence of shoals supporting fish nurseries; and important avian nesting and stopover habitats. There are thousands of islands that range in size from the very large, such as Isle Royale in Lake Superior and Manitoulin Island in Lake Huron, to the extensive archipelagos of smaller islands, such as the 30,000 Islands of Georgian Bay and the Thousand Islands and the Sorel Archipelago in the St. Lawrence River. Most of these islands are naturally formed, but some may be anthropogenic, usually a result

Sorel Inlands, Quebec
Source: Environment Canada

of the deposition of dredge material. The environmental condition of these islands also varies from pristine habitats in Lake Superior to the highly degraded islands of the Detroit and St. Lawrence rivers.

One of the most serious threats to islands is the loss of biodiversity, caused by increased development and recreation, unsustainable forestry and agricultural practices, introduction of non-indigenous species, contaminants, water level change, habitat fragmentation, and deposition of dredge material. Reduced biodiversity on islands may be more ecologically significant than in non-island habitats because of the limited connection islands have with adjacent mainland habitats, making them less resilient to perturbations. The introduction of non-indigenous species may present a greater threat to diversity on islands than in mainland habitats because of the lower level of ecological resilience that islands inherently support. Increased human development, including home building and recreation, may serve to jeopardize the ecological isolation that also makes island ecosystems unique.

Erosion is a common phenomenon on islands, and may be more significant on islands made of unconsolidated sediment (e.g., sand, silt) or sedimentary rock. Water, waves, and wind-related erosion may be exacerbated by human activities, such as the removal or modification of shoreline vegetation or placement of armouring or jetties that interfere with normal littoral drift processes.

Development and operation of the commercial navigation channels have removed islands or affected islands through direct operational practices, such as dredging and dredge material disposal, and through water level regulation. Commercial navigation has involved vessel-induced wakes, ice scour, and pressure waves under the ice, all of which contribute to shoreline alteration and erosion.

Aquatic ecosystems

Water Quality: Bodies of water are categorized by their biological productivity and nutrient levels. Within the Great Lakes, at one end of the spectrum is Lake Superior, which has been least affected by agriculture, urbanization and industrial development: it is characterized as *oligotrophic*, which means it contains low levels of nutrients. Such lakes are typically very clear and rich in oxygen with low levels of algal growth and biological activity. At the other end of the spectrum are the *eutrophic* lakes, such as Lake Erie. In these lakes the accumulation of nutrients accelerates algal growth and, as biomass decays, oxygen may decrease to levels that affect species in the lake.

While open water phosphorus concentrations have decreased in lakes Michigan, Erie and Ontario, every lake still features high local concentrations in some areas. The nutrient load, both phosphorus and nitrogen, of the St. Lawrence River impairs the St. Lawrence maritime estuary and the Gulf of St. Lawrence. Oxygen concentrations decrease in the deep Laurentian Channel, partly as a result of the increased oxygen demand due to remineralization of augmented amounts of organic matter in the sediment. A decrease in nutrient loads of both nitrogen and phosphorus in the river could improve the situation.

While efforts to reduce nutrients were successful during the 1980s and early 1990s, Lake Erie continues to show signs of eutrophication, as is the case in Lake Ontario and Lake St. Pierre in the St. Lawrence River, although the situation is probably less severe in these two lakes. From 1995 through 2003, the winter and early spring concentrations of phosphorus increased continuously. Recently, scientists have observed anoxic events and dense blooms of cyanobacteria, regularly noted in the 1950-1970s. The major difference, however, is that toxic cyanobacteria species are now common.

The Great Lakes basin and St. Lawrence River contain a legacy of chemical contamination. Throughout the basin, trends in contaminant levels show that polycyclic aromatic hydrocarbons, polychlorinated biphenyl (PCBs), pesticides, heavy metals and other toxins have generally decreased. Even so, there are still localized high concentrations that remain a concern. In addition to traditional or legacy contaminants, concerns are being raised about the levels of pharmaceutical, personal care products and chemicals such as polybrominated diphenyl ether (PBDEs) that are now found in the lakes and the St. Lawrence River.

Municipal infrastructure improvements throughout the basin have significantly improved the effectiveness of municipal sewage treatment. However, continuing problems and challenges remain for many cities due to aging infrastructure and the limited capacity to treat water during storm events.

To address these water quality concerns, the governments of Canada and the U.S., in cooperation with the provincial and state governments, have designated the most polluted areas of the Great Lakes as Areas of Concern (AOCs) and are developing and implementing Remedial Action Plans (RAPs) to address each area's specific water quality problems and sources. In total, 43 AOCs were designated, of which 3 have been remediated and taken off the list. Currently there are 25 areas in the U.S., 10 in Canada, and 5 that are shared by the two countries. Some of these AOCs are located in or close to port areas. A companion program of Priority Intervention Zones (ZIPs) was initiated by St. Lawrence River communities in Quebec to develop local and regional action plans for addressing chemical contamination, physical and biological degradation, and socio-economic opportunities for development.

Contaminants may also affect lake and river sediments, which in turn, can affect overall water quality. The decreasing concentrations of PCBs and heavy metals in the water column, for example, have led to a decrease in concentrations of these contaminants in surface sediments. However, deeper sediment still maintains high levels of legacy pollutants that may become exposed during dredging operations. Erosion and deposition, brought about by changes to flow patterns associated with river channelling and flow controls and in some circumstances by ship wakes, has also affected sediments.

There are both direct and indirect effects on water quality attributable to navigation. Indirect contributions include the development of port facilities, the resulting discharge of contaminants from construction and maintenance activities, and industrial and population growth resulting from port availability. Direct contributions occur with dredging and channel maintenance activities, ship passage impacts, waste disposal, accidental or incidental discharges of contaminants, and cargo sweeping activities. Ship passage impacts include bottom scouring and prop wash, both of which contribute to increased turbidity and a re-suspension of sediments and trapped contaminants in the water column. Dredging and channel maintenance activities can also release contaminants into the water column. Inappropriate waste disposal and the incidental release of petroleum products or bilge water also contribute to degraded water quality. The activity of cargo sweeping in ports may lead to elevated nutrient levels resulting from incidental discharge of dry cargo residue, such as wood chips, coke, potash, limestone, iron ore, foundry sand, salt, fertilizer, and grain. Generally, the impacts of this practice are poorly understood.

Water Quantity: The ecology of the Great Lakes basin and St. Lawrence River is highly dependent on water levels and circulation patterns in the system. Water levels and flows are affected by both natural features and human activity.

The Great Lakes were formed during the retreat of the Wisconsin glacier some 10,000 years ago. The retreating glaciers formed ridges of land, between which melting waters formed immense lakes. The shape of the lakes changed over time as the glaciers retreated northward. The immense size and weight of the glaciers, thousands of metres thick in places, depressed the Earth's crust, which began to rebound as the glaciers retreated. This glacial rebound continues today at varying rates, with areas north of Lake Superior rebounding at rates of up to 60 cm (20 inches) per century while the southern reaches of the basin are rebounding at only 10 cm (4 inches) or less per century causing a shift in elevation around the lakes and thus affecting the shoreline. Since the retreat of the glaciers, lake levels have fluctuated enormously in response to climate variations and the ongoing evolution of the drainage basin. Levels have varied by more than 100 metres (300 feet), leaving the marks of ancient shorelines high up on the hillsides of the lakeshores and the remains of an ancient forest on the floor of southern Lake Huron. Even today, crustal rebound, climate variations, and erosion and deposition processes continue to alter the size and shape of the lakes.

Natural variations in precipitation and evaporation cause fluctuations in lake levels on both a seasonal and a decadal scale. The annual cycle of precipitation and runoff results in the lowest lake levels occurring at the end of winter after which water levels rise in response to snowmelt, runoff and precipitation. Winds, barometric pressure fluctuations and ice jams also contribute to short-term variations in lake and river levels throughout the system. Ice cover has a considerable influence on water levels by influencing the amount of evaporation.

Humans affect water levels through the manipulation of locks, dams and control gates constructed as part of the Seaway and hydroelectric system. In fact, a major effect of GLSLS infrastructure was to reduce natural fluctuations of the water levels in the St. Lawrence River and on lakes Ontario and Superior.

Diversion of water out of the Great Lakes system has faced public and government scrutiny. There are three primary water diversion locations, but none are part of the Seaway system. There are two diversions into Lake Superior from Long Lac and Ogoki, both in Canada. The Chicago diversion directs water out of Lake Michigan and eventually into the Mississippi River for purposes of sanitation, navigation and hydroelectric production. Taken together, these three diversions result in a net inflow of water of 67 cubic meters per second (m^3/sec) and represent one percent of the average annual inflow into the Great Lakes.

The ongoing operation of the navigation system relies, in part, on the regulation of water levels and flows within the Great Lakes and the St. Lawrence River region. The International Joint Commission (IJC) was established by the Canadian and U.S. governments to address boundary water issues. It has the authority to permit construction and oversee the operation of structures to regulate water levels on the Great Lakes. Water levels on Lake Superior are regulated by compensating gates located on the St. Marys River and water levels on the St. Lawrence River are regulated by controlled releases of water from the Moses-Saunders power generating station, which also directly affects levels in Lake Ontario. These control measures take into account anticipated natural rates of precipitation, runoff and evaporation.

The construction of navigation-related infrastructure has resulted in a significantly altered flow regime. The dredging of the upper St. Clair River has permanently lowered the water levels of lakes Huron and Michigan by 38 cm (15 in). Prior to regulation of its outflow in 1959, water levels in Lake Ontario fluctuated by as much as 2 m (6.6 ft). The existing regulation plan has a narrower target range of 1.2 m (4 ft). The reduction in water level fluctuations has also led to a greater range of flows in the St. Lawrence River. What is more, with the influence of climate change, predictive models suggest that the flow of water to the St. Lawrence River will likely decrease by 4 to 24 percent by 2050. Depending on the scenario used, significant water level declines may be experienced in all of the Great Lakes.

Substrates: The term substrate refers to the soil, sediment and other material found at the bottom of a waterway that provide the medium for aquatic plants, bottom-dwelling (benthic) organisms and bacteria. These substrates often contain contaminants that enter the water and then settle to the bottom. Chemical contaminants often remain in the substrates until they are disturbed. Near shores, substrate material is generally sandy but away from the shore, the sand is mixed with silt and/or clay. At greater depths, the sediments are a mixture of clay and fine-grained sediment.

Infrastructure construction, maintenance and ship operations can affect substrates. The construction of channels and ports was associated with significant dredging and deposition of dredge material. This substrate disturbance often releases toxic contamination and alters habitats. Ship operations can result in scouring of substrate materials, re-suspension of materials, and erosion of shallow water areas. Ice breaking operations can result in bottom scouring. All of these effects can be exacerbated by reduced water levels.

Wetlands: Wetlands are generally saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation, and various kinds of biological activity that are adapted to a wet environment. The extensive coastal wetlands of the Great Lakes basin and St. Lawrence River are vital ecosystems that contain a diversity of plants, including many significant and rare species; and provide important breeding and migratory habitat for waterfowl, as well as feeding, shelter and spawning areas for many species of fish. Wetlands also provide natural water storage and a cleansing function contributing to the natural hydrologic processes. The loss of wetlands reduces both the quantity and the quality of suitable habitat for hundreds of species of flora and fauna, and thus diminishes biodiversity.

Little Canal, Lake Superior, Wisconsin
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office, www.epa.gov

In the past, wetlands were often viewed as wastelands and subjected to development, shoreline hardening and land-filling, creating widespread habitat loss, degradation and reduced diversity. More than two-thirds of the region's natural wetlands have been filled or drained over the past century. The losses are most pronounced in the lower lakes, most notably in the St. Clair – Detroit River region, Lake Erie and Lake Ontario, and in the Montreal area along the St. Lawrence River where wetlands were either lost or changed character as a result of the permanent flooding caused by creation of the Seaway.

The rate of wetland habitat loss and degradation has slowed considerably during the past decade with the implementation of more comprehensive habitat protection programs and policies, and because there are so few wetlands left. Incremental losses still occur, however, in locations experiencing increased development pressure and water level regulation.

Climate change and its potential to permanently lower water levels may reduce the size, complexity, and accessibility of some wetlands. In other places, it may result in the opposite: deeper areas may become shallow enough to support the development of wetlands. A change in geographic range inhabited by some species will affect overall species composition in the region.

Most wetland depletion has occurred as a result of non-navigation-related activities. However, future land-based development in support of commercial navigation could eliminate or alter wetlands if it is not properly located, designed and operated. In narrow channels, wetlands are adversely affected by prop wash and surge. The impacts include erosion of the shoreline and littoral zone and the dislodging of submerged vegetation. Water level changes can adversely affect wetlands either through flooding or drying. The introduction of NIS by shipping activities can affect the diversity of species in wetlands.

Plankton: The bacteria and plankton that support the food chain in the Great Lakes have been affected by nutrient concentrations associated with various types of pollution. As regards navigational impacts, the most significant has arisen from the introduction of NIS. For example, the larval stage of the zebra mussel has become prevalent within zooplankton communities in parts of the Great Lakes basin and St. Lawrence River and adults of this species reduce their phytoplankton density by their filtering activities. This seems to be exerting pressure on other species that are key components of the food web. In general, the functioning of the traditional zooplankton community throughout the region has been significantly altered as a result of NIS. This is an impact that is directly attributable to navigation inasmuch as the new species seem to have entered the region in the ballast water of vessels using the GLSLS system.

Lakebed organisms: Bottom dwelling organisms have experienced major changes over the past two decades. Non-indigenous zebra mussels and quagga mussels have severely decreased native mussel populations. They have also taken over or modified part of the habitat, with a corresponding impact on other species and changes to the native food web. The deposition of faeces and pseudofaeces has locally increased the organic matter content in sediment. This, in turn, has increased microbial activity and stimulated activity of other benthic organisms as well as their diversity and density.

Increased biogenic carbon content in sediment increases the consumption of oxygen by lakebed organisms and can result in oxygen depletion in the deeper layers of the lakes. This, in turn, may kill a large portion of the lakebed community. This phenomenon is important especially in Lake Erie and in the deep Laurentian Channel in the Gulf of St. Lawrence.

In addition, there are direct vessel-induced impacts resulting from grounding and anchoring. Effects include crushing, scraping and displacement of lakebed organisms and the altering of their habitat. Scouring from prop wash or drawdown and surge waves in shallow areas can have similar impacts on lakebed organisms. Development of the navigation system altered the habitat in the connecting channels and dredging or new construction can cause the displacement or burying of organisms as well as the permanent alteration of habitat.

Fish: Fish communities in the Great Lakes basin and St. Lawrence River have been negatively affected by habitat loss, over-fishing, chemical contamination, and other disruptions to the ecosystem, and especially the introduction of NIS. Prior to the invasion of the sea lamprey above Niagara Falls, Great Lakes fish communities were stressed by high fishing pressure and habitat loss. Once sea lamprey populations were established above Lake Ontario in the 1930s, the increased stress from sea lamprey predation was the straw that broke the back of the native lake trout in all lakes except Lake Superior where remnant lake trout stocks persisted until efforts to control lamprey numbers took hold. With top predator numbers reduced to near zero, populations of invading prey fish such as alewife, rainbow smelt and gizzard shad exploded: in Lake Michigan massive die-offs of alewife created a public nuisance by the 1960s.

Effective measures to control sea lamprey numbers and the mortality they inflicted on Great Lakes fish began in the 1960s. Shortly after lamprey control efforts were initiated, federal hatcheries increased the number of lake trout stocked for rehabilitation and state fishery agencies introduced pacific salmon to control the over abundance of alewife. The increase in trout and salmon predators led to the stabilization of fish communities. With the rehabilitation of self-sustaining lake trout populations in Lake Superior, the fish community is generally considered to be restored and re-stocking efforts have therefore been somewhat reduced. Walleye

Lake St-Pierre, Quebec
Source: Environment Canada

populations have also recovered in Lake Erie. The stocking of trout and Pacific salmon continues in the other Great Lakes, though there are self-sustaining populations of Pacific salmon in Lake Huron. Other native species such as lake herring deepwater ciscoes, lake whitefish, and yellow perch, were once extremely reduced after the invasion of sea lamprey and alewife, but they also have generally rebounded. Fish communities have also changed over the last decades in the St. Lawrence River because of many dynamic factors, some of which are related to the modification of the hydrology and the use of shorelines.

Even so, persistent and continued invasions by species such as zebra and quagga mussels, round and tubenose gobies, ruffe and other zooplankton remain a serious threat to the stability of the food webs and fish communities of the Great Lakes.

The passage of vessels may affect fish populations directly through the entrainment of fish in propellers; by disturbing resting fish, and by inducing abnormal activity and stress during winter months as a result of ice breaking; by displacing egg and larval stages from spawning and nursery areas; and by causing siltation in spawning areas. Other significant impacts have been connected to the alteration of habitats during the development of the navigation system.

Evaluation of Stressors

In evaluating the stressors affecting VECs, the study differentiated between those associated with navigation and those associated with other factors, such as population pressure, economic development, or tourism and recreation (see Table 4.2). Climate change was considered separately because of its far-reaching effects and because it can influence both navigational and non-navigational stressors. Non-navigational stressors are those related to development and land use and those related to water-based recreation and tourism. Navigation-related stressors include:

- stresses to shorelines and channels as a result of dredging operations and port maintenance;
- stresses related to the management of water levels for navigational requirements;
- stresses caused by land based activities in support of navigation such as facility construction or maintenance; and
- numerous stresses arising from ship operations, including pollution and spills, turbulence associated with ships' wakes, and the introduction of aquatic non-indigenous invasive species (NIS).

Issues related to channel and port maintenance

Parts of the GLSLS system require ongoing dredging to maintain the navigability of ports and channels. Environmental impacts related to dredging activities may include:

- turbidity, reduced light penetration and increased suspended particles, during both dredging and disposal of the dredged materials;
- re-suspension of materials from waterway bottoms and possible release of contaminants, nutrients, gasses and oxygen-consuming substances trapped in bottom sediments;
- impacts on fish and fish spawning habitat;
- removal of important organisms living in or on the bottom substrate;
- altered water flows in wetlands and the loss of wetland habitat; and
- decreased water flow velocities in areas outside of the navigation channel with associated sedimentation.

For example:

- the dredging of shipping channels in near-shore waters, harbour construction and shipping at river mouths contributed to a decline in the organisms living in areas of Lake Superior and changed the wetland regime in parts of the St. Lawrence River such as Lake St. Pierre;
- channelling in the St. Marys River may have eliminated many of the spawning sites used by lake herring; and
- the dredging of the St. Clair and Detroit rivers have cumulatively lowered the levels of Lake Huron and Lake Michigan by some 38 cm (15 in). This dredging included commercial gravel mining (in the 1920s) and navigational improvements (from the 1800s to 1962).

The disposal of dredged material causes additional impacts. Terrestrial placement can result in odour, dust and reduced air quality. Ground and surface water quality may also be affected by turbidity and/or chemical contamination. Disposal in wetlands is of particular concern inasmuch as dredged materials can alter or disrupt a wetland ecosystem. Effects can include animal disturbance or displacement, changes to surface water quality, discharge of fine particulate matter, sedimentation and burial of organisms, release of toxic substances, loss of productive habitat, and introduction of invasive species. Dredged material deposited in open water or in confined waters may alter currents or water flows, promote siltation, increase turbidity, release toxic materials, bury or displace organisms, or deprive species of spawning or rearing habitats.

There are cases, however, where the placement of dredged material can actually benefit the environment by creating new habitats in highly altered sites such as old quarries. Careful placement of dredged materials can also offset the erosion of natural shorelines or build artificial wetlands. Over the past 20 years, regulations regarding the potential environmental impact of dredging activities have been strengthened. Ports and federal government agencies throughout the basin follow these new more stringent regulations and apply "best management practices" to dredging and dredged material placement programs under the guidance of project-specific environmental impact assessments. In some instances, significant efforts go into ensuring that dredged materials are used beneficially in creating or restoring wetland habitats, although such activities are limited to the scale of the system .

Table 4.2
Environmental stressors

Class of stressor		*Stressor*
Global	Climate change	
Non-navigational related	Development and land use	Water withdrawal & diversions
		Introduction & transfer of aquatic NIS
		Air emissions
		Industrial/municipal effluent
		Solid waste disposal
		Landscape fragmentation
		Runoff
		Shoreline alteration/hardening
		Noise & vibration
		Erosion and sedimentation
	Water-based recreation and tourism	Introduction & transfer of aquatic NIS
		Shoreline alteration/hardening
		Waste disposal/pollution
		Erosion and sediment re-suspension
		Wildlife conflicts
Navigational related	Channel & port maintenance	Channel modification
		Dredge material placement
		Shoreline alteration/hardening
		Maintenance dredging
	Water management	Water management for all purposes
	Land-based support activities	Infrastructure development
		Facility maintenance
		Uncontrolled releases
	Ship operations	Introduction & transfer of aquatic NIS
		Ship's air emissions
		Biocides (antifouling)
		Accidents/spills
		Noise & vibration
		Waste disposal
		Prop wash, surge and wake
		Cargo sweeping
		Groundings/anchoring
		Wildlife encounters
	Ice breaking	

Water management

Human regulation of water levels is undertaken throughout the region for a number of reasons including power generation and shoreline protection, and to a lesser extent for recreation and navigation. Water management can interfere with the natural cycles prevalent in certain ecosystems. Flora and fauna in the region have adapted to seasonal fluctuations in water levels but, when these are reduced or disrupted by water level regulation, there can be significant impacts on factors such as breeding cycles. Regulation of water levels can transform entire ecosystems, as in the case of Lake St. Francis and Lake St. Lawrence, which were river environments until the advent of water regulation.

Land-based support activities

The GLSLS system is associated with a variety of environmental impacts that are related to infrastructure development, facility maintenance and uncontrolled releases of various materials. The construction of its ports, harbours and marinas has had major individual and cumulative environmental impacts. These include:

- loss of, or serious modifications to, terrestrial and aquatic habitats important to breeding, spawning and rearing;
- loss of staging areas for migratory species;
- hardening and other alterations to shorelines that affect coastal processes;
- release of nutrient, toxic and noxious substances into local air and watersheds as a result of construction and operations; and
- noise, traffic, and other social impacts to local communities.

Water flow patterns that have been permanently altered because of land development can drastically affect the local aquatic environment through changes in water quantity and quality. Routine repair and maintenance of facilities perpetuate many of these impacts since infrastructure is aging and requires more major maintenance work or even replacement. Expansion or replacement of multimodal connections has generated construction-related effects and long-term impacts such as habitat fragmentation or removal. Shoreline hardening and modifications can destroy riparian communities and alter near-shore aquatic habitats. Air quality suffers from industrial and transportation-related emissions, dust and other particulate matter. Soil and ground water contamination can result from uncontrolled releases such as bulk storage facilities. Both terrestrial and aquatic fauna can be displaced or disturbed and habitat destroyed.

Ship operations

Ship operations can have direct and indirect impacts. Direct impacts are those that cause damage or mortality to a resource. Examples of these direct impacts include:

- shoreline erosion;
- risks associated with accidental groundings, including spills;
- waste discharges;
- disturbance of the benthic layer;
- habitat disturbance and wildlife encounters;
- larval or adult fish entrainment by ship propellers;
- physical impacts to plants or shorelines due to passing vessels (wake and propeller wash);
- crushing/scraping of bottom-dwelling aquatic organisms; and
- impacts of vessels in turning basins or fleeting areas where, for example, turning propellers or dragging anchors might mechanically disrupt sediments.

Indirect or secondary impacts from ship operations are those that decrease the survival rates of a resource over time or that have a negative impact on the requisites for life. Examples of indirect impacts include:

- the effects of suspended sediment on plant growth and mussel physiology;
- sediment deposition into backwaters and secondary channels; and
- reduction or loss of spawning or over-wintering habitat through sedimentation.

In the St. Marys River, for example, wetland and spawning habitat loss, shoreline erosion and habitat degradation have resulted from wave action and turbidity. Traffic by large vessels has affected the survival of lake herring eggs due to excessive wakes and turbulence. Wake and drawdown flows from passing ships disturb bed sediments, resulting in a loss of lake-dwelling organisms and may result in the re-suspension of contaminants. Some areas of the St. Lawrence River have been subject to intensive shoreline erosion and the biological impacts of this have not yet been thoroughly assessed.

The following are the most significant environmental influences observed within the Great Lakes basin and St. Lawrence River as a result of the normal operation of ships navigating through the GLSLS.

Air emissions: Ship engines do cause some air pollution. It can be argued, however, that a much larger amount of potential pollution is eliminated because of the transfer of traffic away from road and rail. Shipping is more fuel efficient than rail or truck which means that relatively less energy is consumed and there are lower emissions. On the other hand, it has been argued that ships have a tendency to burn dirty fuel, a result of which is that their emissions discharge relatively high amounts of pollutants such as sulphur dioxide. There are also practices such as "hotelling" during which ships at anchor continue to run their engines to generate electrical power, though these are little used in the GLSLS today. As far as air emissions are concerned, there are opportunities to switch ships to cleaner fuels. Some progress in this area should be encouraged in the future.

Wash, surge and wake: The regular passage of shipping close to shore has a long-term effect on shorelines, wetlands, and islands, as well as on species living in the water. Habitat disturbance results from heavy wake action and propeller motion causing hydrodynamic disturbances. Nesting waterfowl are particularly sensitive to ship wakes, which cause changes in flow patterns, in wave conditions, in near-shore vegetation patterns, in turbidity, as well as in substrate and shore profiles. For property owners, wakes can cause damage to their shoreline infrastructure. To a large extent, ship wake issues were first raised between 1930 and 1962 when the various locks were constructed and the navigation channels were dredged to their present configuration. A large portion of the shoreline affected by wakes has been armoured with seawalls and riprap. However, there are many areas where wakes continue to generate turbidity, erosion and habitat disturbances, most notably along the St. Lawrence River downstream of Montreal in the Varennes-Contrecoeur area and along unprotected reaches of the Detroit and St. Clair Rivers and the St. Marys River downstream of Sault Ste. Marie. As noted, one response to wakes consists of hardening the shoreline with revetment to limit erosion, which can, however, cause other problems with loss of habitat and access. The other response is to introduce speed controls in sensitive areas. Voluntary speed guidelines have been effective where applied in the St. Lawrence River to control wakes and their impact on shoreline habitats. The SLSDC and SLSMC use their Automatic Identification System /Global Positioning System (AIS/GPS) vessel tracking system to monitor and enforce vessel speeds.

Accidents/spills: Accidents and spills, while relatively infrequent, can have a long-term and spatially extended impact. In other words, the risk is low but the consequences can be devastating. Routine discharges, such as effluent from holding tanks or petroleum products from bilge discharge can have an incremental impact on aquatic life. Though there is always a danger of accidental spills and discharge, it is important to note that remedial action has been prompt and effective. Active spill response teams are in place throughout the system. Moreover, Canada's Marine Transportation Safety Board's recent accident reports show few spills despite several groundings, and when they do occur, such spills have been dealt with quickly and with minimal environmental impact. A less known impact is associated with the cumulative effect of many small spills related to transhipments.

Anti-fouling paints: The use of anti-fouling paints has resulted in the release of tributyltin (TBT), which is extremely toxic to molluscs. One effect of TBT pollution is the development of male sex characteristics in the females of some species of molluscs, sterilizing populations of molluscs and eventually leading to local extinction. Cumulative toxicity can be a particular problem in docking areas. However, the use of TBT paint is declining as a growing number of countries, including Canada and the U.S., prohibit its use.

While the use of TBT is now regulated under the *Canadian Environmental Protection Act* (CEPA) there are no data on the quantities of TBT used in the aquatic environment of the study area. Data are also incomplete on TBT concentrations in water and sediments in the freshwater portion of the GLSLS. Furthermore, there is no recognized criterion for the quality of sediments. However, it is important to note that the shipping industry has developed and applied economically viable and environmentally sound substitutes to TBT.

Other impacts: There are a number of other environmental impacts that are attributable to shipping. For example, cargo ships have displaced and collided with marine mammals. Noise and vibration have a known effect on nesting birds and marine mammals as well as on molluscs and other lake-dwelling organisms. Fish displacement or heightened activity in winter months can be harmful but little is known about the effects of noise on other aquatic organisms.

NIS: The introduction of NIS into the Great Lakes basin and St. Lawrence River, particularly through ballast water from trans-oceanic ships, is one of the most pervasive and challenging environmental problems facing these waters. Evidence shows that a ship ballasted with freshwater from overseas sources typically has much higher numbers of NIS organisms within its hold than a ship that carries no ballast or that has exchanged its ballast water with salt water before entering the GLSLS system.

More than 180 species of NIS have been introduced into the Great Lakes basin and St. Lawrence River during the past two centuries and at least 85 of these are reported from the St. Lawrence River. NIS threats exist from intentional introductions through aquaculture, live fish markets, sport fishing, pet trade, bait fish and garden plants, as well as from unintentional introductions through such mechanisms as ballast water discharge by ships or via interbasin connections, such as the current concern regarding Asian carp moving toward the Great Lakes from the Mississippi River via the man-made Chicago Sanitary and Ship Canal.

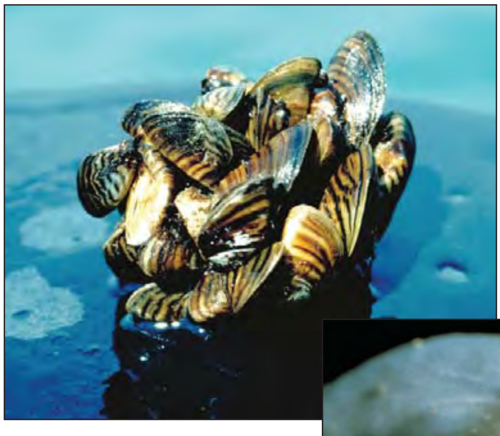
Given the growing recognition of the importance of the NIS issue, strategies are being put in place to address it. The most important of these is to prevent ocean-going vessels from bringing foreign ballast water into the GLSLS system. This can be accomplished by ballasted ships exchanging ballast water in the mid-Atlantic and by non-ballasted ships flushing their holding tanks and related piping in the mid-Atlantic. The number of ballasted ships bound for the Great Lakes has fallen over the past several decades. Vessels that declare 'no ballast on board' (NOBOB) now account for some 90 percent of all inbound traffic to the Great Lakes.

While these practices represent a positive trend, more work needs to be done to ensure that vessels entering the GLSLS system do not serve as vectors for the introduction of additional NIS. The exchange of fresh ballast water with salt-water is clearly an important element of ballast water treatment to prevent NIS introduction, but it is not 100 percent effective. The residue of unpumpable sludge (water and sediment) in the bottom of the tanks can still harbour NIS. Great Lakes and St. Lawrence River shippers and federal agencies, in conjunction with the International Maritime Organization, are working on the development of appropriate treatment methods to eliminate aquatic NIS. The "Great Ships Initiative" is a recently developed industry-led cooperative effort to resolve the problem of ship-borne NIS in the GLSLS system. In addition, strong controls are needed to guard against the movement of NIS through waters connecting the Mississippi River to Lake Michigan.

Ice breaking

The final navigation-related impact listed in table 4.2 is ice-breaking. Ice cover plays a significant role in the physical and biological processes of the Great Lakes and St. Lawrence River. The ice that forms in early winter protects the intertidal zones of the St. Lawrence River; the shores of the estuary would otherwise be severely eroded by waves generated by violent winter winds. The opposite occurs at the end of winter: drifting ice during break-up can transport sedimentary material and erode intertidal zones and shallow areas.

Ice breaking activities in the GLSLS system include ice clearing in harbours, approaches and connecting channels near both the start and end of the shipping season. Situated downstream of Montreal, the St. Lawrence Ship Channel is kept open for navigation year-round and therefore has more active ice clearing and ice management activities. Ice cover provides an important pathway for wildlife movement across bodies of water. Ice breaking can upset these important processes and can directly affect mammals by blocking their movements across the ice. Ice breaking activities can also increase propeller wash, drawdown and surge waves, dislodge or destroy aquatic vegetation and lake-dwelling organisms as well as disturb resting fish or induce abnormal activity in them. Though limited in geographic scope, ice-breaking activity can also alter migratory waterfowl habitats and their use by over-wintering birds.



Zebra mussel and Sea lamprey (aquatic NIS)
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office, www.epa.gov

Cumulative effects analysis

Commercial navigation and the infrastructure required to support it have had a significant environmental influence on the Great Lakes basin and St. Lawrence River. Through a review of the environmental stressors acting upon the various ecosystem components of the waterway, a qualitative sensitivity assessment was undertaken. This analysis was performed using a workshop approach wherein the study team debated and arrived at a consensus sensitivity ranking for each stressor. A summary of these results is presented in Table 4.3. This table lists the VECs in columns across the top of the table and the stressors in rows along the left-hand side. The check marks indicate a VEC-stressor combination where significant interactions can occur. In the rightmost columns of this table, the sensitivity of the overall ecosystem to a particular stressor is assessed.

The assessment criteria that were used are as follows:

- Areal extent of the stressor. The more widespread the stressor, the greater the potential impact and the more difficult it will likely be to mitigate. In the matrix, a stressor that has an impact at only a local level scores 1, regional level scores 2, and system wide scores 3.
- Temporal extent of the stressor. Many stressors are short lived or seasonal in duration and this may reduce the significance of their impact. Alternatively, the effects of some stressors such as persistent heavy metal pollution may be very long term. A stressor with a short term effect scores 1, medium term scores 2, and long term scores 3.
- Reversibility of the effect of the stressor. This is a subjective assessment of the potential for the effect to be reversed through the application of mitigating measures or policy decisions that would limit the severity of the impact. A high degree of reversibility scores 1, medium degree scores 2, and low degree scores 3.

Each of these measures is given a numeric ranking, which is then summed to provide an aggregate score. This aggregate score is then used to provide a ranking of sensitivity to that particular stressor.

A total of 35 environmental stressors have been identified, 29 (83 percent) of which are deemed to be of high or medium importance. At the same time,29 stressors out of 35 (83 percent) fall into the medium or low degree category of reversibility, meaning their impact cannot easily be undone. This suggests that the region is quite vulnerable to the stressors that are present and that minor management adjustments are unlikely to result in appreciable gains in environmental quality. The most influential non-navigation related stressors at the scale of the entire basin are climate change, air emissions, water withdrawals and diversions, and introduction and transmittal of NIS. Most non-navigation related stressors will act synergistically with other stressors affecting aquatic ecosystems.

Navigation related stressors have the greatest number of interactions with the aquatic ecosystem. The stressors of greatest concern are local channel modification, water level management, introduction and transfer of NIS, infrastructure development, and ship air emissions. While these five navigation-related stressors are significant from a system-wide perspective, other stressors such as shoreline erosion have serious implications at local or regional levels and their impacts should be addressed at the appropriate scale.

Future trends

The traffic trends forecasted by the economic component of the GLSLS study were used to anticipate the likely future condition of the VECs. The key economic trend considered was that the relatively modest changes in bulk cargoes predicted in the economic forecast would not result in substantial changes to trade patterns (origin-destination routings) nor to shipping services (vessel size and type) up through 2020. Over the longer term, socio-economic structural changes could modify these patterns. It was assumed that the potential growth of shortsea shipping would generate an increase in cross-lake and internal system traffic.

Climate change: Changes to the climate are projected to reduce water levels throughout the Great Lakes in the coming 50 years. A reduction of 4 to 24 percent in net water supply may lead to a drop in water level of between 26-112 cm (10-44 in) in Lakes Huron and Michigan, which would have an important impact downstream. The impact on Lake Superior would be about half of that level while the potential effect on Lake Ontario is unknown because of water-level regulation. Depending on the pattern of regulation and capacity to manage extreme climatic situations, the impact on the St. Lawrence River may be reduced or increased. Changes in water level caused by climate change would have their greatest environmental effects on wetlands, coastal and riverine habitats. A rise in the sea level would increase water levels in the St. Lawrence estuary and river accompanied by a landward (upstream) migration in the salt-fresh water interface. The tidal change may be more important than migration from saltwater and this would likely have a major impact on

TABLE 4.3
Stressor analysis

Group	Class of stressor	Stressor	Air: Air quality[1]	Terrestrial systems: Soil and ground water	Terrestrial systems: Vegetation[2]	Terrestrial systems: Fauna[3]	Terrestrial systems: Special features[4]	Aquatic systems: Water and substrate[5]	Aquatic systems: Flora/wetlands[6]	Aquatic systems: Aquatic fauna[7]	Areal extent	Temporal extent	Reversibility	Sensitivity ranking (Low 3 4, Medium 5 6 7, High 8 9)
Global	Climate change			✓	✓	✓	✓	✓	✓	✓	3	3	3	9
Non-navigational related	Development and land use	Water withdrawal & diversions		✓				✓	✓	✓	3	3	3	9
		Introduction & transfer of aquatic NIS			✓	✓	✓		✓	✓	3	3	3	9
		Air emissions	✓		✓	✓		✓	✓	✓	3	3	2	8
		Industrial/municipal effluent				✓	✓	✓	✓	✓	2	3	2	7
		Solid waste disposal		✓				✓			1	3	3	7
		Landscape fragmentation			✓	✓	✓		✓	✓	2	3	2	7
		Runoff		✓		✓		✓	✓	✓	2	2	2	6
		Shoreline alteration/hardening		✓	✓	✓	✓	✓	✓	✓	1	3	2	6
		Noise & vibration				✓				✓	1	3	2	6
		Erosion and sedimentation		✓	✓		✓	✓	✓	✓	1	2	2	5
	Water-based recreation and tourism	Introduction & transfer of aquatic NIS							✓	✓	3	3	3	9
		Shoreline alteration/hardening		✓	✓	✓	✓	✓	✓	✓	1	2	2	5
		Waste disposal/pollution		✓				✓	✓	✓	1	2	1	4
		Erosion and sediment re-suspension		✓			✓	✓	✓	✓	1	2	1	4
		Wildlife conflicts				✓				✓	1	1	1	3
Navigational related	Channel & port maintenance	Channel modification					✓	✓	✓	✓	1	3	3	7
		Dredge material placement		✓	✓	✓	✓	✓	✓	✓	1	3	2	6
		Shoreline alteration/hardening		✓	✓	✓		✓	✓	✓	1	3	2	6
		Maintenance dredging						✓	✓	✓	1	2	2	5
	Water management	Water management for all purposes					✓	✓	✓	✓	3	3	2	8
	Land-based support activities	Infrastructure development	✓	✓	✓	✓		✓	✓	✓	1	3	3	7
		Facility maintenance	✓		✓	✓		✓	✓	✓	1	3	2	6
		Uncontrolled releases	✓	✓		✓		✓	✓	✓	1	2	2	5
	Ship operations	Introduction & transfer of aquatic NIS						✓	✓	✓	3	3	3	9
		Ship's air emissions	✓		✓	✓		✓	✓	✓	2	3	2	7
		Biocides (antifouling)						✓		✓	1	3	2	6
		Accidents/spills					✓	✓	✓	✓	2	2	2	6
		Noise & vibration				✓				✓	1	1	3	5
		Waste disposal						✓	✓	✓	1	2	2	5
		Prop wash, surge and wake					✓	✓	✓	✓	1	2	2	5
		Cargo sweeping						✓		✓	1	2	1	4
		Groundings/anchoring						✓	✓	✓	1	1	1	3
		Wildlife encounters								✓	1	1	1	3
	Ice breaking					✓	✓	✓	✓	✓	2	2	2	6

1 Nox, SOx, CO_2, CO, Particulates
2 Limited to nearshore upland vegetation
3 Terrestrial fauna, excluding aquatic/shore birds
4 Islands
5 Quality and quantity
6 Submergent and emergent (wetlands), phytoplankton
7 Fish, marine mammals, benthic invertegrates, zooplankton, amphibians, aquatic/shore birds

Sensitivity rankings

Areal extent	Temporal extent	Reversibility
1 Local	1 Short	1 High
2 Regional	2 Medium	2 Medium
3 System	3 Long	3 Low

wetland habitats such as those of Lake St. Pierre. Increased temperatures would alter species habitats and could reduce levels of oxygen dissolved in the water. Warmer conditions may also reduce the duration of ice cover throughout the region which, in turn, can increase evaporation and reduce the need for ice breaking. Changes in ice cover may also disrupt fish and mammal behaviour.

Air Quality: Air quality is best in the upper lakes and deteriorates in the more populated and heavily industrialized lower lakes. With continued growth in the basin, overall emissions will likely grow, despite improvements in emission controls. One result may be an increase in the number of smog alerts or longer periods of bad air quality, especially in the downtown areas of major cities or in some ports.

Various measures are being taken to reduce polluting emissions, but the rate of decrease is anticipated to be significantly less for the marine sector than for the overall transportation sector. Currently, marine transportation represents almost 40 percent of the SOx emissions attributable to the entire transportation sector. This is mainly due to the relatively poor quality of marine fuel compared to fuels used in other modes of transportation. Even so, according to Environment Canada,[2] the transportation sector is responsible for only 4 percent of total Canadian SOx emissions: the vast majority of SOx emissions come from the oil and gas industry (22 percent), electric power generation (27 percent) and mining and smelting operations (33 percent).

Wetlands: Wetland protection policies have slowed the rate of wetland loss, but wetlands will remain under pressure. Increasing nutrient loads, decreasing water levels and higher temperatures are all negative factors, leading to the potential for continuing loss of wetland diversity as well as increases in the frequency and extent of algal blooms and anoxic conditions at the end of the summer and beginning of autumn.

Islands: Islands will continue to provide important habitats for fish and wildlife including both nesting colonial birds and migratory birds. Future development pressure will combine with any potential increases in ship traffic to exert continued pressure on islands, though it is likely that the major impact on islands will be felt from the pressures of urbanization.

Lotus-in situs, Lake Michigan
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office, www.epa.gov

Water quality is expected to improve over the coming years in terms of many types of contaminants as the standards and availability of waste water treatment continue to increase. There is uncertainty, however, regarding the capacity and ability of existing treatment plants to cope with new and emerging contaminants. While increased ship traffic could bring a commensurate increase in water quality deterioration due to spills and leakages, such negative impacts will often be short-lived and localized, particularly compared to urban, industrial and agricultural water quality degradation.

Fauna: Increases in shipping will increase stress on aquatic fauna exposed to the effects of erosion and shipping activities in confined waterways. Measures directed at improved treatment of ballast can reduce the danger of new NIS introduction. The NIS already introduced, however, will continue to spread, altering both the structure and functioning of the aquatic community.

2 http://www.ec.gc.ca/cleanair-airpur/Main_Emission_Sources-WS0D5AD9F6-1_En.htm

Managing the environmental impacts of navigation

Assessment systems

U.S. and Canadian environmental assessment legislation provide for rigorous assessments of impacts of proposed projects and can include impact mitigation measures to be part of any approval. While this legislation provides a solid foundation for assessing environmental impacts, most ongoing operations, maintenance and repair activities envisioned in the GLSLS Study would not require further assessment under these federal regimes, though some state or provincial assessments might apply. If the GLSLS Study or follow-up work should result in a recommendation to the Cabinet (Canada) or a federal agency (U.S.) regarding how best to ensure the continuing viability of the GLSLS system, it is possible that a Strategic Environmental Assessment (Canada) and/or Environmental Assessment or Environmental Impact Statement (U.S.) may be required as part of the process of approving any proposed investments.

Current environmental management actions

Many of the environmental pressures presently facing the system are well-known and a wide range of practices and policy initiatives are either in place or in the process of being implemented. For example:

- Speed limits have been established in narrow channel areas to reduce shoreline erosion and to improve safety of operations;
- Safety measures and draft advisories are in place to respond to water level changes and reduce the potential for grounding and bottom disturbances;
- Minimum fuel quality standards have been set to reduce ships' emissions;
- Port regulations control anchoring, waste management and other operational practices while in port;
- Anti-fouling paint using Tributyltin (TBT) has been banned in Canada and the U.S. in response to toxicity concerns;
- Programs have been established to monitor changes to wetlands. Not all wetlands have been catalogued, however, and improvements to the cataloguing methodology will provide more accurate estimates of wetland boundaries;
- To reduce the likelihood of introducing new NIS, ballast water management has received considerable attention, as described in detail further below.

While the preceding actions represent individual initiatives, there are also examples of comprehensive strategies aimed at promoting environmentally sustainable navigation. One of these is the Sustainable Navigation Strategy for the St. Lawrence River. This cooperative initiative involves the commercial and recreational boating industry, the governments of Canada and Quebec, environmental groups and riverside communities. It is presently the most comprehensive strategy dealing with the impacts of navigation and focuses on consensus building and communications, planning, research and development. Among the issues it has addressed are dredging, adaptation to water level fluctuations, shoreline erosion, sewage and ballast water management, and the risks of hazardous product spills. Another example of stakeholder involvement in addressing navigation-related environmental concerns is the U.S. St. Marys River Winter Navigation and Soo Locks Operations Memorandum of Agreement This is a multi-agency agreement to protect some 5,400 hectares (13,300 acres) of Michigan's coastal wetlands through the implementation of a winter navigation agreement that fixes operation dates, speed limits and monitoring responsibilities. Broader environmental initiatives, such as lake-wide management plans on all the Great Lakes and the St. Lawrence River Action Plan downstream, are directed at fostering environmental sustainability.

Measures to control the effects of ballast water

Responding to the NIS challenge, both government and industry have sought to implement measures that would regulate ballast water. In Canada, the first guidelines to address ballast water management were developed in 1989 and strengthened in 2000. At the same time, the Shipping Federation of Canada adopted a Code of Best Practices for Ballast Water Management and members of the industry were involved in consultations on the development of Canadian regulations. In 2001, the American Lake Carriers' Association (representing the U.S. laker fleet) and the Canadian Shipowners Association (representing the Canadian laker fleet) adopted voluntary management practices to reduce the transfer of non-indigenous invasive species within the Great Lakes.

In the following year, they were incorporated into the joint practices and procedures mandated by the Canadian St. Lawrence Seaway Management Corporation and the U.S. Saint Lawrence Seaway Development Corporation for transit of the Seaway system.

In 1993, the U.S. established ballast water exchange regulations pursuant to the 1990 *Non-indigenous Aquatic Nuisance Prevention and Control Act*. These regulations were amended in 2004 to make reporting mandatory for all shipping in U.S. waters, and again in 2005 to make ballast water management mandatory in all American waters. As of 2003, Canada did not prohibit the discharge of ballast water within its 200-mile exclusive economic zone. But in 2006, Transport Canada published regulations making it mandatory to follow several of the measures outlined in the Department's Publication *Guidelines for the Control of Ballast Water Discharge from Ships in Waters under Canadian Jurisdiction* (TP 13617). The *Canada Shipping Act*, 2001 , which entered into force in 2007, is expected to further enhance the Canadian regulatory regime by extending the current authority available to regulate the prevention of introductions of aquatic invasive species by ships. The regulations apply to ships that take on local ballast water if that ballast water is mixed with other ballast water that was taken on board the ship outside waters under Canadian jurisdiction, unless the other ballast water was previously subjected to exchange or treatment. The regulations also include provisions relating to international NOBOB ships entering waters under Canadian jurisdiction.

Practices for treatment of ballast water clearly exist, and new technologies are being developed and tested. These have to be coupled with comprehensive regulatory and monitoring systems to ensure that best practices are followed and that action is taken in due time.

Ongoing monitoring

Many of the measures already in place have to be thought of as only the beginning of a long-term and ongoing process of environmental management. In the future, the operation and maintenance of the GLSLS system will have to be accompanied by ongoing monitoring of seven key issues:

- Controlling the introduction and transmittal of NIS;
- Addressing the social, technical and environment impacts of long-term declines in water levels including right-sizing the infrastructure;
- Minimizing the impact of ship emissions;
- Ensuring that dredged materials are placed in an environmentally responsible manner;
- Protecting islands and narrow channel habitats from the effects of ship passage;
- Minimizing the re-suspension of contaminated sediments; and
- Managing the impacts of ships' grey and black water and bilge waste.

There have been considerable resources devoted to research and planning but, with the exception of some specific areas related to NIS, there have been few initiatives that have seen "on-the-ground" changes. Impacts related to planned works, such as maintenance of infrastructure, maintenance dredging and placement of dredged material can be minimized through effective application of environmental assessments, remedial actions, sound environmental management strategies and best practices.

Other stress-related changes pose greater challenges. The rate at which new NIS are identified may be too slow, allowing them to become established and expand through the system before they are discovered. Also, NIS may expand and colonize in freshwater environments as well as in estuarine environments such as the Mitten Crab recently discovered in the St. Lawrence River, and be able to colonize both environments.

The loss of wetlands may be accelerated by climate changes that reduce water levels. Such changes will be keenly felt in shallow and narrow channel areas. In addition, reductions in water levels may result in pressure for more dredging and suitable dredged material placement sites will become increasingly scarce.

Numerous measures have been identified by various environmental interests throughout the region that, if implemented, could have a beneficial impact, though any evaluation of their technical feasibility, social acceptance and cost effectiveness was deemed outside the scope of the present GLSLS Study. Consequently, more work is needed around protection measures and new technologies that can reduce or halt further ecological deterioration from navigation-related stressors. Environmental management systems are needed in many areas to ensure that environmental stewardship is built into standard operating procedures. Finally, monitoring of shipping practices and enforcement of regulations will be an important part of any future impact mitigation strategy.

Conclusions

The overall health of an ecosystem reflects the cumulative effect of all the stresses to which it is exposed. The ecosystems of the Great Lakes basin and St. Lawrence River are under enormous pressures from a wide variety of sources. The GLSLS navigation system represents an additional stressor in this complex mix. Taking stock of the environmental impact of navigation on the system turns up a mix of positives and negatives.

Marine transport of bulk goods is safer and may be more fuel efficient than the alternatives of road and rail transport, especially with regard to the emission of greenhouse gases. Statistics indicate that the risk of accidents and spills with marine transport is significantly less than for either road or rail transport. Marine transport also offers relief to urban congestion and the associated pressure this congestion exerts on public infrastructure.

However, non-indigenous invasive species are an enormously disruptive force on basin ecosystems and shipping is a major vector for the transportation of NIS. The operation of the navigation system in some areas is associated with the regulation of water levels, which has reduced the range of water level fluctuations and adversely affected biodiversity. Ship wakes can erode shorelines and wetland habitats, increase turbidity and trigger the propagation of man-made shore protection, which further disturbs the natural shoreline. The fuels burned by most ships are high in sulphur and particulates leading to unnecessary air pollution. Dredging activities in support of marine navigation can result in deterioration of water quality and disruption of the environment. Even though the risk of accidents and spills is lower than for road or rail transport, impacts could still be significant.

In practical terms, many of the navigational impacts described in this chapter have already occurred and cannot be easily reversed. Where impacts continue, however, regulations should be introduced to reduce their severity.

Over the past 20 years, the industries that use the GLSLS and the agencies responsible for the GLSLS have taken up the role of environmental stewardship. The inter-agency collaboration between groups such as Environment Canada, the U.S. Fish and Wildlife Service and the regulatory and operational agencies of the GLSLS system needs to be continued and further fostered. Regulations and codes of practice have been implemented to minimize many of the environmental impacts mentioned above. That said, much more needs to be done. New technologies for ballast water treatment and other NIS-related issues need to be developed and implemented. Current initiatives, such as the Asian Carp Barrier in the Chicago Sanitary and Ship Canal and sea lamprey remediation programs, focused on dealing with NIS, should continue as well as the development of a comprehensive plan to address the inadvertent introduction and transmittal of NIS. Ships need to use cleaner fuels and adopt emission-reducing technologies. Ship wake problems need to be assessed as an integral part of waterway management, particularly in addressing how changes in navigation and/or ship characteristics can affect the environmental impact of wakes.

Through continued diligence in this area, society can capitalize on the environmental benefits offered by marine transportation within the GLSLS, while reducing the environmental impacts of navigation.

Chapter 5

Maintaining the Infrastructure

While the infrastructure of the Great Lakes St. Lawrence Seaway system continues to provide reliable service, the age of the infrastructure has reached and or exceeded its original design life. The likelihood that any one of its hundreds of different components will fail increases with each passing year. To maintain operational integrity, an analysis of maintenance needs has been performed that takes into account the current condition of the lock systems and associated infrastructure on which navigation depends, the probabilities that certain components will fail, the costs of such failures and their likely impact on navigation, the costs of maintenance, and the earliest practical timing for repairs and maintenance to ensure the continued high level of system reliability. The analysis incorporates both the expected economic benefits arising from the continued operation of the system as well as the potential environmental impact associated with some maintenance activities. The result is a planning tool that can be used to help inform the development of maintenance strategies.

The age of the infrastructure of the Great Lakes St. Lawrence Seaway (GLSLS) system is 75 years for the oldest components. The Montreal-Lake Ontario lock components in the St. Lawrence River date back to 1959. The Welland Canal locks date back to 1932. At the Soo Locks, the Poe Lock was opened for navigation in 1969, while the MacArthur Lock has been in operation since 1943. The age of these components, along with their exposure to infrastructure stressors including winter conditions, means that they have experienced a significant amount of wear and tear. As a result, a considerable amount of effort is devoted to maintaining the system at its current operational level. Where and when to deploy that effort is a major decision that has a direct impact on the overall efficiency and hence viability of the GLSLS system.

The Engineering Working Group was mandated to examine the current condition of the GLSLS system's infrastructure and to examine approaches toward its ongoing maintenance necessary to ensure the continued high level of system reliability. To carry out this objective, the Working Group started with a thorough examination of the current condition of the lock systems and their associated components. Each of its key elements was evaluated in terms of its importance to the operations of the system, the likelihood of its failure, the consequences of its failure, and the costs of keeping it operational.

An important aspect of this analysis is that it was undertaken on a system-wide basis. All infrastructure components on both sides of the border have been assessed using the same techniques and evaluated against the same standards. The Working Group was able to assess the reliability of individual lock components and, more importantly, it integrated all these components into a system-wide reliability analysis that identified maintenance and rehabilitation priorities across the system.

System infrastructure

Though the GLSLS system is conventionally thought of as a series of locks, its locks are actually part of a much more elaborate transportation system that includes not only the lock chambers, but also bridges and tunnels, and the channels that link the locks together. Each of these has a distinctive function in the seamless operation of the overall navigation system and each has specific operational and maintenance requirements.

The locks

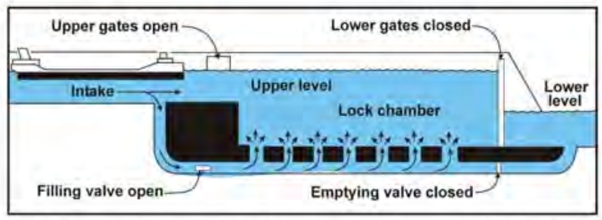
As was highlighted in the system overview included in Chapter 2 of this report, the GLSLS system includes navigation locks located at 16 different sites throughout the St. Lawrence River, Welland Canal and St. Marys River. These locks allow vessels to bypass the rapids and falls throughout these rivers, and serve to raise and lower the vessels in order to overcome the water surface elevation differentials encountered.

Figure 5.1 displays how these locks are operated to raise or lower a vessel.

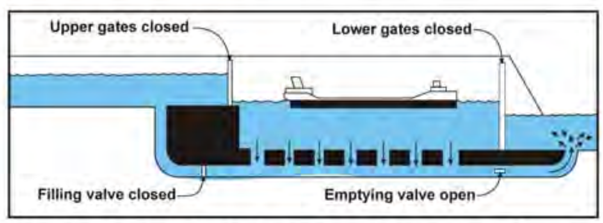
Figure 5.1

How navigation locks operate

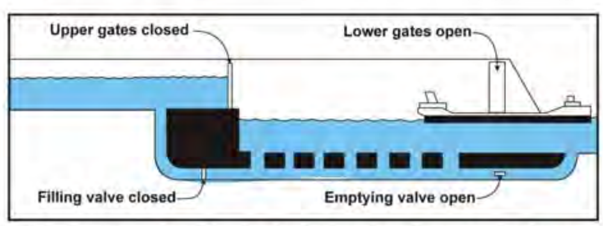
These diagrams show how a ship is lowered in a lock. A ship is raised by reversing the operation. No pumps are required; the water is merely allowed to seek its own level.



With both upper gates and lower gates closed, and with the emptying valve closed and the filling valve open, the lock chamber has been filled to the upper level. The upper gates are then opened, allowing the ship to enter the lock chamber.



Now the ship is in the lock chamber. The upper and lower gates and the filling valve are closed. The emptying valve has been opened to allow water to flow from the lock chamber to the lower level.



With the water level in the lock chamber down to the lower level, the lower gates have been opened, and the ship is leaving the lock chamber, After this, the lock is ready for an upbound ship to come in and be lifted, or may be filled to lower another downbound ship.

While the basic operating principle of these locks appears to be fairly straightforward, in actuality each one of the locks is comprised of a myriad of structural, mechanical and electrical components required to facilitate this operation. As such, the locks of the GLSLS system constitute its costliest and most critical components.

Each individual lock includes numerous components, including:

Approach and guide walls: These structures are typically comprised of concrete monoliths or a combination of a concrete cap supported by either rock filled timber cribbing or rock filled steel sheet pile cells. These structures help to align the vessels as they approach the lock and guide the vessels into the lock chamber. These walls also provide a location where vessels can tie-off while awaiting entry to a lock chamber.

Lock chambers: These structures are comprised of concrete monolith walls and either concrete or rock floors. There are concrete culverts running in either the walls and/or floors through which the water flows during emptying and filling of the lock chamber, and within which are located the emptying and filling valves used to regulate flow. There are also numerous cut-outs, openings and galleries located throughout the chamber to house mechanical and electrical operating machinery, and for placement of stop logs.

Lock gates: Generally large steel miter gates which open to allow vessels to enter or exit the chamber, and which close to hold back water to allow levels within the chamber to be raised or lowered. As the name suggests, these gates form a mitered angle when closed. Steel sector gates are also used at the upstream end of the Montreal Lake-Ontario segment of the Seaway where the pool differential is only of the order of magnitude of 1 meter (3.28 feet) and at other sites to allow closure of the gates against the full pool differential should the miter gates be so damaged that water level control would be lost. Miter gates use the difference in water levels across the gate to provide the force required to achieve a nearly water-tight seal. Typically, lock lifts in the GLSLS range from 6.4 meters (21 feet) at the Soo Locks to 15 meters (49.2 feet) at the Welland and Montreal-Lake Ontario locks. Generally, the upper and lower lock gates are of different heights. The upper gates range in height from about 10 to 11 meters (32.8 to 36 feet), whereas the lower gates are higher by the pool differential, which is the difference in the level of water upstream and downstream of the locks.

Vessel being raised in the lock chamber
Source: The St. Lawrence Seaway Management Corporation

This massive gate must be capable of maintaining a nearly water-tight seal. At the same time it needs to be opened and closed on an hourly basis.

The gate itself is typically formed by a set of horizontal girders sitting within a frame. Diagonal bracing is used to provide additional rigidity.

Lower miter gate at Eisenhower Lock
Source: Saint Lawrence Seaway Development Corporation

The photo on page 75 shows the lower miter gate at the Eisenhower Lock viewed from the downstream side. These gates are massive and have to be capable of maintaining a nearly water-tight seal. At the same time they need to be opened and closed on a routine basis. The gate itself is comprised of two miter gate leaves and is typically formed by a set of horizontal girders sitting within a frame. The alignment and rigidity of the gate is essential to ensuring its smooth operation. Diagonal braces are used to provide additional rigidity. The gate leaves rest on a pintle system (essentially a ball and socket) at the base of the gate leaves and are secured to the lock wall at the top of the gate leaves.

The seal between the two miter gate leaves and the joint between the gate leaves and the lock wall (at a recess or quoin) both need to be watertight. Both the quoin and miter blocks are subject to wear and need to be changed when either the seal has deteriorated or there is excessive deformation and stressing of the gate.

Safe and reliable operation of navigation locks requires that systems be in place to provide backup should one of the lock gates fail either because of wear and tear or because of ship impact. Some of the locks are equipped with redundant gates that can be brought into operation should the main gates fail. Other locks have spare gates, but changing out a failed gate requires a significant amount of time and energy. Some of the locks have dewatering gates upstream and downstream of the main gates to facilitate dewatering and servicing of the gates. Other locks use stoplogs, which can be lowered into place to allow for dewatering.

Stoplogs: These steel structures can be used to form a temporary barrier placed across the lock, typically both upstream of the upper gate and downstream of the lower gate, to allow dewatering of the lock chamber for maintenance and repairs. Stoplogs used throughout the GLSLS system consist of a series of steel plate girders that are lowered into slots in the upstream and downstream walls of the lock. Placement of the stoplogs requires a large derrick crane and many of the lock facilities have stiff-leg derrick cranes for this purpose.

Valves: Lock operations require a large array of mechanical components, including numerous valves for control of water. Culvert valves are opened and closed during each locking cycle to fill and drain the lock chamber. These valves are actually large steel gates located within the concrete culverts which are raised and lowered to control flow of water through the culverts.

Other mechanical & electrical machinery: Ongoing safe and efficient operation of the lock systems relies on a wide range of additional components. Control systems and motors are required to operate the machinery of the lock gates, valves and lift bridges. Many of these functions are still being performed with original equipment installed as part of initial construction of the locks. Some of these components have already been upgraded, others are in need of an upgrade. All of the locks throughout the GLSLS are equipped with similar ship arrestors. These are heavy cables strung across the lock in front of the lock gates prior to a ship entering the chamber. Should the ship lose control for any reason, the arrestors are designed to stop the ship before it can strike the lock gate.

Bridges, roads and tunnels

The GLSLS navigation system is crossed by numerous bridges, both fixed and moveable, as well as by tunnels at certain locations. Both bascule and vertical lift bridges are raised to allow for the passage of ships. At the Eisenhower Lock on the Montreal-Lake Ontario section of the system, access to the Moses-Saunders hydropower generating system is provided for via a highway tunnel passing through the upper lock sill. The maintenance of many of these crossing structures falls under the jurisdiction of the same organizations responsible for operation and maintenance of the locks. In the case of the Welland Canal, these bridges are all owned by Transport Canada and operated by the St. Lawrence Seaway Management Corporation (SLSMC). Bridge controls for several of the vertical lift and bascule bridges over the Welland Canal were recently automated and are now remotely controlled. The bridges' electrical power and control systems were all upgraded at the same time.

Navigation channels

Navigation channels are maintained in the St. Marys River, the St. Clair River and Lake St. Clair, the Detroit River and the Lake Erie entrance to the Welland Canal as well as at various locations along the St. Lawrence Seaway. The nominal allowable vessel draft has been as high as 8.08 meters (26.5 feet) depending on available water levels for the St. Lawrence Seaway, and 7.77 meters (25.5 feet) for the Upper Great Lakes waterway (as controlled by the Soo locks and the St. Marys River navigation channel).

Raising of lift bridge during vessel transit
Source: Thies Bognor, photographer

Infrastructure stressors

The various infrastructure components of the navigation system are subjected to an array of stressors that contribute to the overall degradation of the condition of these components over time. The majority of these stressors can be associated with the day to day passage of vessels, and are typically either a result of wear and tear from vessel movement or wear and tear from the cyclical operation of the various mechanical components (gates, valves, bridge machinery, etc.). In addition, there are certain stressors unique to the GLSLS system due to its geographic location (freeze-thaw cycles, ice loads), and associated with the original construction of the structures (construction quality, impacts associated with changes in vessel operations).

The U.S. Army Corps of Engineers (USACE), and the Saint Lawrence Seaway Development Corporation (SLSDC) to a much lesser extent, undertakes some 2 to 4 million cubic meters (3 to 5 million cubic yards) of maintenance dredging annually within the Great Lakes Basin. This includes maintenance dredging for 47 deep draft ports, 55 shallow draft harbors and maintenance of some 1,200 kilometers (745 miles) of navigation channels. Many of the major ports served by the GLSLS system also require significant maintenance dredging on a routine basis. At the Port of Duluth-Superior, 80,000 cubic meters per year (100,000 cubic yards per year) of regular dredging is required just to maintain the status quo. Maumee Harbor (Port of Toledo) requires a minimum of 650,000 cubic meters per year (850,000 cubic yards per year) of dredging. An additional 230,000 cubic meters per year (300,000 cubic yards per year) would be needed over the next nine years to clear an existing backlog in maintenance dredging. This type of routine maintenance dredging is carried out for these port facilities by the USACE as federally-authorized navigation projects.

There are additional areas, including the Seaway canals, that require maintenance dredging by the SLSDC and SLSMC.

Vessel movement impacts: Over time concrete can degrade due to abrasion from ships as they rub against approach walls, guide walls and lock chamber walls. In addition, these structures are often subject to vessel impacts as these large freighters attempt to navigate into and out of the lock approaches and chambers. Lock gates can sometimes also be subject to minor impact by vessels when entering the lock chamber.

Cyclical operation impacts: Each time a vessel transits a lock, the lock operating machinery is subject to a cycle of operation (gate movement, ship arrestor raising, culvert valve movements, etc.). This continual cycling of these lock components results in long term wear and tear and the ultimate degradation of the condition of these components. Lock cycles not only result from passage of commercial vessels, but also from passage of maintenance fleet vessels, recreational craft, tour boats, as well as operations needed to routinely pass ice during winter and spring. The moveable bridges spanning the navigation system are also subjected to this cyclical operation.

Excessive wear of components can ultimately result in the cracking of steel members due to fatigue. In the case of a lock gate, cracking to the extent that plastic deformation occurs might indicate that some of the steel gate components have been over-stressed resulting in an irreversible ('plastic') deformation and can be an indicator of potential structural problems.

North Lock Wall at Snell with Vertical Wall Armor. (Note typical damage at monolith vertical joints)
Source: Saint Lawrence Seaway Development Corporation

Concrete lock wall surface deterioration at Welland Canal Lock #7 (note exposed rebar at damaged area)
Source: The St. Lawrence Seaway Management Corporation

Cold weather operation impacts: Because of the geographic location of the system, the infrastructure is subject to an additional set of stressors associated with sub-freezing temperatures. Concrete structures are subject to freeze-thaw cycles that cause cracking and spalling of the surface as well as corrosion of the reinforcing steel underneath the surface. Passage of ice early and late in the shipping season results in additional abrasive forces on lock walls and can produce additional forces on gates and valves.

Other factors: There are a number of additional stressors acting on infrastructure, the most critical of which is an Alkaline-Aggregate Reaction (AAR) that is present within the concrete structures at several of the locks located in the Montreal-Lake Ontario corridor of the system. This condition is causing the concrete to expand over time, resulting in misalignment of lock machinery and a gradual narrowing of the lock chambers. This condition also results in cracking of the concrete as a result of the separation of the aggregate from the cement mortar. This condition is resulting in as much as a 2.5 centimeters (1 inch) narrowing of the affected locks every five years. The impact of this narrowing is compounded during early winter and early spring operations when ice is also present.

In some instances, the original design and construction of the infrastructure has been subjected to operational conditions associated with changes in vessels and vessel operations which have resulted in accelerated degradation.

The MacArthur Lock upper approach wall at the Soo Locks was built in the 1940s with mixed construction types, including mass concrete gravity monoliths founded on rock as well as monoliths founded on timber cribbing. The approach channels were excavated into the underlying bedrock. The underlying rock ledge is composed of the local sandstone bedrock which is interlayered with silt bands. Movement of the concrete wall has occurred and is attributed to erosion of the underlying rock ledge. This erosion has been accelerated by the use of ship bow thrusters, which have been used during maneuvering since about 1975.

The timber pile tie-up walls at the Welland Canal were built in the late 1950s as an extension of the existing concrete lock approach walls. They provided for securing vessels close to the locks and thus allowed two vessels to pass each other much closer to the lock than would otherwise be possible. These walls were further extended in the mid 1960s when it was anticipated that a new canal would be needed, and as such, the walls were deemed to be temporary and designed for only 25 years. There has been much damage to the walls over the years from ship impacts both at the fender level and from bulbous bows below water. In some areas, instability of the sloped bank behind has affected the walls and sections have been replaced. The timber piles are also deteriorating and there is an ongoing program of repairs to piles and beams. In many areas the timber decks have shrunk leading to loss of fill material, which has to be replaced constantly.

Navigation channel maintenance factors: Navigation channels require periodic maintenance dredging to maintain their authorized depths. Vessel drafts, however, depend on water levels which vary both by season and long term. Climate change modeling indicates that overall lake and river levels within the GLSLS are on a downward trend associated with long-term predictions of the various natural factors which influence lake levels. Since the elevations of the lock chambers and sills are fixed and navigation channel depths limited to authorized depths, a long-term reduction in lake levels would reduce the available draft for shipping which would, in turn, lead to reduced vessel carrying capacity and increased vessel transits. A long-term reduction in lake levels could also result in changes to harbor sedimentation patterns and, potentially, an increased need for dredging. In addition to the potential increase in maintenance dredging, disposal of the dredged material is becoming a significant challenge with tighter environmental restrictions and an ever decreasing availability of disposal facilities.

Current condition of the infrastructure

One of the primary goals of the GLSLS study was to conduct a systematic engineering assessment of the overall infrastructure in order to determine the long-term investments needed to keep the system safe, efficient and reliable. It should be noted that the condition assessment and subsequent engineering analyses focused primarily on the physical infrastructure components directly related to transiting commercial navigation. There are numerous additional assets at each of the lock facilities throughout the system which also require significant operation and maintenance costs that are not necessarily directly related to the day to day transiting of commercial vessels.

On-site infrastructure inspections were conducted for each of the major lock systems: the Soo Locks, the Welland Canal, and both the U.S. (SLSDC) and Canadian (SLSMC) locks of the Montreal-Lake Ontario system. The objective was to present a general picture of issues such as wear, steel aging, redundancy, and problems with concrete, as well as to categorize the outstanding maintenance issues affecting the system and to develop a system-wide set of maintenance requirements with associated cost schedules. To ensure a uniform and consistent assessment, the same technical team participated in the inspections and reporting for all lock systems. In all, a total of 160 separate components were analyzed ranging from massive concrete lock chambers and gates to the electrical controls for operating the machinery.

On the basis of this review, an infrastructure criticality index was developed to quantify risk (potential loss) and the relative importance of the maintenance work needed for major engineering components and features. The index reflects a combination of the physical condition, the importance to navigation, and the redundancy associated with each component. The same engineering team members who conducted the infrastructure inspections undertook this comparative ranking process.

Ranking involved a combination of distinct factors: the current condition of the component, the availability of backup and/or replacement parts, the likelihood of future problems occurring with this component, the relative cost of replacement or upgrading, the impact on navigation, and the impact on other services. This ranking system was then used to identify the more critical infrastructure components that should be prioritized for detailed reliability analysis.

The Criticality Index

The Engineering Team developed a systematic way of determining the most critical infrastructure throughout the GLSLS system. A numerical rating system was used to measure the criticality of each component in several categories relative to one another. A weighted sum of these ratings was used to determine the most critical infrastructure. To ensure consistency across the entire system, the same multi-disciplinary team of engineers from SLSMC, SLSDC, and USACE that did the GLSLS inspections also undertook this criticality analysis. The following rating categories were used in this analysis:

Decision Already Made to Replace/Upgrade

This category is the only non-numeric ranking. A 'yes' indicates that the component was recently replaced or significantly upgraded or that a formal decision has been made to replace/upgrade the component. In this case, numerical ratings of redundancy, etc. will not be done for the component. The term "recently" reflects a replacement or upgrade that is within the first 1/3 of the expected service life of that component.

Redundancy

1. Component has no redundancy. No means or back-up component can perform the intended function of the component.
2. Component has back-up or spare part. It will take over two weeks to put in place.
3. Component has back-up or spare part. It will take up to two weeks to put in place.
4. Component has back-up or spare part. It will take between 1 hour and 3 days to put in place.
5. Component is highly redundant. Immediate placement (less than 1 hour) or other measures available to perform the same function.

Current condition

1. Poor or Failed. Component is currently in a condition that is "failed" or in very poor condition. Component is not serviceable or is anticipated to become non-serviceable in the very near future.
2. Serviceable. Component requires a significant level of investment above normal maintenance levels in order to stay operational or component currently provides only limited serviceability due to its current condition.
3. Serviceable. Component provides adequate service. No known major problems with the structure that can not be addressed without normal maintenance.

Likelihood of future problems

This category reflects the likelihood of having significant future problems with the performance of a component without aggressive maintenance levels well beyond what is considered "normal" for typical navigation locks. It is important to note that "normal" maintenance is assumed to continue throughout the study period.

1. Certainty of future problems without aggressive maintenance being undertaken to address problems.
2. Very good chance of future problems without aggressive maintenance. This rating indicates a component that is expected to have problems, but not as soon or as problematic as those rated with a value of 1.
3. Chance of future operational problems. Currently does not indicate any problems.
4. Unlikely that future problems will occur. Practically certain no significant problems will occur in the future as long as normal maintenance continues in the future.

Relative cost to replace (cost rating x quantity rating/5)

Unit Cost	Cost Rating	Quantity	Quantity Rating
> $25 M	1	>20	1
$5M - $25M	2	11-20	2
$1M - $5M	3	5-10	3
$200K - $1M	4	2-4	4
<$200K	5	1	5

The Criticality Index (continued)

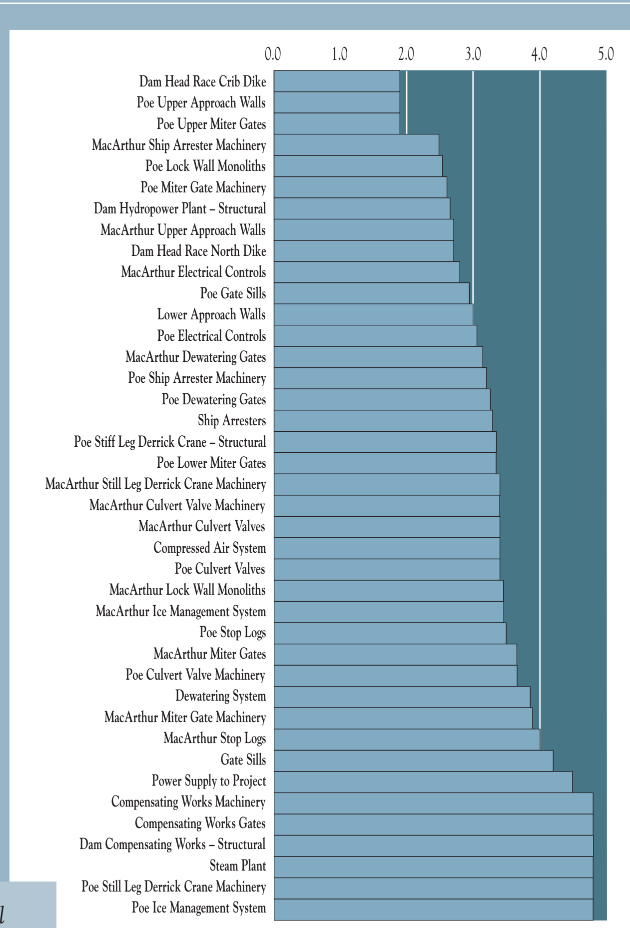
Impact on navigation	This category reflects the relative impact on navigation in the event that the component is not useable. The repair may be necessary during the navigation season or it may be a component that can wait until the winter shutdown season for repairs to be made. For some components, the repair can wait and the locks may continue to be open, but the traffic may be impaired somewhat due to special procedures or slowing filling/emptying times, etc.: 1. Navigation is shut down for a considerable length of time. The "failure" of the component requires navigation to shut down for that facility until adequate repairs or other means can be used to accomplish the same tasks. 2. Navigation is shut down for a significant amount of time, but not the level required for a rating of 1. 3. Navigation is shut down or special procedures/operations require traffic to transit through the facility slowly for a length of time. 4. Navigation is shut down very briefly or special procedures/operations have a limited effect on navigation traffic. 5. No significant impact on navigation.
Other impacts	This category is used to rate the effect of component performance on non-navigation issues. This would include structures like bridges, tunnels, and other components that if they failed to perform satisfactorily would have an adverse impact on things like vehicular traffic, rail transport, hydropower generation, flooding, environmental damages, etc. These structures may also have an adverse impact to navigation, but that is reflected in the previous category. 1. Extensive adverse impact on non-navigation related issues. The "failure" of the component would mean a potentially lengthy delay in order to restore the intended function or other similar use. 2. Significant impact on non-navigation related issues, but not to the level of those rated with a 1. 3. Impact on non-navigation related issues. 4. Little impact to non-navigation related issues. 5. No impact to non-navigation related issues.
Overall ranking	The overall ranking will be the value that is ultimately used to determine the most critical infrastructure for the purpose of this study. It is a relative value that combines the effects of the component's condition, operational redundancy, and potential impacts given unsatisfactory performance. It is relative in terms of how it compares against other GLSLS components from all agencies (SLSMC, SLSDC, and USACE). Components with the lowest values in this ranking system are considered the most critical across the system's for the purposes of this GLSLS Study. These components will be analyzed individually through probabilistic means by completing a reliability analysis on them and integrating them into the systems economic model. This will allow the overall GLSLS team to determine the overall impacts associated with the performance of the most critical GLSLS infrastructure. The overall ranking is a weighted sum of all the ratings for that component. The weighting applied to the various ratings is as follows:

Rating Category	Weighting factor
Redundancy	10%
Current condition	10%
Likelihood of future problems	30%
Relative cost to replace/upgrade	15%
Impact on navigation	25%
Other impacts	10%
Sum	100%

Soo Locks

More than 80 million tons of commercial cargo passes through the Soo Locks every year. Virtually all cargo vessels use the MacArthur and Poe locks. Only the Poe Lock has the necessary dimensions to pass all of the vessels that are presently in operation on the Great Lakes. If the Poe Lock is out of service, a significant amount of commercial cargo is unable to transit the facility.

Mass concrete	The lock walls are formed by 76 independent mass concrete gravity monoliths. The miter gate sills are also mass concrete sitting on bedrock. There are no major issues for a structure of this age. Surface deterioration around the seal area of the miter gate sills is addressed by routine maintenance.
Approach walls	Movement because of erosion of underlying rock ledge. Accelerated by the use of ship bow thrusters to maneuver. Heaviest damage is being repaired but wall will continue to deteriorate. The rock ledge is eroding at rates of 0.025 -.05 m (1-2 in) per year. Voids beneath the concrete monoliths range from 1 – 3 m (3-10 ft).
Gates	Original gates are still in use and in good condition. Upper gate of Poe Lock has been bowed by impacts from ships. It travels about 1 cm (1/2 inch) vertically during operation. Some steel gate components are deformed and may cause structural problems.
Secondary gates	The MacArthur Lock has intermediate gates that can be used in an emergency, but they would limit lock length. The Poe Lock has one set of upper miter gates. Its dewatering gates could be used as spare upper gates, but then the chamber could not be dewatered. At the Poe Lock's lower end a set of intermediate gates could be used as backup for the lower miter gates.
Stoplogs	There are no stoplogs for the downstream end of the Poe Lock, meaning that there is no redundancy for (and little ability to service) the downstream dewatering miter gates.
Valves	The culvert valves, which also date from the original construction, are used to control the filling and draining of the lock chamber. One valve failed a few years ago and had to be repaired.
Ship arrestors	The ship arrestors at the Soo Locks date to the original construction and need to be upgraded.
Machinery & controls	All original equipment which is in good condition but there are not spare parts and the equipment is in need of upgrading. The controls for the Poe Lock miter gates are inadequate. The entire system needs to incorporate programmable logic controllers. The MacArthur control panel operates at 480 volts, which is considered dangerous.



At the Soo Locks, the most critical infrastructure relates to structural wall components such as headrace dikes for the power canal and approach walls. The Poe Lock's upper miter gates and the MacArthur Lock's electrical controls also rank as critical components.

Welland Canal

The locks of the Welland Canal underwent an extensive rehabilitation program between 1985 and 1992 at a cost of $146 million. It involved: removing and replacing backfill behind lock walls to reduce earth pressure; anchoring lock walls weakened by the earth pressure; and refacing the lock walls that had deteriorated because of freeze-thaw action. All the necessary backfill replacement and anchoring has been completed as was much of the refacing work. The rest of this work program, however, continues today.

Mass concrete

Original concrete has suffered from freeze-thaw action, especially around the waterline. Refacing has been done on the most degraded concrete but some work remains. About 90 percent of the locks' surface has already been re-faced.

Approach walls

The timber pile tie-up walls, which were intended to be temporary when installed 45 years ago, have been damaged by vessel impacts or unstable earth banks, and the timber piles are deteriorating. Piles and beams are being repaired continuously. Shrinkage to timber decks led to loss of fill material, which has to be replaced constantly. These structures will be replaced within ten years by a concrete deck and supporting steel piles.

Gates

Because the steel miter gates, dating from 1932, have steel plating covering both sides of the girders, they are stiffer but harder to inspect and maintain. The gates are secured to the lock walls by a pair of adjustable turnbuckles that are replaced regularly. The quoin and miter blocks are maintained to ensure the gates fit with a good seal. Because the miter gates of the Welland Canal are riveted, they are more resistant to fatigue.

Secondary gates

Redundant intermediate gates at some of the Welland Locks and three sets of spare miter gates stored underwater near Lock 1. A set of sector gates near the upstream end at Lock 7 can be used in an emergency but would have to be placed under flowing conditions. There are also dewatering gates upstream of Lock 8 and downstream of Lock 1.

Stoplogs

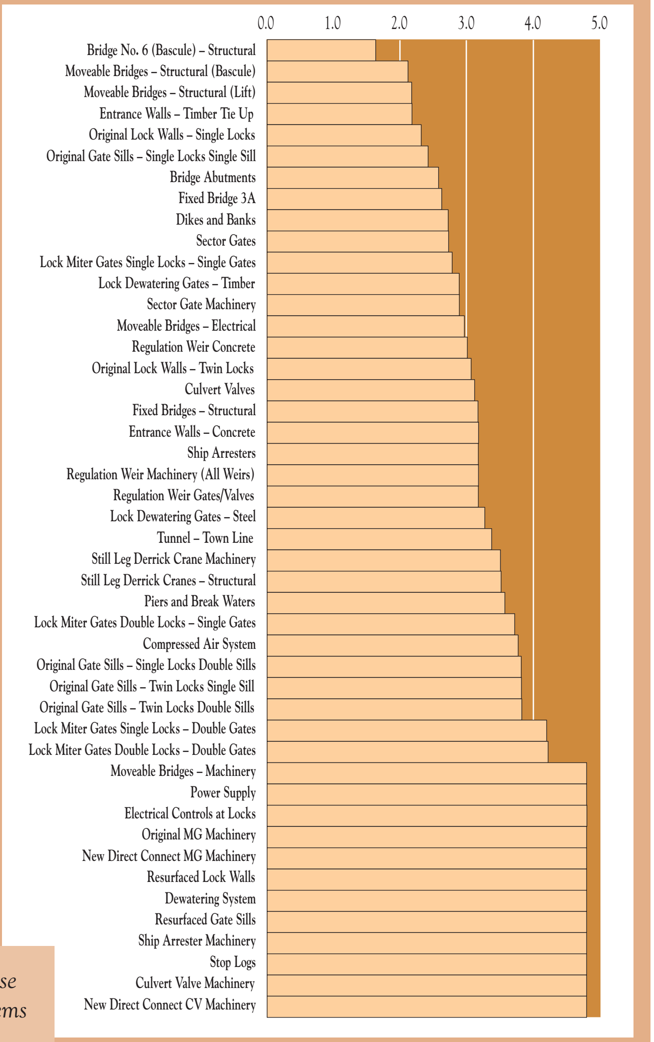
There are no stoplogs downstream of the lower dewatering miter gates at Lock 1, nor at Lock 8, meaning that servicing of those dewatering miter gates would require removal of the gates by crane.

Ship arrestors

The ship arrestors have all either already been upgraded to direct connect hydraulic connections or they are in the process of being upgraded.

Machinery & controls

The machinery for operating the lock gates and valves consists of mechanical gears driven by electric motors. In 2005, a six-year program was initiated to replace the original machinery with hydraulic direct-connect machinery for both the lock gates and the valves. The controls are being upgraded to programmable logic controllers.



At the Welland Canal, the most critical infrastructure components are those associated with moving lift bridges and approach walls. Many of the problems associated with concrete lock walls and machinery are presently being addressed under ongoing rehabilitation work.

MLO Section – U.S. Components

The U.S. portion of the St. Lawrence Seaway consists of the Snell and Eisenhower Locks, which are virtually identical in design but which manifest significant differences in their condition. The Eisenhower Lock suffers from poor concrete quality, which has led to advanced concrete degradation of the lock walls and seepage around a road tunnel that provides access to the Moses-Saunders hydroelectric dam.

Mass concrete

While concrete at the Snell Lock is in relatively good shape, the concrete at the Eisenhower Lock has deteriorated significantly. Up to 1.2 m (4 ft) of concrete has to be removed to get to sound underlying concrete. The service tunnel through the lock sill has experienced cracking, leakage, and ice build-up in winter. Grouting has been used repeatedly but the problem continues to worsen.

Approach walls

The approach walls and guide walls at both the Snell and Eisenhower Locks have suffered considerable wear and tear from ship impacts. They maintain their integrity, though regular maintenance is required.

Gates

The upper miter gates are in good operating condition at both locks. The pintles, quoin blocks and miter blocks are subject to significant wear and are replaced on a 'fix-as-fails' basis. The lower gates at both Snell and Eisenhower show considerable cracking. Cracking in the Snell gates is about three times as extensive as in the Eisenhower gates and is a major cause for concern.

Stoplogs

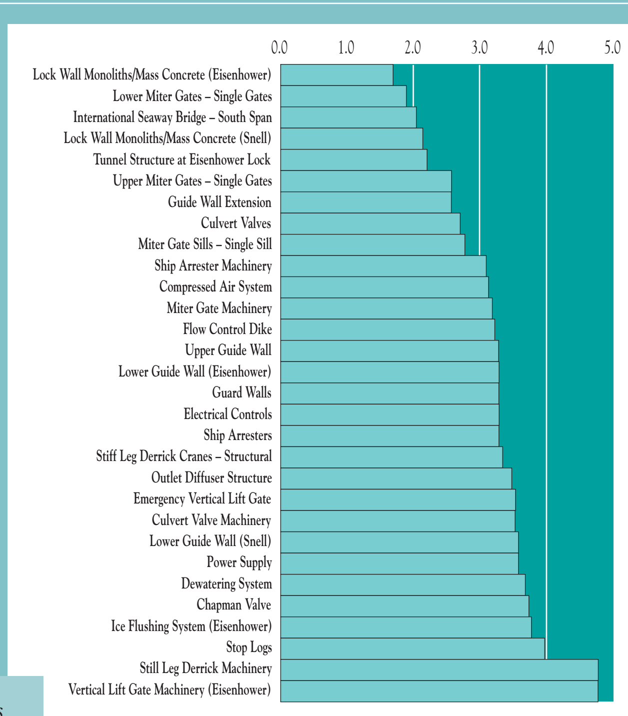
The Snell and Eisenhower locks have complete sets of stoplogs for dewatering. They are installed using stiff-leg derrick cranes. The Eisenhower Lock also has an emergency vertical lift gate that protects the upstream pool level in the event of a catastrophic failure of the miter gates.

Ship arrestors

The ship arrestors at the Eisenhower and Snell Locks date from the original construction and are in need of modernization.

Machinery & controls

Programmable logic controllers are used to control both the Snell and Eisenhower Locks. The latter houses the control room for SLSDC's new vessel tracking system, which monitors ship movements throughout the Seaway. The SLSDC will need new ship positioning, hydraulics and ship mooring technology to harmonize lock operations with the SLSMC.



At the SLSDC facilities on the St. Lawrence River, the most critical areas are associated with concrete quality at the Eisenhower Lock, the condition of the lower miter gates at both locks, the south span of the Seaway International Bridge, and the Eisenhower Lock highway tunnel.

MLO Section – Canadian components

The Canadian portion of the St. Lawrence Seaway is managed by the St. Lawrence Seaway Management Corporation (SLSMC), operating under a long-term contract from Transport Canada.

Mass concrete

Four of the locks suffer from long-term concrete degradation caused by Alkaline-Aggregate Reaction (AAR). This causes a steady narrowing of their width as well as alignment problems with the lock gates. The most severely affected are the quoin blocks where the lock gate hinges are attached to the wall. Some repairs to the quoin blocks have already been undertaken, but more are needed. The lock walls at the St. Lambert and Beauharnois locks are the most severely affected by AAR.

Gates

Seven sets of miter gates have been realigned because of AAR. An entire winter maintenance season is required to reset miter gates, which involves reworking the concrete recesses and resetting contact blocks. It costs more than C$1 million to realign each miter gate. There are double gates at the downstream end of St. Lambert, the upstream end of Cote Ste. Catherine, the downstream and upstream ends of the Lower Beauharnois Lock and at the upstream end of the Upper Beauharnois Lock.

Secondary gates

The other operational lock gates all have spare gates hanging in recesses on the lock wall but without any operating machinery connected. The exception is the lower gates of the Upper Beauharnois Lock, which has only single gates and no spare gates.

Stoplogs

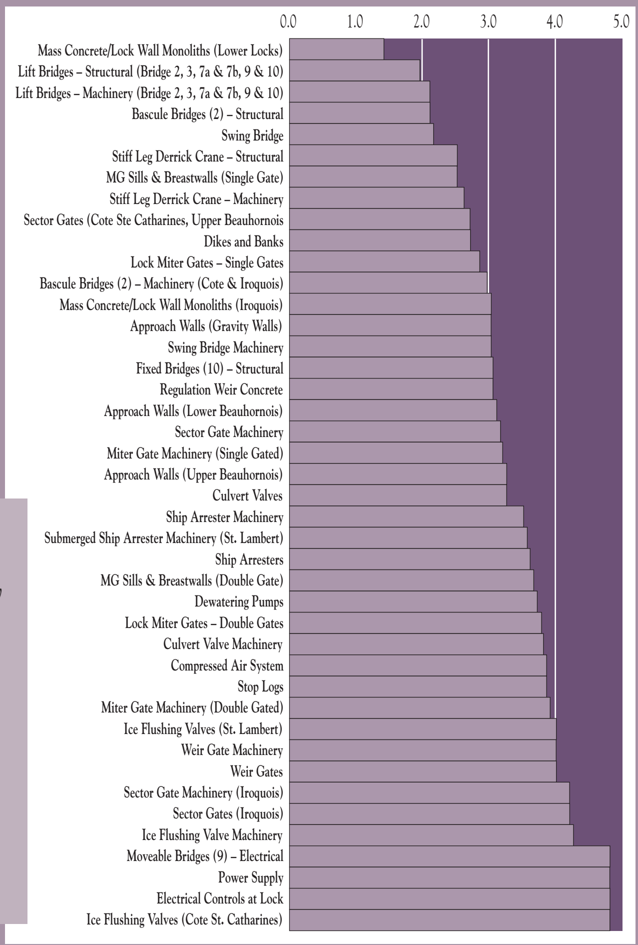
All of the SLSMC locks at Maisonneuve are equipped with stoplogs at both the upstream and downstream end. The only exception is at Beauharnois, where the upper and lower locks are treated as a single unit with stoplogs at the upper end of the upper lock and at the lower end of the lower lock. All stoplogs are installed and removed using a stiff-leg derrick crane.

Ship arrestors

The SLSMC arrestors use a similar boom and wire arrangement as used elsewhere throughout the system. The system is regularly maintained and operational. An upgrade to hydraulic connections similar to those at Welland has not yet been undertaken.

Machinery & controls

All of the locks, bridges and weirs managed by Canada's SLSMC have implemented programmable logic controllers (PLCs). There is an initiative currently under way to upgrade the PLCs to a more modern design. Operator interfaces are computerized and the application software is being upgraded. The system is also changing to a remote control system. Control wiring and panels are due for replacement because of corrosion caused by high levels of humidity in the galleries.



The Canadian locks near Montreal are suffering from long-term concrete degradation caused by Alkaline-Aggregate Reaction (AAR). This results in gradual expansion, deterioration, cracking, porosity and loss of integrity of the concrete. AAR is resulting in as much as a 2.5 centimeters (1 inch) narrowing of locks every five years. If lock width shrinks below 79 feet 6 inches then larger vessels will not be able to pass in December or March or special operational procedures will have to be implemented. Forecasts based on the engineering analysis suggest that at the current rate of concrete swelling, the St. Lambert lock will meet this critical width before 2015. AAR is also causing ongoing alignment problems with the lock gates and valves. The most severe of these involves the quoin blocks where the lock gate hinges are attached to the wall. Some repairs to the quoin blocks have already been undertaken, but more are needed.

The four charts presented in the insets show the criticality rankings of each of the lock components examined within each navigation corridor. A brief examination of these charts shows that each site has several high priority components (rankings lower than 2), the majority of the components rate around 3 (indicating some reliability issues and concerns over repair and/or maintenance) and a few rate over 4 (indicating components that are in new or good condition and/or have relatively low failure consequence impacts). Generally one can observe that the patterns of the criticality curves are the same from lock-to-lock indicating a general similarity in the overall state of repair of the various components.

Despite differences in construction and maintenance strategies, one important result of the criticality assessment was the finding that the rankings for locks across all four parts of the GLSLS are remarkably similar. The overall mean for the four sets of facilities are remarkably similar (table 5.1), ranging closely around 3.4. The worst rank (1.4) is associated with the concrete at four Maisonneuve lock sites that are affected by Alkaline-Aggregate Reaction (AAR), followed closely by the concrete problems at the Eisenhower Lock, the timber tie-up walls at Welland and the upper approach walls at the Soo Locks. The most critical gates are the upper miter gates on the Poe Lock and the lower miter gates at the Snell and Eisenhower locks.

Operations and maintenance

The locks on the GLSLS have an excellent history of service to the navigation industry. The Seaway locks operate a little more than nine months a year, typically closed between late December and late March because of winter conditions. The extent and duration of ice cover is a factor in determining the length of the shipping season. Over the period 1996 to 2005, the average Seaway navigation season lasted 276 days. The upper lakes season lasts some ten and a half months. The Soo Locks generally close between January 15 and March 25 in accordance with mandated operating seasons.

The winter shutdown period is a key element in the operational sustainability of the system. Far from being dormant time, the winter shutdown is used for detailed inspections, repairs and ongoing maintenance. The ability to dewater and inspect the structures on a fairly routine basis during the winter shutdown means that problems can often be identified before they reach a critical stage. Once a problem is recognized, it can be scheduled for repair.

Each region has an Asset Renewal Plan or Recapitalization Plan to make planned investments to maintain or upgrade the system.

On the Canadian side of the system, the SLSMC has a five-year Asset Renewal Plan that involves risk-based inspections and funding. This is a key component of the SLSMC's commercialization agreement with Transport Canada. The current asset renewal plan, which covers the five-year period between 2003/04 to 2007/08, allocates a spending envelope of $170 million for major maintenance and capital expenditures on the Canadian portion of the Montreal-Lake Ontario section of the Seaway and the Welland Canal. The Asset Renewal Plan is managed by the SLSMC and overseen by the Capital Committee, which is composed of two members from Transport Canada and two members from the SLSMC. The Committee approves, within a predetermined envelope, asset renewal projects on an annual basis and meets regularly to review and approve changes to the plan, if needed, to ensure the reliability of the system.

On the U.S. side of system, the SLSDC and USACE both depend on congressional appropriations to provide funding for infrastructure renewal. This process often makes it difficult to plan for long term investment in maintenance. On the other hand, it should be noted that none of the U.S. infrastructure is as old as that in the Welland Canal nor does the U.S. side have the problems with concrete that are found at the Montreal-Lake Ontario section of the Canadian Seaway. As the systems continue to age, the USACE and SLSDC components are coming due for rehabilitation on a scale similar to those already undertaken or under way on the Canadian side.

Table 5.1

Summary of criticality assessments

Summary of criticality indices	*Overall*	*Soo-USACE*	*Welland-SLSMC*	*MLO-SLSDC*	*MLO-SLSMC*
Mean	3.40	3.42	3.51	3.20	3.35
Min	1.40	1.90	1.60	1.70	1.40
Max	4.80	4.80	4.80	4.80	4.80

Forecasting maintenance requirements

It is expected that cyclical and emergency maintenance costs will continue rising at an ever increasing rate because of age and wear on its infrastructure. The safety, reliability and efficiency of the GLSLS continue to be paramount considerations for planners. In this regard, past operations and maintenance have proven to be highly successful: the system is available more than 98 percent of the time with a superior record of operational safety. Even so, the costs associated with operations and maintenance are rising and problems with the age or condition of the infrastructure have resulted in vessel delays: in 1985 a lock wall failure interrupted traffic through the Welland Canal and in 2004 a miter gate at the Poe Lock disrupted passage through the Soo Locks. Even more critical is the fact that the majority of the lock sites throughout the system possess only one lock chamber instead of parallel or auxiliary chambers. This means that there are numerous single points of failure throughout the system that can shut down entire navigation corridors if individual components break down.

If the system is to retain its competitive advantage, resources must be deployed in a way that optimizes overall system integrity and safety. Three areas in particular require attention. The first is routine maintenance of basic lock operations. The second is maintenance of the physical structures of the system, including bridges and tunnels, together with their ancillary machinery. The third category involves dredging of channels to maintain the waterways at authorized depths. Maintenance also incurs costs associated with the personnel and overhead associated with day-to-day operations. It also includes buildings and grounds, the floating plant required for ongoing maintenance activities as well as various material costs.

Physical infrastructure maintenance

In terms of the physical infrastructure, the following are the key areas that require ongoing attention:

- ensuring the structural integrity of the lock gates,
- addressing wear on lock gate mechanisms,
- preserving the structural integrity of the lock chambers and their approaches,
- keeping flow control mechanisms functional, and
- maintenance of the bridges and tunnels that cross the system.

The infrastructure inspections and criticality analyses developed by the Engineering Working Group provide a prioritized list of infrastructure components that are at high risk because they are likely to fail, have high repair costs or have a significant impact on navigation. Building on this, a reliability analysis was completed to predict the likely long-term performance of these major lock components. A combination of computer models, analytical methods and expert elicitation was used to determine which elements were priorities for maintenance or upgrade. This analysis also predicted the consequences of unsatisfactory performance in terms of both navigation delays and repair costs as structures age.

The reliability of infrastructure components through 2050 was assessed in two different ways. Where the nature of the component and its failure mechanism is readily amenable to a technical analysis, detailed engineering analysis was undertaken. In other cases, where the failure process consists of a less clearly-defined cause-and-effect relationship, the experience and judgment of the engineering team combined with local engineering staff was drawn upon through a formal evaluation process known as 'expert elicitation'.

While these two processes are quite different, their outputs are similar. They consist of: a probabilistic analysis of the likelihood of failure over time (reliability analysis); event trees to identify the expected sequence of events given various levels of failure (minor, major or catastrophic); descriptions of the nature of repair required depending upon the failure mode of the component; and cost estimates for each of the event scenarios identified.

There are two types of reliability modeling: time-dependent and non-time-dependent. Time-dependent reliability analysis is used for system components that degrade as the number of usage cycles and/or age increase. For these cases, reliability changes over time. This analysis is used for gates, machinery, valves, mass concrete degradation, mechanical and electrical components, anchors and walls subject to fatigue and wear. In these cases, the component's probability of failure or unsatisfactory performance increases over time. For components where the risk of failure is constant over time, such as the seat abutments at Welland Bridge 4, non time-dependent reliability analysis is used.

This process of reliability analysis modeling consists of a combination of engineering and probabilistic analyses that reflect the approaches to infrastructure maintenance commonly adopted by maintenance engineers at both the Canadian and U.S. facilities. In order to provide a uniform reliability analysis across the entire GLSLS system, a unified reliability analysis procedure has been employed. The USACE has applied a systematic approach to reliability analysis to other lock systems throughout the U.S. and has adapted it for use in the GLSLS.

The reliability modeling results in probabilities of unsatisfactory performance for non time-dependent components and hazard rates for time-dependent components. These values are identified for the period 2010 through 2050. For non time-dependent components, the values are the same in each year. For time-dependent components, each year could have a different value.

The reliability modeling also provides consequence event trees for each component, depicting several repair options given the limit state of the component. Such analysis includes the cost of physical repair, the time that the chamber will have to be closed for each repair option, and the effect that repair will have on future reliability. Event trees vary for each component but the following pattern generally applies:

- The first branch of the event tree is the annual probability of unsatisfactory performance (PUP) for the component for any particular year between 2010 and 2050. Since the PUP typically increases through time as the component ages and becomes less reliable, this first branch of the event tree is typically represented as a hazard function curve.
- The second branch is the level of repair associated with the annual PUP. In general, this branch will have two or three legs whose total percentage must equal 100 percent. The percentages were selected by the team of engineers that developed the model, in consultation with operations personnel experienced with the repair techniques for the particular component.
- For each branch, there is an estimate of the cost to repair the component for each level of repair, along with the amount of time in days the chamber is closed to navigation. These cost and closure estimates were also developed by the engineering team that produced the model, in consultation with appropriate operational personnel.
- For each branch, the upgrade to future reliability based upon the repair is identified. This effect is based upon the engineering judgment of the team that developed the model.

Several key system components have been identified for detailed reliability analysis. This work has involved the development of predictive relationships for the progression of wear and the initiation of damage for each identified component. In some instances, this analysis has been based on detailed computer modeling and engineering stress analysis. In other cases, it has relied on the expert evaluation of the engineering staff responsible for operation and maintenance of the facilities.

As an example, Figures 5.2 and 5.3 show the results of the reliability modeling undertaken on the structural members of the Seaway International Bridge which crosses the Montreal-Lake Ontario section of the system.

The first figure shows the likelihood of failure over time (reliability analysis) in blue superimposed on the event tree (which identifies the expected sequence of events given either a minor or major failure) under a scenario where the investments necessary to ensure continued reliable performance the bridge members are made. This maintenance approach is generally referred to as 'proactive'. In this case, maintenance and rehabilitation works are initiated earlier in order to reduce the risk of long, unscheduled shutdowns. This strategy is undertaken

FIGURE 5.2

Likelihood of failure if investments are made in maintenance

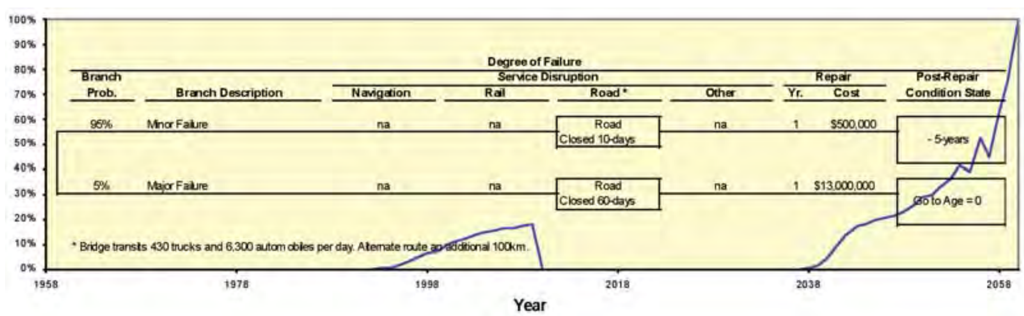


FIGURE 5.3

Likelihood of failure if no investment is made in maintenance

on the basis of forecasts of risk and reliability in the system. It uses a variety of analytical tools to develop reasonably accurate estimates of when components are likely to fail and deals with them before they occur. Since timing is of the essence in pursuing a proactive strategy, reliability analysis is used to evaluate the probabilities of failure and thus optimize system reliability.

The second figure shows the same relationship (with the reliability analysis now shown in red) reflecting the situation where the bridge members continue to degrade without any significant maintenance reinvestments. Such components are either repaired or replaced when they are observed to have reached the end of their service life. This approach is often referred to as a 'reactive' approach: repairs are initiated when parts reaching a certain level of allowable wear or deformation. It is important to note that 'reactive' does not necessarily mean that components are not replaced until they fail. Components are monitored as wear, fatigue, degradation, and aging progress. Engineering analysis sets 'hazard limit states' which define the maximum allowable wear or degradation at which point safety or reliability risks become unacceptable. When a component reaches this hazard limit, maintenance or repair works are initiated. This approach to maintenance has the benefit of getting the maximum use out of every component. It also delays maintenance expenditures for as long as possible. On the other hand, by delaying maintenance, the strategy also runs the risk that at least some components may fail unexpectedly, before they can be replaced. If they do, the system incurs lengthy, unscheduled maintenance.

As can be seen when comparing the 'proactive' and 'reactive' approaches, increased structural maintenance under a proactive strategy will result in the hazard function dropping back down upon completion of the maintenance, thereby reducing the probability of failure through the period of analysis. Rehabilitation or replacement of components before problems and failures begin to occur is often cost effective because unplanned/unscheduled reactive repairs are often more costly, less effective, and more disruptive to navigation.

Navigation channel maintenance

Maintaining navigation through the GLSLS depends, in part, on ensuring that all channels in the system have a minimum navigable depth. In addition to dredging, there is also a need to maintain aids to navigation such as buoys, channel markers and range markers.

A 2005 survey of U.S. flagged Great Lakes carriers reported that the most important issue facing Great Lakes operators was the critical need for dredging [U.S. Department of Transportation, Maritime Administration 2005]. The U.S. Lake Carriers Association [2005] reports that the backlog of required USACE maintenance dredging at Great Lakes ports has resulted in a reduction in drafts ranging from 0.46 m (18 in) at Duluth and in the St. Marys River to as much as 1.37 m (54 in) at Cleveland and Fairport on Lake Erie. Ship draft directly affects the cargo capacity of bulk carriers. A 1.37 m (54 inch) reduction in draft on a 1,000 ft ore carrier results in a loss of 13,000 tonnes (14,400 tons) of carrying capacity.

Surveys are regularly undertaken to map channel bathymetry. Areas of shoaling are identified and marked for maintenance dredging. Though the GLSLS has an overall length of 3,700 km (2,300 miles), maintenance dredging is only needed in limited sections of the system – proportionally far less than is required for other North American navigational systems. Unlike inland waterways such as the Mississippi system, the waters of the Great Lakes do not carry a lot of sediment because of their depth and because water flows are low relative to the size of the lakes. In effect, the Great Lakes act as decanters: the average residency time for water in the Great Lakes ranges from as much as 190 years for Lake Superior to as little as two years for Lake Erie. Sediments carried into the Great Lakes have a long time to settle before those waters exit through the rivers that form the navigable waterways of the system. Thus sedimentation is minimal in the majority of the navigation channels and generally consists of recirculation of local sediments.

On average, maintaining channel depth costs the equivalent of $20 million per year for both the dredging itself and the management of the dredged material. Funding for this work is contingent upon congressional approval. To put these statistics in perspective, an average of about 185 million tonnes annually is shipped through the GLSLS upstream of Montreal. Dredging three million cubic meters per year represents roughly one tonne of dredged material for every 40 tonnes of goods passing through the system.

Of the two to four cubic meters of annual maintenance dredging, some 10 percent consists of contaminated sediments – a legacy from past decades when industrial pollution controls were less stringent. These sediments are routinely re-worked through the action of waves and currents, settling out of suspension in the deeper, quiescent waters of the navigation channels and berths. Consequently, the sediments that are dredged in order to maintain a navigation channel can be contaminated, and thus require containment within dikes to prevent them from spreading through the environment.

There are also many locations throughout the GLSLS system where environmental dredging is being undertaken as opposed to maintenance dredging. Environmental dredging is undertaken for the sole purpose of removing harmful contaminants from the environment, independent of navigational concerns. In many cases, sediments gathered during maintenance dredging activities are clean and can be reintroduced into the water column in areas adjacent to the dredging site. From an environmental perspective, this is the most desirable alternative since regional-scale sediment management (under programs such as the USACE Regional Sediment Management program) is the most prudent means of responding to interruptions in the natural flow of sediments caused by development and coastal structures such as harbors and navigation systems.

USACE records indicate that some 32 percent of sediments from maintenance dredging are clean enough to allow for open-water disposal, and 12 percent of the sediments dredged are re-introduced into the coastal zone as beach nourishment (average of 1993-96 statistics). Where containment is required, the development of approved sediment containment sites is both lengthy and costly. As a result, dredging costs in the Great Lakes average about $8 per cubic yard considerably higher than the average of $3 per cubic yard across North America. The capacity of contaminated sediment disposal sites is an ongoing concern for port operators throughout the system. Dredging costs in the St. Lawrence River typically run significantly higher due to a lack of dredging contractors and the higher mobilization costs associated with use of contractors from the Great Lakes. In addition, contained upland spoiling of dredged materials is typically required in this area, and if contaminated the dredged material has to be transported to a special landfill.

Optimizing maintenance

The infrastructure of the GLSLS must be maintained to keep it operational. It is possible to plan for and schedule maintenance so as to minimize disruptions to shipping: for example, most of the work on lock chambers is performed over the winter shutdown when there is no shipping. However, not all maintenance can be planned in this way. Criticality assessments coupled with reliability data have identified key operating components with an elevated risk of failure. If such components fail unexpectedly, unscheduled repairs must be performed that incur additional costs and disrupt shipping. The timing and duration of any system closure imposes costs on the transportation industry through delays or diversions that can be many times larger than the cost of the repair itself.

Informing future maintenance strategies

Determining an optimal strategy for maintaining the GLSLS infrastructure demands consideration of diverse factors over a long time horizon. It requires an understanding of the economics and competitiveness of waterborne trade, the existing and future conditions of system infrastructure and fleets, and the behavior or decision making of shippers when faced with system closures. To form a sound and reasoned basis for understanding these and other issues, the GLSLS Study undertook numerous detailed economic and engineering studies and developed a suite of sophisticated analytical tools to support the infrastructure maintenance optimization:

- **Vessel Movement Database** provides detailed vessel-specific and movement-specific information for historical periods so that the “existing conditions” of system usage are understood;
- **Cargo Forecasts** describes expected movements of cargo through the system (by lock corridor) so that “future conditions” of system usage are understood;
- **Existing Infrastructure Conditions** provides a detailed component level assessment of the current state of each lock component;
- **Component Risk Model** simulates the engineering condition reliability information over time and tabulates the system service disruptions for the calculation of expected repair costs over time;
- **Vessel Trip Cost Simulator** forecasts the effect of lock failures on marine transportation within the GLSLS system. The simulation calculates vessel transit times and associated operating costs with and without lock or system failures over the forecast horizon. The simulation also documents individual vessel movements lost from the shipping season because a structural failure did not allow all of a season’s vessel movements to be completed.
- **Shipper Survey / Transportation Rate** estimates the expected shipper response to discrete closure events and the shipping cost differences between waterborne cargo movements relative to the least cost overland routing for the variety of cargo movements through the system.

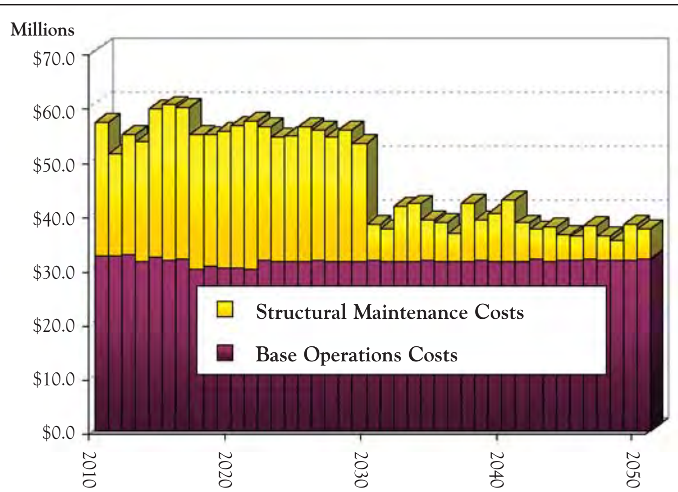
While each of these tools and data sources can be viewed in isolation, they are linked together to facilitate the quantification of the net economic benefits associated with different maintenance strategies. The various databases, forecasts and lock risk and vessel simulation modeling tools feed data into an economic evaluation model that aggregates all of these distinct but inter-related inputs. The evaluation model processes the data from all of the above components over a fifty year time horizon to determine if the additional costs associated with a more intensive maintenance regime are economically justified.

Cost estimates

The figures that follow show the projected operation and maintenance costs (all costs are in 2007 nominal dollars) for the physical infrastructure necessary to ensure the system continues to provide the same degree of reliability as in the past. These costs include navigation channel maintenance for the Seaway portion of the system, but do not include navigation channel maintenance for the balance of the connecting channels (St. Clair River, Lake St. Clair, Detroit River) or federally maintained port areas.

These projections apply the results of the reliability analyses to project the timing of major infrastructure investments required to minimize the potential for system interruptions due to component failures and associated repair downtime. Each figure offers a profile of expected costs, year by year, given the current condition, reliability analysis and criticality indices prepared by the Working Group. It should be noted that the graphs consistently show an initial spike early in the projected operation and maintenance requirements for each corridor that reflects the fact that past funding limitations have resulted in the delay in various operation and maintenance activities. These delayed activities need to be addressed on a priority basis in order to ensure continued system reliability, and as such are typically timed to occur early in the period of analysis.

FIGURE 5.4
SLSMC – Montreal-Lake Ontario (MLO)



As shown in Figure 5.4, the SLSMC – Montreal-Lake Ontario (MLO) region has the highest structural maintenance costs in the system although it contains the second highest amount of infrastructure: five lock chambers, six lift bridges, two bascule bridges and one swing bridge (the most infrastructure is located in the SLSMC – Welland Canal section). Base operation costs in the SLSMC-MLO region averages $31 million annually.

Of the structural maintenance costs, the largest single maintenance component is the Alkaline-Aggregate Reaction (AAR) issue which exists at four of the five lock chambers in the region. From 2013 through 2029, approximately $20 million is assumed annually for vertical face resurfacing at the four sites ($80 million total for each site). Repair dates for the AAR resurfacing at Lower Beauhornois and Cote St. Catherine have been accelerated ahead of the optimal time (beyond 2040) predicted in the reliability model hazard rates. The hazard rate limit state was defined by the growth of the concrete that would reduce lock width and restrict ship passage. There is also a secondary problem that exists with spalling and degradation of the wall surfaces due to freeze/thaw cycles, ship impact and AAR cracking. The Engineering Working Group considers this secondary problem significant enough to expedite the wall resurfacing for these projects. Despite this rehabilitation there is an additional $1 million required annually, on average, to address other AAR issues at the structures.

In addition, the remaining seven stiff leg derrick cranes (one assumed replaced in 2009) are replaced from 2010 through 2013 at a cost of $1 million each. Six lift bridges are assumed to be rehabilitated at a cost of $0.5 million each from 2010 through 2015 (and again from 2035 through 2040). The remainder of the structural maintenance costs are primarily for gates, valves, ship arrestors, ice management, concrete repair and electrical/mechanical repairs and upgrades.

As shown in Figure 5.5, the SLSMC – Welland Canal region has the second highest structural maintenance costs in the system and contains the most infrastructure (11 lock chambers, three lift bridges and eight bascule bridges) of any of the regions. Base operation costs for the region are expected to average between $38 to $41 million annually.

Of the structural maintenance costs, a total of $82.5 million is needed for replacement of five of the six timber tie-up walls from 2010 through 2019 ($8.25 million per year). The ramp up in structural maintenance costs from 2025 through 2044 is for refacing of the lock walls at all 11 lock chambers at a cost of approximately $16 million per year. The lift bridges are estimated to require approximately $0.5 million annually for maintenance and a total of $3.8 million in rehabilitation ($1.9 million in years 2010 and 2035). The bascule bridges are estimated to require approximately $1.4 million annually for maintenance and a total of $19.3 million in rehabilitations and replacements ($2.65 million for fixed Bridge 3a rehabilitation, $3.18 million for Bridge 4 abutment rehabilitation, $8.5 million for Bridge 6 tread plate replacement and $5 million for Bridge 19 rehabilitation).

Figure 5.6 presents the SLSDC – MLO region, which contains two lock chambers, one bridge and one tunnel. Base operation costs average around $17 million annually. It should be noted that the base operations costs for this region reflects, among other requirements, the fact that certain base requirements were delayed in the past due to funding limitations and the requirement to address other higher priority maintenance needs within the available annual funding. As such, the initial base operations level of funding reflects the need to accomplish these activities early in the analysis period. The base operation cost spike in 2015 occurs from a $18.2 million floating plant investment and $5 million in channel maintenance costs while the spike in year 2017 occurs from a $10.2 million floating plant investment and an additional $5 million in channel maintenance costs. Additional $5 million spikes for channel maintenance occur in years 2010, 2023, 2031, 2039 and 2047.

Of the structural maintenance costs, general maintenance accounts for roughly $7 million annually and lock wall mass concrete maintenance amount to approximately $1.5 million annually. The spike in 2010 through 2012 structural maintenance costs occur from a $10.6 million investment in the Seaway International Bridge for sandblasting and painting. In addition, there is a $13.6 million investment in 2020 and 2021 for bridge deck replacement.

Figure 5.5
SLSMC – Welland Canal

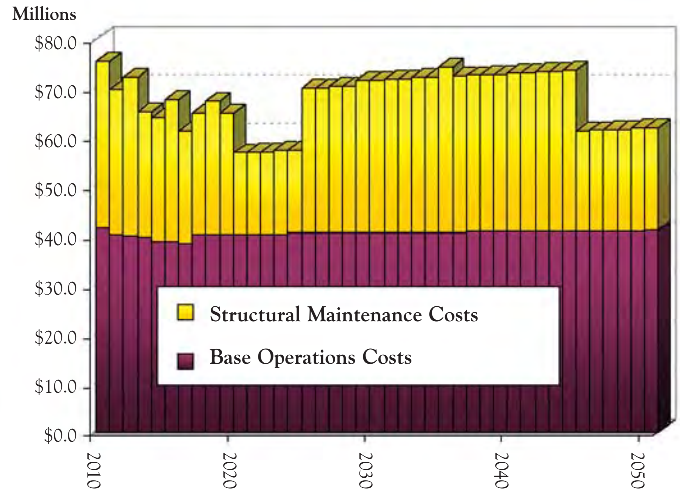


Figure 5.6
SLSDC – Montreal-Lake Ontario (MLO)

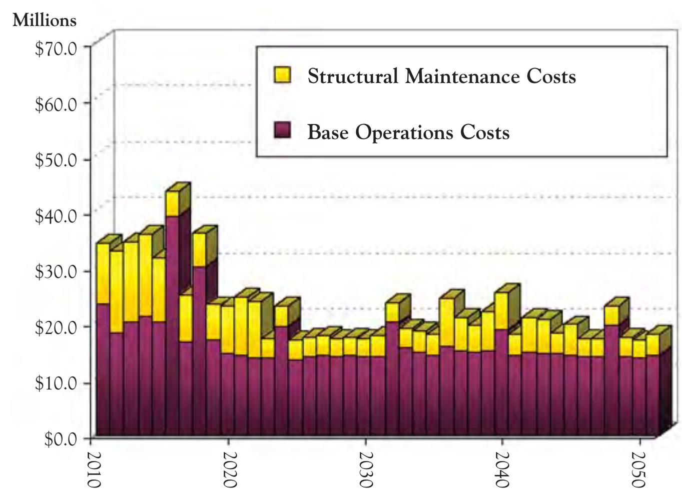


Figure 5.7
Soo Locks

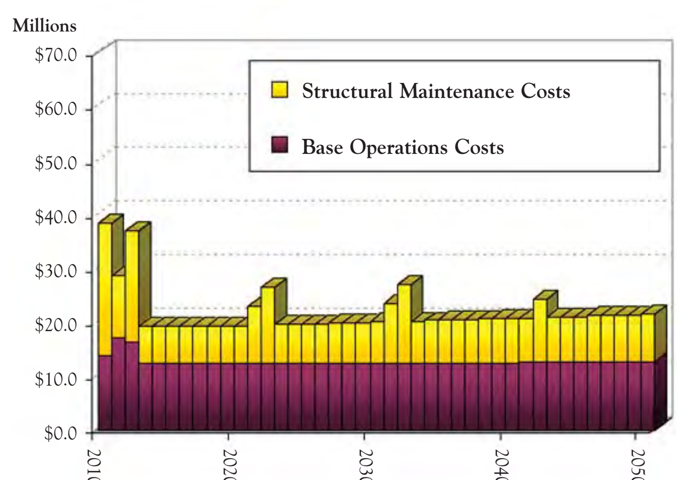


Figure 5.7 presents the Soo Locks, which consists of two operating lock chambers and a hydropower plant which supplies power for lock operations. Base operation costs average around $12.6 million annually.

Of the structural maintenance costs, an average of $7 million annually is needed for general maintenance. The initial surge in costs in 2010 come from the west center pier wall extension ($3.1 million), miter gate machinery rehabilitation at both lock chambers ($5.85 million) and crib dike rehabilitation at the north hydropower plant. The spike in costs in 2012 are from Poe Lock upper miter gate rehabilitation ($3.5 million) and work on the upper approach walls at both chambers.

As noted previously, these are the projected costs necessary to continue to maintain system reliability. If the priority components (as determined through the engineering criticality index method) are not maintained as recommended, risk of unscheduled repair costs and transportation disruptions increase. Through simulation modeling of the priority component engineering reliability data (hazard functions and event trees) expected unscheduled repair costs can be estimated.

This comparison of costs with and without proactive maintenance of the priority components to maintain these components in a reliable condition reveals that the costs to the governments are not significantly different in total, although the timing of the expenditures are. The real benefit, however, for maintaining them in a reliable condition lies in the potential traffic disruptions that would occur if they were not maintained.

Service disruptions in the system temporally stop or slow down vessel transits through the system. Through the same simulation modeling of the priority component engineering reliability data, expected transportation impacts / costs can be estimated. Impacts include increased vessel delay costs and potentially unmet tonnage flows.

The consequences of service disruption vary by shipment and will be dependent upon the service disruption type (closure or service time increase), location of the disruption (at a single or dual lock chamber site), duration and timing (beginning, middle or end of the navigation season). Impacts from a service disruption can include not only shipment delay, but also return trips to unload a shipment for re-routing on an alternative transportation mode, vessel idling, stockpile depletion and plant shutdowns.

With the system consisting of essentially a series of structures that must be transited with no alternatives (except at the Welland Canal flight locks and the dual chambers at the Soo Locks complex) the probability of completing a trip is the probability of each of the potential obstruction points (locks and bridges) operating. A closure of one of the structures in the series essentially closes the system. Closures or a sequence of closures, during the navigation season can result in incomplete vessel trips since there is a limited number of vessels that shuttle the cargo from origin to destination.

Figure 5.8

Scheduled costs under the reliable system scenario versus expected unscheduled repair costs and transportation costs from under funding the priority components

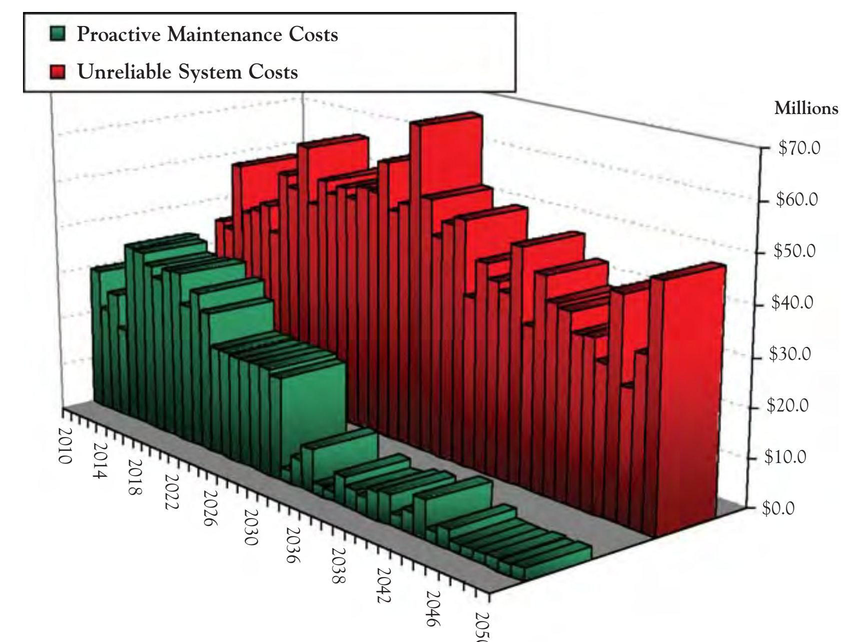


Figure 5.8 includes the projected maintenance costs required to proactively address those infrastructure components for which detailed engineering reliability analyses were undertaken. These costs are then compared to the projected impacts of system disruptions if these high priority components are not addressed in a proactive manner. This includes a total of approximately 35 relatively 'high risk' components located throughout all four lock corridors. The unreliable system costs are considered conservative in that they assume that vessels incur no return trip and unloading costs, no vessel idling costs, no stockpile depletion costs, no plant shutdown costs, and assuming unmet tonnage flows are able to acquire alternative mode transportation (when needed) at their long-run least-costly

all-overland alternative rate. This comparison shows the value of scheduling the expenditure needed to maintain system reliability in a proactive manner. Totaling these projected costs through 2050 shows that approximately $1.2 billion in costs can be avoided by ensuring a proactive approach to system maintenance is followed in order to minimize the potential for system disruptions.

Conclusions

To determine an optimal strategy for maintaining the GLSLS system infrastructure, one must understand or forecast issues such as the following:

- The current state or condition of all components of the lock infrastructure;
- How likely is it that a particular component will fail given its condition and level of use at a particular point in time, and if a failure occurs what is the impact – a lock closure (15, 30, 90, 180 days?), a shutdown?, and what is the costs of repairs?
- What shippers will do if a discrete lock closure does occur – wait or route the shipment via an alternative mode and at what cost?
- How will a closure affect the costs of transporting cargoes and will it result in a vessel making fewer trips in a given season?
- How will shippers react if there is a perception of existing system unreliability?

In addition to the above issues, there are related factors that must also be considered, such as:

- How traffic will evolve over the next fifty years through the system (by cargo type, origin and destination)?
- How the vessel fleet will change over time and will there be new types of vessels using the system?
- How vessel operating costs, including fuel costs, will change over time?

The various databases, forecasts, and suite of lock risk and vessel simulation analytical tools developed as part of the GLSLS Study can be used to help inform and support the infrastructure maintenance optimization. It allows planners to assess over a fifty year time horizon the additional costs associated with a more intensive maintenance regime and to determine if the value of the economic benefits associated with a proactive maintenance strategy exceed these additional costs.

The general conclusion to be drawn from the study analysis, which considered the reliability and risk associated with those system infrastructure components categorized by the Engineering Working Group as high priority, is that a proactive maintenance strategy is preferable to avoid the additional costs of unscheduled maintenance repairs and general system unreliability. The real benefit, however, lies in avoiding the additional costs associated with unanticipated failures. Infrastructure failures yield higher transportation costs because vessel transit times are longer as a result of waiting and queuing; shippers switching to alternative more expensive transportation modes during closure events; and, in the long run, switching to more expensive modes if they perceive that the system is unreliable. A more reliable GLSLS system with less disruptive lock events (delays, closures, speed reductions, etc.) is likely to attract more commercial traffic, which will, in turn, make the system more cost-effective.

Chapter 6

Opportunities and Challenges

Continuing growth in international trade, regional population, economic activity, and highway and rail traffic will eventually increase congestion in the bi-national transportation network that serves the Great Lakes basin and St. Lawrence River region. With additional capacity available, the Great Lakes St. Lawrence Seaway system can help to relieve some of the pressures on landside corridors by expanding into container service and shortsea shipping to provide new intermodal services, particularly around road and rail bottlenecks. By addressing the stated preferences of shippers and deploying the right kinds of new vessels, the system can improve its intermodal competitiveness and make significant new contributions to regional transportation needs in the near future.

As part of its mandate to examine the current and future commercial role of the GLSLS system, the Economic Working Group of the GLSLS Study considered the potential impact of new types of cargoes and vessels on the system. A primary objective of this investigation was to develop insights into the future role of the system within an integrated North American transportation network, along transcontinental as well as regional trade corridors. The investigation included an assessment of a wide range of interrelated issues including: trade growth, evolving and emerging markets, changing trade patterns, shortsea shipping, modal integration, new vessel technology, economic efficiency and associated infrastructure needs.

The role that the GLSLS system will play in the coming half century is being determined by the interaction between external and regional economic forces as well as regional system-oriented actions undertaken to accommodate the resulting transportation demands. It has become clear that the GLSLS can continue to play a pivotal role in the economy of the Great Lakes and St. Lawrence River basin, but only if its infrastructure evolves in a way that satisfies the transportation needs anticipated in coming decades. Consequently, it is vital to understand the interrelated forces driving regional economic growth and the transportation industries that support it.

The global context

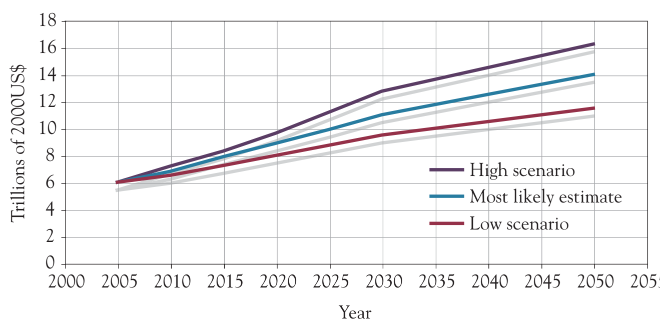
A significant external force transforming transportation needs around and through the GLSLS system has been the explosive growth in North American international trade and investment. In part, this is due to integrative forces that have led to increased economic globalization: trade barriers are falling, electronic communication is linking the world's markets, and new technologies in intermodal transportation networks are making it easier to move goods and services around the world. As a result, countries such as China and India are able to find new North American markets and enter onto a path of rapid development and growth.

The economies of the Great Lakes and St. Lawrence River are already strongly integrated into the global economy, in part because of the waterway linking it to world markets. As a result, the binational region has already experienced remarkable growth in its trade: adjusted for inflation, it grew twenty-fold from $50 billion in the 1960s to $1 trillion in 2000.

In recent decades, the rapid expansion of trade with Asia has led that relationship to overtake traditional trade ties to Europe. Even so, all trading relationships have grown at extremely high rates. The explosion of trade with every part of the world is transforming the character of what used to be a bi-national regional economy. In fact, the Great Lakes and St. Lawrence River region is now a major market and transshipment center for global exports as well as imports flowing through Pacific, Atlantic and even Gulf Coast ports.

As these trading relationships continue to evolve, forecasts suggest that the region's gross domestic product (GDP) will more than double, growing from $6 trillion in 2005 to $14 trillion in 2050 (see Figure 6.1). This boom is likely to be accompanied by growth in the region's population. This growth, however, is dependent on the continued diversification of the region's economy and the development of technology-intensive and highly competitive businesses, since many older more traditional manufacturing activities are likely to move offshore.

Figure 6.1
Projected growth in gross domestic product of the GLSLS region



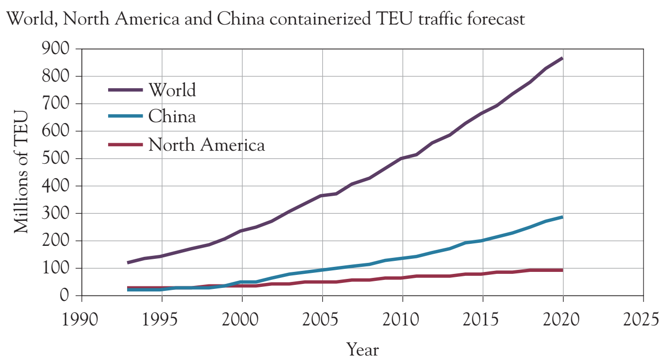
Global trends in containerization

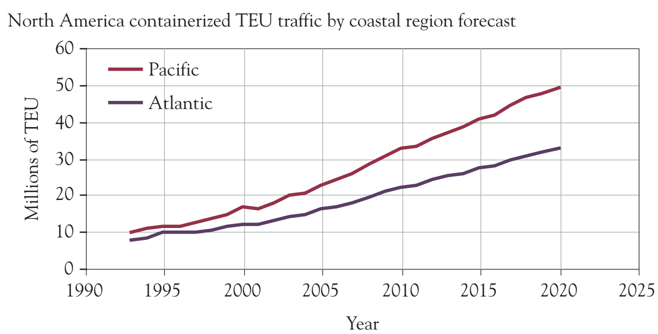
Parallel to the rapid expansion of international trade, there has been explosive growth in global container traffic over recent decades. The Asia-Pacific region in general and China in particular are leading this upsurge by rapidly developing containerized transportation markets. As China and other Asian countries are significant trading partners with the U.S. and Canada, this is having a dramatic impact on containerized traffic through major North American ports, especially on the Pacific coast. Trade with Asia generates the highest containerized cargo volumes in the world and largely defines the container shipping industry. China is already the world's largest single exporter of containerized cargo and is soon expected to become the fastest-growing importer of containerized trade. As Figure 6.2 shows, world containerized traffic is expected to grow by an average of 6.3 percent a year to reach 854 million twenty-foot equivalent units (TEU) in 2020. China's share of that traffic should reach approximately 33 percent, while North America's share will grow at a slower rate and account for 10.4 percent by 2020.

In North America, as Figure 6.2 illustrates, containerized traffic will grow at a slightly faster rate on the Pacific Coast, which is expected to account for 55.5 percent of all North American containerized traffic by 2020. Over the same period, the Atlantic Coast is expected to account for 36.6 percent of the continent's containerized traffic.

Figure 6.2

Projections of world container traffic compared to that of North America





Driving the growth in containerization are shipping strategies that continually enhance efficiency by reducing unit costs, using larger ships and calling at fewer ports. Shippers are also looking for new alliances, mergers and pooling agreements to optimize the use made of their larger capacity.

Containerization requires specialized ports with appropriate water depth, handling facilities and modal interchange capabilities. Ultimately, a handful of deepwater hub ports with feeder services to shallower regional ports could handle much of the international container traffic destined for North America. To attract increased containerized traffic, a port benefits from proximity to the major markets, suitable physical characteristics, availability of inland transportation, competitive port charges and reliable port services.

With trade liberalization, Asian exports to the U.S. and Canada have grown rapidly. The introduction of double-stack container trains in 1984 facilitated the use of large post-Panamax vessels, and improvements in the efficiency of inland rail distribution prompted an inter-modal shift to transcontinental rail shipping, instead of a previous dependence on direct all-water service to American ports on the east coast. The increasing use of rail and truck for inland distribution has been reinforced by greater integration between container-handling systems in ports and inland transportation. Over the last decade, however, landside highway and rail networks are experiencing increasing strains as they strive to accommodate continuing growth in containerized freight.

Regional trends

The challenge of congestion

Within the Great Lakes basin and St. Lawrence River, growth in population, economic activity as measured by GDP and international trade means that private and commercial traffic throughout the region will expand to unprecedented levels. This will put significant pressure on transportation networks. Forecasts prepared for the U.S. Department of Transportation by its Federal Highway Administration suggest that peak-period vehicular congestion threatens to exceed the capacity of the American national highway system, not only in all major urban centres adjacent to the Great Lakes, but virtually everywhere in the region. Canadian growth patterns are similar and analysts believe that similar levels of congestion may develop in the Windsor-Toronto-Montreal-Quebec City corridor.

Planners have recognized the challenge and are trying to respond. The U.S. Transportation Research Board has even stated that highway capital stock is being added faster than it is wearing out. Even so, the trucking industry is keenly aware of and grappling with the effects of local and regional congestion and capacity limits:

- There is a shortage of skilled drivers, especially on longer-haul routes, and the truck-driving workforce is aging.
- Trucking rates are now increasing, to factor in recent increases in driver compensation, fuel prices and insurance costs.

- More stringent security procedures at Canada-U.S. border crossings impose a disproportionate burden on the trucking industry, in terms of increased administrative costs and lower service levels to clients.
- Highway networks throughout the system are nearing capacity, thus facing increased traffic congestion.
- Some border crossings, such as Detroit-Windsor, are also nearing capacity limits.

Efforts are underway to address these challenges, but it is certain that most responses will add to costs in one way or another, making the trucking industry less competitive vis-à-vis other modes of transportation. This opens up new opportunities for both rail and water transport.

Congestion on the highways is mirrored by congestion in intermodal facilities serving ocean-going traffic. The growing demand for containerized services has led to bottlenecks at the major North American Pacific ports and along the rail and trucking networks to which they are connected. In coming decades, limits to port capacity expansion are anticipated at many west and east coast ports. This problem is exacerbated by the increasing size and draft of container ships, which cannot be accommodated at many shallower coastal ports. While new deepwater container port facilities are being developed or proposed (i.e. Canada's Prince Rupert and Mexico's Lazaro Cardenas, as well as the proposed facility at Punta Colonet on the west coast), opportunities for expansion at many existing west coast ports are limited. In many areas, analysts fear that it will not be possible to add new infrastructure quickly enough to keep pace with the even more rapidly expanding needs of global trade.

One alternative is to re-direct traffic to less travelled routes. Carriers sailing from Asia-Pacific ports have resumed all-water shipping via the Panama Canal. As a result, that waterway is now operating near capacity and will not be able to absorb more traffic until its current expansion is completed by around 2015. When that happens, some traffic will flow to American southern and eastern ports to avoid the congested west coast.

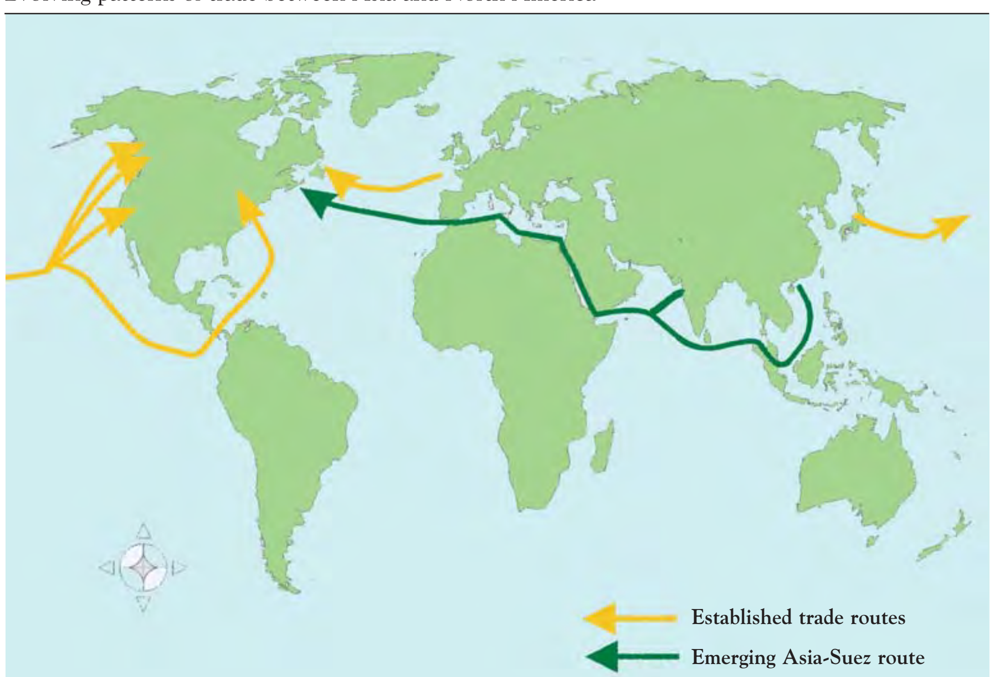
In addition, the Suez Canal route appears to be an increasingly viable alternative. This is because of the continuing expansion of North American trade with Southeast and South Asian countries such as Malaysia, Thailand, India and Pakistan. Moreover, the Suez Canal (where no locks are needed to facilitate vessel passage) can handle the larger and deeper draft Suez max vessels, including recently deployed container ships that are too large to fit even within the planned new locks of the soon-to-be expanded Panama Canal.

Both these trends could favor the deployment of additional container ships to North America's east coast ports. It is anticipated that at least 30 percent of West Coast port growth will be diverted, half through the Panama Canal and the other half via a round-the-world route through the Suez Canal. Such traffic could eventually find its way to east coast ports such as Halifax, Nova Scotia, Norfolk/Portsmouth, Virginia, and Freeport, Bahamas.

As the map in Figure 6.3 shows, it is entirely feasible for ships to leave Asian ports, sail through the Suez Canal for potential stopovers in Europe, and then continue on across the Atlantic to North America. Because ships on the Suez route can be larger and carry both European and American cargoes at the same time over very long distances, vessel operators can seek greater economies of scale. On the Great Circle route from the Straits of Gibraltar to New York, deepwater ports such as Halifax are in an ideal position to benefit from the forecasted growth of trade with Asian ports west of Hong Kong via

FIGURE 6.3

Evolving patterns of trade between Asia and North America



the Suez. Other east coast ports such as Norfolk, Virginia have benefited from Panama Canal trade, but since the Panama Canal is near maximum capacity, further growth on that route will be severely constrained until Panama's expansion project is completed as scheduled in 2015.

At the same time, Montreal will continue to remain competitive vis-à-vis its traditional transatlantic trade, which is currently carried in relatively smaller ships that range up to the current Panamax vessel capacity of 4,500 TEUs. Montreal's container traffic is also forecast to grow significantly, if not at the potentially faster pace of Asian traffic at a deeper draft port like Halifax.

These pressures and trends may open up opportunities for the GLSLS system. As the system is operating at about half its potential capacity, it can be used to relieve at least some of the traffic being added to the increasingly congested roads and railways of the region. Exploiting such opportunities requires investment to strengthen intermodal linkages, the feasibility of which depends in large part on the attitudes and preferences of the transport service providers who use these networks.

Shortsea shipping

One way to ease traffic congestion is shortsea shipping. The term shortsea shipping refers to the practice of adding a waterborne leg to an intermodal shipment that normally would travel by road or rail. The objective is to reduce travel time, avoid congested routes and reduce cost. It also holds out the promise of improving energy efficiency and lowering greenhouse gas emissions. For example, goods that normally travel by truck through congested metropolitan areas might be rerouted across a lake, if fast and cost-effective water transport were available.

Taking advantage of this opportunity would involve developing the capability of rolling the truck trailer right onto the vessel and then rolling it off on the other side so as to avoid lengthy stays in port as well as the expense of loading and unloading cargo. That requires investment in suitable roll-on, roll-off (Ro-Ro) vessels as well as appropriate port facilities. As congestion on the roads increases, this kind of investment may well be worth making. To fully realize the potential for shortsea shipping in the Seaway and on the Great Lakes, American and Canadian hurdles to such services with respect to taxes, user fees, and customs practices are coming under reexamination. For example, legislation providing for exemptions to the harbour maintenance fee in the Great Lakes/Seaway system has been introduced into the U.S. Congress.

Related to shortsea shipping are neobulk (or "break bulk") cargoes. Neobulk cargoes are often palletized and typically rolled on or crane-loaded onto a ship. This represents a cargo category that is neither a traditional bulk good, such as iron ore, nor is it normally shipped by container. It consists of commodities such as steel and aluminum ingots, plate and coil steel, finished automobiles, rail transportation equipment, farm machinery and tractors, to take a few examples. Loading neobulk cargoes into containers for shipping through container-handling ports is an increasingly common method of transporting such goods.

Because the trend in shipping is strongly toward containerization, neobulks constitute a small and declining freight category. In the U.S., containerized cargo accounts for about 95 percent of all general cargo import/export tonnage, leaving neobulks with only 5 percent, a share that is declining. This market share also holds for the Port of Montreal, where in 2005, non-containerized general cargo accounted for 0.50 million metric tons (Mt) or 4.3 percent of a total of 11.63 Mt. The majority of this neobulk cargo consisted of imported iron, steel and other metal products.

Neobulk shipments are characterized by very short distance trips. Consequently, there are only a limited number of movements that lend themselves to using the GLSLS. There are, however, specialized trips that might be developed for the future. For example, the amount of neobulk traffic on the GLSLS might increase if there were specific agreements between metal manufacturers and carriers. As many steel and aluminum production facilities in the Great Lakes region are located in close proximity to water, some estimates suggest that the GLSLS could attract as much as a 20 percent share of the total traffic originating in such locations. For the study's base year of 2005, that could have generated a total of 284 forty-foot equivalent units (FEU[1]) per day of neobulk traffic on the GLSLS system, as compared to the total forecast of 1,765 FEU per day for containerized traffic, or 16 percent of the total. Their impact on specific portions of the GLSLS could even be higher, depending on the ability of GLSLS vessel operators to capture flows from specific steel or aluminum production facilities. Traffic of 284 FEU per day, however, is only sufficient to support two or three north-south specialized neobulk shortsea shipping operations. Given the characteristics of neobulk traffic, such cargo growth would be expected to level off by the period of 2030 to 2050, at which point it might involve the potential operation of four to six specialized services.

1 Two standards exist for container traffic: The twenty-foot equivalent unit, TEU, and the forty-foot equivalent unit, FEU. For shortsea shipping analysis, the FEU is often a more appropriate measure of capacities and traffic levels since typical trucking and multimodal operations use FEU and it is the number of FEU that typically controls drayage costs. To convert from FEUs to TEUs simply multiply by two.

Impact on the GLSLS transportation network

Emerging opportunities

All of the drivers of change discussed above suggest that there are opportunities for the GLSLS to capture larger markets by focusing on new vessels and new cargoes. Such opportunities would be based on growth in container traffic through the system, supported by the introduction of new vessels that are able to carry that traffic more efficiently. The combination of containerization and new types of vessels offers both shorter travel time and lower cost, which can be extremely appealing to shippers looking for alternatives to their current transportation choices.

Containers and the GLSLS

Continued growth in domestic, cross-border, and import/export trade means that traffic volumes could soon be sufficient to achieve the economies of scale needed to support a viable and competitive cargo vessel service within the GLSLS system. In fact, all container traffic through the region is expected to grow by a factor of up to 2.5 times current volumes by 2050 and about one-third of this could be moved using the waterway.

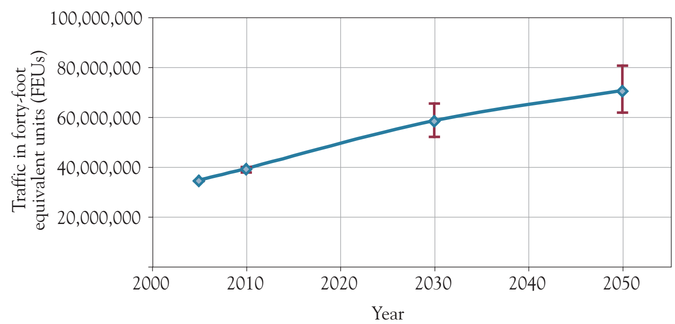
As noted, congestion significantly raises truck and rail transit times and costs, as both transport modes adopt measures to accommodate an expected doubling in traffic by 2030. This presents an opportunity for water transportation, particularly if it can address the needs and preferences of the shipping community.

The study's Economic Working Group conducted a modal diversion analysis which showed that with a maximum open-water speed of 20 knots, container ships on the GLSLS could have gained a market share of 2 percent of total cargo traffic in 2005, a level comparable to that of intermodal rail. Much of this market share would have been on routes that are not well served by rail intermodal services.

In an "uncongested" environment where the impact of congestion on rail and highway is fully mitigated, water's share of total traffic in the region could still increase to 3 percent by 2050. If there is no investment in mitigating highway congestion, a "congested" environment could encourage both rail intermodal and water's market share to grow to more than 4 percent each, reducing truck traffic to 92 percent. Since rail and water diversion tends to be in long-haul traffic, this would result in much more than an 8 percent reduction in haulage distance. Figure 6.4 shows forecasted growth in the container market for the GLSLS region under combinations of congested/uncongested and moderate/high growth scenarios. These are the markets for which the GLSLS would compete with other available modes of transportation.

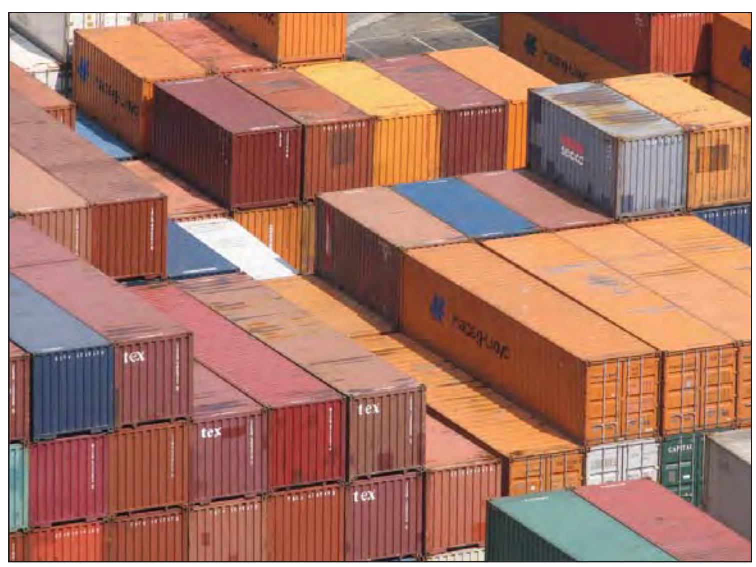
Figure 6.4

Forecast of market for container traffic carried in the GLSLS binational region



New service deployment

To determine the water routes on which such vessels could be deployed, the GLSLS was divided into two sections (see Figure 6.5). The eastern section consists of the Canadian portion of Lake Ontario and the Seaway downstream from the Welland Canal – essentially the system from Hamilton to Halifax. The western section consists primarily of the American portions of the upper Great Lakes upstream from the Welland Canal – from Chicago and Duluth to Hamilton.



Containers at port
Source: U.S. Department of Transportation

Figure 6.5
GLSLS vessel routes

In the eastern portion of the system, there is an immediate opportunity for the GLSLS to carry domestic, cross-border and import/export traffic at Montreal, as well as a longer-term opportunity for extending GLSLS vessel services to Halifax. The latter's opportunity depends on its ability to attract the larger number of vessel calls that are expected to come from growth in Suez trade with Asia. In the future, the ports of Halifax, Quebec City and Montreal are all expected to see increased traffic for both the American Midwest and Central Canada, and so should grow accordingly.

As for the western segment of the GLSLS, there are substantial domestic and cross-border flows from Chicago and eastern Wisconsin to Lake Erie ports, Central Canada and Montreal. Given increasing congestion in Chicago and the limited ability of railroads to expand terminal capacity there, the Great Lakes could provide by-pass service for some West Coast container traffic. The Burlington Northern Santa-Fe (BNSF), Canadian National (CN) and Canadian Pacific (CP) railroads can extend freight service from the western ports of Tacoma, Seattle, Vancouver and Prince Rupert to ports on Lake Superior at Duluth and Thunder Bay. From there, an intermodal transfer could be made to vessels that could move this traffic to ports in the American Midwest. Thus, there is an immediate opportunity to develop domestic and cross-border traffic on the upper Great Lakes, and a longer-term opportunity to develop land-bridge traffic in conjunction with west coast ports and the railroads.

To realize such possibilities, the GLSLS could stake out an initial position in the container business by using individual small ships. As traffic grows, however, this vessel traffic can be coordinated to operate as a single network, thereby improving reliability and frequency. Eventually, Seaway-max ships would replace the smaller vessels. Implementation of vessel service should start by focusing on attracting the domestic and cross-border traffic that currently moves by truck in trailers rather than in standard shipping containers, so a Ro-Ro trailer service would be more conducive to its needs. Such services would likely be a welcome complement to the trucking industry given some of the challenges it is facing with respect to driver shortages and delays at border crossings.

Existing markets suggest that it would be feasible to offer a service between Hamilton and Duluth or Thunder Bay and Chicago as well as a daily service between Hamilton and Montreal, using small Ro-Ro vessels. Such vessels do not have the cost advantages of larger craft and they would be vulnerable to a competitive response from rail during the start-up period. However, Hamilton's location provides a drayage cost advantage to some shippers, which could help protect the market share of waterborne transportation. A connection to American-based services at Hamilton would provide an additional measure of protection, since direct rail intermodal service is currently not provided through the Niagara gateway, so cross-border traffic to Lake Erie would have to move by truck.

There is also a market for largely domestic American freight moving from Lake Superior to ports on Lake Michigan and Lake Erie. A small vessel could shuttle traffic from Duluth and Thunder Bay to Cheboygan, where a connection would be made to a larger ship that would serve both lakes Michigan and Erie.

The strongest current GLSLS traffic flow is American domestic and cross-border traffic from Chicago and eastern Wisconsin to ports on Lake Erie, with smaller flows connecting to Lake Superior and Canadian ports. Chicago and the ports of Wisconsin offer an attractive opportunity for waterborne transportation that could support a daily, large Ro-Ro vessel service at 2005 traffic levels. A Chicago to Hamilton vessel service would connect to Lake Superior service at Cheboygan and to Lake Ontario and Montreal service at Hamilton.

Filling a single GLSLS-max Ro-Ro vessel daily to its capacity of about 700 TEUs would nearly double the volume at the Halifax port. While the traffic currently available at Montreal can sustain a small vessel service from Hamilton to Montreal, a major traffic influx at Halifax would permit extension of GLSLS service all the way to Halifax, and a large vessel could be substituted for the small one. Another example is the development of land bridge traffic at Duluth and Thunder Bay, which depends on the cooperation of the west coast ports, the BNSF, CN and CP railroads connecting to them, and the interest and willingness of ocean carriers to use GLSLS shipping services.

Determinants of new waterborne services

Shipper preferences

Any projected enhancements to the transportation routes or services used in the GLSLS will ultimately depend on the attitudes and preferences of the shipping community that uses them. The GLSLS Economics Working Group conducted a survey of shipper preferences to determine the feasibility of the proposed innovations to the system.

Because of ongoing growth in global trade, the transport industry operates in a highly competitive environment. A survey of shippers found that almost all of them (99 percent) rated cost as an important or very important attribute in their choice of transportation modes. Time and frequency were rated as important or very important by 89 percent of the shippers surveyed, and 98 percent rated reliability as important or very important.

Further analysis showed the trade-offs that shippers of different goods were willing to make to obtain the level of service that was important to them. For example, all shippers say that time is an important consideration in their planning, but when asked how much they were willing to spend to save one hour of freight shipment time, those typically moving finished goods in containers and trailers were willing to spend more than those moving raw materials. And those who shipped goods by truck assigned a far higher value to time than those shipping by rail or water.

The same pattern held in attempting to estimate the value of frequency and reliability in terms of the premium shippers, who were willing to pay in order to ship immediately or to guarantee the shipment. In both cases, the shippers of finished goods assigned higher values to frequency and reliability than shippers of unfinished goods.

Finally, shippers were asked about the extent to which they value the ability to use a single mode of transportation all year round. This is significant because part of the GLSLS system is affected by seasonality inasmuch as the St. Lawrence Seaway is closed for roughly three months of the year. The issue is what kind of a discount could persuade shippers to switch from an all-season mode to a seasonal mode, should it become available. The answer is that for raw materials shipped by rail, a discount of 5 percent in transportation costs would be sufficient to induce a switch to the seasonal mode. For food, semi-finished and finished goods, the required discount would be 14 percent. The least flexible commodity is food shipped by truck, which requires a discount of nearly 25 percent before it would switch to a seasonal mode, probably because of the highly specialized nature of the equipment needed to transport it. Otherwise, seasonality was found to be of less concern to most shippers because they draw up their transport contracts according to spot markets, monthly arrangements or on short terms, and thus for them switching to other modes is less problematic.

Shipper attitudes suggest that the GLSLS is highly competitive against road and rail in the transport of semi-unfinished goods. As the global economy grows, the challenge for the GLSLS is to capture a share of this expanding market, using its competitive advantages to provide a valuable complement to multimodal transport services based on road or rail. One way of doing so is to address the service factors that shippers value in moving semi-finished and finished goods as well. That means, above all, reliability, shipment time and cost.

New vessel technologies

Since shippers value cost and time, the GLSLS can successfully compete against road and rail, if it deploys vessels that are cheaper and faster. There are four new vessel technologies that offer these advantages and can be used to move containers on the GLSLS system:

Containers on barges is a term used for flat-bottomed barges that can move stacks of containers through the system. Such vessels consume usually little fuel, making them relatively inexpensive. On the other hand, they move very slowly.

Container ships are now available that have a cruising speed that is almost double that of older vessels. Although their energy consumption is higher, the faster vessels are still very energy-efficient when compared to truck, rail and even container on barge services because their higher energy consumption is offset by savings in crew and capital costs. Higher speeds directly address shipper concerns about time, making this mode competitive against ground transportation. Ship speeds will still be limited by locks and channels; but on open water, faster ship speeds reduce travel time significantly.

Fast freighters (or ferries) use very powerful engines to operate at high speeds. They are often used as automobile and truck ferries. Speed, however, is achieved through high fuel consumption: they can use almost 20 times more fuel per FEU-mile than a container ship. That also means that a fast freighter (ferry) consumes substantially more fuel per container shipped than does a truck for the same distance.

Partial air cushion support catamaran (PACSCAT) is a surface-effect ship – a vessel that uses an air cushion to partially lift itself out of the water. This reduces the draft of the vessel as well as its wakes. The vessel operates in water displacement mode at lower speeds but raises itself out of the water for faster travel. Again, its higher speeds are achieved at the expense of fuel efficiency.

The performance characteristics of the four vessel types are summarized in Table 6.1. In terms of optimizing container traffic on the GLSLS, the two critical parameters are: fuel economy, expressed as the weight of fuel needed to move one twenty-foot container (TEU) a distance of one kilometer; and transit times between different ports on the system. A comparison of these two factors suggests that container ships specifically designed for the GLSLS offer the best fuel economy, coupled with transit times that are competitive with those of rail.

Table 6.1 does not yet tell the full story since it does not include cargo costs. Actual costing, however is derived from highly complex calculations that factor in variables such as capital cost of the vessel, amortization and depreciation schedules, average speed given locks and channels, crew size, and time spent loading and unloading cargo as well as the fees and charges levied to pay for a wide variety of support services. Container and other vessels can be configured either as Ro-Ro, in which the vehicles carrying containers (trucks or rail cars) can simply roll on or roll off the vessel, or lift on/lift off (Lo-Lo), in which cargo has to be physically lifted (usually by crane) from the land-based vehicle and loaded into the vessel, and then lifted out again for reloading onto a truck or rail car at the other end. Clearly the time spent on the process of loading and unloading cargo plays a role in overall costs.

Table 6.1

Performance characteristics of potential new vessels

Performance parameter	*Container on barge*	*GLSLS container ships*	*Fast freighter*	*PASCAT (open water)*
Top cruise speed (km/h)	14.8	37	63.9	63.9
Fuel consumption at cruise speed (kg/hr)	560	2,680	6,510	8,683
Fuel consumption (kg/TEU-km)	0.061	0.054	1.07	0.647
Loaded TEU/FEU capacity	620/310	1330/665	95/42	210/105
Crew	9	14	9	11
Transit time between Lake Erie and Montreal (hours)	48	43	40	37
Transit time between Halifax and Montreal (hours)	84	50	25	25
Transit time between Halifax and Chicago (hours)	202	135	86	83

When all of these considerations are factored into the calculation, transportation using container ships customized for the GLSLS continue to be the optimal choice in today's competitive environment. They can be designed in both small and large versions and can carry international and domestic traffic. A smaller ship could be deployed initially and could eventually be replaced with a larger ship once traffic levels are high enough to maintain daily service. Additional vessel frequencies would be added on an "incremental" basis to increase capacity as needed. To compete with ground transportation, however, daily service frequency must be maintained.

New cargo and new vessel forecasts

The Economic Working Group developed forecasts for the four different vessel technologies under consideration, using both congested and uncongested traffic scenarios and assuming moderate economic growth. Additionally, high and low economic growth scenarios were developed as sensitivities to the congested large ship scenario.

The results of the analysis indicate that modern waterborne technology can compete with rail and truck for inland container distribution from Halifax, Montreal, Duluth and Thunder Bay, as well as for domestic traffic moving across the system. The most promising waterborne technologies are small and large 20-knot container ships that can carry both international and domestic traffic.

Forecast traffic volumes for the GLSLS are significant. For a large container ship service at the demand levels seen in 2005 and under current market conditions, traffic through the GLSLS could reach as much as 0.6 million FEUs, split equally between international and domestic traffic. If congestion increases throughout the system, this traffic could grow to more than 3 million FEUs by 2050.

On the basis of this analysis and considering all forecasting limitations, assumptions and institutional issues raised, there is a strong case for further development of plans for both sections of the GLSLS, particularly as regards Lo-Lo and Ro-Ro container ship scenarios. The planning needed includes further business studies to:

- develop investment grade traffic forecasts;
- consider the potential for public-private partnerships; and
- explore sources of funding and financing of port and intermodal development with a view to providing incentives for infrastructure development by local port authorities.

These studies should also include a further detailed assessment of vessel operations and costs, port and hinterland services, and the potential of niche market opportunities including ferry operations, neobulk services, railcar ferries, and accompanied truck and trailer services.

Constraints and assumptions

Forecasts of potential opportunities are largely an extrapolation of historic trends and projected GDP growth. Those trends, however, may not continue as expected. For example, it may turn out that the growth of trade with Asia will slow. If this occurs, it would affect the volumes of traffic overflowing from west coast ports onto other trade routes.

The forecasts are also sensitive to assumptions relating to the diversion of Asian traffic via the Suez route through northeast ports and the willingness of the railroads to cooperate in the development of land-bridge services from the Pacific Northwest to Duluth and Thunder Bay. Increased traffic through Halifax is an important component in the viability of container movements through the Seaway. There is also a need for further examination of the extent of congestion at U.S. ports, its likely impact, and possible mitigation strategies.

Intermodal-rail service will provide major competition, but GLSLS-max vessels could offer an advantage, particularly on American-oriented traffic from areas where rail container service is poor. It is assumed that the railways will continue to focus on long-haul container movements through rail mergers, but public policy decisions for new port facilities and changes in the structure of the railway network could affect short-haul and mainline routing options. If there were significant changes in the U.S., the forecasts for water movements would have to be revisited.

It is assumed that Suez express ships would be willing to unload Midwest bound freight at Halifax. Halifax would be competing with New York, particularly if "double stack" container routes between New York and Ohio were promoted. Similarly, new port facilities with rail connections to the Great Lakes could divert traffic away from the Seaway to the American northeastern ports.

All the new services proposed depend on extended container shipping through the Seaway to Montreal and Halifax. Competition will remain strong from trucking (shorter distances) and rail (long haul). It has been estimated that any significant diversion of traffic to the water mode would require vessels to maintain minimum open-water speeds of 20 knots. It also means that much of the initial diversion of market share will be in areas not well served by intermodal rail. Further business planning studies are needed to develop investment grade traffic forecasts, assess potential public-private partnerships, and evaluate port and intermodal port financing.

Environmental considerations

The opportunities described in this chapter will lead to an increase in traffic flows within the GLSLS. This, in turn, could have an impact on the environment unless appropriate measures are adopted. At the most basic level, increased traffic will mean more emissions from ship engines, though it should be noted that this effect could be offset by reductions in land-based transportation emissions as some traffic growth is diverted from land to water. Clearly, there is scope for ensuring that vessels are more fuel-efficient and equipped either to control emissions or burn cleaner fuels.

Similarly, the wakes from increased vessel traffic will put additional pressure on eroding shorelines. Again, these impacts could be mitigated through measures such as adjustments to ships' speed.

Bringing additional seagoing vessels into the GLSLS could pose a challenge with regards to aquatic non-indigenous species (NIS), unless there is careful monitoring and enforcement of regulations pertaining to the discharge of ballast water. Increases in shortsea shipping, however, do not involve external ballast water and thus would have no aquatic NIS impact.

Finally, more traffic will inevitably require either more maintenance of existing infrastructure, or the development of new port and other facilities to handle increased volumes and new cargos, such as containers. The maintenance or construction activities involved will be accompanied by additional environmental implications.

All of these impacts will have to be anticipated and mitigated in any planning for new opportunities. On the other hand, it should also be stressed that there will be beneficial impacts on the environment if road traffic is diverted to water routes that are relatively more fuel efficient and emit lower levels of greenhouses gases.

Engineering considerations

The scenarios described above have no direct implications for the existing lock systems since the vessels proposed would all fit within the current facilities. Additional traffic volumes, however, could involve more ship passages through the locks and thus greater wear and tear on these facilities, thereby requiring more frequent maintenance.

New cargos and new vessels, however, will require new loading and unloading facilities. Many ports on the GLSLS are not equipped to handle container traffic and would require upgrades to their capabilities. That might involve not just work in the port itself, but also construction of road or rail linkages. Such upgrades would require planning and financing in addition to environmental impact assessments, as mandated by the jurisdiction in which the work is to be done.

Conclusions

Today, trucks move an overwhelming 98 percent of all containerized tonnage in the Great Lakes basin and St. Lawrence River region. It is clear that the dominance of trucking will continue into the future. However, it is also clear that trucking is suffering from deteriorating service because the roads it uses are becoming congested by growth in automobile traffic, especially around major cities. In the case of railroads, attempts to enhance productivity over the past two decades have led to increased concentration, amalgamation, and the abandonment of secondary lines. As a result, moving containers by truck and rail in the future should cost more and probably take longer, since traffic is expected to outgrow any improvements in capacity and congestion is expected to increase. This opens up opportunities for waterborne transport to capture a larger share of commercial traffic through the region.

Detailed analysis using conservative assumptions about constraints to highway and rail capacity suggests that:

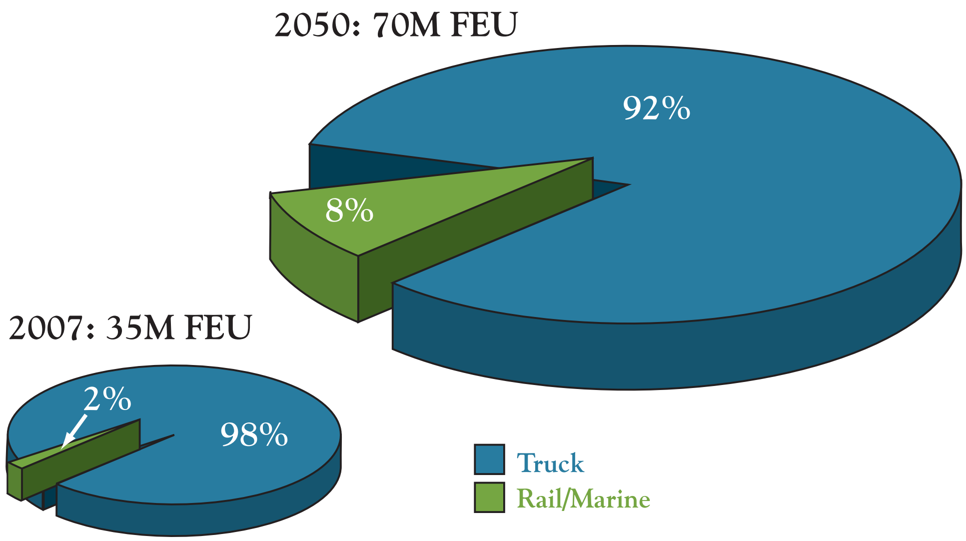
- The share of container traffic moved by truck could decline from 98 percent to 92 percent by 2050 because of diversion of growth to other modes caused primarily by congestion.
- The volume of containerized traffic carried by rail could double from two to four percent by 2050 if the railroads reintroduce unused capacity in secondary lines and bypass routes.
- A competitive "marine intermodal" option could accomodate four percent of containerized traffic by 2050, if it is competitive with rail and highway.

All of this suggests that there are opportunities for the waterway to accomodate part of the container traffic growth to the waterway in selected transportation corridors.

All of these assessments point in one direction: as traffic volumes grow and capacity limits are experienced by other modes of transportation, the GLSLS system can continue to play a vital and probably expanding role in the economy of the Great Lakes and St. Lawrence River region. Even if no changes are made and current trends continue, the marine mode is likely to experience slow and steady growth in its existing mix of bulk and neobulk cargoes. A more desirable outcome, however, is that the GLSLS can be positioned to capitalize on the continuing growth in international trade. It can attract more traffic and emerge as a more effective component of the North American intermodal network, providing alternative routings to congested highways. In this way, it can finally participate in the container revolution.

All of these trends represent real and emerging opportunities that will provide an important new focus for the GLSLS of the future. Realizing such opportunities will not require new or different vessels: those shown to be most efficient on these routes already exist. Taking advantage of those opportunities, however, will depend on maintaining current infrastructure, while investing in facilities that can support emerging opportunities in containerization, neobulk cargoes, and shortsea shipping.

FIGURE 6.6
Present and projected share of container traffic



Chapter 7

Policy and Planning

In developing policies and plans for the future of the Great Lakes St. Lawrence Seaway system, it is necessary to balance several different factors: the current and future economic potential of the waterway, the condition of its infrastructure, the likely costs of maintaining it, and its potential impact on the environment. Sound policy must provide for overall system efficiency, integration into regional transportation networks and optimization of infrastructure within the overall context of environmentally responsible and sustainable development.

Through their diverse efforts, the three working groups participating in the Great Lakes St. Lawrence Seaway (GLSLS) study have arrived at a broad consensus regarding the current state and possible future evolution of the GLSLS system.

The GLSLS system continues to play a decisive role in the economic life of North America. It attracts a significant amount of waterborne traffic. In addition, much of this traffic serves industries that play an important strategic role in the economy. Since these industries are integrated into value chains stretching into virtually every sector, the traffic moved on the waterway has a broad economic significance beyond the absolute volumes of shipments.

Economic highlights

- **The waterway flows through two provinces and eight states where 25 percent of North America's population is located.**
- **The GLSLS is part of the continent's largest inland transportation corridor and carries traffic to and from the industrial heartland. The system provides access to half of Canada's 20 largest ports and to numerous U.S. regional ports of significance in terms of international marine trade.**
- **Over the past decade, the system has carried an average of more than 260 million tonnes of cargo every year.**
- **The volume of cargo, including strategic commodities such as iron ore, coal, minerals and grain, is expected to experience a modest, steady growth over the coming 50 years.**
- **The GLSLS system has the potential to carry more cargo, but there are currently impediments to diversifying its traffic base.**
- **It is estimated that the waterway saves shippers approximately $2.7 billion a year in transportation and handling costs that they would otherwise have incurred had they used other modes of transportation.**
- **The GLSLS is well placed to accommodate the new vessels and the containerized new cargoes that will dominate tomorrow's international trade.**

The GLSLS system is situated within a unique freshwater resource of major significance to the environment. This ecosystem is vulnerable to the overall stressors at play. Factors such as urban growth, economic development, commercial navigation, and recreational use have all played a role in degrading the various ecologies in the basin.

Environmental highlights

- **The Great Lakes basin and St. Lawrence River region encompasses the world's largest freshwater ecosystem.**
- **The most significant current environmental impact of navigation through the GLSLS is associated with the inadvertent introduction of aquatic non-indigenous invasive species (NIS). Navigation is also associated with other environmental impacts resulting from channel dredging, the disposal of dredged material, erosion caused by ship wakes, water level management, and ships' air emissions.**
- **These impacts are intertwined with a variety of non-navigational impacts that cumulatively affect the environment in the GLSLS region.**
- **In recent years, greater awareness of the potential negative impact of navigation on the environment has led to the creation of various forums of discussion and to the development of mitigation measures to manage dredging, slow ship speeds in narrow channels, reduce engine run-times, and reduce the possible inadvertent introduction of aquatic non-native invasive species from ships' ballast water into the system.**

The GLSLS system is more than half a century old and its infrastructure is beginning to show the signs of age. While the majority of the system's infrastructure remains serviceable, the likelihood of component failure continues to increase. In order to ensure uninterrupted operations in the future, it is necessary to address those components that would have the greatest potential impact on the system's integrity should they fail.

Photo caption to come
Source: Transport Canada

Engineering highlights

- **The condition of approximately 160 components of the GLSLS system was examined: the review included locks, approach walls, water-level control structures, road and railway bridges as well as tunnels.**
- **Despite the system's age, most of the components have been kept in good operating condition and remain serviceable. A criticality index was developed to identify the highest priority infrastructure components throughout the GLSLS system based on factors such as age, current condition, availability of replacement parts, and potential impact on navigation arising from failure.**
- **The majority of the highest priority infrastructure components are associated with the lock structures. These were found to be of remarkably similar condition, despite being located in different places throughout the region and despite variations in construction and maintenance methodologies.**
- **The age of the system infrastructure and several site-specific conditions have resulted in a critical need for capital investment to ensure that the system continues to operate reliably in its current configuration. While some of this investment is already being made, its level is projected to increase significantly in the future.**

Framing the future of the GLSLS system

The GLSLS system is an incredibly valuable North American asset. Marine transportation on the waterway provides shippers with a safe, efficient, reliable and competitive option for the movement of goods. However, there is also unrealized potential in the system in terms of the important future contribution it could make to regional and continental transportation.

The fundamental understanding of the opportunities and challenges acquired through the course of the GLSLS study can be applied to identify priority areas and develop a balanced approach across economic, environmental and engineering factors, while addressing four strategic imperatives:

1. What role should the GLSLS system play within the highly integrated North American transportation system?
2. What transportation solutions are available to guarantee a dynamic future for the waterway?
3. What measures need to be taken to ensure the continued reliability of the system's infrastructure? and
4. How should the GLSLS system sustain its operations in a way that responds to concerns about environmental integrity?

The following sections will consider each of these strategic imperatives by summarizing the information gathered through the GLSLS study and by presenting some observations and key considerations.

Role in North American transportation

North America is part of a global trade network that has experienced explosive growth over the past two decades. Part of this growth has a geographic dimension: East and South-east Asia have emerged as major players in international trade. Another part involves new types of cargoes, travelling primarily in containerized vessels. Both of these trends are having an impact on North America as a whole and the GLSLS system in particular.

As the volume of goods transported internationally continues to grow, bottlenecks on North America's west coast are leading shippers to look for alternative routes through both the Panama and Suez canals. Some of this redirected traffic is finding its way into the Great Lakes basin and St. Lawrence River. Yet the surface transportation routes in this region are already facing pressures. Both roads and railways are strained in terms of increasing congestion and tightening capacity. This is exacerbated by the fact that most of this surface traffic is funnelled through a small number of transit points, and security requirements are slowing clearance procedures at borders. Moreover, there is limited scope for the construction of additional roads or railways to alleviate such congestion.

The inescapable conclusion is that waterborne traffic could help to ease some of these pressures. The GLSLS is currently operating with spare capacity that could be used to redirect some traffic from overland routes. Moreover, redirection of traffic through the GLSLS system is directly connected with the other major trend in international trade – the move toward containerization of cargos. Much of the traffic now entering North America consists of containerized shipping. As a result, when it arrives at a port of entry, shippers have a choice in how to move those containers inland inasmuch as ships, trucks and railway cars are now all adapted to carry containers.

In the past, container ships entering northeastern North America would either discharge cargo at the main eastern seaboard ports or carry their cargo inland as far as the Port of Montreal. Given the anticipated growth in traffic on road and rail routes in the region, there is an opportunity to move at least some portion of this containerized cargo by water through the GLSLS system.

For the GLSLS to emerge as a viable complement to the movement of goods by road and rail, the system must focus on enhancing and maintaining its competitiveness. In the shipping industry, this is determined by a combination of factors: cost, time, frequency and reliability. Clearly the cost per unit per kilometre or mile is a fundamental determinant of competitiveness. In this case, waterborne shipping enjoys a clear advantage. That is why it has been used to move large volumes of bulk goods. If waterborne shipping is to compete for more diverse cargo traffic, however, it must also focus on the other determinants of competitiveness. Total trip times need to be shortened. Sailing frequencies need to accommodate shipper requirements. Unplanned closures and traffic interruptions must be minimized. In fact, the GLSLS system already has a good record in these areas, but any additional improvements will enhance its overall competitiveness and strengthen its position as a viable transport alternative.

OBSERVATION:

The GLSLS system has the potential to alleviate congestion on the road and rail transportation networks as well as at border crossings in the Great Lakes Basin and St. Lawrence River region.

KEY CONSIDERATIONS:

- The GLSLS system is currently only operating at about half its potential capacity and is therefore under-utilized.
- Given projected growth in the economy and trade, all modes of transportation in both countries will be faced with increases in traffic. When integrated with rail and trucking, the region's marine mode can greatly increase the overall capacity of the transportation system while reducing highway, railway and cross-border congestion.
- A research and development agenda would help to advance the use of new technologies to improve the efficiency of marine transportation as well as strengthen its linkages to other transport modes.

Solutions for a dynamic future

The North American transportation system is more than just the sum of its parts: it also involves linkages between and integration of various modes and jurisdictions. Within this context, the GLSLS system cannot be thought of as a stand-alone mode restricted to one type of traditional traffic.

The GLSLS can play an important role in contributing another set of capabilities, while offering shippers greater flexibility. In order to fulfill this complementary role, policy and planning should focus on developing the waterway's shortsea shipping potential to enhance its intermodal capabilities and its ability to handle container traffic.

Optimizing the role played by the GLSLS within the transportation system of the Great Lakes Basin and St. Lawrence River region requires a holistic view of the entire system. Marine transportation must be integrated seamlessly with the other modes in terms of cost, time, frequency and reliability.

To make this vision a reality, there are several aspects of modal integration that will have to be addressed. There need to be highly efficient intermodal linkages at the nodes of the system. The ports of the GLSLS system must have suitable road and rail connections. They must also have the right kinds of equipment to move containers easily between vessels, rail flatcars and tractor-trailers.

There are other factors which come into play in this area. There is a need for appropriate electronic tracking and communication to direct and monitor shipments. New technologies, improvements in traditional infrastructure, streamlined border crossing procedures and the harmonization of regulations will also be important in designing systems and managing the demands of enhanced interconnectivity across transport modes.

Advancing the concept of marine intermodal services also requires suitable vessels adapted for different corgoes: bulk commodities versus containers or neobulk shipments. The routes travelled by the cargoes also need to reflect the potential advantages of waterborne transport. For example, shipping by vessel straight across a lake can be preferable to moving goods around its shore along congested roads. Apart from taking a faster, more direct route, it may also be the case that border procedures at the respective ports can be significantly faster than those at highly congested land crossings.

Observation:

A stronger focus on shortsea shipping would allow the GLSLS system to be more closely integrated with the road and rail transportation systems, while providing shippers with a cost-effective, timely and reliable means to transport goods.

Key considerations:

- Incentives need to be identified and promoted to encourage the use of marine transportation as a complement to the road and rail transportation modes.
- Institutional impediments that discourage the provision of shortsea shipping services need to be addressed.
- Potential opportunities to encourage the establishment of cross-lake shortsea shipping services could be identified on a pilot project basis.
- The existing Memorandum of Cooperation and Declaration on Shortsea Shipping, adopted by Canada and the U.S. in 2003 and 2006, respectively, could be used to continue to advance the North American shortsea shipping agenda.

Shortsea shipping
Source: Transport Canada

Optimizing the existing infrastructure

It is clear that the marine transportation infrastructure of the GLSLS system involves more than just a series of locks. There are also ports and terminals, channels, bridges and tunnels, systems for control and communication, as well as interfaces to other transportation modes. Collectively, this constitutes an integrated system that needs to be optimized if it is to contribute to solving the transportation needs of the future.

Each of the following elements represents a distinct set of requirements, all of which need to be managed in an integrated fashion to ensure the competitiveness of the GLSLS system.

Locks: Because of their age, locks need to be subjected to a maintenance schedule that deals with potential failures in a way that sustains traffic with the fewest possible interruptions and preserves overall system integrity.

Shipping channels: The normal flow of water inevitably carries silt deposits that must be removed to maintain channels at authorized depths for shipping.

Ports: Ports and terminals that are likely to support shortsea shipping or to serve as nodes in multimodal networks will require appropriate loading and unloading facilities and equipment together with seamless links to other forms of surface transportation.

Bridges and tunnels: There are a number of bridges and tunnels spanning the locks and channels of the Welland Canal and Montreal-Lake Ontario section of the Seaway that must be maintained in ways that do not impede traffic.

Control and communication: Logistics systems today depend on advanced electronic systems to monitor movements and track shipments in real time.

Vessels: In addition to the traditional bulk carriers, there will be a need for ships capable of loading, carrying and unloading containerized cargoes.

While all of these diverse systemic elements form part of an integrated whole, each demands its own investments, technologies and scheduling. Planning must factor in the specific requirements of each element in a way that harmonizes the components of the whole system.

It is clear that burgeoning trade, a capacity crunch, aging transport infrastructure and increasing pressures on transportation lands in urban settings are an integral part of the marine environment. The locks, ports, terminals and other infrastructure of the GLSLS are now critical components of North America's transportation gateways and, as such, they require investment and tools to respond to market forces in a timely manner if they are to continue supporting Canadian and U.S. international and domestic trade.

Observation:

The existing infrastructure of the GLSLS system must be maintained in good operating condition in order to ensure the continued safety, efficiency, reliability and competitiveness of the system.

Key considerations:

- Any GLSLS infrastructure components identified as at risk and critical to the continuing smooth operations of the system should be addressed on a priority basis.
- The existing GLSLS infrastructure requires ongoing capital investment to ensure that the system can continue to provide reliable transportation services in the future.
- Modern technology, especially in areas such as control, should be used to maintain the GLSLS system in a state that preserves its capability to respond to changing and unpredictable market conditions.
- The development of a long-term asset management strategy would help to anticipate problems with GLSLS infrastructure before they occur and avoid potential disruptions that would reduce the overall efficiency and reliability of the system.
- Investment options with respect to the system would involve numerous factors such as long-term planning, innovative funding approaches, partnerships among governments and collaboration between the public and private sectors.

Environmental sustainability

The considerations noted above must be examined within the framework of sustainable development. In simplest terms, sustainable development means the ability to foster economic growth in a way that does not cause undue damage to the environment. Consequently, policy and planning must factor in the environmental implications of lock maintenance and repair, channel dredging, construction of new port facilities, or the introduction of new vessels into the system.

The ecosystem of the GLSLS system is vulnerable to the stressors at play. Because many are not directly related to navigation, management of or adjustments to navigational stressors are important but would not necessarily result in appreciable gains to overall environmental quality unless they form part of an approach that is integrated with measures in other economic sectors.

As the requirements of GLSLS operations and maintenance involve some stressors to the Great Lakes-St. Lawrence ecosystems, these must be managed effectively. Organizational and governance frameworks, together with accompanying policies and legislation, are likely adequate to manage and control the navigation-related activities that have a negative impact on the environment.

There have been considerable resources devoted to research and planning but, with the exception of some specific areas related to non-indigenous invasive species, there have been few initiatives that have seen "on-the-ground" changes. There will be a continuation of impacts related to planned works, such as maintenance of infrastructure, maintenance dredging and placement of dredged material, but such impacts can be minimized through effective application of environmental assessments, remedial actions, sound environmental management strategies and best practices.

Yet sustainable development means more than just selecting options that have a minimal impact on the environment. At the broadest possible level, it means attempting to build upon certain environmental advantages of marine transportation over rail and trucking, as one component of an integrated transportation system that can be operated in a more environmentally friendly manner. Transportation by water is significantly more fuel efficient than other modes and consequently could reduce the emission of greenhouse gases and other pollutants. Moreover, increased utilization of waterborne transportation could help to alleviate traffic congestion on roads, which could ultimately result in the reduction of road maintenance and repair costs.

Observation:

The long-term health and success of the GLSLS system will depend in part on its sustainability, including the further reduction of negative ecological impacts caused by commercial navigation.

Key considerations:

- The GLSLS system should be managed in a way that prevents the inadvertent introduction and transmission of non-indigenous invasive species and supports the objectives of programs designed to minimize or eliminate their impact.
- The existing sustainable navigation strategy for the St. Lawrence River could be extended to the Great Lakes Basin.
- The movement and suspension of sediments caused by shipping or operations related to navigation should be managed by developing a GLSLS system-wide strategy that addresses the many challenges associated with dredged material and looks for beneficial re-use opportunities.
- Ship emissions should be minimized through the use of new fuels, new technologies or different navigational practices.
- Islands and narrow channel habitats should be protected from the impacts of vessel wakes.
- There is a need to improve our understanding of the social, technical and environmental impacts of long-term declines in water levels as related to navigation, and identify mitigation strategies.
- Improvements should be made to short- and long-term environmental monitoring of mitigation activities.

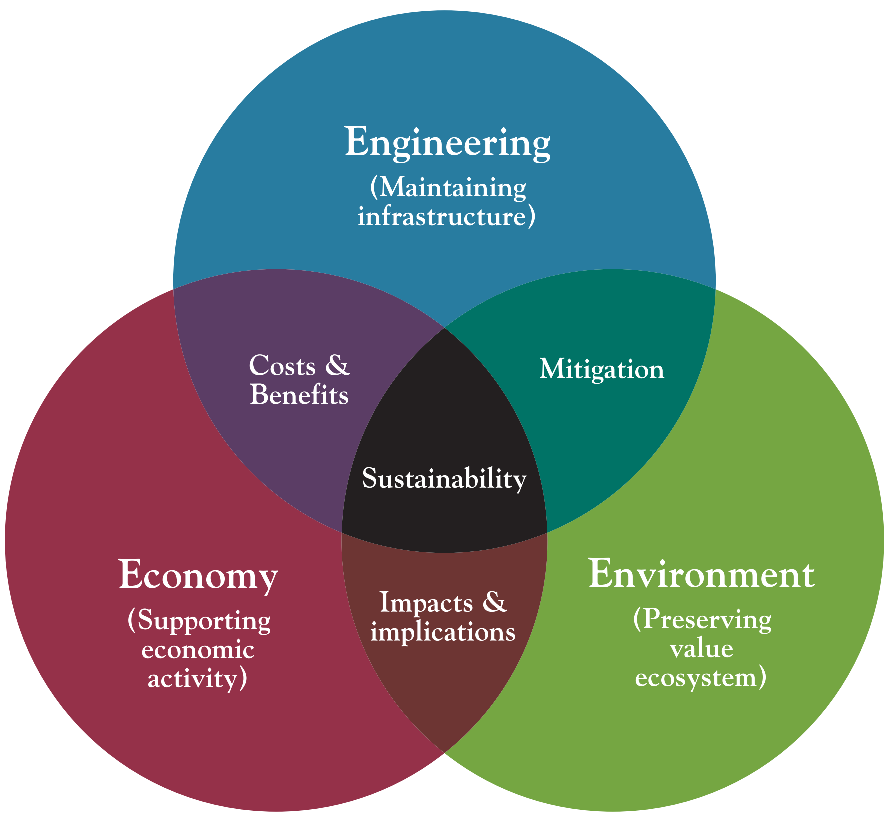
Monitoring future progress and success

The success of any initiative to build the future of the GLSLS system depends on a commitment by government and industry in both Canada and the U.S. to clear objectives and to the continuous monitoring of progress and success.

Canada and the U.S. should maintain their collaborative efforts to plan the future of commercial navigation on the GLSLS system through a binational body of governmental representatives. The role of this body would be to monitor the progress achieved in the areas identified as priorities in the GLSLS study. The two countries would work in partnership to pursue an appropriate policy framework, promote the opportunities represented by the system to other parts of government and ensure an integrated approach to the distinct imperatives of the economy, the environment and engineering. Ultimately, the sustainability of the GLSLS system depends on achieving a viable balance of these three perspectives.

The understanding gained from the expertise of those who contributed to the GLSLS study can be used to inform Canadian and U.S. decision-makers. The study has identified observations and key considerations that need to be taken into account in order to optimize the operations and maintenance of the GLSLS system and ensure it continues to serve North America's economy over the next 50 years.

Integrating three perspectives



CHAPTER 8

Conclusion

The Great Lakes St. Lawrence Seaway system can continue to play a vital role in the economy of North America, both by supporting strategic industries and by carrying the new containerized cargoes dominating the global economy. Its future, however, depends on its reliability. The GLSLS Study has identified areas for future work. Success, however, will depend on balancing economic, engineering and environmental perspectives and securing the active collaboration of the many departments, agencies and stakeholders that have an interest in the region's future.

The Great Lakes St. Lawrence Seaway (GLSLS) system has played a vital role in the economic evolution of North America. Even before the completion of the system that we know today, the St. Lawrence River and the Great Lakes constituted a natural highway into the heart of the continent. For the past half century, the GLSLS has supported strategic industries such as iron, steel and energy, which serve as the foundation of North American prosperity, and there is every indication that this essential role will continue into the foreseeable future.

North America's continuing prosperity also depends on its active participation in international markets. Canada and the U.S. must meet the challenges posed by the rapidly changing dynamics of global trade. International trade patterns manifest both increases in volumes and changes in direction. Here too, the GLSLS can play an important part, carrying the containerized traffic that dominates global shipping and linking into the new routes that are emerging as trade seeks alternatives to congested traditional pathways. Situated in the industrial heartland of North America, the GLSLS links to all of the continent's major ports of entry and can thus play a key role in emerging trade flows.

The GLSLS can therefore serve a dual purpose: it can continue to provide an essential service to North America's resource, manufacturing and service sectors, and it can play a growing role in carrying the new container traffic moving into and through the region. Major industries look to the GLSLS for both these functions because waterborne transportation offers them significant savings. If the system were not available, they would find it difficult to shift traffic to an already congested road and rail network. And the environmental consequences of doing so would be far more severe than those associated with operation of the waterway.

To satisfy regional transportation needs, the GLSLS will have to offer multi-modal integration, flexibility and cost-competitiveness. Above all, however, the main conclusion of the GLSLS study is that the system will have to offer reliability. That means adopting an operational and maintenance strategy that anticipates and addresses potential problems before they interrupt traffic flows. In today's fast-paced economy, there is no room for unanticipated interruptions.

Forward planning must ensure that GLSLS capacity remains fluid and responsive within a stable policy framework and investment climate that can support strategic and timely investment in system capacity, while improving service levels and reliability. Furthermore, it must do so in a manner that satisfies concerns about environmental stewardship and that raises challenges for the shipping industry.

All of this represents an ambitious undertaking. The GLSLS study was a tremendous effort by a partnership of seven departments and agencies. Its main observations and key considerations, however, must now be translated into specific action items. That will require a commitment to implementation that is similar to the Memorandum of Cooperation that initiated the current process. Just as they led the initial effort, the two governments will have to maintain the current momentum to frame future specific actions in the same spirit of collaboration.

All of the initial partners have a stake and a role to play in maintaining the system's economic viability, preserving its physical infrastructure, and ensuring its future environmental sustainability. Ultimately, however, long-term success will depend on the participation not only of these original seven government departments and agencies, but also on the involvement of the industries, not-for profit organizations and stakeholders with an interest in the future of the region.

Participants and stakeholders will succeed if they are able to integrate the three perspectives of engineering, economics, and the environment. Only if a balance is struck among these three differing sets of imperatives will it be possible to maintain truly sustainable commercial navigation in the Great Lakes basin and St. Lawrence River, and leave a lasting positive legacy to future generations.

Great Lakes St. Lawrence Seaway Study

Blurb to come

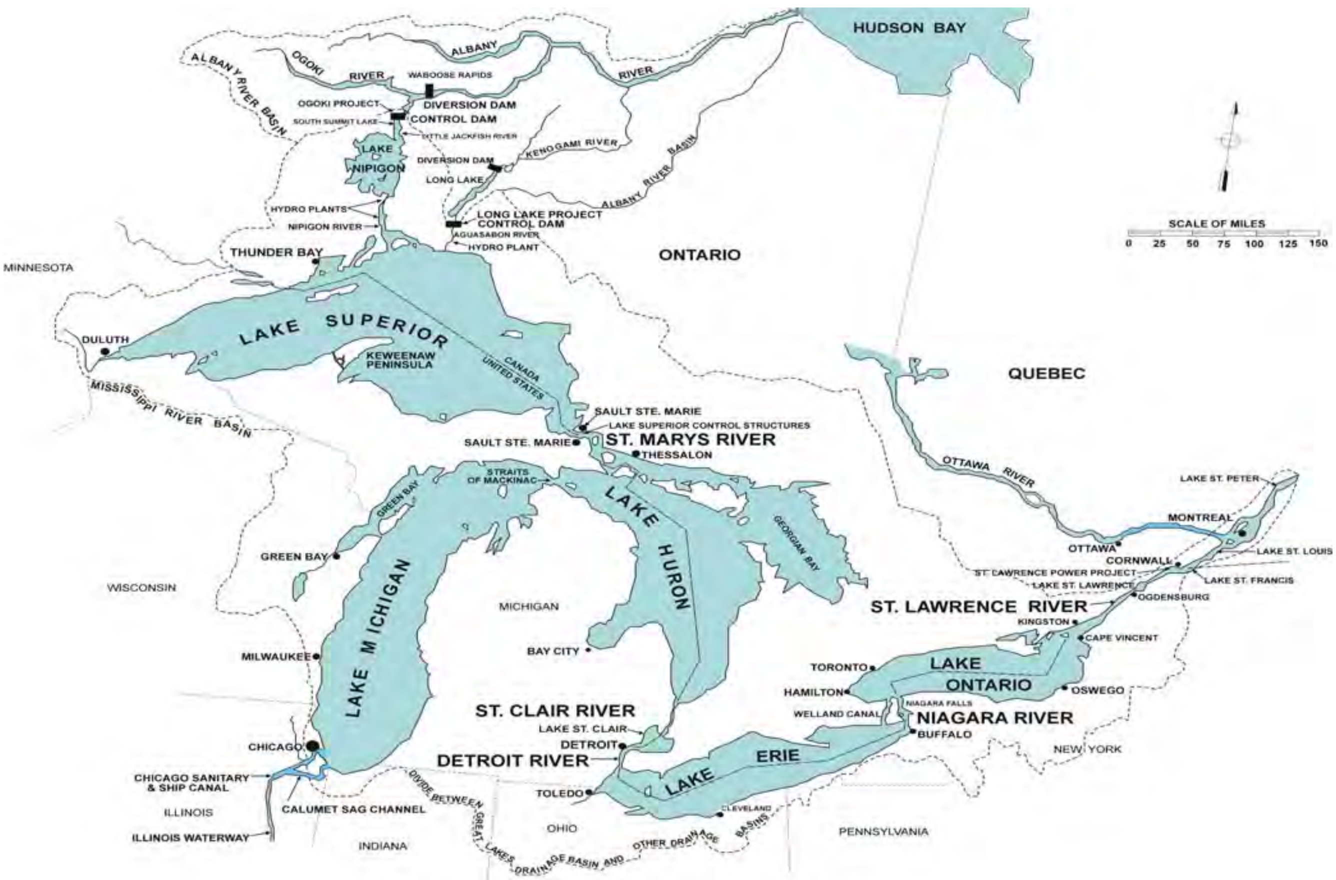
Transport Canada
U.S. Army Corps of Engineers
U.S. Department of Transportation
The St. Lawrence Seaway Management Corporation
Saint Lawrence Seaway Development Corporation
Environment Canada
U.S. Fish and Wildlife Service

SUPPLEMENTAL RECONNAISSANCE REPORT

May 2009

GREAT LAKES NAVIGATION SYSTEM REVIEW

Volume II of II



Great Lakes - St. Lawrence River System

US Army Corps of Engineers®
Great Lakes & Ohio River Division

EXECUTIVE SUMMARY

Previous Reports

Information developed in this economic appendix is intended to supplement that provided in the *Great Lakes Navigation System Review, Reconnaissance Report* (GLNS 2002). That report, completed as a draft, focused on possible improvements to channels within ports, channels connecting the individual Great Lakes and the Lakes to the Atlantic, or channels connecting the Great Lakes to shallow-draft inland waterway systems (most notably the Mississippi River System). Benefits were estimated for improvements to individual harbors, the Chicago and Sanitary Ship Channel, and the St. Lawrence Seaway. A complete benefit-cost analysis was only prepared for an array of Great Lakes Navigation System (GLNS) harbors and for the Chicago and Sanitary Ship Channel. A benefit-cost analysis could not be conducted for the St. Lawrence Seaway because costs had not been prepared for the existing condition nor for the improvement condition (a 35' deep Welland Canal and St. Lawrence River section of the St. Lawrence Seaway). So while benefits were reported for an improved Seaway, net benefits could not be prepared and presented in the 2002 report.

A joint U.S. - Canada study sought to remedy this deficiency of the GLNS 2002 study. This joint study, the *Great Lakes-St. Lawrence Seaway Study* (GLSLS 2007) resulted in the screening-out of any improvement alternative for the St. Lawrence Seaway that would alter its current physical dimensions. A benefit-cost analysis of alternative maintenance plans was completed for the Seaway, as well as a set of forecasts for bulk and container traffic demand, given no change in Seaway dimension. This container traffic forecast is of particular interest because the ports involved are all located on the Great Lakes. So the GLSLS 2007 study effectively addressed a deficiency of the GLNS 2002 report by eliminating the need for analysis of an improved Seaway, while indicating the potential for container traffic existed independently of a channel deepening improvement. Only maintenance of the existing Seaway is required, and the GLSLS 2007 study indicated maintenance and continued operation of the Seaway was economically justified.

Value of the Great Lakes Navigation System (GLNS)

The *Great Lakes Navigation System Review, Supplemental Reconnaissance Report* (GLNS 2008) addresses the key deficiency of the GLNS 2002 report, updates the transportation savings estimates for the GLNS, updates the net benefit estimates for harbor improvements, and expands the discussion of system benefits. Annual transportation savings for shippers using the GLNS are estimated to be $3.6 billion. Add to this estimated annual accident reduction (loss of life and property damage) benefits of $271.9 million and annual health cost savings from reduced exposure to pollutant emissions of $355.9 million. The National Economic Development benefits of the GLNS total to $4.2 billion.

The Great Lakes also provide unique and vast recreational opportunities. While the scope of this effort did not allow for an NED recreation benefit estimate, an estimate of regional economic benefits is reported. The *John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating Report* study dated December 2008 was relied on to get an order of magnitude estimate of the direct, regional benefits of recreation to the Great Lakes basin. Boaters inject an estimated $4.3 billion annually into the basin economy.

Economic Assessment of Infrastructure Investments

Having established the value of the GLNS from a national and regional perspective, the supplement reconnaissance also evaluates specific investments in the maintenance of the harbors (through dredging) and their supporting infrastructure (breakwaters, jetties, and Confined Disposal Facilities). Investment benefits from dredging are estimated using the GL-SAND, a model capable of assessing economic performance within a system context. Cost estimates for dredging alternatives at a number of harbors were developed in the GLNS 2002 report, allowing analysts to update the cost-benefit analysis for selected harbors.

Estimating net benefits for breakwaters, jetties and CDFs was not possible. The framework for economic evaluation is under development and early efforts are presented as a means of documenting what has occurred to date. Much work remains to be done by economists and engineers before cost-benefit analyses of these investments can be completed.

Acknowledgments

The Economics Appendix was prepared by the GLNS Economics team. Members of this team were: Tonya Harrington, Chuck Gould, Jon Brown, Roger Haberly, Doug Gorecki, Paul Yu, Bill Frechione and Wes Walker. Though not on the Economics Team, Paul Bijhouwer and Michael Mohr were primary contributors to the discussion of Risk Based Analysis of Breakwater Maintenance.

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Supplemental Reconnaissance
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1.0 Introduction

1.1 Purpose

This Economics Appendix to the *Great Lakes Navigation System Review, Supplemental Reconnaissance Report* (GLNS 2008) summarizes economic studies and activities performed as part of this study. These studies and activities centered on examinations of demands for waterway transportation service, the value of the Great Lakes Navigation System (GLNS), GLNS infrastructure needs, and the importance of recreational boating to the Great Lakes region. In addition to presenting information developed for the GLNS 2008 report, this Economics Appendix presents information drawn from the *Great Lakes Navigation System Review, Reconnaissance Report* (GLNS 2002) and the *Great Lakes St. Lawrence Seaway Study* (GLSLS 2007).

This appendix is laid out as follows: The scopes and purposes of each of these three studies are discussed below in this section. Section 2 provides an overview of the GLNS. Section 3 presents the value of the system as a route for transporting bulk commodities. Sections 4 and 5 discuss future types and levels of traffic demand. Section 6 addresses recreational usage and the benefits thereof. Section 7 examines system benefits derived by accident and emission reduction. Section 8 describes the GLNS vessel fleet and its characteristics. Section 9 presents benefits associated with maintaining harbors and inventories dredged material disposal facilities (DMDFs). Finally, Section 10 describes a methodology for estimating the return on investment for maintaining breakwaters and jetties.

This appendix has two objectives: 1) to develop and present an expanded, reconnaissance-level assessment of the value of the GLNS and 2) to improve net benefit estimates for specific infrastructure investments. Investments examined are those related to harbors, jetties, breakwaters, and Dredged Material Disposal Facilities (DMDFs). The most comprehensive investment assessments were made for commercial harbors, where both cost and benefit estimates were available. Investment assessments for jetties, breakwaters, and DMDFs were not made; rather, frameworks for future evaluations were explored and presented. The commercial value of and investment in lock facilities, most notably the locks at Sault Ste. Marie, Michigan, are dealt with in other studies and findings from those studies are referenced. Similarly, the locks of the Welland Canal and St. Lawrence River section of the St. Lawrence Seaway are addressed by referencing the recently completed, bi-national *Great Lakes/St. Lawrence Seaway Study*.

1.1.1 The Great Lakes Navigation System Reconnaissance Study (2002)

A Great Lakes Navigation System Reconnaissance study was initiated in 2000 under authority of Section 456 of the Water Resources Development Act of 1999. A draft report was completed in 2002. That report, completed as a draft, focused on possible improvements to channels within ports, channels connecting the individual Great Lakes and the Lakes to the Atlantic, or channels connecting the Great Lakes to shallow-draft inland waterway systems (most notably the Mississippi River System). Benefits were estimated for improvements to individual harbors, the Chicago and Sanitary Ship Channel, and the St. Lawrence Seaway. A complete benefit-cost analysis was only prepared for an array of Great Lakes Navigation System (GLNS) harbors and for the Chicago and Sanitary Ship Channel. A benefit-cost analysis could not be conducted for the St. Lawrence Seaway because costs had not been prepared for the existing condition nor for the improvement condition (a 35' deep Welland Canal and St. Lawrence River section of the St. Lawrence Seaway). So while benefits were reported for an improved Seaway, net benefits could not be prepared and presented in the 2002 report.

National Economic Development (NED) benefits presented in the 2002 GLNS Reconnaissance study were related to transportation cost savings for cargo movements, both current and projected, and emission reduction benefits. Projected cargo movements were based both on continuation of current commodity flows and on flows induced by an improved Seaway. These induced flows were both bulk and container flows, each the result of a separate study that examined the feasibility of these moves. A focused Regional Economic Development (RED) analysis identified the regional job and income effects that might result from successful container service entering the Great Lakes and continued growth of the commercial, overnight cruise industry.

1.1.2 The Great Lakes/St. Lawrence Seaway Study (2007)

Upon review of the 2002 Reconnaissance Study, USACE headquarters directed the study team to address recreation throughout the system and complete a depiction of the without project condition, specifically regarding the Seaway as a connector between the GLNS and the Atlantic Ocean. Concurrently, both the Canadian St. Lawrence Seaway Management Corporation (SLSMC) and the US Saint Lawrence Seaway Development Corporation (SLSDC) expressed an interest in partnering with the US Army Corps of Engineers in examining future maintenance alternatives for the Seaway. Acting on their behalf, Transport Canada (which owns the Canadian locks) and the US Department of Transportation (which owns the two U.S. locks, which are both operated and maintained by the SLSDC) entered into a Memorandum of Understanding for joint management of the *Great Lakes/St. Lawrence Seaway Study* (GLSLS 2007). This study was initiated in 2003 and a public draft was released in the fall of 2007.

This joint study (GLSLS 2007) resulted in the screening-out of any improvement alternative for the St. Lawrence Seaway that would alter its current physical dimensions. A benefit-cost analysis of alternative maintenance plans was completed for the Seaway, as well as a set of forecasts for bulk and container traffic demand, given no change in Seaway dimension. This container traffic forecast is of particular interest because the ports involved are all located on the Great Lakes. So the GLSLS 2007 study effectively addressed a deficiency of the GLNS 2002 report by eliminating the need for analysis of an improved Seaway, while indicating that the potential for container traffic existed independently of a channel deepening improvement. Only maintenance of the existing

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1.1.3 The Great Lakes Navigation System Supplemental Reconnaissance Study (2008)

The *Great Lakes Navigation System Review, Supplemental Reconnaissance Report* (GLNS 2008) addresses the key deficiency of the GLNS 2002 report, updates the transportation savings estimates for the GLNS, updates the net benefit estimates for harbor improvements, and expands the discussion of system benefits. Annual transportation savings for shippers using the GLNS, estimated annual accident reduction benefits (from loss of life and property damage), and annual health cost savings from reduced exposure to pollutant emissions are estimated to total $4.2 billion.

The Great Lakes also provide unique and vast recreational opportunities. While the scope of this effort did not allow for a National Economic Development (NED) recreation benefit estimate, an estimate of regional economic benefits is reported. The *John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating Report* study dated December 2008 was relied on to get an order of magnitude estimate of the direct, regional benefits of recreational boating to the Great Lakes basin - an estimated $4.3 billion annually into the basin economy.

Having established the value of the GLNS from a national and regional perspective, the supplement reconnaissance also evaluates specific investments in the maintenance of the harbors (through dredging) and their supporting infrastructure (breakwaters, jetties, and Confined Disposal Facilities). Investment benefits from dredging are estimated using the GL-SAND, which is described in Section 9. Cost estimates for dredging alternatives at a number of harbors were developed in the GLNS 2002 report, allowing analysts to update the cost-benefit analysis for selected harbors in this GLNS 2008 report.

Estimating net benefits for breakwaters, jetties and CDFs was not possible. The framework for economic evaluation is under development and early efforts are presented as a means of documenting what has occurred to date. Much work remains to be done by economists and engineers before cost-benefit analyses of these investments can be completed.

1.2 Related Studies

The following Corps reports may be referenced or relied upon as secondary sources.

Final Limited Reevaluation Report, Replacement Lock, Sault Ste. Marie, Michigan, 2000.

Soo Lock Reliability and Assessment of Rail as an Alternative in the Event of an Unexpected, 180-day Closure, 23 February 2008.

Reconnaissance Report, Great Lakes Navigation System Review, June 2002.

Great Lakes St. Lawrence Seaway Study, fall 2007

John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating, December 2008.

2.0 Great Lakes Navigation System Overview

2.1 Definition of the Great Lakes Navigation System

For the purposes of this study, the Great Lakes Navigation System (GLNS) is defined as extending from the western most point of the Thousand Islands, just east of Lake Ontario in the St. Lawrence River, to the western most point of Lake Superior at Duluth, Minnesota. Similarly, the Great Lakes Basin is defined to include an area that extends upstream to the point of origin (headwaters) of all streams and rivers flowing into the Great Lakes.

2.1.1 Relationship to the St. Lawrence Seaway

A portion of the GLNS, as it is defined for this study, overlaps what is commonly defined as the St. Lawrence Seaway. The Seaway is prescribed by law as extending from Montreal to Lake Erie, therefore including Lake Ontario. However, as noted above, this study incorporates Lake Ontario into the GLNS. Finally, it should be noted that the terms St. Lawrence Seaway System or Great Lakes/St. Lawrence Seaway System are often used in a broader sense to include the entire St. Lawrence River and the Great Lakes.

2.2 Geographic Description

2.2.1 The Great Lakes Basin

The Great Lakes Basin contains 297,000 square miles, including territory in eight states; Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin; and the Canadian province of Ontario and hosts a population of approximately 34 million people. The Basin population represents over 10% of the United States' population and over 25% of Canada's. About one third of the total surface area of the Basin (95,000 square miles) consists of water in the five Great Lakes: Superior, Michigan, Huron, Erie and Ontario -- and the much smaller Lake St. Clair. It is estimated that the Great Lakes Basin contains 5,439 cubic miles of fresh water, making it the largest depository of freshwater in the world.

2.2.2 The Great Lakes

The five Great Lakes differ significantly from each other in physical characteristics. Each Lakes' physical dimensions are presented in **Table 2.1,** followed by a brief description of each Lake. Note that the terminology "Upper" versus "Lower" Lakes refers to the location of the individual lakes with respect to the Niagara Escarpment (a long sedimentary cliff structure at Lake Ontario's southernmost point extending from Ontario, Canada into New York.) Lakes Superior, Michigan, Huron and Erie, located upstream of the escarpment, are termed upper lakes. Lake Ontario, located below the escarpment, is termed a lower lake; it is the only lower lake.

Table 2.1 - Great Lakes Physical Dimensions

Statistic	Great Lake				
	Superior	Michigan	Huron	Erie	Ontario
Elevation (feet)[1/]	600	577	577	569	243
Length (miles)	350	307	206	241	193
Breadth (miles)	160	118	183	57	53
Average Depth (feet)[1/]	483	279	195	62	283
Maximum Depth (feet)[1/]	1,330	923	750	210	802
Volume (cu. Miles)1/	2,900	1,180	850	116	393
Water Area (miles[1/])	31,700	22,300	23,000	9,910	7,340
Total Drainage Area (miles[2/])	49,300	45,600	51,700	30,140	24,720
Retention Time[3/] (years)	191	99	22	2.6	6

1/ Measured at Low Water Datum.
2/ Land drainage area for Lake Huron includes St. Marys River.
2/ Retention time is a measure based on the volume of water in the lake and the mean rate of outflow.
SOURCE: The Great Lakes: An Environmental Atlas and Resource Book, Ottawa, Canada & Washington, D.C.: Environment Canada and United States Environmental Protection Agency, 1987.

Lake Superior is the largest, northernmost, westernmost, highest and deepest of the Great Lakes. It is also one of the largest freshwater lakes in the world. Its shores are heavily wooded and sparsely populated. Its two major ports are Thunder Bay in Ontario and Duluth-Superior on the border of Wisconsin and Minnesota. Lake Superior is connected to Lake Huron via the St. Marys River.

Although presented separately, hydrologist consider Lakes Huron and Michigan to be the same lake, as their connecting channel is wide enough to allow the water level of each Lake to equilibrate, thereby maintaining the same water surface elevation. Lake Huron contains over 30,000 islands and has the longest shoreline of the Great Lakes. The Huron valley is a heavily forested, lightly populated region engaged in agriculture and some industry. At the tip of Michigan's Lower Peninsula, Lake Huron is connected to Lake Michigan via the Straits of Mackinac. Lake Michigan is the only Great Lake to lie entirely within U.S. territory. Four major ports, Green Bay, Milwaukee, Chicago and Burns Harbor lie on Lake Michigan. Shores along Lake Michigan's southern basin, roughly below Green Bay, are heavily industrialized while those of the northern basin are less developed.

Lake Erie is the southernmost and shallowest of the Great Lakes. It has the distinction of being the only Great Lake with a floor above sea level. The western end of Lake Erie is much shallower than the eastern end. There are ten major ports on the Lake including Buffalo, Cleveland and Detroit. The areas on both shores of Lake Erie are heavily industrialized. Near the Lake's western end, three channels connect Lake Erie to Lake Huron.

Lake Ontario is the easternmost of the five Lakes. The Lake has several major ports including Oswego, Oshawa, Toronto and Hamilton. Canada's commercial, industrial and population heartland is centered on Lake Ontario's northwestern shore. Roughly two-thirds of Canada's steel is produced here. At Lake Ontario's southernmost point, lies the Niagara escarpment, a long sedimentary cliff structure extending from Ontario, Canada into New York. From the higher Lake Erie, the Niagara River cuts 34 miles through this escarpment to reach Lake Ontario. Here, the 327-foot elevation difference between Lakes Erie and Ontario forms a series of waterfalls commonly referred to as Niagara Falls.

2.2.3 Connecting Channels

The lakes are linked by connecting channels. The connecting channels are important in that not only do they canalize commercial navigation on the lakes, they also constrain it. The navigation constraint is the actual depth of water through the channel at any given time during the shipping season. The actual depth of water in the channel varies because of daily and seasonal weather conditions. Each channel's physical dimensions are presented in **Table 2.2**; the controlling depth of the connecting channels is the depth of the water at Low Water Datum (LWD).

Table 2.2 - Connecting Channels Physical Dimensions

Channel	Controlling Depth (feet)	Length (miles)	General Channel Width (feet)	Fall (feet)	Restrictive Width (feet)
St. Mary's River	27.0	63-75	300 - 1,500	22	76,105 [1/]
Straits of Mackinac	30.0	1	1,250	0	na
St. Clair River	27.0	46	700 - 1,400	5	600 [2/]
Lake St. Clair	27.5	17	700 - 800	0	na
Detroit River	27.5	32	300 - 1,260	3	600
Welland Canal	27.0	27	192 - 350	326	78 [3/]

1/ 76-foot restrictive width for MacArthur Lock, 105-foot for Poe Lock.
2/ Width restrictions at the Blue Water Bridge
3/ A 3.0 mile section of the reach between Locks 7 and 8 is restricted to one-way navigation Source: "General Description of Great Lakes/St. Lawrence Seaway Physical Description," submitted to the Department of the Army, North Central Division, Chicago, IL by ARCTEC, Inc., September 1981 as updated by the U.S. Army Corps of Engineers, Detroit District.

The St. Marys River forms the border between two cities named Sault Ste. Marie: one in the Upper Peninsula of Michigan, the other in Ontario, Canada, connects Lakes Superior and Huron and contains the St. Marys rapids. The St. Marys Falls Canal is a U.S. administered canal, with four U.S. and one Canadian lock, used to bypass these rapids. The locks, commonly referred to as the Soo Locks, include the Poe and MacArthur Locks on the south side of the canal, and the Sabin and Davis Locks on the north and one Canadian lock. Only the Poe and MacArthur Locks are still used for commercial navigation, raising or lowering vessels approximately 21 feet between the two Lakes. Each lock's physical dimensions and vessel handling capacity is presented in **Table 2.3**.

Table 2.3 - The Soo Locks

Feature	Lock Chamber				
	MacArthur	Poe	Sabin	Davis	Canadian
Online year	1943	1969	closed	closed	1998
Width (feet)	80	110	na	na	49
Length (feet)	800	1,200	na	na	252
Max. ship beam (feet)	76	105	na	na	na
Max. ship length (feet)	760	1,100	na	na	na
Max. ship draft (feet) [1/]	29.5	30.5	na	na	na
Min. sill depth (feet)	31.0	32.0	na	na	10.0

1/ The depth of the St. Marys River is the current limiting factor for vessels transiting the Soo Locks. Vessels transiting the locks are in practice limited to 26.5-feet of draft at LWD. Source: General Description of Great Lakes/St. Lawrence Seaway Physical Description, submitted to the Department of the Army, North Central Division, Chicago, IL by ARCTEC, Inc., September 1981 as updated by the U.S. Army Corps of Engineers, Detroit District.

The Straits of Mackinac connect Lakes Huron and Michigan and contain two shipping channels. The Straits are crossed by the Mackinac Bridge. At, 8,614 feet (2,626 m) long, the Mackinac is the longest suspension bridge in the Americas and the third longest in the world.

Three channels, the Detroit River, Lake St. Clair and the St. Clair River connect Lakes Erie and Huron. The Detroit River extends north from Lake Erie to Lake St. Clair and separates Detroit, Michigan from Windsor, Ontario. The lower part of the channel contains many small islands and shallow expanses, requiring periodic dredging. Lake St. Clair, colloquially referred to as the sixth Great Lake, is a wide shallow basin connecting the Detroit and St. Clair Rivers. The St. Clair River completes the link between Lakes Erie and Huron. Portions of each of these waterways are routinely dredged to create a passable channel.

The Welland Canal, with its eight Canadian locks, bypasses the Niagara escarpment, thereby commercially linking Lakes Ontario and Erie. Locks 1 through 7 are located in the northern section of the canal, between Lake Ontario and the top of the Niagara escarpment. Each lock raises vessels 46.5 feet on average. At the southern end of the canal, Lock 8 raises vessels an additional 1 to 4 feet, as needed, to make the final adjustment to Lake Erie level. Each lock's physical dimensions and vessel handling capacity is presented in **Table 2.4**.

Table 2.4 – The Welland Canal Locks

Feature	Lock Chamber		
	Lock 1	Locks 2 - 7	Guard Lock 8
Online year	1932	1932	1932
Width (feet)	80	80	80
Length (feet)	865	859	1,380
Max. ship beam (feet)	78	78	78
Max. ship length (feet)	740	740	740
Max. ship draft (feet) [1/]	26.5	26.5	27
Min. sill depth (feet)	30.0	30.0	30.0

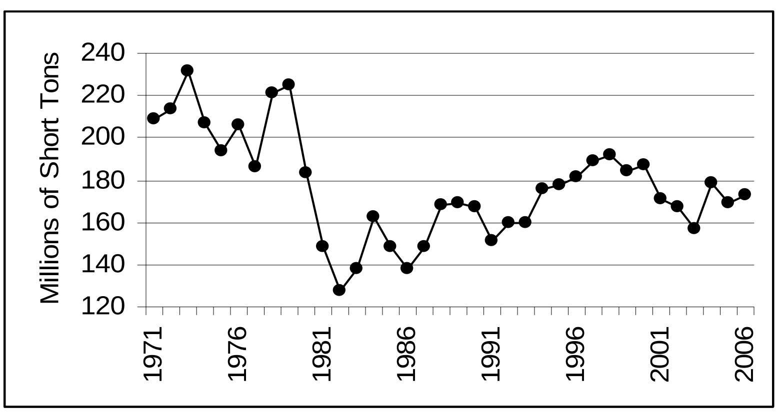
1/ The 26'6" draft presently allowed in the Seaway is not available all of the time due to variable water levels.
SOURCE: General Description of Great Lakes/St. Lawrence Seaway Physical Description, submitted to the Dept of the Army, North Central Division, Chicago, IL by ARCTEC, Inc., September 1981 and The Welland Canal Section of the St. Lawrence Seaway, The St. Lawrence Seaway Management Corporation, November 2000, Seaway Notice #1, 2007 from the SLSMC and SLSDC.

2.3 Commerce of the Great Lakes

The GLNS serves a diverse and dynamic economy in both the United States and Canada, although only U.S. commerce is discussed here. According to the U.S. Bureau of Economic Analysis, the gross domestic products of the states having a direct access to the GLNS total over 2.8 trillion U.S. dollars in 2004. The economic activity of the region is characterized by the durable goods manufacturing industry, especially in the steelmaking and automotive industries of Indiana, Michigan, Ohio, and Wisconsin.

The 76 U.S. ports in the GLNS play a strategic role as part of the integrated North American transportation network for both domestic and overseas trade. Products shipped by land to one of the system's ports gain access to the global marketplace. This link plays a fundamental logistics role for industries of the region.

Figure 2.1 - GLNS Historic Traffic 1971-2006



Source: US Army Corps of Engineers, Waterborne Commerce Statistics Center

Figure 2.1 presents total GLNS cargo traffic between 1971 and 2006. Tonnage carried experienced a sharp decline in the years 1980 through 1982, dropping nearly 100 million tons in those three years. Over the last two decades, GLNS traffic has experienced some fluctuation, but has increased overall. In more recent years, traffic peaked at around 192 million tons in 1998 then declined through 2003. Since 2003, traffic has fluctuated, but risen.

Commercial traffic in the GLNS is dominated by iron ore, coal and stone. As presented in **Table 2.5** below, roughly 81% of all tonnage carried in the system is generated by these three commodity groups. Approximately 75% of the iron ore shipped throughout the GLNS is transported internally between ports on the Great Lakes, much of it originating from mines in Michigan's Upper Peninsula and northern Minnesota and destined for ports on Lake Erie and the southern tip of Lake Michigan. Over the last three decades, iron ore has come to represent a smaller percentage of tonnage carried throughout the system, mostly due to the decline of the domestic steel industry. In 1978, roughly 43% of GLNS traffic was iron ore. From 2002 to 2006, iron ore represented roughly 33% of GLNS traffic.

Table 2.5 - GLNS Traffic by Commodity (thousands of short tons)

Commodity Group	Year					Average
	2002	2003	2004	2005	2006	
Iron Ore	56,075	50,228	60,366	56,418	58,573	56,332
Coal	41,357	41,495	43,095	44,773	44,896	43,123
Stone	36,575	34,289	41,005	36,966	37,157	37,198
Cement & Concrete	6,874	7,102	7,179	7,140	7,151	7,089
Petroleum Products	4,290	4,691	5,069	4,593	5,067	4,742
Grain	4,028	3,671	3,550	4,040	3,871	3,832
Iron and Steel Products	3,486	2,781	4,150	2,820	3,687	3,385
Other	14,541	12,227	14,020	12,661	12,611	13,212
Total	**167,226**	**156,484**	**178,434**	**169,411**	**173,013**	**168,914**

Source: US Corps of Engineers,
Waterborne Commerce of the United States, 2006.

Roughly 47% of the coal transported in the GLNS is internal traffic, largely composed of thermal coal used for power generation. In the U.S., more than one-half the nation's electricity is generated by burning coal. Coal is mined in Montana and Wyoming and loaded in the port of Duluth-Superior; and mined in West Virginia, Pennsylvania, Kentucky, Ohio and Illinois and shipped from Lake Erie and Lake Michigan ports. The remaining coal shipped in the GLNS is mostly exports to Canadian ports along the St. Lawrence River. Over the last three decades, coal traffic has increased slowly, by about 5 million tons, and has increased as a percentage of GLNS traffic, representing roughly 17.3% of GLNS traffic in 1978 and averaging 25.5% from 2002 to 2006.

Stone represents a group composed of numerous commodities such as stone, limestone sand and gravel. All of these products can have multiple usages and their origin-destination patterns vary significantly from year to year. Limestone is by far the most prominent of these, representing nearly 83%, or 30.8 million tons, of all stone traffic and over 18% of GLNS traffic. Another 14.5%, or 5.4 million tons, of stone traffic is sand

and gravel. Approximately 73.1% of stone traffic is internal to the GLNS, with almost all the remaining traffic composed of Canadian imports and exports.

Of the remaining commodities transported on the GLNS, grain traffic bears special mention as it has experienced marked declines over the last three decades. In 1978, over 19 million tons of grain, representing 8.7% of total traffic, was transported in the GLNS. From 2002 through 2006, grain traffic averaged 3.8 million tons annually, or 2.3% of total traffic. Grain is a heavily exported commodity throughout the GLNS, with roughly 38.4% of its annual traffic destined for Canadian ports and another 45.9% headed for overseas destinations.

2.3.1 Harbors

As approximately 62.3% of GLNS traffic travels internally, the GLNS is an interconnected network of ports, wherein the traffic handled at any port is often linked to the traffic handled at another port in the system. All ports of the system have easy road access, making local or regional delivery a simple procedure. In cases where rail access becomes critical, numerous ports are equipped with infrastructure enabling the transfer of products to/from rail to/from marine transport. In the GLNS, almost every port is important to the economic health of another port and; therefore, the system. Even so, there are disparities in tonnages handled among the ports, with some ports handling many times more tons than others. **Table 2.6** presents the tonnages carried at the ten most-trafficked ports in the GLNS. Approximately 86% of total GLNS tonnage moves through these ports annually.

Table 2.6 - GLNS Ten Most-Trafficked Harbors (thousands of short tons)

	Year					
Harbor	**2002**	**2003**	**2004**	**2005**	**2006**	**Average**
Duluth-Superior, MN	44,161	38,295	45,393	44,722	46,974	43,909
Indiana, IN	13,839	14,133	18,228	14,120	16,164	15,297
Cleveland, OH	11,412	16,621	15,775	13,641	15,187	14,527
Two Harbors, MN	14,895	13,033	13,473	10,959	13,420	13,156
Toledo, OH	11,115	9,864	9,862	10,504	11,162	10,501
Rouge River, MI	10,018	9,740	11,170	11,020	10,707	10,531
Presque Isle, MI	10,592	8,776	10,134	10,983	9,074	9,912
Ashtabula, OH	9,838	10,427	10,938	9,714	6,822	9,548
Burns, IN	8,621	8,069	9,802	9,812	8,954	9,052
Gary, IN	9,482	9,010	8,531	7,303	9,112	8,688
Total	**143,973**	**137,968**	**153,306**	**142,778**	**147,576**	**145,120**

Source: US Army Corps of Engineers, Waterborne Commerce Statistics Center

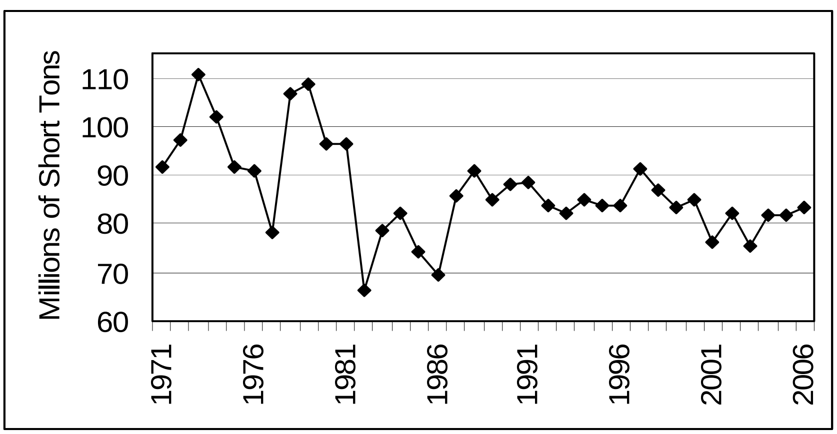
2.3.2 Soo Locks

Although there are two lock systems operating in the GLNS, the Welland Canal and the Soo Locks, only the latter lock system is owned and operated by the U.S. As one purpose of this Supplement is to provide benefit information for use in U.S. water infrastructure investment decisions, discussions regarding Canadian owned and/or operated locks are moot. Therefore, this section will only discuss the Soo Locks.

All commercial traffic through the Soo Locks uses either the Poe or the MacArthur locks. The Poe Lock is the most important of the locks as it is the only one capable of passing Class X vessels (vessels of 1,000-feet in length). Iron ore and western coal from the Powder River Basin of Wyoming are the principal U.S. commodities transported across Lake Superior and most of both commodities are transported in Class X vessels. Most Class VII vessels can use either the Poe or the MacArthur lock, while some Class VII and all class VIII- X vessels are restricted to using the large Poe Lock.

The traffic information presented in Figure 2.2 presents tonnages transited through the Soo Locks. Tonnage transited fluctuated sharply from 1971 through 1982. Over the last two decades, Lock traffic has risen and fluctuated less intensely. For example, traffic in 2006 stood at nearly the same level it did in 1996.
As stated previously, iron ore and coal are the two primary commodities transited, with iron ore representing approximately 53.7% of traffic and coal, 24.8%. Together, these two commodities total 78.5% of all Lock traffic.

Figure 2.2 - Soo Locks Historic Traffic



Source: US Corps of Engineers

Over the past two decades, U.S. traffic through the Lock has increased while Canadian has decreased. Today, approximately 70% of Lock traffic is comprised of U.S. commodities, roughly 24% Canadian and the remainder, foreign commodities.

3.0 Transportation Rate Savings Analysis

3.1 National Economic Development Benefits

One purpose for investing public funds in a waterborne navigation system, whether in maintenance or new construction, is to generate economic benefits to the Nation. These benefits are called National Economic Development (NED) benefits. The U.S. Army Corps of Engineers, *Planning Guidance Notebook*, ER 1105-2-100 categorizes four types of navigation NED benefits[1]. This section of the Supplemental Reconnaissance study focuses on one of the four benefit categories, transportation rate savings.

Transportation rate savings can most easily be defined as the reduction in the economic cost of transporting freight over the waterway compared to transporting freight via land. Savings can be aggregated to many levels, the most basic being by movement. A movement is composed of one specific commodity moving between one specific origin and destination. For example, iron ore moving from Duluth, MI to Cleveland, OH is a movement. The transportation rate saving of this movement is the cost difference between transporting the iron ore between these two points using the waterway and the least-costly land alternative route, whether it is by truck, rail or both. By summing the rate savings of all movements on the waterway, base savings are estimated. ER 1105-2-100 recognizes base savings as a proxy for the long run NED benefit attributable to USACE developed and maintained waterways.

Investments in the waterway can increase base savings, thereby increasing NED benefits. An investment that allows freight to be moved over the waterway more quickly, e.g. lock improvements that reduce vessel waiting and transit times; or more efficiently, e.g. channel deepening that allows vessels to carry more freight per trip, reducing waterborne transportation costs. By further reducing waterborne transportation cost, the transportation rate savings between waterborne and land-based transportation increases. This increase in base savings is the NED benefit generated by the waterway investment.

3.2 Methodology

3.2.1 General

In 2005, the Tennessee Valley Authority (TVA) conducted a transportation rate analysis under contract with USACE in support of the bi-national Great Lakes/St. Lawrence Seaway (GLSLS) study. That analysis incorporated 857 movements that had either and origin, destination or both in the U.S. or Canada in the GLSLS (Montreal to the head of the Lakes). This data was obtained from the Corps of Engineers Waterborne Commerce Statistics Center data and from Transport Canada. The 857 movements accounted for all moves that exceeded 20,000 net tons annually, representing over 40 individual commodities. Though by including Canadian traffic the scope of this rate analysis was greater than that required by this supplemental reconnaissance, the sample of 857 movements includes 739 U.S. movements.

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[1] ER 1105-2-100, 22 April 2000, page 3-5.

This large representation of 2002 U.S. moves in the sample coupled with the inclusion of all annual moves exceeding 20,000 tons allows this sample to provide the basic information necessary to estimate system benefits (presented in Section 9.2.2.1).

3.2.2 Movement Samples

The movements selected for this transportation rate analysis account for roughly 92.7% of GLNS waterborne traffic. These movements were drawn from the U.S. Army Corps of Engineers' Waterborne Commerce Statistics Center (WCSC) 2002 movement data and aggregated into 731 annual movements, each representing an annual flow of a given commodity between a unique origin and destination. Movements of less than 20,000 annual tons are excluded. Data from 2002 was considered representative of the bulk flows that currently use, or might be expected to continue to use the GLNS. Each of the sample movements can be characterized as either US to US, US to Canada (CN), US to Foreign (FN), and vice versa, referred to as country pairing in this analysis.

Table 3.1 displays the number of GLNS commodity movement flows by country pairing and commodity type used in the 2005 analysis. The 10 commodity group names are an arbitrary convention developed for this supplemental study to group unique commodities of interest. Table 3.2 presents the annual tonnages represented by each movement.

Table 3.1 - Sample Commodity Movement Flows

Commodity Group	CN-US	FN-US	US-US	US-CN
Wheat			4	7
Corn				15
Soybeans				6
Other Grains		2		
Aggregates	49		167	26
Non-Metallic Minerals	46	1	14	13
Metallic Minerals	22	2	58	9
Coal, Coke, Pet Coke	11		83	47
Petroleum Products	8		24	1
Iron & Steel and Other	44	28	26	11
Total	180	33	376	135

Commodity Group	US-FN	CN-CN	CN-FN	FN-CN	Total
Wheat	2	16	11		40
Corn	3				18
Soybeans	4	1	1		12
Other Grains	2	5	7	2	18
Aggregates		13			255
Non-Metallic Minerals	1	22		1	98
Metallic Minerals		5			96
Coal, Coke, Pet Coke	2	1			144
Petroleum Products		18		1	52
Iron & Steel and Other	1	3	1	10	124
Total	15	84	20	14	857

Table 3.2 - Sample Commodity Movement Tonnages (in short tons)

Commodity Group	CN-US	FN-US	US-US	US-CN
Wheat			325,474	428,278
Corn				996,799
Soybeans				1,045,486
Other Grains		84,462		
Aggregates	2,879,728		27,353,359	3,115,878
Non-Metallic Minerals	4,685,847	22,548	960,963	833,581
Metallic Minerals	3,223,342	121,193	46,850,694	6,041,391
Coal, Coke, Pet Coke	747,425		19,045,553	20,651,300
Petroleum Products	300,478		1,755,254	23,458
Iron & Steel and Other	4,004,345	2,510,544	3,679,692	1,137,407
Total	15,841,165	2,738,747	99,970,989	34,273,578

Commodity Group	US-FN	CN-CN	CN-FN	FN-CN	Total
Wheat	1,544,508	4,550,337	1,197,750		8,046,347
Corn	172,617				1,169,416
Soybeans	478,989	94,494	73,106		1,692,075
Other Grains	155,894	509,975	1,152,675	277,826	2,180,832
Aggregates		4,463,963			37,812,928
Non-Metallic Minerals	103,175	2,200,974		76,379	8,883,467
Metallic Minerals		6,083,699			62,320,319
Coal, Coke, Pet Coke	80,711	258,213			40,783,202
Petroleum Products		1,756,080		96,838	3,932,108
Iron & Steel and Other	31,736	430,767	70,291	722,001	12,586,783
Total	2,567,630	20,348,502	2,493,822	1,173,044	179,407,477

3.2.3 Transportation Rate Estimation

Many GLNS movements have off-lake origins and or destinations. The transportation rate analysis recognizes this fact in making a full accounting of all transportation charges; from the ultimate origin to ultimate destination. The rates include rail or truck or rail legs to/from the ports; all loading, unloading and transfer costs; and vessel transportation costs. However, the rates exclude any probable storage costs.

Vessel Rates - Vessel class and type, an important determinant of vessel rate, is based on the commodity shipped and port-to-port flow characteristics. Generally speaking, grains, aggregates, coke, iron and steel products, and all exports and imports move in Class 6 (650–699 feet in length) and 7 (700–730 ft) self-unloaders and straight deck vessels. Petroleum products and other liquid cargo move in Class 4 (550–599 ft), Class 5 (600-649 ft) and Class 6 tankers. Cement moves in Class 5 & 6 pneumatics. Class 10 (950-1,099 ft) self-unloaders are typically used to transport coal and iron ore from Lake Superior docks to docks on Lake Michigan and Lake Erie. Vessel loading is determined by vessel type, commodity, and the minimum available draft at dock or en-route.

Actual rates, as provided by shippers, receivers, or port operators, are used whenever possible. Unobservable vessel rates are calculated through the Great Lakes Vessel Costing

Model (GLVCM) developed by TVA. Key inputs to this model include fixed and variable cost information obtained from the vessel operating industry and the Institute of Water Resources (IWR) deep-draft vessel operating costs: labor, fuel, depreciated value of construction cost, stores, lube oil, insurance, administrative over head, etc. The methodologies employed in the estimation of unobservable rates were developed through extensive contacts with shippers, railroads, motor carriers, and the barge industry.

The GLVCM contains a one-way general vessel service module that calculates rates by simulating the use of specific vessel type and class, including the potential for a loaded return. Empty back hauls are an important consideration in the characterization of the economics of GLNS waterborne movements. Interviews with GLNS carriers and shippers and review of the Corps' Lock Performance Monitoring System (LPMS) data at Soo locks provided guidelines for TVA analysts to use when constructing vessel rates. It was found that vessel backhaul potential is greatest for moves in vessels in Class 7 or smaller and for moves of greater than 200 miles. Where backhaul potential exists, it is used to reduce the head haul costs. The GLVCM does not explicitly model backhaul moves but instead recognizes the backhaul potential of this movement.[2]

The GLVCM calculates rates based on the overall industry's fully allocated fixed and variable cost factors, including a reasonable rate of return on assets. The GLVCM allows the calculation of vessel rates under a variety of different operating scenarios.

Rail Rates - Reported rail rates are used if available, however, most movements require the calculation of probable rail rates. The Reebie Rail Costing Model is used to generate a base estimate of rail cost. This estimate is adjusted to reflect rail carrier market attributes to produce a most likely rail rate. Rail carrier market attributes are derived from the Surface Transportation Board (STB) 2003 Waybill Sample and from shipper and terminal interviews. Specific attributes include weight per car; car type; single car, multi car, or unit train shipment; and the ratio of carrier revenue to variable cost. These attributes are allocated on a commodity, regional, and carrier basis.

Truck Rates - Actual truck rates for off-lake movements are used whenever possible. All other rates are estimated based on published motor carrier tariffs, regional rate quotations from truck brokers and contract motor carriers, or the U.S. Department of Agriculture (USDA) quarterly truck survey of rates.

Handling Charges - Handling charges between modes of transportation are estimated on the basis of information obtained from shippers, receivers, stevedores, and terminal operators. Handling charges for transfer of commodities from or to ocean-going vessels are on the basis of information obtained from ocean ports or stevedoring companies. For import or export movements that involved mid-stream transfer operations, handling costs to or from land modes at a competing port with rail access are applied.

[2] The GL-SAND model, discussed in Section 9, was developed by the study team subsequent to this rate analysis. Like the GLVCM, it is a vessel costing model; however, it explicitly models vessel utilization on all legs of its trip. Great Lakes transportation rate savings for individual ports estimated using the GL-SAND are presented in Section 9 for the GLNS.

<u>Loading and Unloading Costs -</u> Because loading and unloading costs are not usually documented by shippers and receivers, they are particularly difficult to obtain. Moreover, these costs can vary considerably across firms. In an attempt to provide the best possible estimates of these costs, this analysis uses available shipper and receiver information in combination with data from previous USACE and TVA studies.

3.3 Base Savings for Sampled GLSLS Moves

This rate information presented below has been updated from $2005 price level presented in the TVA report to a more current $2008 price level. The TVA transportation rates were updated to October 2008 price levels using Bureau of Labor Statistics indices. Indices from the Bureau of Labor Statistics were used to develop the update. A BLS website provided access to over 200 indices by industry. Indices that reflect cost increases in the various components of the existing routing transportation costs and the all-land transportation costs were acquired at this site. Once the appropriate category that fit the transportation mode and method and the corresponding index was identified, indices for December 2004 and October 2008 were obtained to develop the update index for that leg of the movement. These update indices were then used to update each commodity handling/line haul cost component associated with each of the sampled 847 commodity movements. Since there were different handling charges based on the mode used, as well as differing line haul transportation costs by mode for each of the 847 origin destination routes evaluated, update factors were developed for each loading/unloading cost by mode involved, as well as line haul costs by mode. The sampled GLSLS moves total $3.6 billion in transportation rate savings in $2008.[3] U.S. GLSLS movements account for 86.0 percent of sample move total base savings (see **Table 3.3).**

[3] Note that the $3,644,234,118 figure shown in the text and in Table 3.3 below is transportation rate savings for the 857 sampled GLSLS movements. It does not represent the system savings for the GLNS. The system savings for the GLNS is presented in Section 9.2.2.1.

Table 3.3 Sample GLSLS Commodity Group Base Savings (in 2008 dollars)

Commodity Group	CN-US	FN-US	US-US	US-CN
Wheat			$10,632,014	$20,600,829
Corn				$30,264,795
Soybeans				$30,143,359
Other Grains		$4,291,932		
Aggregates	$58,504,737		$612,512,591	$64,707,467
Non-Metallic Minerals	$150,066,280	$1,107,432	$11,891,631	$16,873,691
Metallic Minerals	$88,218,464	$5,819,959	$506,976,969	$66,367,117
Coal, Coke, Pet Coke	$13,587,375		$380,855,017	$348,307,640
Petroleum Products	$8,647,727		$36,420,786	$452,508
Iron & Steel and Other	$188,797,675	$135,359,242	$162,895,625	$35,364,314
Total	$507,822,258	$146,578,565	$1,722,184,633	$613,081,720

Commodity Group	US-FN	CN-CN	CN-FN	FN-CN	Total
Wheat	$76,785,710	$56,132,827	$29,130,589		$193,281,969
Corn	$7,360,427				$37,625,222
Soybeans	$17,821,955	$1,674,323	$2,145,605		$51,785,242
Other Grains	$7,882,006	$12,948,852	$48,869,499	$12,112,280	$86,104,569
Aggregates		$87,736,755			$823,461,550
Non-Metallic Minerals	$8,247,454	$42,486,666		$7,211,460	$237,884,614
Metallic Minerals		$136,016,346			$803,398,855
Coal, Coke, Pet Coke	$5,351,557	$1,729,467			$749,831,056
Petroleum Products		$51,710,225		$2,080,048	$99,311,294
Iron & Steel and Other	$2,820,809	$11,075,637	$2,824,544	$22,411,901	$561,549,747
Total	$126,269,918	$401,511,098	$82,970,237	$43,815,689	$3,644,234,118

Table 3.4 expresses the average transportation saving rate per ton for each commodity group and country pairing for the sample moves. The averages presented are weighted averages. The average saving rates are higher for those movements representing foreign trade (FN), FN to US and US to FN. This is not surprising given the long distances foreign inbound and outbound freight has to travel and the economies of scale available by shipping larger quantities via the waterway. Movements between the U.S. and Canada exhibit higher savings rates for most commodity groups.

Table 3.4 – Sample Movement Savings Rates per Ton (in 2008 dollars)

Commodity Group	CN-US	FN-US	US-US	US-CN
Wheat			$ 32.67	$ 48.10
Corn				$ 30.36
Soybeans				$ 28.23
Other Grains		$ 50.81		
Aggregates	$ 20.32		$ 22.39	$ 20.77
Non-Metallic Minerals	$ 32.03	$ 49.11	$ 12.37	$ 20.24
Metallic Minerals	$ 27.37	$ 48.02	$ 10.82	$ 10.99
Coal, Coke, Pet Coke	$ 18.18		$ 20.00	$ 16.87
Petroleum Products	$ 28.78		$ 20.75	$ 19.29
Iron & Steel and Other	$ 47.15	$ 53.92	$ 44.27	$ 31.09
Weighted Ave. Savings	$ 32.06	$ 53.52	$ 17.23	$ 17.89

Commodity Group	US-FN	CN-CN	CN-FN	FN-CN	Weighted Average
Wheat	$ 49.72	$ 12.34	$ 24.32		$ 24.02
Corn	$ 42.64				$ 32.17
Soybeans	$ 37.21	$ 17.72	$ 29.35		$ 30.60
Other Grains	$ 50.56	$ 25.39	$ 42.40	$ 43.60	$ 39.48
Aggregates		$ 19.65			$ 21.78
Non-Metallic Minerals	$ 79.94	$ 19.30		$ 94.42	$ 26.78
Metallic Minerals		$ 22.36			$ 12.89
Coal, Coke, Pet Coke	$ 66.31	$ 6.70			$ 18.39
Petroleum Products		$ 29.45		$ 21.48	$ 25.26
Iron & Steel and Other	$ 88.88	$ 25.71	$ 40.18	$ 31.04	$ 44.61
Weighted Ave. Savings	$ 49.18	$ 19.73	$ 33.27	$ 37.35	$ 20.31

4.0 Transportation Forecasts

4.1 Purpose

Waterway traffic forecasts were not prepared as part of this supplemental report. The discussions that follow relate to forecasts prepared for earlier Great Lakes navigation studies, each of which indicates continued demand for waterway service. These forecasts also suggest that waterway values presented in subsequent sections are representative of annual values that might be realized over the life of the GLNS infrastructure. Note that economic analyses completed specifically for this supplemental reconnaissance study do not use these traffic forecasts; the benefit-cost analysis presented in Section 9 assumes no traffic growth over the 50 year investment period.

4.2 Background

Waterway traffic demand forecasts were prepared for the *Great Lakes Navigation System Review, Reconnaissance Report* (GLNS 2002) and updated and expanded for the *Great Lakes St. Lawrence Seaway Study* (GLSLS 2007). The GLNS 2002 report presented bulk commodity forecasts for the GLNS that combined a forecast of U.S. waterway traffic demand and a forecast of Canadian waterway traffic demand. The U.S. traffic forecasts were prepared by the study team by using 1998 traffic flows as a base, indexed to future years using growth factors based upon forecasts for industries that use the GLNS. The Canadian traffic forecasts were prepared by TAF Consultants and purchased by the study team. TAF's Canadian traffic forecasts were econometrically-based forecasts that relied on industry and demographic forecasts for the appropriate industry sectors and regions.

Where the primary focus of the GLNS 2002 study was bulk commodity moves to and from harbors, the focus of the GLSLS 2007 study was on these moves through the 15 Seaway Locks and the Soo Locks. Consequently, the GLSLS 2007 study combined forecasts that focused on Seaway traffic and Soo Locks traffic. These forecasts were available from: 1)TAF for Seaway traffic and 2)the *Final Limited Re-evaluation Report, Replacement Lock – Sault Ste. Marie, Michigan, Appendix B – Economic Analysis,* February 2004 for Soo Locks traffic.

Both the GLNS 2002 and GLSLS 2007 reports addressed the potential for container traffic. This potential demand represented a major uncertainty in projecting future usage levels of locks, channels and harbors. Tons (short tons in the GLNS 2002 and metric tons in the GLSLS 2007) were the unit of measure for bulk commodity forecasts, while the unit of measure for container traffic was Twenty Foot Equivalent Units (TEUs) in GLNS 2002 and Forty Foot Equivalent Units (FEUs) in GLSLS 2007. In the final analysis, though, units of measure in all instances (bulk and container) were converted into transits by vessel, by draft in the economic analyses in both studies. The GLNS 2002 study's examination of container feasibility was framed within the context of a system capable of accommodating 35 foot draft vessels. Because this alternative was screened from further consideration during the GLSLS 2007 study, these GLNS 2002 container forecasts are not presented in this supplemental report; however, the forecasts prepared for the GLSLS 2007 report (and discussed in Section 5 of this supplemental report) are presented. These forecasts were prepared within the context of the currently configured GLSLS system.

Finally, the GLNS 2002 study did include forecasts of bulk commodity traffic that would occur if the Seaway and Soo dimensions were altered to accommodate 35 foot draft vessels. Again, because this alternative was screened from further consideration during the GLSLS study, these forecasts are not presented in this supplemental report.

4.3 Methodology and Results

Forecasts prepared for the GLNS 2002 and the GLSLS 2007 reports shall be discussed separately. Detailed descriptions of methods and results can be found in these respective studies.

4.3.1 GLNS 2002

4.3.1.1 Methodology

Forecasts prepared for the GLNS 2002 report reflected the level of traffic that would be expected to materialize if system constraints were not a consideration. To the extent practicable, future traffic demands for the Great Lakes and St. Lawrence Seaway were projected as a function of future economic growth in the markets served by waterway-using industries. These markets include both end-use/industry markets and geographic markets, whether local, broader regional, national, or international. In this context, the traffic demand projections were developed by reference to specific company plans; industry-produced supply/demand forecasts; economic and demographic forecasts from U.S. and Canadian government sources and private consultants; and other transportation-related forecasts.

Actual waterway traffic is the most visible component of traffic demand, and consequently, existing traffic served as the starting point for identifying and forecasting waterway traffic demands. From the combined WCSC-Statistics Canada database, a base year of commodity movements was identified that was considered to be representative in terms of tonnage volumes and commodity flows. In this instance, the base year selected was calendar year 1998.

Iron ore and utility coal are two of the largest-volume and most important commodities moving on the Great Lakes and St. Lawrence Seaway. They were treated somewhat differently in the forecasting process than the other commodities. Initially, market surveys were conducted involving the major U.S. and Canadian regional utilities, steel companies, and resource suppliers. These surveys are described in greater detail in subsequent paragraphs. The major purpose of the surveys was to obtain information on expected future waterborne shipments/receipts of iron ore, coal and other commodities.

This information was the major source of short-term forecasts for these commodities. These short-term forecasts were then extrapolated over the planning horizon using growth indices developed from longer-term economic and demographic forecasts.

For most of the other commodities, flow forecasts were developed by applying growth indices to the 1998 base traffic. Over the short term, industry forecasts were sometimes available. Similar to iron ore and utility coal, extrapolation over the planning horizon was accomplished using growth indices developed from long-term economic and demographic forecasts.

For the utilities, the shipper survey was targeted mainly toward utility companies operating waterside coal-fired power plants. Other companies contacted included operators of coal-handling facilities, and shipping companies. A formal mail-type survey was sent out to nine major utility companies that are either currently receiving coal via the Great Lakes or the St. Lawrence Seaway or that could potentially use these waterways for coal delivery. In addition to these companies, 23 other utilities and related companies were contacted informally to solicit coal movement information. As a result of these efforts, four companies contacted in the formal survey and an additional 15 companies contacted in subsequent informal contacts provided coal movement information. The major finding from the shipper survey was that utility respondents planned to continue to shift from eastern to western coal producing areas, with increased utilization of both the Great Lakes and rail modes.

Informal, confidential surveys were conducted with steel companies, iron ore mining and processing firms, steel companies and grain brokering entities. These firms represented the largest Canadian or U.S. firms of their kind operating on the Great Lakes/St. Lawrence Seaway system. Responses were given in direct interviews or through questionnaires.

The forecasts used in the GLNS 2002 effort came from a variety of U.S. and Canadian and government and private sources. A listing of the specific sources used, by major commodity grouping, is provided in **Table 4.1.** Descriptions of these forecasts can be found in the GLNS 2002 Economics Appendix.

Table 4.1
Summary of Short and Long Term Forecasts

Commodity Group	Short-Term Forecasts	Long-Term Forecasts
Coal & Coke	1. utility company responses 2. RDI electricity demands 3. Woods & Poole EA mfg earnings 4. National Energy Board electricity / met coal demands 5. steel company responses 6. World Steel Dynamics-iron ore	1. Woods & Poole EA personal income 2. Woods & Poole EA mfg earnings 3. National Energy Board electricity / met coal demands 4. EIA U.S met coal consumption
Petroleum Fuels	1. Woods & Poole EA population 2. Woods & Poole EA mfg earnings 3. Ontario Ministry of Finance-population 4. TAF Consultants-MLO forecast	1. Woods & Poole EA population 2. Woods & Poole EA mfg earnings 3. Ontario Ministry of Finance-population 4. TAF Consultants-MLO forecast
Crude Petroleum	1. Woods & Poole EA population 2. Ontario Ministry of Finance-population 3. TAF Consultants-MLO forecast	1. Woods & Poole EA population 2. Ontario Ministry of Finance-population 3. TAF Consultants-MLO forecast
Aggregates	1. Woods & Poole EA constr earnings 2. TAF Consultants-Ontario GDP 3. TAF Consultants-MLO forecast	1. Woods & Poole EA constr earnings 2. TAF Consultants-Ontario GDP 3. TAF Consultants-MLO forecast
Grains	1. Woods & Poole EA mfg earnings 2. TAF Consultants-MLO forecast 3. Woods & Poole EA mfg earnings 4. TAF Consultants-Ontario GDP	1. Woods & Poole EA mfg earnings 2. TAF Consultants-MLO forecast 3. Woods & Poole EA mfg earnings 4. TAF Consultants-Ontario GDP
Chemicals	1. Woods & Poole EA mfg earnings 2. TAF Consultants-Ontario GDP 3. TAF Consultants-MLO forecast	1. Woods & Poole EA mfg earnings 2. TAF Consultants-Ontario GDP 3. TAF Consultants-MLO forecast
Ores & Minerals	1. Woods & Poole EA mfg earnings 2. Woods & Poole EA constr earnings 3. Ontario Ministry of Finance-population 4. TAF Consultants-Ontario GDP 5. TAF Consultants-MLO forecast	1. Woods & Poole EA mfg earnings 2. Woods & Poole EA constr earnings 3. Ontario Ministry of Finance-population 4. TAF Consultants-Ontario GDP 5. TAF Consultants-MLO forecast
Iron and Steel	1. steel company responses 2. World Steel Dynamics-iron ore	1. EIA U. S. met coal consumption 2. National Energy Board electricity met coal demands
All Others	1. Woods & Poole EA mfg earnings 2. Woods & Poole EA constr earnings 3. Woods & Poole EA population 4. Woods & Poole EA personal income 5. TAF Consultants-MLO forecast 6. Ontario Ministry of Finance-population	1. Woods & Poole EA mfg earnings 2. Woods & Poole EA constr earnings 3. Woods & Poole EA population 4. Woods & Poole EA personal income 5. TAF Consultants-MLO forecast 6. Ontario Ministry of Finance-population

4.3.1.2 GLNS 2002 Forecast Results

The waterways under consideration for navigation improvements in the GLNS 2002 study included the five Great Lakes and their connecting channels (and U.S. harbors) and the St. Lawrence Seaway, made up of the Montreal-Lake Ontario section and the Welland Canal. Traffic demand forecasts are presented for the Great Lakes Navigation System, the St. Lawrence Seaway, and the aggregation of the two, the Great Lakes/St. Lawrence Seaway. The overlap in these waterway definitions is considered in data compilation and forecasting. The forecasts are comprehensive, including all Canadian and U.S. traffic. While the GLNS 2002 study did consider potential bulk and container traffic that a deeper Seaway might induce to move, these are not presented here. This option was screened from further consideration in the GLSLS 2007 study.

Total traffic demands for the Great Lakes Navigation System, the St. Lawrence Seaway, and the aggregate Great Lakes/St. Lawrence Seaway system are presented in **Table 4.2**. Total traffic demand for bulk commodities on the Great Lakes/St. Lawrence Seaway is shown to increase from a level of 228 million tons in 1998 to about 357 tons by year 2060, reflecting annual growth of about 0.7 percent. The St. Lawrence Seaway subsystem grows slightly faster, at about 0.8 percent per annum and annually accounts for about one quarter of the traffic on the larger system. The Great Lakes Navigation System grows at a rate of about 0.7 percent and annually accounts for around 99 percent of traffic demand in the overall system. A detailed discussion of the industries that drive traffic demands and forecasts for individual commodities are presented in the Economics Appendix of the GLNS 2002 report.

Table 4.2
GLNS 2002, Bulk Commodity Traffic Forecasts
(millions of short tons)

Year	GLNS	Seaway (Welland and MOLO Sections)	GLSLS
1998	227	61	228
2000	232	62	232
2010	255	67	255
2020	275	73	276
2030	291	80	292
2040	314	84	315
2050	335	93	336
2060	356	99	357
Annual Growth Rate	0.7%	0.8%	0.7%
NOTE: Data includes all US and Canadian traffic.			

4.3.2 GLSLS 2007

The focus of the GLSLS 2007 study was the locks in the GLSLS system; therefore, forecast development concentrated only on lock traffic. The GLSLS study team used forecasts prepared by Traffic Analysis and Forecasting (TAF) Consultants for bulk commodity traffic demands on the Welland and the Montreal-Lake Ontario sections of the St. Lawrence Seaway and bulk commodity forecasts prepared for the most recent Soo Locks study for Soo lock demands. Forecasts were not prepared for movements that do not use a GLSLS lock. In addition to bulk commodity forecasts, container forecasts were prepared. These are discussed in Section 5.

4.3.2.1 GLSLS 2007 Methodology

4.3. 2.1.1 Seaway Bulk Commodity Forecasts

Transport Canada contracted Traffic Analysis and Forecasting (TAF) Consultants to prepare bulk commodity forecasts for traffic transiting the Welland and the Seaway (Montreal- Lake Ontario) Locks. TAF began by analyzing traffic patterns beginning with 1959, looking at changes in cargo mix and direction. TAF then used a variety of statistical and econometric models to project the kind of traffic that might be expected in the system over the coming half century. Both the internal dynamics of the system as well as foreseeable external trends likely to influence that traffic were examined. The forecasts were completed in 2002, revised in 2004, and revised again in December 2006. This last set of forecasts was used in the GLSLS Study.[1]

The US Army Corps of Engineers (USACE) forecast future traffic transiting the Soo Lock for its *Final Limited Re-evaluation Report, Replacement Lock*, dated February 2004. USACE established a baseline growth trend utilizing econometric techniques and input from academic and industry experts. USACE then used a probabilistic model to extrapolate future trends. The referenced report is *Final Limited Re-evaluation Report, Replacement Lock - Sault Ste. Marie, Michigan, Appendix B - Economic Analysis*, February 2004.

Using historical data up to 2003, these forecasts focused only on existing cargo and traffic mix and explored three potential scenarios: optimistic, pessimistic and most probable. In projecting future traffic, TAF incorporated assumptions regarding future economic conditions and other factors likely to affect system traffic up to 2020. Statistical methods were used to smooth forecasts in extending projections from 2020 to 2050.

The alternative nodes, routes and modes forming the GLSLS System compete for various commodities moving between several North American and overseas supply and demand centers. The amount and direction of commodities flowing through this transportation

[1] The referenced report is *Future Competitiveness of the St. Lawrence Seaway System*, dated March 2004. Note that this report will contain the 2004 forecast numbers. No report has been released as of yet containing the 2006 forecast numbers, but the bulk of the information regarding analysis and methodology remains the same.

network is influenced by a multitude of interrelated economic, political, technological, institutional and environmental factors, at domestic and global levels. By identifying the supply and demand center(s) for each commodity/group and then determining the impact of these factors on the commodity supply, demand, trade, market and transportation modal choice, the process of assessing future competitiveness of the Seaway vis-à-vis alternative route and mode is greatly enhanced and its credibility increased.

The methodology combined econometrics, market research, regional analysis and industrial complex analysis directed toward the analysis of markets as well as the region and its industrial complexes. Each commodity was analyzed separately and the methodology applied was adjusted to the specific characteristic of each commodity.

First, world demand and supply for the major commodities using the GLSLS system were analyzed and projected. Next, the North American balances between domestic supply and demand were estimated and the exports, imports and domestic shipments that could move via the system were segregated. The weight of the combined factors that influence the selection of the mode(s) and route(s) through which the cargo could move was applied in order to estimate the system's share of this movement. A number of equations are developed to represent the major variables related to a commodity/industry and the relationships among them. These equations are then solved simultaneously to obtain a forecast for the key variables.

TAF Consultants use several types of econometric software systems to develop its forecasting equations including Micro TSP and Econometric Views from QMS Quantitative Micro Software of Irvine, California, and Forecast Pro from BFS Business Forecast Systems of Belmont, MA. The equations are updated and tested periodically to reflect latest developments and are an integral component of TAF's comprehensive Traffic Analysis and Forecast Information System (TAFIS).

Validation and testing the equations consist in running a correlation of estimates with past movements. The accuracy and significant of the quantitative forecasting method used, such as regression analysis, are substantiated by providing the statistics results of the regression equation. Reports, data and forecasts relevant to the Seaway traffic forecast have been gathered from several reliable sources. In addition, TAF Consultants' proprietary Commodity Flows Information Systems "COMFIS©", was used extensively for the efficient preparation of the forecast and TAF's Electronic Gathering Information System (TAF-EGIS©) was used to collect the latest information on Seaway commodity traffic related issues.

4.3. 2.1.2 Soo Locks Bulk Commodity Forecasts

To forecast traffic transiting the Soo Locks, USACE first analyzed supply and demand factors of major Soo Lock commodities using methods that were considered to be most relevant to the nature of the activities being forecasted. This meant using different approaches for different commodities. The forecasts for grain, stone and "*other commodities*" were derived by applying econometric techniques to the historical data.

Iron ore forecasts relied more heavily on expert input from industry sources. Coal forecasts were derived by surveying coal demand industries, and developing demand growth rates. Coal shippers were surveyed to further develop demand patterns. These results were compared to coal forecasts developed by a variety of other governmental agencies and industry sources. In all three cases, forecasts were developed for three potential scenarios: optimistic, pessimistic and most probable. The econometric methodology used in forecasting grain, stone and other commodities is more fully discussed below. For more information regarding the survey methodology and analysis for coal and iron ore, see Appendix B of the Soo Locks LRR, specifically Addendum 2.

The forecasts for grain, stone and other commodities were based on a "*best fit*" method incorporating trend line extrapolation. In order to propagate uncertainty around the mean estimate through time, a Monte Carlo method was employed. This approach yields the theoretically correct result of increasing uncertainty as estimates move farther into the future. The historical period for the statistical regression analysis is 1989-2000.

The cyclical component from the data was removed and the data analyzed for statistically significant secular trends using a four-year moving average. Four years was chosen because it is approximately the average length of the business cycle exhibited over about the last 150-years. The remaining variation in the data is treated as random variation. After this, USACE regressed the data to estimate the trend value and standard error.

Then USACE built a forecasting model with an iterative random walk approach. The fundamental aspect of the random walk approach is the assumption that the volume of traffic in any particular year is equal to the volume in the preceding year plus changes due to the secular trend and random influences. The change factor was drawn from a normal distribution with parameters equal to the slope and standard error computed in the regression analysis. If there was no statistically significant trend, as in the case of grain, zero was used as the distribution mean. It should be noted that this approach allows for decreases in volume as well as increases from year to year, putting it more in line with reality than compound growth models often used in the past.

Fifty years of shipments were forecasted with the iterative model. There were 10,000 iterations for each commodity modeled in this way. The data generated in this manner were used to estimate probability distributions for tonnages in each of the forecast period years. These in turn were used to establish tonnage ranges which could be associated with a given probabilities, that is, to establish confidence intervals.

4.3.2.2 GLNS 2007 Forecast Results

Bulk commodity forecasts for GLSLS system locks prepared by Traffic Analysis and Forecast (TAF) Consultants and the U.S. Army Corps of Engineers projected relatively slow growth in bulk traffic over the next four decades. **Table 4.3** summarizes the bulk traffic demand forecasts for the Seaway Locks, the Welland Locks and the Soo Locks. The Economic Appendix of the GLSLS 2007 report contains commodity specific forecasts. As noted earlier, because this study focused on lock infrastructure, no forecasts of intra-lakes traffic were prepared. Traffic demands are in metric tons. Transit (vessel trip) forecasts for bulk commodities were also prepared; however, these grew at the same rate as tonnage demands and are not shown here, though they are presented in the GLSLS 2007 Economics Appendix.

Table 4.3
GLSLS 2007, Lock Forecasts
(millions of metric tons)

Year	Seaway Locks	Welland Locks	Soo Locks
Historic			
1960	18.4	26.5	82.9
1970	46.4	57.1	90.8
1980	49.5	59.6	87.4
1990	36.7	39.4	79.8
2000	35.4	36.6	82.0
Future			
2010	32.3	34.3	89.5
2020	37.6	36.2	91.8
2030	39.5	40.1	94.0
2040	40.8	41.3	102.3
2050	42.1	42.4	107.3
Forecast Avg. Annual Growth Rates	0.70%	0.54%	0.44%

4.4 Conclusion

Results from both the GLNS 2002 and GLSLS 2007 suggest sustained long term demand for waterway services. Examination of these two sets of forecasts also indicates little change in outlook over the intervening years for bulk commodity traffic flows.

5.0 New Cargoes/New Vessels

5.1. Purpose

New cargo/new vessels in this report refers to investigations into the potential for neo-bulk goods and containers to move on the GLSLS system without altering the current dimensions of GLSLS channels or locks.[1] These investigations were completed as part of the *Great Lakes St. Lawrence Seaway Study* (GLSLS 2007). While the *Great Lakes Navigation System Review, Reconnaissance Report* (GLNS 2002) did look at container and new bulk cargo potential, it did so only within the context of a GLSLS system capable of handling vessels drafting 35 feet – deeper than the current physical configuration channels and locks in the GLSLS. This alternative was screened-out in the GLSLS 2007 report, so results from the GLNS 2002 examination of new cargoes is not reported in this GLNS 2008 Economics Appendix. While current physical and legislative (most prominently the Jones Act) parameters were assumed unchanged in the GLSLS 2007 report, the New Cargoes/New Vessels work did look at alternative vessel fleets that might favorably alter the prospects for container movement on the existing system.

The objective of these examinations was to determine if additional usage beyond what is forecast for bulk commodities needs to be considered when evaluating the level of investment and reliability necessary for the GLSLS system. Secondarily, the GLSLS could prove to be a feasible alternative route for moving containers off congested rail and highway systems. If this were to be the case, the GLSLS would yield significant additional benefits by reducing transportation costs to overland system users, reducing overland accidents and reducing emission exposure.

5.2. Potential Container Traffic in GLSLS System

5.2.1 Introduction

This section summarizes the *Great Lakes – St. Lawrence Seaway New Cargoes/ New Vessels Market Assessment Report* prepared by Transportation Economics and Management Systems, Inc (TEMS) and RAND Corporation, dated January 2007. This report was prepared under a contract with the Maritime Administration, U.S. Department of Transportation to assess opportunities for growth from emerging neo-bulk and new container traffic through the Seaway and into the Great Lakes. The report focused on three areas of investigation:

- An evaluation of the economic significance and growth of industrial sectors and markets in the GLSLS region as a basis for projecting the transportation needs of this region's evolving economy,
- Market investigations and forecasts of emerging and potential cargo movements through 2050, focusing on potential growth in neo-bulk and containerized trade, and

[1] Like steel and aluminum ingots, plate and coil steel, transportation equipment, farm machinery – not bulk goods, but goods that cannot be shipped in containers.

- An evaluation of the ability of water options and vessel technologies to address shippers' service requirements for both container and neo-bulk traffic.

5.2.2 Regional Economy, Trends and Transportation

Trade flows were analyzed; indicating that the GLSLS serves a large region of North America, including Atlantic and Central Canada and the U.S. Midwest and Northeast. This region encompasses Northeast Atlantic gateway ports, major agricultural and mining areas, and the largest and historically integrated manufacturing, business, consumer, and market centers of Canada and the United States. TEMS reported that the region's economy continues to diversify and move toward a New Economy that is heavily dependent on trade with other countries. The explosion in trade was seen as driving a need for changes in the character of transportation services in the GLSLS region.

As the region's population, employment, GDP, and trade are projected to grow significantly through 2050, the region's freight traffic is expected to expand at an even faster rate. Furthermore, it is anticipated that a growing share of traffic moved by all modes of transportation will be by containers (including truck trailers). The total market for containerized traffic (which includes raw materials, food, and semi-finished and finished products) to and from the region is expected to more than double by 2050, from 35 million to over 70 million forty-foot equivalent units (FEUs) annually. This growth creates a number of issues.[2]

In the GLSLS basin, trucks move over 98 percent of containerized freight tonnage, while rail moves the remaining 2 percent. However, both highway and rail are suffering from deteriorating levels of service due to growing congestion. In the case of highways, congestion is largely due to the growth of automobile traffic, particularly around major cities, that outstrips highway departments' ability to add capacity. In the case of railroads, a move to increase productivity and improve revenue structures over the past two decades has resulted in fewer railroad companies and the abandonment of secondary lines. Both rail and truck also face increasing congestion on routes into the ports themselves.

In addition, the report noted that many West and East Coast ports have reached capacity. These ports are unable to expand in areas that are often highly urbanized and developed and where capacity expansions of connecting roads and rail lines may be physically constrained. This problem is exacerbated by the increasing size of container ships. These new, larger vessels cannot be accommodated at many of the East and West Coast ports, which are shallow by mega port standards. While new container port facilities have been developed on the West Coast (such as Prince Rupert in Canada and Lazaro Cardenas in Mexico), opportunities for expansion at existing West Coast ports are limited, and increased throughput will become increasingly dependent upon productivity gains. As such, it is anticipated that at least 30 percent of West Coast port growth will be diverted via the Panama Canal (15 percent) and by a round-the-world route via the Suez Canal (15 percent) to East Coast ports, such as: Halifax, Nova Scotia; Norfolk, Virginia;

[2] A container measuring 40 feet x 8 feet x 8 feet equal to about 25 metric tons or 72 cubic meters.

and Freeport, Bahamas. In addition, the Suez Canal route appears to be an increasingly viable alternative due to, first, the expansion of trade south and west in Asia (to include countries like Malaysia, Thailand, Pakistan, and India) and to, second, the ability of the Suez Canal to handle the larger post-Panamax container ships, and lastly, to capacity constraints at the Panama Canal. These trends could favor deployment of vessels to North America's East Coast ports.

These factors - continued economic growth, increased Asian trade, capacity limitations at U.S. ports in particular, and capacity limitations on the GLSLS region's highways and railroads – all point to an increased potential for water to play a role in the transportation of container and neo-bulk traffic. Detailed analysis using very conservative assumptions on highway and rail capacity limitations suggested the following:

1. As road freight traffic continues to grow by some 88 percent between 2005 and 2050 to accommodate trade growth, the highway market share moved by truck could decline slightly from 98 to 92 percent of total freight traffic due to congestion-related diversion of traffic growth.
2. Railroad carryings could double from 2 to 4 percent for inter-modal (container) traffic volume between 2005 and 2050, assuming that the railroads begin to bring back unused capacity in secondary lines and bypass routes.
3. An inter-modal water option could also capture 4 percent of inter-modal traffic by 2050, if it is competitive with rail and highway.
4. If highway infrastructure is not able to absorb the 88 percent increase in road freight traffic due to an inability to mitigate bottlenecks, both water and rail traffic could increase beyond the combined 8 percent share of traffic currently forecast. In the case of water it could grow to as much as 8 percent without reaching GLSLS waterway capacity restrictions. In the case of rail capacity, restrictions may prevent it reaching a similar share of traffic.

5.2.3 Potential for New Water Services

The study sought to determine if there was potential for the movement of containerized traffic on the GLSLS given its existing configuration of lock and channel dimensions. An in-depth market survey of the freight transportation needs of some 200 shippers in Canada and the U.S. found a willingness to use water container services if they were comparable and competitive to truck and rail in terms of time, cost, and reliability. In addition, the survey found that "seasonality" of service was not such a critical factor, because the winter closure of the Seaway and Welland Canal occurs during the low traffic period after Christmas when inter-modal traffic volumes are reduced by 15 to 20 percent.

In evaluating the potential for water transportation to offer service competitive with rail and truck, an analysis was made of the time, cost, and performance of four water technologies. A detailed, supply-side analysis of four available vessel types found that a modern GLSLS-max Container Ship (20 knots) would be the most cost and time effective for east-west movements along the GLSLS and could be competitive with rail and truck.

Specifically, the analysis of the potential role of a 20-knot GLSLS-max vessel found that it could serve three types of inter-modal markets: (see referenced report for mapped routes of these markets).

- **I-H20 East** - Inland distribution from the East Coast container ports of Halifax and Montreal to inland ports and to Lake Ontario and Erie ports such as Hamilton and Cleveland.
- **I-H20 West** - Using a mini-land bridge (rail) from the Northwest Coast ports of Seattle, Tacoma, Vancouver, and Prince Rupert to Great Lakes ports such as Duluth and Thunder Bay would provide access to inland container markets such as Detroit, Cleveland, and Hamilton.
- **GLSLS Domestic Connector** - Services that provide an inter-lake/inter-Seaway connection for domestic containers from Chicago to Montreal would bypass major rail and road congestion areas such as Chicago, Detroit/Cleveland, Buffalo/Toronto, and Northeast coastal cities.

Initial volumes and service requirements suggest that 150-200 FEU capacity, 20-knot, Roll-On/Roll-Off (Ro/Ro) container vessels could meet market demand, while also keeping inter-modal transfers to truck and rail services as simple and as fast and cheap as possible. As traffic builds, however, the study concluded that higher volume containerships (GLSLS-max with 300-400 FEU capacity) and new port container handling facilities should become cost-effective for moving both domestic and international freight.

The report concluded that due to the continuing trend towards freight containerization, and despite rapid growth, neo-bulk goods (which include steel and aluminum ingots, plate and coil steel, finished automobiles, rail transportation equipment, and farm machinery such as tractors) would remain a relatively small share of non-containerized waterborne freight. Neo-bulk traffic was seen to largely reflect the increasing integration of the U.S. and Canadian economies, firms seeking economies of scale and looking for niche markets could generate commodity flows moving north-south across the GLSLS system, functioning as a reliever to highway bottlenecks at U.S.-Canadian border crossings. For these north-south, cross lake shipments of both neo-bulk and container traffic it was found that the use of either a small fast container (20 knot) Ro/Ro ship or a somewhat faster (25-35 knot) vessel known as a Partial Air Cushion Support Catamaran (PACSCAT) would be cost and time effective. These vessels are highly competitive when the only other option is congested U.S./Canadian rail and highway bridge crossings.

TEMS found that the critical determinants of success for new ship services for neo-bulk and containers alike include the magnitude of growth of the regional economy and its expanding trade with Asia; congestion in the rail network converging on Chicago, Kansas City, and St. Louis, in bottlenecked highway corridors, and at East and West Coast ports; and traffic overflows from West Coast ports through the Suez Canal. TEMS developed two scenarios – the Uncongested Overland Routes and the Congested Overland Routes – to test the sensitivity of findings to overland congestion pressure on waterway flows.

Additionally, the results were tested using four vessel categories. The first category – Small Ship - corresponds to vessels designed for speeds of 20 knots carrying 90 – 175 FEUs. The Ship category is the GLSLS-max vessel also designed to travel at speeds of 20 knots, but carrying from 340 – 665 FEUs. The third category is called PASCAT (Partial Air Cushion Support Catamaran) – a vessel capable of 40 knots and carrying 105 FEUs. The final category is the Container-on-Barge category – a towboat and two barge configuration with a speed of 12 knots and FEU capacity of 310 FEUs.

5.3 Results and Conclusion

The results of the evaluation of potential container traffic are summarized by congestion scenario for four general vessel categories: Small ship, Ship, PASCAT, and COB (container-on-barge). The TEMS and RAND Corporation study indicates the potential for the GLSLS system to play a significant part in helping to relieve anticipated capacity shortfalls in the movement of containers to U.S. and Canadian markets. Under very conservative assumptions about the future growth of the economy and trade, and continuing difficulties in building new highway and rail capacity, this study reports that modern GLSLS-max container ships (20 knots) can be competitive with truck and rail on specific trade routes, and attract significant container traffic. In this way the system can play a role as an inter-modal reliever in helping to move containers to, from, and within the system's market areas.

Tables 5.1 and **5.2** summarize the container traffic demand forecasts under an uncongested overland transportation scenario and a congested overland scenario. The first table displays traffic in terms of FEUs, while the second table shows traffic in terms of vessel transits. In recognition of the fact that each vessel type has its own cost and performance profile, both tables show traffic potential for a given vessel type. While the larger, GLSLS max ship (ships that have a 665 FEU capacity) can carry more, they are not cost effective when demand for container moves is less than 1,000,000 FEUs. Small ships (ships carrying 150 FEUs per trip) are the most cost effective at volumes less than 1,000,000 FEUs. The TEMS/RAND report indicates that small ships would be used in 2010, gradually giving way to the use of GLSLS-max vessels in the uncongested overland routes scenario.

Table 5.1 Potential Container Traffic by Vessel Type (in 000s of FEUs)

Uncongested overland route scenario: Midrange Growth			
Vessel	**2010**	**2030**	**2050**
Small ship	655	1,143	1,531
Ship	824	1,442	1,935
PASCAT	368	634	845
COB	159	287	388
Congested overland route scenario: Midrange Growth			
Vessel	**2010**	**2030**	**2050**
Small ship	686	1,568	2,361
Ship	883	2,135	3,184
PASCAT	373	763	1,175
COB	166	375	578
* Small ships are most cost effective until traffic levels reach 1,000,000 FEUs, then the ship becomes the most cost effective. It is assumed that the cost effective traffic for a given forecast year is all that moves.			

Table 5.2 presents vessel transit forecasts for each of the two scenarios. Again, small ships are assumed to carry all container traffic in 2010 and give way to GLSLS max ships by 2030 when container demand exceeds 1,000,000 (see **Table 5.1**).

Table 5.2 - Potential Container Vessel Transits by Vessel Type Congested Overland Route Scenarios

Uncongested overland route scenario: Midrange Growth			
Vessel	**2010**	**2030**	**2050**
Small ship	3,743	6,531	8,749
Ship	1,239	2,168	2,910
PASCAT	3,505	6,038	8,048
COB	513	926	1,252
Congested overland route scenario: Midrange Growth			
Vessel	**2010**	**2030**	**2050**
Small ship	3,920	8,960	13,491
Ship	1,328	3,211	4,788
PASCAT	3,552	7,267	11,190
COB	535	1,210	1,865
* Small ships are most cost effective until traffic levels reach 1,000,000 FEUs, then the ship becomes the most cost effective. It is assumed that the cost effective traffic for a given forecast year is all that moves.			

The TEMS/RAND report indicates a cost-effective potential for container shipment in 2010 regardless of the level of congestion along overland routes, though congestion conditions do increase demand for waterborne carriage of containers. Though all vessel types could carry containers at a cost savings, the total savings was greatest when using small ships at volumes of less than 1,000,000 FEUs and greatest for GLSLS max vessels when volumes exceeded 1,000,000 FEUs. I n 2010 the TEMS/RAND report indicates that in the unconstrained overland route scenario a potential demand for 3,743 vessel transits carrying 655,000 containers, but because GLSLS max vessels are more efficient when container volumes exceed 1,000,000, the number of vessel transits in 2030 actually declines to 2,168 though the number of containers moving increases to 1,442,000. To place these forecasts in perspective relative to bulk commodity forecasts, traffic in the Congested Overland Scenario represents as much as 52% of Montreal-Lake Ontario transits, 46% of Welland transits, and 29% of Soo transits. The share of container traffic in the Uncongested Overland Scenario is only slightly lower than Congested Overland Scenario forecasts in 2010 and 2020, but is significantly lower in the outer years.

6.0 Recreational Boating Spending in the Great Lakes Navigation System

6.1 Introduction

In 2003, the U.S. Army Corps of Engineers (USACE) partnered with the Great Lakes Commission and the Recreation Marine Research Center at Michigan State University to prepare a report to detail the economic benefits of recreational boating in the Great Lakes basin. This report was prepared in response to Section 455(c) of the Water Resources Development Act of 1999, which directed the Secretary of the Army, in cooperation with the Great Lakes States, to submit such a report to the U.S. Congress. This report is known as the *John Glenn Great Lakes Basin Program, Great Lakes Recreational Boating Report,* released in December 2008. This section of the Economics Appendix to the *Great Lakes Navigation System Review, Supplemental Reconnaissance Report* presents a portion of the information found in the referenced report as well.

This analysis does not attempt to estimate National Economic Development benefits. Rather, it details regional recreational boating expenditures of boat owners that operate their water craft on the Great Lakes. Boating in the Great Lakes is a popular recreational activity for residents of and visitors to the region, which has an economic impact at the local, state and regional levels. Recreational boaters spend money in two ways: 1) by purchasing and maintaining their boats, and 2) by purchasing gas, oil, food and lodging each time they take a boating trip, whether it be for a short outing of an hour or two, or a multiple day cruise.

6.2 Study Area

This analysis encompasses the counties that border the Great Lakes in the following eight states: Illinois, Indiana, Wisconsin, Minnesota, Michigan, Ohio, Pennsylvania and New York. Many references are made in media and academia to the Great Lakes states. To avoid confusion, it is important to note the distinction between these specific Great Lake bordering counties and the Great Lakes states. This analysis evaluates the economic impact of recreation boating generated by recreational watercraft registered in the counties bordering the Great Lakes. This analysis does not take into account any economic impacts generated on the inland rivers or lakes of these eight states. It is also important to distinguish this analysis's study area from what is commonly referred to as the Great Lakes basin. The Great Lakes basin is normally defined to include the headwaters of all streams and rivers flowing into the Great Lakes, therefore encompassing a much larger region than the subject study area.

6.3 Recreational Boating Spending

Direct effects are the changes in sales, income and jobs in those business or agencies that directly receive the boater spending.

6.4 Recreational Boaters

The first step in estimating the economic impacts of recreational boating on the Great Lakes is to determine how many recreational boats, or similar watercraft, operate on the Great Lakes.

Although seemingly a simple task, it can prove to be problematic. Public law requires states to register recreational vessels and authorizes the U.S. Coast Guard (USCG) to annually track numbered recreational vessels. Because the terminology "numbered recreational vessels" refers to watercraft propelled by a motor, the USCG information likely misses some non-motored vessels. Adding to the difficulty is the inconsistency among the Great Lakes states in registering non-motored craft. Each state has its own requirements for types of watercraft needing registration.

Given the inconsistencies between the USCG and each state's registration protocol, and given the need to establish a consistent basis for counting recreational vessels across the Great Lakes states, this analysis uses registration estimates provided by USCG. The USCG estimates reflect the most consistently applied and most accurate data obtainable for the Great Lakes basin. The USCG estimates that there were approximately 911,000 recreational boats registered to people residing in Great Lakes shoreline counties in 2003.

As the purpose of this analysis is to quantify the economic impacts of Great Lakes recreation, it is important to isolate the number of watercraft most likely to be operated on the Lakes. Previously conducted boating surveys indicated that residence does not necessarily indicate the county in which boats are stored and operated[1]. Many boaters who do not live in counties adjacent to the Great Lakes store their boats at Great Lakes marinas or nearby seasonal homes. Also, owners of larger boats living near the Great Lakes are more likely to use them on the Lakes while many smaller boats in these counties are predominantly used on inland waters.

The referenced December 2008 report estimated the number of recreation vessels operating on the Great Lakes by adjusting the USCG estimate to reflect the propensities of boats of each size class to be used on the Great Lakes[2] and the number of Great Lakes marina slips available in each state. See section 6.3. The results are presented in **Table 6.1**. Because the economic impacts generated by boats in the Great Lakes vary according to length and whether they are stored at a marina or not, the estimates are categorized by state of registration, length and marina storage. Each such data point, e.g. boats with lengths of 16 to 20 feet, registered to a county in the State of Illinois and being stored at a marina; is referred to in this analysis as a boat segment.

Table 6.1 Estimated Boats Operated on the Great Lakes (2003)

Boats not in Marinas									
	IL	**IN**	**MI**	**MN**	**NY**	**OH**	**PA**	**WI**	
Under 16'	20,866	15,585	99,343	17,314	28,583	24,179	5,222	55,400	**266,492**
16-20'	26,503	23,669	88,217	55,391	28,548	22,207	3,077	61,047	**308,659**
21-27'	5,562	10,305	29,181	11,180	13,390	4,881	826	16,292	**91,617**
28-40'	999	1,103	3,778	1,070	1,095	788	192	1,575	**10,600**
Over 40'	124	376	255	306	332	190	17	259	**1,859**

[1] p. 36-42. Stynes, Daniel J., Tsung Chiung Wu, and Edward M. Mahoney, 1998. *1994 Michigan Boating Survey. Clean Vessel Act/Michigan Boating Study, 1994-95, Report II.* East Lansing, MI: Michigan Agricultural Experiment Station, Michigan State University.

[2] Ibid p. 25-26.

Table 6.1 Estimated Boats Operated on the Great Lakes (2003), continued

Boats in Marinas									
	IL	**IN**	**MI**	**MN**	**NY**	**OH**	**PA**	**WI**	
Under 20'	472	218	3,143	232	3,337	6,249	1,149	852	**15,652**
21-27'	4,373	1,758	23,660	428	7,631	18,475	1,202	3,625	**61,152**
28-40'	3,424	673	13,666	238	3,533	5,543	321	1,437	**28,835**
Over 40'	1,000	248	2,441	65	283	374	27	302	**4,740**
Total	**63,323**	**53,935**	**263,684**	**86,224**	**86,732**	**82,886**	**12,033**	**140,789**	**789,606**

Michigan, with its considerable coastline, leads the Great Lakes states with over a quarter million recreational boats operated on the Lakes, followed distantly by Wisconsin at roughly 141,000. Three states, Minnesota, New York and Ohio exhibit relatively similar numbers while Pennsylvania has the fewest number of boats operated on the Lakes, roughly 12,000.

6.5 Inventory of Marina Slips

Marinas serving Great Lakes boaters are obviously key generators of economic benefit to the region. These facilities are where a good share of boater spending takes place, where many jobs are supported and where much investment takes place by both the public and private sectors. To quantify the economic impact of Great Lakes marinas and better understand the importance of this marine sector, information was needed on the number of marina slips on the Lakes, including seasonal rental slips. It was also necessary to estimate and verify the number of registered boats kept in marinas.

A listing of marinas in Great Lakes states was assembled from various sources including: (1) a national list of permitted marinas compiled by Marine Operators Association, (2) lists of marinas developed for a study of the impacts of low water on Lake Michigan marinas conducted by the Recreation Marine Research Center at Michigan State University, and (3) a 2002 study of marinas and yacht clubs operating along Lake Ontario and the St. Lawrence River conducted by the New York State Department of Environmental Conservation[3].

As much of the marina data was based on marina permits and previous inventories, some of which were up to five years old, marinas were contacted by phone to verify that they were currently in operation, to ascertain the current total number of slips and number of seasonal slips available, and whether they also offered moorings. Marinas for which there was an address but no telephone number were mailed evaluations to gather the same information. Roughly 82% of marina slips used in the analysis were verified. Results indicate that approximately 3% of the marinas identified on various lists are no longer in operation, have been purchased and combined with other marinas, or were never developed even though a permit was issued. Some of these marinas have been converted to other uses including residential and commercial development. **Table 6.2** depicts the number of Great Lakes marinas and slips.

[3] New York State Department of Environmental Conservation, 2002. *Listing of Marinas, Lake Ontario and St. Lawrence River*. Oswego, NY: New York Sea Grant, Empire State Marine Trades Association.

Table 6.2 Estimated Marina Slips Operated on the Great Lakes (2003)

	IL	IN	MI	MN	NY	OH	PA	WI	
Seasonal Slips	8,232	2,479	45,948	565	16,423	33,928	2,902	7,044	**117,521**
Transient Slips	255	404	8,108	42	1,624	5,987	322	1,243	**17,986**
Total Slips	**8,487**	**2,883**	**54,056**	**607**	**18,047**	**39,915**	**3,224**	**8,287**	**135,506**

Slips operated on the Great Lakes comprise approximately 51% of all slips in these eight states. Roughly 89% are seasonal rental slips.

6.6 Calculating Boating Days, Craft Spending and Trip Spending

Data used to estimate boating days, craft spending and trip spending for boats were obtained independently from on-line assessments conducted of the National Recreation Marine Research Center's National Boater Panel in 2003 and 2004. This continuing series of on-line assessments surveys boaters to identify trends in "…boater preferences, levels of involvement, spending, life cycles of ownership and related behaviors**."**[4] One benefit of collecting panel data is that spending and boating day data are easily disaggregated into boating segments.

Money spent by boaters can be separated into two types: boat-related expenditures such as equipment, repairs, insurance, slip fees; and boating trip expenditures such as gas, oil, food, and lodging.

6.6.1 Boating Trip Expenditures

The first step in estimating boating trip expenditures is to estimate the number of trips, normally measured in days, undertaken by recreational boaters annually. Great Lakes boat days are estimated by multiplying the number of boats using the Great Lakes (**Table 6.1**) by the average days of use for each segment, combination of state, boat length and marina us, as estimated from the Boater Panel data. Although this data is collected from Boater Panel participants nation wide, only responses specific to the study area are used in the number of boating days spent on the Great Lakes. **Table 6.3** shows the resulting boating days.

Table 6.3 Estimated Great Lakes Boating Days (2003, in thousands)

Boats not in Marinas									
	IL	**IN**	**MI**	**MN**	**NY**	**OH**	**PA**	**WI**	
Under 16'	313	234	1,490	260	429	363	81	831	**4,001**
16-20'	530	473	1,764	1,108	571	444	71	1,221	**6,182**
21-27'	167	309	875	335	402	146	43	489	**2,766**
28-40'	34	38	128	36	37	27	8	54	**362**
Over 40'	5	16	11	13	14	8	1	11	**79**

[4] Recreational Marine Research Center Website, http://www.prr.msu.edu/RMRC/index.html, December 2008.

Table 6.3 Estimated Great Lakes Boating Days (2003, in thousands), Continued

Boats in Marinas									
	IL	**IN**	**MI**	**MN**	**NY**	**OH**	**PA**	**WI**	
Under 20'	13	6	88	7	93	175	2	24	**408**
21-27'	153	62	828	15	267	647	12	127	**2111**
28-40'	140	28	560	10	145	227	10	59	**1179**
Over 40'	44	11	107	3	12	16	1	13	**207**
Total	**1,399**	**1,177**	**5,851**	**1,787**	**1,970**	**2,053**	**229**	**2,829**	**17,295**

The next step is to estimate the amount of expenditures per boating trip. Average expenditures in various recreational industries are estimated from the 2003-2004 Boater Panel data. Although this data is collected nation wide, an analysis of spending profiles showed that there were no statistically significant differences in averages between national and Great Lakes averages. As such, the national data averages are used because of the added reliability associated with larger sample sizes. **Table 6.4** provides the average expenditures per boating trip by type of expenditure**.**

Boating activity and spending vary with boat length and storage. Average spending per boat day on trips varies from $92.28 for boats less than 16 feet in length to $344.93 per day for boats larger than 40 feet. The greatest trip expenses are for boat fuel (27.6%), restaurants and bars (17.2%) and groceries (16.3%). Boat storage location, in a marina or not, slightly influences trip spending; those in marinas spend slightly more. Boat use also varies directly with the size of the boat from 18 days per year for boats less than 16 feet to 42 days for the largest craft. Boats stored at marinas are used slightly more days per year than boats stored elsewhere.

Table 6.4 Average Expenditures per Boating Trip (in 2008 dollars)

Boats not in Marinas					
Expenditure Category	**Less than 16'**	**16-20'**	**21-27'**	**28-40'**	**More than 40'**
Lodging	$14.19	$10.90	$16.86	$2.77	$11.06
Marina Services	$1.57	$2.93	$7.68	$19.78	$35.12
Restaurant/Bar	$15.63	$20.78	$29.52	$44.17	$56.03
Groceries	$15.51	$16.13	$23.81	$29.64	$48.74
Boat Fuel	$13.27	$29.14	$48.01	$58.91	$90.77
Auto Fuel	$13.96	$16.23	$17.19	$7.94	$7.58
Repair/Maintenance	$9.97	$13.50	$14.73	$36.26	$28.66
Marine Supplies	$5.26	$8.49	$13.68	$17.92	$25.34
Recreation/Entertainment	$2.00	$2.89	$8.18	$7.31	$13.69
Shopping	$0.92	$2.42	$5.24	$8.42	$9.88
Total per Boat Day	**$92.28**	**$123.42**	**$184.91**	**$233.10**	**$326.88**
Average Boat Days/Year	17.7	24.4	33.4	39.9	42.1

Table 6.4 Average Expenditures per Boating Trip (in 2008 dollars), Continued

Boats in Marinas					
Expenditure Category		**Less than 20'**	**21-27'**	**28-40'**	**More than 40'**
Lodging		$10.71	$21.12	$12.82	$14.58
Marina Services		$1.73	$7.45	$25.23	$38.47
Restaurant/Bar		$21.21	$35.41	$44.84	$59.83
Groceries		$16.22	$25.07	$30.58	$60.83
Boat Fuel		$27.63	$56.11	$53.16	$94.48
Auto Fuel		$15.87	$13.52	$7.77	$7.10
Repair/Maintenance		$13.14	$13.45	$12.29	$23.34
Marine Supplies		$11.19	$12.39	$12.97	$17.94
Recreation/Entertainment		$1.57	$6.56	$9.92	$9.16
Shopping		$2.98	$6.57	$8.44	$19.21
Total per Boat Day		**$122.24**	**$197.65**	**$218.03**	**$344.93**
Average Boat Days/Year		28.0	34.7	40.7	44.3

Source: National Boater Panel Report (2004)

6.6.2 Boat-Related Expenditures

Annual boat-related expenses vary more dramatically by boat length. Boat lengths are therefore good predictors of spending. The annual estimates are drawn from the same Boater Panel data discussed in section 6.4.1. and are shown in **Table 6.5** in 2008 dollars. For boats not stored at marinas, boat owners spend an average of $1,096 per year for boats under 16 feet, $2,854 for boats 21-27 feet in length and $11,896 per year for boats over 40 feet. Boats stored at marinas incur additional expenses for slip rentals, raising their annual craft expenses to an average of $4,579 for 21-27 foot boats and $13,567 per year for boats over 40 feet. The majority of annual craft expenses are for maintenance and repair (29.3%), equipment (17.7%) and insurance (16.9%). New boat purchases are not included in these figures.

Table 6.5 Average Boat-Related Expenditures (in 2008 dollars)

Boats not in Marinas					
Expenditure	**Less than 16'**	**16-20'**	**21-27'**	**28-40'**	**More than 40'**
Slip [1]	$11	$7	$10	$11	$7
Yacht dues	$11	$23	$68	$323	$895
Off season storage	$23	$34	$83	$283	$235
Put in and haul out	$51	$40	$120	$358	$681
Insurance	$137	$233	$443	$1,094	$2,563
Repairs	$298	$509	$888	$1,913	$4,718
Equipment	$533	$613	$1,118	$1,923	$2,244
Taxes	$33	$52	$125	$305	$553
Total	**$1,096**	**$1,512**	**$2,854**	**$6,210**	**$11,896**

Table 6.5 Average Boat-Related Expenditures (in 2008 dollars), Continued

Boats in Marinas					
Expenditure		**Less than 20'**	**21-27'**	**28-40'**	**More than 40'**
Slip		$1,059	$1,573	$2,741	$4,291
Yacht dues		$180	$172	$363	$613
Off season storage		$133	$243	$590	$589
Put in and haul out		$71	$162	$425	$691
Insurance		$323	$415	$898	$1,748
Repairs		$665	$988	$1,783	$2,753
Equipment		$622	$953	$1,576	$2,265
Taxes		$59	$73	$225	$617
Total		**$3,113**	**$4,579**	**$8,601**	**$13,567**

Source: National Boater Panel Report (2004)

[1] Although boats are not stored at marinas, some transient slip fees are incurred.

6.7 Total Recreational Boat Spending on the Great Lakes

After estimating annual boat trips and boating-related expenditures, these averages are multiplied by the number of boating days, **Table 6.3**, and the number of boats, **Table 6.1**, to determine total annual recreational boat spending on the Great Lakes. Annual totals for both boat trip and boat-related expenditures are illustrated in **Table 6.6**.

Owners of registered watercraft operated on the Great Lakes spend roughly $4.3 billion on boating trips and boat-related expenses. Boats stored at marinas account for more than 33% of total spending. Approximately 65% of spending is done by owners of boats between 16 and 27 feet.

Table 6.6 Total Recreational Boat spending on the Great Lakes (in millions of 2008 dollars)

	Boats not in Marinas	**Boats in Marinas**	**Total**
Less than 16'	$661.3	NA	$661.3
16-20'	$1,229.7	$98.6	$1,328.3
21-27'	$772.9	$697.2	$1,470.1
28-40'	$150.2	$505.1	$655.3
More than 40'	$47.9	$135.7	$183.6
TOTAL			**$4,298.6**

With some disaggregation, total boat spending by State of registration can be derived. State totals are shown in **Table 6.7**. These totals represent expenditures by boats registered in Great Lake bordering counties, only. Note that due to rounding, summing the state total will not exactly equal the total previously shown in **Table 6.5**.

Table 6.7 Total Recreational Boat Spending on the Great Lakes by State (in millions of 2008 dollars)

Boats not in Marinas								
	IL	**IN**	**MI**	**MN**	**NY**	**OH**	**PA**	**WI**
Under 16'	$51.8	$38.7	$246.4	$43.0	$70.9	$60.0	$13.2	$137.4
16-20'	$105.5	$94.2	$351.1	$220.5	$113.6	$88.4	$13.4	$243.0
21-27'	$46.8	$86.5	$245.1	$93.8	$112.5	$40.9	$10.3	$136.9
28-40'	$14.1	$15.7	$53.3	$15.4	$15.4	$11.2	$3.1	$22.4
Over 40'	$3.1	$9.7	$6.6	$7.9	$8.5	$4.9	$0.5	$6.7
Boats in Marinas								
	IL	**IN**	**MI**	**MN**	**NY**	**OH**	**PA**	**WI**
Under 20'	$3.1	$1.4	$20.5	$1.6	$21.8	$40.8	$3.8	$5.6
21-27'	$50.3	$20.3	$272.0	$4.9	$87.7	$212.5	$7.9	$41.7
28-40'	$60.0	$11.9	$239.6	$4.2	$62.0	$97.2	$4.9	$25.2
Over 40'	$28.7	$7.2	$70.0	$1.9	$8.0	$10.6	$0.7	$8.6
Total	**$363.4**	**$285.6**	**$1,504.6**	**$393.2**	**$500.4**	**$566.5**	**$57.8**	**$627.5**
Percentage of Total Spending	8.5%	6.6%	35.0%	9.1%	11.6%	13.2%	1.4%	14.6%

Michigan boaters lead the other seven states in recreational boating expenditures on the Great Lakes, not surprising given the length of Michigan's Great Lakes coast line. Also not surprising is the relatively small percentages of spending represented by Pennsylvania boaters as Pennsylvania has one of the smallest Great Lakes coast lines.

6.8 Conclusion

This analysis has detailed the impact on Great Lakes recreational industries generated by recreational boating in the Great Lakes Navigation System. Approximately $4.3 billion annually is spent by boaters on the Great Lakes. These impacts are regional and should not be confused with National Economic Development (NED) benefits. However, it is evident that these economic impacts are significant to the local economies of the eight Great Lakes states and that the recreational boating industry can be greatly affected, positively or negatively, by infrastructure expenditure allocations in the Great Lakes Navigation System.

7.0 Externalities – Accidents and Emissions

7.1 Introduction

An externality exists when one individual's actions affect the well-being of another individual in ways that do not involve compensation. A “negative externality" results when part of the cost of producing a good or service is born by a firm or household other than the producer or purchaser. A "positive externality" results when part of the benefit of producing or consuming a good or service accrues to a firm or household other than that which produces or purchases it. Shipping on the Great Lakes results in lower overland traffic, reducing the amount of land-based accidents, noise, vibrations and air pollution from engines that would occur if the traffic were moved to land-based transportation alternatives.

Section 7.2 presents an evaluation of the human physical costs associated with the increased numbers of roadway accidents that would occur due to a diversion of Great Lakes waterborne traffic to all land routings. Section 7.3 evaluates the human and environmental impacts associated with the all land routing related to increases in emissions.

7.2 Rail Externalities

7.2.1 Introduction

Closure of shipping on the Great Lakes would cause tonnage that is normally moved by water to divert to all overland routings consisting of rail and truck. A number of externalized costs would result from this additional overland traffic, including noise, vibrations, and air pollution from engines. In addition, the number of collisions at railroad crossings between trains and vehicles are apt to increase as would the number of accidents involving trucks on the roadways. This analysis concentrates on developing the external costs associated with the value of these accidents (referred to as damage costs) under both existing and expected future shipping levels assuming full diversion to overland transportation. Conversion of these external costs into a monetary value allows for a partial determination of the value of keeping the Great Lakes open for shipping. This analysis does not attempt to quantify the external effects of noise, vibrations or additional air pollution impacts such environmental or property damages due to acid rain.

7.2.2 Background

Information on Railroad safety statistics were obtained from the U.S. Department of Transportation’s Federal Railroad Administration’s (FRA) Railroad Safety Statistics, 2006 Annual Report. All basic data on the value of accidents are from the FRA. Trucking safety statistics were provided by the Federal Motor Carrier Safety Administration’s (FMCSA) Large Truck Crash Facts, 2005.

The definition of safety benefits as used by the FRA, specifically includes: 1) prevention of fatalities, 2) prevention of nonfatal casualties and 3) property damages that are avoided/precluded. These are the benefit categories used by the FRA to support safety regulations of a Federal agency.

The first two categories are based on Willingness to Pay (WTP) values. The derivation of these values is based on guidance furnished by the Office of the Secretary of Transportation (OST) via memorandum dated February 5, 2008. This guidance provides recommendations on the treatment of the value of a statistical fatality and the value of injuries in economic analyses. The last category (property damages) is based upon actual property damages incurred during collisions. These three values of accidents prevented serve as the basis for evaluation of the safety costs avoided by allowing continued shipping in the Great Lakes.

7.2.3 Methodology

The basic approach taken to value an avoided fatality is to determine how much an individual or group of individuals is willing to pay for a small reduction in risk. Once this amount is known, it is necessary to determine how much risk reduction is required to avoid one fatality. The total willingness to pay for the risk reduction required to avoid one fatality is termed the value of a statistical life. For example, if people are willing to pay $3.50 to reduce the risk of a fatality by one chance in one million, this implies they will be willing to pay $3.5 million to prevent one fatality. From another perspective, $3.5 million represents the amount a group, as a whole, would be willing to pay to purchase the risk reduction necessary to avoid one expected fatality among its members. The "value of a statistical fatality" has no application to the actual death of any identifiable individual and it is not per se, the value of a human life.

For analyses conducted in 2008, OST guidance suggested that $5.8 million be used as the minimum value of a statistical fatality avoided. This value was based upon a survey of studies evaluating the value of a statistic fatality avoided, adjusted to 2008 dollars. Consequently, this is the value of a statistical fatality avoided used in this analysis for rail, truck, and vessel collisions.

OST guidance also established a procedure for valuing averted injuries based on the current value of a statistical fatality and the Abbreviated Injury Scale (AIS). AIS is a comprehensive system for rating the severity of accident-related injuries which recognizes six levels of injury severity. It classifies nonfatal injuries into five categories depending on the short-term severity of the injury. A sixth category corresponds to injuries that result in death after 30-days of the accident. The five nonfatal AIS categories are based primarily upon the threat to life posed by an injury. The weighted average of values associated with each of the AIS injury categories results in a non-fatal accidents/incidents value of $1,189,000.

Finally, rail safety data indicated the value of physical damages per train/vehicle incident was $5,269. This included damages to rail rolling stock, trackage as well as automotive damage. Physical damages for truck accidents as provided by the FMCSA totaled $15,114.

These values were used to produce an estimate of the value of accidents that would be incurred due to various types of collisions. The next step would be to develop an accident rate per ton mile. This accident rate per ton mile would then be multiplied times the additional number of miles generated due to a closure to generate total accidents per year. Multiplying accidents per year times the value of accidents incurred would result in annual accident values per year.

7.2.4 Modal Alternatives

As previously mentioned, closure of Great Lakes shipping would cause tonnage normally moved by water to be delivered via all-overland routings, either rail or truck. The increase in land miles traveled associated with this change has external costs associated with them including noise, vibrations, air pollution and additional accidents. Therefore, the continued maintenance of the Great Lakes for shipping allows for the avoidance of these costs to be claimed as a benefit.

All data on tonnages of commodities affected by diversions were generated from the Great Lakes System Analysis Navigation Depth (GL-SAND) model. Mileage data for each of the 6,210 origin/destination routes used in the GL-SAND model were provided by the Tennessee Valley Authority. Special care was taken to ensure any rail or truck mileage existing under current shipping scenarios was subtracted from the truck/land mileages currently used in conjunction with the water movements. This assured that all additional land mileages were the net increases that would occur with closing of the Great Lakes. These net increases were then summed for all affected origin/destination routes to arrive at total number of additional rail/truck miles traveled in the absence of Great Lakes shipping. Additional miles totaled 11,506,000 and 274,343,157 for rail and truck respectively.

7.2.5 Land Routing Damage Costs

The additional train/truck miles calculated above were then converted to projected number of incidents based on incidence rates per train mile for each safety benefit category - fatalities, non-fatal human accidents, and incidences of physical damage. These incidence rates per train mile, for each benefit category, came from 2006 national incidence rates published in the FRA's Annual Report. Projected incidence rates by damage category were multiplied by the projected total additional train miles to produce a projected number of incident events for each damage category.

The resulting number of incident events, for each benefit category and each disruption event, were then multiplied by the appropriate incident value - value of a statistical fatality, weighted value of a non-fatal human accident, and mean value of physical damages per incident to produce a resulting estimated value of annual damages for each safety benefit category. The value of a statistical fatality was placed at $5,800,000. The weighted value of a non-fatal accident was placed at $1,189,000. The value of physical damages per incident was placed at $5,269 for rail and $15,114 for truck. These values were used to produce an estimate of the total monetary damage that would be incurred annually. **Table 7.1** shows the calculation of annual rail accident damage costs associated with closure in the year 2008. Annual rail damage costs due to closure came to $69,622,106. **Table 7.2** shows the calculation of annual truck accident damage costs associated with a closure. Estimated truck damage costs totaled $210,438,421.

Table 7.1
CALCULATION OF RAIL DAMAGE COSTS
(FY *2008* dollars)

Category	**Value**
1) Fatal Accidents	
Total Deaths In 2006	369
Train Miles Operated In 2006	809,045,000
Deaths/Train Mile in 2006	0.00000045609
Additional Train Miles	11,506,000
Projected Train Deaths per year	5.24777
Value/Human Life Lost	$ 5,800,000
Value/ Human Life Lost from Diverted traffic	$ 30,437,066
2) Non Fatal Accidents/Incidents	
Total Non Fatal Accidents In 2006	1,052
Train Miles Operated In 2006	809,045,000
Non Fatal Accidents /Train Mile in 2006	0.0000028482
Additional Train Miles	11,506,000
Projected Non Fatal Train Accidents per year	32.77139
Value/Non Fatal Accidents/Incidents	$ 1,189,000
Value/Non Fatal Accidents/Incidents from Diverted traffic	$ 38,965,183
3) Value of Physical Damages	
Total Physical Damage Accidents In 2006	2,934
Train Miles Operated In 2006	809,045,000
Physical Damage Accidents /Train Mile in 2006	0.0000036265
Additional Train Miles	11,506,000
Projected Physical Damage Accidents per year	41.72651
Value of Physical Damage Per Incident	$ 5,269
Value Of Physical Damages from Diverted traffic	$ 219,857
TOTAL Rail Damage Costs from Diverted Traffic	$ 69,622,106

Table 7.2 CALCULATION OF TRUCK DAMAGE COSTS (FY 2008 Dollars)	
Category	**Value**
1) Fatal Accidents	
Total Deaths In 2005	5,212
Truck Miles Operated In 2005	222,836,000,000
Deaths/Truck Mile in 2005	0.0000000233894
Additional Truck Miles	274,343,157
Projected Truck Deaths per year	6.41672
Value/Human Life Lost	$ 5,800,000
Value/ Human Life Lost from Diverted traffic	$ 37,216,986
2) Non Fatal Accidents/Incidents	
Total Non Fatal Accidents In 2005	114,000
Truck Miles Operated In 2005	222,836,000,000
Non Fatal Accidents /Truck Mile in 2005	0.000000511586
Additional Truck Miles	274,343,157
Projected Non Fatal Train Accidents per year	140.35012
Value/Non Fatal Accidents/Incidents	$ 1,189,000
Value/Non Fatal Accidents/Incidents from Diverted traffic	$ 166,876,290
3) Value of Physical Damages	
Total Physical Damage Accidents In 2005	341,000
Truck Miles Operated In 2006	222,836,000,000
Physical Damage Accidents /Truck Mile in 2005	0.00000153027
Additional Truck Miles	274,343,157
Projected Physical Damage Accidents per year	419.81910
Value of Physical Damage Per Incident	$ 15,114
Value Of Physical Damages from Diverted traffic	$ 6,345,145
TOTAL Truck Damage Costs from Diverted Traffic	$ 210,438,421

7.2.6 Water Shipment Fatalities and Damages

Fatalities for water shipment that the land movements would replace are also calculated and subtracted from the rail/truck damage costs to derive the incremental damage cost. These incremental damage costs constitute the total safety benefits attributable to Great Lakes shipping. The derivation of these benefits is described in the following sections.

The water accident fatality and injury rates were determined based on information provided in the U.S. Coast Guard Marine Casualty and Pollution Database. A review of the data provided in this database for the years 2004-2007 indicates an average of 0.5 fatalities and 4.25 non-fatal injuries per year as a result of vessel collisions. Using the values of statistical fatal ($5.8m) and non-fatal injuries ($1,189,000) avoided provides water accident costs forgone of $2,900,000 and $5,053,250 respectively. Annual physical damages occurred during collisions were estimated based on information provided in the June 1998 Maumee River at Toledo Harbor, Ohio Reconnaissance Phase Study Report (USACE) and were placed at $244,039 when updated to FY08 dollars. Thus, total vessel costs avoided are $8,197,289.

7.2.7 Total Damage Costs

Closure of the Great Lakes would cause tonnage diversion to all-overland routings. The additional rail and truck miles associated with these changes in transportation modes have externalized costs including additional collisions at rail crossings. The costs associated with these collisions were determined by calculating the additional rail and truck miles, the associated increase in collisions, and the costs attributed to the expected fatal, non-fatal, and property damages. Since transfer to all overland routings would result in a reduction of the vessel damage costs (fatalities/damages) currently experienced, these values were subtracted to give total net damage costs. Overall, closing the Great Lakes to shipping would result in significant increases in both rail and truck collisions, along with substantial increases in both human casualties and injuries. The dollar value associated with these damage costs are shown in **Table 7.3**.

Table 7.3
CALCULATION OF TOTAL DAMAGE COSTS AVOIDED (Safety Benefits)

Category	Value
Rail Damage Costs	$ 69,622,106
Truck Damage Costs	$ 210,438,421
Vessel Damage Costs	($8,197,289)
Total Damage Costs	$271,863,238

7.2.8 Total Safety Benefits

The total damage costs associated with using rail and truck shipping, as opposed to using Great Lakes vessels, equal the safety benefits, or damages avoided, from the use of vessel shipping on the Great Lakes. Thus, the annual safety benefits of Great Lakes vessel shipping is $271,863,238.

7.3 Emissions

7.3.1. Introduction

In addition to providing savings in transportation costs, shipping on the Great Lakes likely provides savings in environmental costs associated with the vehicular usage that would otherwise be required to transport goods throughout the region. A shift in transportation mode from shipping to overland routings would likely lead to increased vehicle trips and vehicle miles traveled (VMT) as well as increases in pollutant air emissions which can lead to a variety of human health and other environmental impacts (ex. smog, crop damage etc.). As a result, it is important to consider the human health and environmental impacts when evaluating changes in transportation modes throughout the Great Lakes.

The health benefits resulting from controlling airborne diesel-fueled vehicle emissions come primarily from reductions in ambient levels of particulate matter. As discussed in the 2004 Soo Lock Study, the benefits of reduced diesel emissions are largely attributable to reductions in ambient levels of total suspended particulate and sulfur oxides. Particulate matter of less than 10 microns (PM-10) affects health, and sulfur oxides are a primary source of property damage. In this analysis, as in the Soo Lock study, damages are restricted to include only the health-related damages associated with exposure to PM-10. This particular subset of damages is the area in which environmental scientists have most successfully valued emissions-related costs and may thus be more defensible than an effort considering all pollutants. Assessing the impacts of emissions on property damages is beyond the scope of this effort, but does constitute another potential benefit category associated with continued shipping on the Great Lakes.

A determination of the pollution abatement benefits associated with continued shipping in the Great Lakes consists of four steps including: (1) determining the most likely traffic diversions based on economic alternatives; (2) estimating the fuel consumption under observed and available route choices (3) the conversion of fuel consumption figures into pollutant emissions and concentrations; and (4) the pecuniary valuation of any changes in emission levels attributable to a modal switch. These steps were executed using the Great Lakes System Analysis Navigation Depth (GL-SAND) model and are discussed in the following sections.

7.3.2. Modal Alternatives

In order to accurately assess the changes in pollutant emissions associated with a closing of shipping in the Great Lakes, it is first important to correctly identify the transportation alternatives likely to be implemented under such a closure. In general, these modal alternatives will be all-land routings consisting of either rail or truck. For purpose of this analysis, it is assumed that both the commodities and the associated quantities would remain that same regardless of whether shipping were to continue in the Great Lakes. In other words, it is assumed that if the Great Lakes were to be closed to shipping, manufacturers would simply find the cheapest alternative available to transport the same quantity of goods that they would have transported via shipping (i.e. no product substitution). Since a significant portion of Great Lakes tonnage consists of coal and iron ore, both commodities that are not generally duplicated by commodities from other regions, it is reasonable to assume that geographic substitution will not occur.

Depending on the specific circumstances, a closure of the Great Lakes could be expected to divert traffic in a number of ways. In this analysis, it is assumed that such a closure would necessitate an all-land routing; either rail, truck or a combination of the two. The alternative routings and associated mileages for 6,210 origin/destination routes were provided by the GL-SAND model based on information provided by the Tennessee Valley Authority (TVA).

7.3.3. Fuel Consumption and Emissions

In order to calculate the cost differentials associated with different modes it was first necessary to estimate fuel consumption under the two routing scenarios. Fuel consumption rates vary largely depending on transportation mode and are shown in **Table 7.4** below. Fuel consumption rates for rail and truck were based on information provided by the Texas Transportation Institute. Fuel consumption rates for vessels were based on estimates provided by the TVA in the Soo Lock Study which utilized the TVA's Vessel Costing Model (VCM).

Table 7.4

Mode Specific Fuel Consumption

Mode	Ton-Miles per Gallon
Barge	690
Truck	413
Rail	155

The calculation of fuel consumption for each origin/destination pair was achieved in the GL-SAND model by multiplying the fuel consumption rates for each mode of transportation times the ton-miles traveled by each mode under each routing scenario. This produced the total gallons of fuel consumed for each origin/destination pair.

Next, it was necessary to convert fuel consumption into pollutant emissions. PM-10 emissions per gallons of fuel consumed for each transportation mode were based on information provided in the Soo Lock Study. These estimates are found in **Table 7.5**.

Table 7.5

Emissions of PM-10 per Gallon of Consumed Diesel Fuel

Mode	PM-10 (lbs)
Barge	0.025
Truck	0.0063
Rail	0.025

Multiplying these emission rates times the total gallons of fuel consumed produced total annual emission estimates for both the current and all-land routing alternatives. These emission estimates totaled 825,887,650 and 5,237,382,128 pounds respectively.

7.3.4. MSA Specific Emissions

The impacts of increased emissions are not constant across geographic areas. Existing concentrations of PM-10 are typically greater in urban areas compared to rural. As a result, it is likely that the incremental impacts of increased emissions will be greater in urban areas. However, the absolute magnitudes of PM-10 concentrations are likely much greater in urban areas making these areas of greater concern when determining the impacts of any additional emissions attributable to a modal change. Due to this fact, and the fact that at-risk populations are many times greater in metropolitan areas, the impacts of rural emissions were excluded from this analysis as these impacts would be relatively minor compared to those in metropolitan areas.

In order to determine the impacts of emissions in individual Metropolitan Statistical Areas (MSA's), it is necessary to discern where pollutants are emitted under the two transportation scenarios under consideration. This could be accomplished in a number of ways. In the Soo Lock study, the total distances traveled within the boundaries of each MSA were calculated using GIS software, along with the corresponding fuel consumption and emissions. However, such an effort was beyond the scope of this current study.

For purpose of this analysis, the emission contributions to each MSA were determined based on a pro-rating of the total emissions. This was accomplished through several steps. First, the total railroad (or truck) miles were determined using GIS for each of the eight Great Lakes states. Next, the total rail (or truck) mileages for each of the MSAs within the Great Lakes were determined. The miles for each mode within each MSA were then divided by the total miles in the Great Lakes to give a percentage that was then applied to the total emissions to give a pro-rated quantity of emissions that could be expected within each MSA. This approach captures a large portion of the emissions and associated impacts associated with a modal change to all-land routings. However, additional impacts would also be expected outside of the Great Lakes states as well as in areas outside of the selected MSAs.

While the approach discussed above allowed for a pro-rating of train and truck emissions, it was still necessary to allocate the existing vessel emissions to each of the various MSAs.   However, MSA boundaries do not typically include navigable Great Lake waters. Consequently, strict adherence to the MSA boundaries would have assigned no fuel consumption or emissions exposure to the Great Lake portion of the water-inclusive alternative. However, a majority of vessel emissions would still be emitted over the Great Lakes miles from any MSA. For purpose of this analysis, it was assumed that 90% of all emissions occur in the lakes far enough from any MSAs such that any health impacts would be minimal. The remaining 10% were pro-rated to the various MSAs based on the percentages of total Great Lakes vessel tonnages moved through any harbors within that MSA.

The total emissions for each MSA under the current and all-land routing scenarios are given in **Table 7.6**.

Table 7.6
Emissions under Current and All-Land Routing Scenarios

MSA	Total Emissions Current Shipping (lbs)	Total Emissions All Land Routing (lbs)	Emissions Increase Due to Modal Change
Akron, OH	5,517,373	32,922,182	27,404,809
Ann Arbor, MI	1,475,450	9,332,091	7,856,641
Appleton, WI	2,730,874	14,947,645	12,216,772
Battle Creek, MI	1,366,119	8,887,200	7,521,081
Bloomington, IN	2,843,988	15,369,636	12,525,649
Bloomington-Normal, IL	3,198,171	17,709,571	14,511,400
Buffalo-Niagara Falls, NY	7,847,282	45,962,259	38,114,977
Canton-Massillon, OH	4,531,922	23,645,464	19,113,542
Champaign-Urbana, IL	5,380,306	27,432,536	22,052,230
Chicago-Naperville-Joliet, IL-IN-WI	48,997,977	221,427,461	172,429,484
Cincinnati-Middletown, OH-KY-IN	12,879,431	91,377,043	78,497,612
Cleveland-Elyria-Mentor, OH	11,569,980	70,889,505	59,319,525
Columbus, OH	10,944,757	77,457,249	66,512,493
Davenport-Moline-Rock Island, IA-IL	4,049,316	29,714,487	25,665,171
Dayton, OH	2,490,651	28,126,667	25,636,017
Decatur, IL	2,268,747	10,770,648	8,501,901
Detroit-Warren-Livonia, MI	15,425,476	79,803,435	64,377,959
Duluth, MN-WI	17,951,092	68,063,007	50,111,916
Elkhart-Goshen, IN	1,384,777	8,759,494	7,374,717
Erie, PA	4,091,179	23,331,003	19,239,825
Flint, MI	2,081,708	12,521,461	10,439,753
Fort Wayne, IN	4,201,779	25,784,890	21,583,112
Grand Rapids-Wyoming, MI	3,730,490	25,262,667	21,532,177
Green Bay, WI	3,213,370	19,476,136	16,262,766
Huntington-Ashland, WV-KY-OH	5,705,266	32,701,811	26,996,545
Indianapolis-Carmel, IN	8,701,232	62,381,455	53,680,223
Kalamazoo-Portage, MI	2,863,993	15,516,573	12,652,579
Lafayette, IN	3,372,547	19,165,501	15,792,954

TABLE 7.6, Emissions under Current and All-Land Routing Scenarios, Continued

Lansing-East Lansing, MI	2,547,578	21,399,030	18,851,452
Mansfield, OH	1,839,327	11,225,776	9,386,449
Milwaukee-Waukesha-West Allis, WI	7,448,829	42,987,278	35,538,449
Minneapolis-St. Paul-Bloomington, MN-WI	17,718,352	103,359,043	85,640,691
Muncie, IN	1,272,566	6,679,902	5,407,336
Peoria, IL	6,704,310	37,719,638	31,015,328
Pittsburgh, PA	24,498,983	134,993,954	110,494,971
Racine, WI	1,281,614	7,457,956	6,176,342
Rochester, NY	7,179,104	57,519,754	50,340,650
Rockford, IL	1,678,441	10,700,836	9,022,395
Saginaw-Saginaw Township North, MI	2,805,389	12,616,313	9,810,924
Sheboygan, WI	1,373,863	8,339,064	6,965,202
South Bend-Mishawaka, IN-MI	3,005,019	16,313,383	13,308,364
Springfield, OH	1,496,031	9,818,041	8,322,009
St. Cloud, MN	1,651,531	13,798,948	12,147,417
Syracuse, NY	4,886,379	41,157,695	36,271,316
Toledo, OH	8,930,801	45,109,762	36,178,962
Youngstown-Warren-Boardman, OH-PA	5,693,940	42,918,129	37,224,189
TOTAL	**302,827,306**	**1,742,853,580**	**1,440,026,275**

7.3.5. Estimating the Benefits of Reduced Diesel Emissions

The health effects that form the basis of emissions-related damages are mortality and morbidity. Accordingly, the current analysis estimates the reduction in mortality, or statistical lives lost, caused by changes in PM-10 concentration as PM-10 induced morbidity Work Loss Days (WLD). Additional types of morbidity not analyzed in this evaluation include Restricted Activity Days, and Direct Medical Expenses (from acute respiratory problems). Based on the reasonably conservative techniques used in this analysis, the estimated navigation-related value of the health benefits $355.9 million when water routings are compared to the all-land alternative.

7.3.5.1 PM-10 Emissions and PM-10 Concentrations

The magnitude of air quality improvements resulting from changes in emissions depends on several complex factors including topographical and meteorological conditions. However, consideration of these factors requires complex pollutant dispersion and meteorological modeling, both of which are beyond the scope of this effort. The calculation of pollutant concentration is important as it is concentration that determines human health impacts, not total volume. For purpose of this analysis, it is assumed that changes in pollutant concentrations are directly proportional to changes in emissions. As a result, this analysis utilizes the “linear rollback” technique used in the Soo Lock Study which assumes that any percentage change in emission volume is converted directly into a change in pollution concentrations. For an Urban Area, i, the general linear rollback formula for the determination of the change in Annual Average Diesel Fuel PM-10 Concentration is:

$$\Delta U_i = ((E_i' - E_i'') / E_i') * (C_i) * (U_i) \qquad [1]$$

where:

ΔU = Change in Annual Average Urban Area PM-10 Concentration ($\mu g/m^3$)

E' = Annual PM-10 Emissions from Rail, Barge, and Truck in Base Scenario (lbs)

E'' = Annual PM-10 Emissions from Rail, Barge, and Truck in Altered Scenario (lbs)

C = Contribution of Rail, Barge, and Truck Emissions to PM-10 Pollution (%)

U = Average Urban Area PM-10 Concentration as measured by monitors ($\mu g/m^3$)

i = Urban Area

For each MSA, emissions from rail, barge, and truck before and after the predicted diversions (E_i' and E_i'') were determined using the transportation modeling described in Section 4. The annual average PM-10 concentration for each MSA (U_i) was determined using a report generated from the USEPA AirData website.[1] However, monitoring stations were not located directly inside several of the MSA's studied. In these cases data were substituted from the closest monitoring stations. Based on information provided in the Soo Lock Study, the contribution of rail, barge, and truck emissions to PM-10 pollution (C_i) were assumed to total 2.4%.

7.3.5.2. Human Exposure to PM-10

The health benefits associated with maintaining the Great Lakes for shipping are attributable to the fact that lower pollutant concentrations result in less human exposure to these pollutants. Human exposure is determined by multiplying the ambient pollution concentration times the population for each MSA as provided by 2006 U.S. Census data[2]. Exposure is then used in a concentration response function to predict changes in various health and welfare effects given changes in ambient concentration. For an Urban Area, i, the general formula for the determination of change in exposure to PM-10 is:

$$\Delta X_i = \Delta U_i * P_i \qquad [2]$$

where:

ΔX = Change in Annual Average Urban Area PM-10 Exposure ($\mu g/m^3$*person)

ΔU = Change in Annual Average Urban Area PM-10 Concentration ($\mu g/m^3$)

P = Urban Population (persons)

i = Urban Area

[1] USEPA AirData can be found on the US EPA's web site at <http://www.epa.gov/air/data/>.

[2] MSA level Information search and retrieval from the U.S. Census Bureau is available on the web at <http://venus.census.gov/cdrom/lookup/>.

7.3.6. The Value of Health Benefits Derived from Reduced Exposure

The basic approach taken to value an avoided fatality is to determine how much an individual or group of individuals is willing to pay for a small reduction in risk. Once this amount is known, it is necessary to determine how much risk reduction is required to avoid one fatality. The total willingness to pay for the amount of risk reduction required to avoid one fatality is termed the value of a statistical life. For example, if people are willing to pay $3.50 to reduce the risk of a fatality by one chance in one million, this implies they will be willing to pay $3.5 million to prevent one fatality. From another perspective, $3.5 million represents the amount a group as a whole would be willing to pay to purchase the risk reduction necessary to avoid one expected fatality among its members. The "value of a statistical fatality" has no application to the actual death of any identifiable individual and it is not per se, the value of a human life.

For analyses conducted in 2008, OST guidance suggested that $5.8 million be used as the minimum value of a statistical fatality avoided. This value was based upon a survey of studies evaluating the value of a statistic fatality avoided, adjusted to 2008 dollars. Consequently, this is the value of a statistical fatality avoided used in this analysis.

7.3.6.1. Mortality

As indicated in the Soo Lock Study, the Statistical Lives Saved, or change in annual mortality rate, for each Urban Area, i, can be calculated as:

$$SLS_i = \beta * \Delta X_i \quad [3]$$

where:

SLS = Annual Statistical Lives Saved (lives)

β = Schartz Coefficient (1.464×10^{-6})

ΔX = Change in Annual Average Urban Area PM-10 Exposure ($\mu g/m^3$*person)

i = Urban Area

The value for the Schartz Coefficient used in this analysis (1.464×10^{-6}) was once again based on the Soo Lock Study. The SLS estimate generated by multiplying the Schartz Coefficient by the change in annual average urban exposure was then multiplied by the value of one SLS (5.8m) to give an estimate of the total value of lives saved in each MSA. Based on this analysis, Great Lakes shipping results in the saving of approximately 51 lives with an associated dollar value of $294.8 million.

7.3.6.2 Work Loss Days Morbidity

There is extensive evidence linking PM-10 exposure to respiratory illness. This illness can frequently lead to a loss in work days (WLD). Work Loss Days are illnesses occurring during work time. The change in WLD can be valued at the opportunity cost of employee time, or the wage rate for each Urban Area. As with population and employment, wage information was drawn from the 2000 Census. For each MSA, the average annual wage rate was determined by dividing the aggregate annual wage and salary income data by the number of workers in the MSA receiving wage or salary income. The hourly wage rate was determined by dividing the average annual wage and salary income by 2000 (the approximate number of working hours in 1 year). Each WLD was valued at 8 times this average hourly wage.

The reduction in respiratory-related WLD due to a change in Annual Average Urban Area PM-10 Concentration can be calculated using the equation below. All parameters used are based on the Soo Lock Study.

$$\Delta WLD_i = (b * \underline{RRAD} * \Delta U_i) * (0.47 * EMP_i) * 26 \qquad [4]$$

where:

ΔWLD = Change in Respiratory-related Work Loss Days

b = Coefficient equal to 0.01 (range of 0.0067 to 0.0221)

$\underline{RRAD}$ = Average RRAD (point estimate equal to 0.39)

ΔU = Change in Annual Average Urban Area PM-10 Concentration ($\mu g/m^3$)

0.47 = Percent of a Worker's RAD that are WLD

EMP = Number of Employees

26 = Factor to Adjust the Two-Week Model to an Annual Measure

i = Urban Area

7.3.7. Estimation Results

Table 7.7 summarizes the estimated monetary benefits of Great Lakes navigation that result from human exposure to PM-10 within metropolitan areas. Great Lakes emissions and pollution abatement savings total just over $355.9 million when compared to the all-land routing alternative. These savings of $1.76 per ton are very similar to the estimation results obtained when a similar analysis was performed in the Soo Lock Study ($2.94).

Table 7.7
Health Effects across MSA's Attributable to Navigation
(in 2008 dollars)

MSA	Value of Lives Saved	Value of Reduced WLD	MSA Total
Akron, OH	4,207,746	840,851	5,048,597
Ann Arbor, MI	2,682,685	1,000,973	3,683,658
Appleton, WI	1,469,814	438,819	1,908,634
Battle Creek, MI	1,077,688	206,551	1,284,238
Bloomington, IN	1,554,783	301,443	1,856,226
Bloomington-Normal, IL	1,558,081	498,793	2,056,874
Buffalo-Niagara Falls, NY	4,634,707	695,629	5,330,336
Canton-Massillon, OH	1,736,292	280,470	2,016,762

Table 7.7, Health Effects across MSA's Attributable to Navigation, Continued

Champaign-Urbana, IL	1,297,099	304,500	1,601,599
Chicago-Naperville-Joliet, IL-IN-WI	60,229,970	12,792,900	73,022,871
Cincinnati-Middletown, OH-KY-IN	10,698,311	2,352,451	13,050,761
Cleveland-Elyria-Mentor, OH	11,996,388	1,637,595	13,633,982
Columbus, OH	31,720,244	8,076,393	39,796,637
Davenport-Moline-Rock Island, IA-IL	2,255,335	489,464	2,744,799
Dayton, OH	8,017,187	1,291,274	9,308,460
Decatur, IL	1,500,352	308,234	1,808,586
Detroit-Warren-Livonia, MI	25,890,040	3,461,142	29,351,183
Duluth, MN-WI	1,236,176	275,093	1,511,268
Elkhart-Goshen, IN	1,576,353	323,313	1,899,666
Erie, PA	1,590,387	251,060	1,841,447
Flint, MI	1,787,684	266,385	2,054,069
Fort Wayne, IN	6,891,321	1,495,201	8,386,522
Grand Rapids-Wyoming, MI	4,653,274	920,793	5,574,067
Green Bay, WI	2,532,539	595,872	3,128,411
Huntington-Ashland, WV-KY-OH	1,538,759	265,692	1,804,451
Indianapolis-Carmel, IN	23,591,722	6,094,707	29,686,429
Kalamazoo-Portage, MI	1,458,527	304,618	1,763,145
Lafayette, IN	1,560,773	372,784	1,933,556
Lansing-East Lansing, MI	3,952,156	816,781	4,768,937
Mansfield, OH	1,488,239	267,443	1,755,682
Milwaukee-Waukesha-West Allis, WI	15,671,477	2,699,311	18,370,788
Minneapolis-St. Paul-Bloomington, MN-WI	9,798,868	2,879,754	12,678,622
Muncie, IN	1,459,744	260,681	1,720,425
Peoria, IL	2,768,269	609,171	3,377,440
Pittsburgh, PA	8,610,150	1,752,280	10,362,430
Racine, WI	2,090,129	392,953	2,483,083
Rochester, NY	3,454,585	563,431	4,018,016
Rockford, IL	4,604,453	998,234	5,602,687
Saginaw-Saginaw Township North, MI	616,604	80,159	696,763
Sheboygan, WI	1,364,392	312,321	1,676,713
South Bend-Mishawaka, IN-MI	2,042,921	374,153	2,417,074
Springfield, OH	1,852,280	323,653	2,175,933
St. Cloud, MN	2,480,702	643,569	3,124,271
Syracuse, NY	2,896,811	449,155	3,345,966
Toledo, OH	6,213,834	1,176,383	7,390,216
Youngstown-Warren-Boardman, OH-PA	2,513,460	295,411	2,808,871
TOTAL	**294,823,312**	**61,037,839**	**355,861,151**

7.3.8. Summary and Conclusions

As shown in the previous sections, closure of the Great Lakes to shipping and re-routing to all-land movements would result in significant increases in pollutant emissions, including PM-10. This was determined by evaluating the mode specific mileages traveled under two specific scenarios – the current route including the mileage traveled through the Great Lakes and an alternative routing consisting solely of land transportation. These mileages were then converted to fuel consumption, total and MSA specific emissions, concentrations, exposure and health impacts. Overall, this initial analysis shows transportation of the existing tonnages through the Great Lakes yields measurable benefits in terms of reduced human exposure to PM-10. When compared with the all-land routings Great Lakes navigation leads to $355,900,000 in annual health savings.

Closure of the Great Lakes would also result in significant increases in both rail and truck collisions. As discussed in Section 7.1, the total cost associated with an increase in collisions is estimated to total $271,863,238. Overall, closing the Great Lakes to shipping would result in significant increases in both rail and truck collisions, as well as significant increases in PM-10 emissions. These externalities represent substantial impacts to human health that are currently avoided through the continued maintenance of Great Lakes shipping. The total value of these externality costs avoided total $627,724,389.

8.0 Vessel Fleet and Operating Costs

8.1 Introduction

The Great Lakes/St. Lawrence Seaway (GLSLS) has three distinct fleets: 1) an Intra-Laker fleet, 2) a Laker/Seaway fleet, and 3) a Laker/Seaway/Oceangoing fleet of Salties. Each fleet is compatible with the traffic and market the fleet is designed to serve. The intra-laker fleet is comprised of U.S. vessels. This fleet is dominated by the Class 10 thousand footers and the smaller Class 8 vessels. These vessels move bulk commodities such as iron ore, coal, grain and stone. These commodities service steel mills, power plants, the export market and the building trades. The laker/Seaway fleet, primarily a Canadian fleet, is dominated by the Class 7 vessels making complementary moves of grain from Lake Superior to grain elevators on the lower St. Lawrence and iron ore from the lower St. Lawrence to steel mills on Lake Ontario and the upper lakes. The oceangoing fleet of salties is dominated by tramp operators bringing commodities such as steel slab from overseas origins into the lakes, taking-on light loads of grain in Lake Superior before moving back to the lower St. Lawrence where they are topped-off with grain before continuing on to overseas destinations.

8.2 Existing Fleet - U.S. and Canadian

An examination of the existing fleet will be limited to U.S. and Canadian vessels. This fleet can be categorized three ways: by nation, by vessel type and by vessel size. **Table 8.1** provides an overview of the U.S./Canadian fleet from 1990 to 2005. This section examines the fleet in terms of its composition by vessel type and size. It also examines changes that have occurred in the fleet in the past two decades. Differences between the U.S. and Canadian fleets will be discussed. The fleet discussion will be limited to bulk carriers, self-unloaders and powered tankers.

Table 8.1 Great Lakes Fleet, 1980 - 2005

Type of Vessel	1980	1990	2000	2005
Bulk Carriers				
United States	78	7	4	0
Canada	85	55	33	18
Subtotal	**163**	**62**	**37**	**18**
Self Unloaders				
United States	58	55	49	50
Canada	35	35	32	32
Subtotal	**93**	**90**	**81**	**82**
Tankers				
United States	14	6	4	5
Canada	32	27	10	12
Subtotal	**46**	**33**	**14**	**17**
Total Fleet	**302**	**185**	**132**	**117**
United States	150	68	57	55
Canada	152	117	75	62

8.2.1 Fleet Composition by Vessel Type

There were 117 U.S. and Canadian commercial vessels operating on the Great Lakes in 2005 compared to 185 in 1990 and 302 in 1980. The decline has been fairly even between the American and Canadian fleet. In the twenty-five years from 1980 to 2005, the American fleet declined by 63% while the Canadian fleet declined by 59%. The decline in the number of vessels in the latter period was most pronounced in bulk carriers, followed by tankers and then self unloaders. There were 145 bulk carriers removed from service in the 1980-2005. There were 29 tankers and only 11 self unloaders removed from service in the same period. Self unloaders had risen to represent about 70 percent of the fleet by 2005.

8.2.1.1 U.S. Fleet-Vessel Type, Size

An examination of the data on the composition of the United States fleet in 1980 and 2005 indicates the drastic decline of bulk carriers during the 1990s was primarily responsible for the decline in the United States fleet. Of the 85 vessels removed from the United States fleet 78 were bulk carriers; eight self unloaders and nine tankers. The decline in bulk carriers was due to the age of the bulk carriers, as well as the need for vessels that did not require shore side equipment to unload the vessels cargo. U.S. bulk freighters were either scrapped or converted to self unloaders. The resulting ships were made more efficient by not being tied to the availability of shore side unloading equipment. Vessels could now unload their cargo any time of the day or night, thus reducing vessel turnaround times.

8.2.1.2 Canadian Fleet-Vessel Type, Size

An examination of the data on the composition of the Canadian fleet provides a different picture of fleet mix. There is a role for bulk freighters in the Canadian fleet. First of all, the Canadian bulk carriers are more modern than their American counterparts having been largely constructed after the opening of the Seaway in 1959. Thus in the 1980s the Canadian fleet of bulk carriers was more efficient than the United States fleet of bulk carriers. In addition the bulk freighters were engaged in the Canadian grain traffic from Thunder Bay on Lake Superior to deep water ports on the St. Lawrence such as Montreal. Grain storage facilities were located at these deep water ports, which could unload these bulk carriers and transfer their cargoes to deep draft ocean going vessels. On the return haul the downbound grain vessel returned with an upbound load of iron ore from the iron ore ports on the north shore of the St. Lawrence River.

8.2.2 Fleet Carrying Capacity

Table 8.1 shows that the number of vessels in the aggregate fleet has declined, from 302 in 1980 to 185 in 1990 to 117 in 2005. The aggregate capacity of the fleet has also declined, especially for Bulk Carriers and Tankers (**Table 8.2**). However the average trip capacity has increased for all vessel types (bulk freighters, self unloaders and tankers) for both countries. Average trip carrying capacities for all self unloaders increased by 40%

from 1980 to 2001 (26,990 to 37,890 tons per trip). Bulk freighter carrying capacity increased by 38% during the same time period (19,030 to 26,195 ton per trip). The tanker fleet had the lowest increase (25%) in average carrying capacity (from 52,990 barrels to 66,345 barrels per trip).

Table 8.2 Great Lakes Fleet Carrying Capacity in Tons or Barrels, 1980-2001

	1980	1990	2001
Bulk Carriers (1)			
United States	1,380,790	147,050	105,056
Canada	1,721,110	1,301,245	995,154
Subtotal	3,101,900	1,448,295	1,100,210
Self Unloaders (1)			
United States	1,621,185	1,893,275	2,045,075
Canada	888,895	986,475	1,251,342
Subtotal	2,510,080	2,879,750	3,296,417
Total Fleet (1)	5,611,980	4,328,045	4,396,627
Tankers (2)			
United States	401,335	168,500	205,500
Canada	2,036,224	1,781,101	988,710
Subtotal	2,437,559	2,049,601	1,194,210
Average Trip Capacity			
Bulk Carriers (1)			
United States	17,702	21,007	26,289
Canada	20,248	23,659	26,188
Subtotal	19,030	23,360	26,195
Self Unloaders (1)			
United States	27,951	34,423	41,736
Canada	25,397	28,185	32,930
Subtotal	26,990	31,997	37,890
Tankers (2)			
United States	28,667	44,750	51,375
Canada	63,632	65,967	70,622
Subtotal	52,990	62,109	66,345

Notes: (1) Capacity of bulk carriers and self-unloaders are in short (2,000 lbs.) tons.
(2) Capacity of tankers is in barrels.
Source: Greenwood's Guide to Great Lakes Shipping, 1980, 1990 & 2001.

These increases in carrying capacity indicate that the vessels removed from the fleet were smaller sized vessels, with lower than average carrying capacities. A number of Canadian and U.S. vessels were actually converted from bulkers to self unloaders, and lengthened in the process. This resulted in an increase in the average size of vessels in the fleet between 1980 and 2001.

The data also indicates that the average capacity per trip of United States self-unloaders increased more than their Canadian counterparts. The United States self-unloading fleets carrying capacity increased by 49% (from 27,951 to 41,736 tons per trip) while the

Canadian self-unloading fleet increased its average trip capacity by 29% (from 25,397 to 32,930 tons per trip).

8.3 Projected Fleet

Tables 8.1 and **8.2** have shown that there has been a major restructuring of the U.S/Canadian fleet in the last 25 years. The overall fleet has declined from 302 vessels in 1980 to 117 in 2005; however the total carrying capability of bulkers and self unloaders has only declined by 22%. The average carrying capacity of bulkers and freighters has actually increased by 59% and 40% respectively from 1980 to 2001. The types and sizes of vessels found in the 2005 fleet are considered to be representative of the type and sizes of vessel that will be used to move bulk commodities on the Great Lakes for the foreseeable future. Consequently, the projected fleet is assumed to be the same as the 2005 fleet.

8.4 Vessel Operating Costs

The Great Lakes Navigation System (GLNS) Supplemental Reconnaissance Study is an ongoing effort to quantify the commercial value of the Great Lakes Navigation System. Lake vessel operating costs are used to develop transportation benefits (transportation cost increases avoided) that would accrue due to harbor improvements and or continued maintenance of harbor channels.

Vessels on the Great Lakes predominately move bulk commodities, with a majority of the vessels self-unloading. The vessels are characterized by Corps of Engineers vessel classifications, which are based on vessel length with vessel classes 2-10.

The U.S. Maritime Administration (MARAD) formerly provided information on Great Lakes vessel class operating costs but they stopped providing this information in the early 1990's. Since that time, Great Lakes vessel operating costs have been updated based on previous MARAD data and changes in deep draft ocean-going vessel operating costs provided by the Corps of Engineers, Institute for Water Resources (IWR) every 3-5 years.

Table 8.3 displays the latest version (2005) of Great Lakes vessel operating costs based on the above data. This data represents vessel operating costs used in the Soo Locks Evaluation (2003) updated by price level changes in ocean going vessels of similar size to Great Lakes vessels, by vessel class. The percent changes in vessel operating cost components come from IWR bulletins on ocean going vessel costs issued in 2002 and 2004.

The various vessel cost categories provided in **Table 8.3** (Fixed and Variable Vessel Cost categories are in Gray) need to be updated to reflect 2008 prices by developing cost update indexes for the identified vessel cost components (fixed and variable). The updated indexes are based on ocean going vessel cost data developed by the Corps of Engineers (IWR) in 2005 and 2008 for coastal U.S. Harbors. Ocean going vessels of specific dead weight tonnage are chosen that are representative of various Great Lakes vessel classes. The percent increase in the representative ocean going deep draft vessel operating cost categories are used as inputs to derive the actual update indices. In summary, the update process included the following steps:

1. Obtain 2005 and 2008 COE Deep Draft Vessel Operating Costs (Ocean going Vessels)
2. Calculate percent increases in various fixed and variable vessel operating costs between 2005 and 2008 for various deep draft vessels that represent a Corps of Engineers (COE) vessel class.
3. Use format of vessel costs (variable and fixed) developed for the Great Lakes/ St Lawrence Seaway Study (**Table 8.3**).
4. Populate this format with estimated 2005 Great Lakes vessel operating costs.
5. Develop indices to update the various vessel operating cost categories using as input the percent change in these cost categories from 2005 to 2008 for the representative ocean-going vessels.
6. Apply the update factors to arrive at a 2008 Great Lakes vessel operating cost.

Table 8.3 Great Lakes Vessel Operating Costs - 2005

Interest rate =		5.1250%									
1+% Rate		1.051250									
Project Life		50									
PP Factor		0.0558381									
Profit Factor		10.00%									
Overhead Factor		12.00%									
Season Length		275									
Great Lakes Vessel Costs		Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	10
Daily Variable Operating Costs											
Wages		$10,238	$10,238	$10,238	$10,385	$10,559	$10,735	$11,193	$11,697	$11,697	11,697
Subsistence		$300	$300	$300	$300	$300	$350	$350	$350	$350	$350
Stores, Supplies & Equip		$374	$450	$561	$594	$671	$722	$858	$951	$951	$951
Insurance		$960	$1,003	$1,047	$1,194	$1,379	$1,647	$2,113	$2,603	$2,603	$2,603
Maintenance & Repair		$1,624	$1,859	$1,868	$1,972	$2,102	$2,284	$2,470	$2,581	$2,581	$2,581
Fuel		$1,543	$2,348	$2,996	$3,364	$3,624	$4,092	$4,760	$5,212	$5,212	$5,212
Other		$918	$1,009	$1,101	$1,120	$1,143	$1,176	$1,215	$1,241	$1,241	$1,241
Total		$15,957	$17,207	$18,111	$18,929	$19,778	$21,006	$22,960	$24,636	$24,636	24,636
Construction Costs	5.1250%	$40,484,395	$44,982,661	$49,480,927	$54,338,946	$60,393,266	$68,838,216	$83,230,971	$97,924,955	$97,924,955	24,955
Total Daily Fixed Costs											
Construction Costs		$40,484,395	$44,982,661	$49,480,927	$54,338,946	$60,393,266	$68,838,216	$83,230,971	$97,924,955	$97,924,955	24,955
Amortization Rate		0.0558381	0.0558381	0.0558381	0.0558381	0.0558381	0.0558381	0.0558381	0.0558381	0.0558381	558381
Annual Fixed Cost/Year		$2,260,570	$2,511,745	$2,762,919	$3,034,182	$3,372,243	$3,843,793	$4,647,457	$5,467,940	$5,467,940	67,940
Season Length	275	275	275	275	275	275	275	275	275	275	275
Fixed Costs Per Day		$8,220	$9,134	$10,047	$11,033	$12,263	$13,977	$16,900	$19,883	$19,883	19,883
Profit Factor	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	10.00%	0.00%
Total Daily Fixed Costs		$9,042	$10,047	$11,052	$12,137	$13,489	$15,375	$18,590	$21,872	$21,872	21,872
Total Daily Variable Costs											
Daily Variable Costs		$15,957	$17,207	$18,111	$18,929	$19,778	$21,006	$22,960	$24,636	$24,636	24,636
Overhead Factor	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	2.00%
Total Daily Variable Costs		$17,872	$19,272	$20,284	$21,201	$22,152	$23,527	$25,715	$27,592	$27,592	27,592
Total Hourly Vessel Costs											
Total Daily Fixed Costs		$9,042	$10,047	$11,052	$12,137	$13,489	$15,375	$18,590	$21,872	$21,872	21,872
Total Daily Variable Costs		$17,872	$19,272	$20,284	$21,201	$22,152	$23,527	$25,715	$27,592	$27,592	27,592
		---------------	---------------	---------------	---------------	---------------	---------------	---------------	---------------	---------------	---------
Total Daily Vessel Costs		$26,915	$29,319	$31,336	$33,338	$35,641	$38,902	$44,305	$49,464	$49,464	49,464
October 2005 Daily Vessel Operating Costs		$26,915	$29,319	$31,336	$33,338	$35,641	$38,902	$44,305	$49,464	$49,464	49,464
Hourly Vessel operating Costs		$ 1,121	$ 1,222	$ 1,306	$ 1,389	$ 1,485	$ 1,621	$ 1,846	$ 2,061	$ 2,061	2,061

8.4.1 2005 and 2008 COE Deep Draft Ocean Going Vessel Operating Costs

The Corps of Engineers (IWR) provided Deep Draft Ocean Vessel operating costs in 2005 and 2008 representing vessel operating costs in 2004 and 2007 prices, respectively. The last Great Lakes Vessel operating cost update had vessel operating costs in 2005 prices. An assumption was made that the increase in ocean going vessel operating costs between 2004 and 2007 could be representative of the increase in Great Lakes vessel costs between 2005 and 2008.

Ocean going vessel operating costs provided by IWR includes a wide range of vessel types: from bulk freighters to container vessels to tankers. The vessel type cost category most representative of the Great lakes vessels is the U.S. Flag Bulker Costs -7 Year Old Diesel Ships. Ocean going vessel operating costs were supplied for a number of Bulker vessel dead weight tonnages (DWT.) Vessels of various DWT were identified as being either representative of various Great Lakes Vessel classes, or pairs of DWT were used to develop costs associated with a Great Lakes Vessel Class. For example, ocean vessels with a 15,000, 25,000 and 35,000 DWT were representative of Great Lakes vessel classes 4, 6 and 8. The 15, 000 and 25,000 DWT classes were used to develop costs associated with a Class 5 Great Lakes Vessel. Also the 25,000 and 35,000 DWT classes were used to develop costs associated with a class 7 Great Lakes vessel. Great Lakes class 9 and 10 vessel costs were developed from ocean going vessel groups of 60,000 to 80,000 DWT. The various DWT classes used to calculate various Great Lakes vessel class operating costs is provided in **Table 8.4**.

Table 8.4 DWT Vessels Representative of Great Lakes Vessel Classes.

		Intrpolated		Intrpolated			Intrpolated	
Rep U.S. G.L. Class	3 & 4	5	6	7	8		9-10	
DWT	15,000	20,000	25,000	30,000	35,000	60,000	75,000	80,000

Tables 8.5 and **8.6** provide the vessel operating costs associated with these ocean going DWT vessel classes for 2004 and 2007.

Table 8.5 – Ocean-going Vessel Operating Costs by DWT-2004

Vessel Operating Costs- U.S. Flag Bulker Costs- October 2004- 7 Year Old Diesel ship								
% rate	0.05625							
1+% Rate	1.05625							
Project Life	25							
Partial Payment Fctr	0.075461269							
Season Length	345							
		Intrpolated		Intrpolated			Intrpolated	
Rep U.S. G.L. Class	3 & 4	5	6	7	8		9-10	
DWT	15,000	20,000	25,000	30,000	35,000	60,000	75,000	80,000
Replacement Cost	35,213,000	37,205,000	39,197,000	41,188,500	43,180,000	53,139,000	60,245,250	62,614,000
CRF 5 5/8, 25 years	0.075461269		0.075461269		0.075461269	0.075461269		0.07546127
Annual Capital Cost	2,657,218		2,957,855		3,258,418	4,009,936		4,724,932
Crew Cost	3,128,490	3,153,850	3,179,210	3,204,575	3,229,940	3,356,750	3,363,245	3,365,410
Lubes And Stores	171,240	177,570	183,900	190,235	196,570	228,230	241,573	246,020
Maintenance & Repair	358,400	406,525	454,650	502,770	550,890	791,500	852,993	873,490
Insurance	226,660	233,745	240,830	247,915	255,000	290,410	310,008	316,540
Administration	350,400	356,355	362,310	368,265	374,220	404,000	419,090	424,120
Fixed Annual op Costs	4,235,190	4,328,045	4,420,900	4,513,760	4,606,620	5,070,890	5,186,908	5,225,580
Tot Annual Fixed Cost	6,892,408		7,378,755		7,865,038	9,080,826		9,950,512
Total Daily Fixed Cost	19,978		21,388		22,797	26,321		28,842
Daily Fuel Cost At Sea	$ 4,030	$ 4,250	4,470	4,635	4,800	5,700	6,180	6,340
Daily Fuel Cost in Port	$ 360	$ 420	480	480	480	600	600	600
Daily Total Cost At Sea	$ 24,008		$ 25,858		$ 27,597	$ 32,021		35,182
Daily Total Cost in Port	$ 20,338		$ 21,868		$ 23,277	$ 26,921		29,442
Days At Sea	179		179		179	179		179
Days In Port	96		96		96	96		96
total Season Days	275		275		275	275		275
Season Cost At Sea	4,297,431		4,628,528		4,939,901	5,731,801		6,297,589
Season Cost In Port	1,952,447		2,099,299		2,234,612	2,584,439		2,826,438
Total Season Cost	6,249,878	6,488,852	6,727,827	6,951,170	7,174,513	8,316,240	8,922,081	9,124,027
	[1.] Based on adjustment(s) as generally described per Engineering Guidance Memorandum for DDVOCs for FY 04							

Table 8.6 – Ocean-going Vessel Operating Costs by DWT-2007

Estimated U.S. FLAG BULKER COSTS (US$ 2007 PRICE LEVELS)										
(7 Year Old - Diesel Ships)										
		Interp		Interp					Interpolated	
Rep U.S. G.L. Class	3 & 4	5	6	7	8				9-10	
Displacement Tonnage (DSP; approximate; metric tonne	17,840		29,740		41,640	47,590	59,480	71,380		95,170
Deadweight Tonnage (DWT; metric tonnes)	15,000	20,000	25,000	30,000	35,000	40,000	50,000	60,000		80,000
Replacement Cost (s)	$ 56,085,500	$ 63,000,650	$ 69,915,800	$ 76,830,950	$83,746,100	$90,661,200	$104,491,500	$ 109,384,800	$ 116,724,750	$119,171,400
Light Displacement Tonnage (LDT; metric tonnes)	2,844	3,792	4,740	5,688	6,636	7,585	9,481	11,377	14,221	15,169
Scrap\Salvage Price (per LDT)	$ 1,049,500	$ 1,399,350	$ 1,749,200	$ 2,099,050	$ 2,448,900	$2,798,700	$3,498,400	$ 4,198,100	$ 5,247,575	$ 5,597,400
Scrap\Salvage Value Discounted	$ 251,700	$ 335,600	$ 419,500	$ 503,300	$ 587,200	$671,100	$922,700	$ 1,161,200	$ 1,451,500	$ 1,548,300
Replacement Costs Less Scrap Value	$ 55,833,800	$ 62,665,050	$ 69,496,300	$ 76,327,650	$83,158,900	$89,990,100	$103,568,800	$ 108,223,600	$ 115,273,250	$117,623,100
Capital Recovery (CRF; % per year; 4 7/8% [4.875%]; 3(	0.0641275	0.0641275	0.0641275	0.0641275	0.0641275	0.0641275	0.0662135	0.0673904	0.0673904	0.0673904
Average Annual Equivalent (AAEQ) Capital (Hull Asset) C	$3,596,600	$4,040,100	$4,483,500	$4,927,000	$5,370,400	$5,813,900	$6,918,700	$7,371,500	$7,866,100	$8,031,000
AAEQ Capital (Hull Asset) Cost Adjusted for Scrap\Salv	$3,580,500	$4,018,600	$4,456,600	$4,894,700	$5,332,800	$5,770,800	$6,857,700	$7,293,200	$7,768,300	$7,926,700
Fixed Annual Operating Cost(s)										
Crew Cost	$ 2,796,648	$ 2,966,190	$ 3,135,732	$ 3,247,410	$ 3,359,088	$3,447,720	$3,595,848	$ 3,573,912	$ 4,275,259	$ 4,509,042
Lubes and Stores	$ 80,670	$ 86,050	$ 91,430	$ 96,815	$ 102,200	$107,580	$118,340	$ 129,100	$ 145,240	$ 150,620
Maintenance & Repair	$ 808,830	$ 865,305	$ 921,780	$ 978,255	$ 1,034,730	$1,091,200	$1,204,150	$ 1,317,100	$ 1,486,518	$ 1,542,990
Insurance	$ 210,010	$ 228,735	$ 247,460	$ 259,790	$ 272,120	$281,910	$298,270	$ 311,640	$ 327,450	$ 332,720
Administration	$ 79,290	$ 91,550	$ 103,810	$ 111,885	$ 119,960	$126,370	$137,080	$ 145,830	$ 156,180	$ 159,630
Total Annual Fixed Operating Cost(s)	$ 3,975,448	$ 4,237,830	$ 4,500,212	$ 4,694,155	$ 4,888,098	$5,054,780	$5,353,688	$ 5,477,582	$ 6,390,647	$ 6,695,002
Total; Annual Capital & Fixed Operating Cost(s)	$6,881,400		$7,360,410		$7,839,350	$8,078,860	$8,557,790	$9,036,820		$9,891,820
Applied Operating Time										
Applied Number of Operational Days Per Year	348		348	348	348	348	348	348	348	348
Applied Number of Operational Hours Per Day	24.0		24.0		24.0	24.0	24.0	24.0		24.0
Total Daily Capital & Fixed Operating Costs	$19,950		$21,330		$22,720	$23,420	$24,810	$26,190		$28,670
Daily Fuel Costs										
Daily Fuel Cost; At Sea	$ 7,784	8,069	$ 8,354	8,639	$ 8,924	$9,209	$9,779	$ 10,349	$ 11,204	$ 11,489
Daily Fuel Cost; In Port	$ 912	987	$ 1,062	1,118	$ 1,173	$1,221	$1,304	$ 1,377	$ 1,469	$ 1,500
Daily Total Costs										
Daily Total Costs; At Sea	$23,980		$25,800		$27,520	$28,370	$30,200	$31,890		$35,010
Daily Total Costs; In Port	$20,310		$21,810		$23,200	$23,900	$25,410	$26,790		$29,270
Daily Total Costs; At Sea; Adjusted\Applied for FY	$26,690		$28,610		$30,380	$31,220	$33,100	$34,920		$39,050
Daily Total Costs; In Port; Adjusted\Applied for FY 2	$23,180		$24,770		$26,230	$26,980	$28,560	$30,020		$33,530
Hourly Total Costs										
Hourly Total Costs; At Sea	$999.00		$1,075.00		$1,147.00	$1,182.00	$1,258.00	$1,329.00		$1,459.00
Hourly Total Costs; In Port	$846.00		$909.00		$967.00	$996.00	$1,059.00	$1,116.00		$1,220.00
Hourly Total Costs; At Sea; Adjusted\Applied for FY	$1,112.00		$1,192.00		$1,266.00	$1,301.00	$1,379.00	$1,455.00		$1,627.00
Hourly Total Costs; In Port; Adjusted\Applied for FY	$966.00		$1,032.00		$1,093.00	$1,124.00	$1,190.00	$1,251.00		$1,397.00
Vessel Characteristics\Physical Specifications										
Length Overall (LOA; feet)	470.9		549.1		607.6	632.5	676.5	714.6		779.2
Beam or Breadth (BX; Extreme; feet)	70.0		81.3		89.7	93.3	99.5	105.0		114.2
Draught; Summer Loadline Maximum (SLLD; feet)	27.2		31.9		35.5	37.0	39.7	42.1		46.0
Immersion Rate (aggregate; metric tonnes per inch; TF	64.7		88.9		109.7	119.2	137.0	153.5		183.7
Horsepower (HP; Total)	8,830		9,650		10,460	10,860	11,670	12,490		14,110
Service Speed (SS; Knots)	14		14		14	14	14	14		14
Bunkerage\Fuel Consumption (metric tonnes per day)										
Main\Primary Propulsion (At Sea)	27.2		29.6		32.0	33.1	35.5	37.8		42.5
Auxiliary (At Sea & In Port)										
At Sea	1.5		2.0		2.0	2.0	2.5	2.5		2.5
In Port	1.5		2.0		2.0	2.0	2.5	2.5		2.5
HVO Price (Heavy Viscosity Oil; per metric tonne)	$135.00		$135.00		$135.00	$135.00	$135.00	$135.00		$135.00
MDO Price (Marine Diesel Oil; per metric tonne)	$239.00		$239.00		$239.00	$239.00	$239.00	$239.00		$239.00
Manning\Crew	25		25		25	25	25	26		26

8.4.2 Vessel Operating Costs between 2005 and 2008

This section presents the calculation of percent increases in fixed and variable vessel operating costs between 2005 and 2008 for various deep draft vessels that represent a COE vessel class.

Given ocean going vessel operating costs in **Tables 8.5** and **8.6**, the percent increases in various vessel operating cost categories between 2004 and 2007 was calculated. Percentage increases were calculated for the fixed and variable vessel operating cost categories shaded in gray in **Table 8.3**. **Table 8.7** provides the data used to calculate these increases as well as the actual cost increase percents, by vessel class, by cost category.

Table 8.7 Percentage Increase in Fixed and Variable Vessel Operating Cost Categories

Rep U.S. G.L. Class	2- 3 & 4	5	6	7	8	9	10
		Interpolated		Interpolated		Assumed= 10	Interpolated
Deadweight Tonnage (DWT: metric tonnes)	15,000	20,000	25,000	30,000	35,000		75,000
REPLACEMENT COSTS							
Replacement Cost (s)- 07	$ 56,085,500	$ 63,000,650	$ 69,915,800	$ 76,830,950	$ 83,746,100	$ 116,724,750	$ 116,724,750
Replacement Cost (s)- 04	$ 35,213,000	$ 37,205,000	$ 39,197,000	$ 41,188,500	$ 43,180,000	$ 60,245,250	$ 60,245,250
Three Year Increase/Decrease-Absolute	$ 20,872,500	$ 25,795,650	$ 30,718,800	$ 35,642,450	$ 40,566,100	$ 56,479,500	$ 56,479,500
Three Year Increase/Decrease-Percentage	59.27%	69.33%	78.37%	86.53%	93.95%	93.75%	93.75%
Yearly Increase/Decrease-Percentage	19.76%	23.11%	26.12%	28.84%	31.32%	31.25%	31.25%
	19.76%	23.11%	26.12%	28.84%	31.32%	31.25%	31.25%
CREW COSTS-Wages-Yearly							
Crew Cost (s)- 07	$ 2,796,648	$ 2,966,190	$ 3,135,732	$ 3,247,410	$ 3,359,088	$ 4,275,259	$ 4,275,259
Crew Cost (s)- 04	$ 3,128,490	$ 3,153,850	$ 3,179,210	$ 3,204,575	$ 3,229,940	$ 3,363,245	$ 3,363,245
Three Year Increase/Decrease-Absolute	$ (331,842)	$ (187,660)	$ (43,478)	$ 42,835	$ 129,148	$ 912,014	$ 912,014
Three Year Increase/Decrease-Percentage	-10.61%	-5.95%	-1.37%	1.34%	4.00%	27.12%	27.12%
Yearly Increase/Decrease-Percentage	-3.54%	-1.98%	-0.46%	0.45%	1.33%	9.04%	9.04%
	-3.54%	-1.98%	-0.46%	0.45%	1.33%	9.04%	9.04%
LUBES AND STORES-Yearly							
Lubes & Stores Cost (s)- 07	$ 80,670	$ 86,050	$ 91,430	$ 96,815	$ 102,200	$ 145,240	$ 145,240
Lubes & Stores Cost (s)- 04	$ 171,240	$ 177,570	$ 183,900	$ 190,235	$ 196,570	$ 241,573	$ 241,573
Three Year Increase/Decrease-Absolute	$ (90,570)	$ (91,520)	$ (92,470)	$ (93,420)	$ (94,370)	$ (96,333)	$ (96,333)
Three Year Increase/Decrease-Percentage	-52.89%	-51.54%	-50.28%	-49.11%	-48.01%	-39.88%	-39.88%
Yearly Increase/Decrease-Percentage	-0.17630	-0.17180	-0.16761	-0.16369	-0.16003	-0.13292	-0.13292
	-17.63%	-17.18%	-16.76%	-16.37%	-16.00%	-13.29%	-13.29%
INSURANCE-Yearly							
Insurance Cost (s)- 07	$ 210,010	$ 228,735	$ 247,460	$ 259,790	$ 272,120	$ 327,450	$ 327,450
Insurance Cost (s)- 04	$ 226,660	$ 233,745	$ 240,830	$ 247,915	$ 255,000	$ 310,008	$ 310,008
Three Year Increase/Decrease-Absolute	$ (16,650)	$ (5,010)	$ 6,630	$ 11,875	$ 17,120	$ 17,443	$ 17,443
Three Year %Increase/Decrease-Percentage	-7.35%	-2.14%	2.75%	4.79%	6.71%	5.63%	5.63%
Yearly Increase/Decrease-Percentage	-0.02449	-0.00714	0.00918	0.01597	0.02238	0.01875	0.01875
	-2.45%	-0.71%	0.92%	1.60%	2.24%	1.88%	1.88%
MAINTENANCE & REPAIR-Yearly							
Main & Repair Cost (s)- 07	$ 808,830	$ 865,305	$ 921,780	$ 978,255	$ 1,034,730	$ 1,486,518	$ 1,486,518
Main & Repair Cost (s)- 04	$ 358,400	$ 406,525	$ 454,650	$ 502,770	$ 550,890	$ 852,993	$ 852,993
Three Year Increase/Decrease-Absolute	$ 450,430	$ 458,780	$ 467,130	$ 475,485	$ 483,840	$ 633,525	$ 633,525
Three Year Increase/Decrease-Percentqge	125.68%	112.85%	102.74%	94.57%	87.83%	74.27%	74.27%
Yearly Increase/Decrease-Percentage	0.418927	0.376180	0.342483	0.315244	0.292763	0.247570	0.247570
	41.89%	37.62%	34.25%	31.52%	29.28%	24.76%	24.76%
FUEL-At Sea- Yearly							
Daily Fuel Cost At Sea							
Fuel Cost (s)- 07	$ 7,784	$ 8,069	$ 8,354	$ 8,639	$ 8,924	$ 11,204	11,204
Fuel Cost (s)- 04	$ 4,030	$ 4,250	$ 4,470	$ 4,635	$ 4,800	$ 6,180	6,180
Three Year Increase/Decrease-Absolute	$ 3,754	$ 3,819	$ 3,884	$ 4,004	$ 4,124	$ 5,024	$ 5,024
Three Year Increase/Decrease-Percentage	93.15%	89.86%	86.89%	86.39%	85.92%	81.29%	81.29%
Yearly Increase/Decrease-Percentage	0.310505	0.299529	0.289635	0.287954	0.286389	0.270982	0.270982
	31.05%	29.95%	28.96%	28.80%	28.64%	27.10%	27.10%
FUEL-In Port- Yearly							
Daily Fuel Cost In Port							
Fuel Cost (s)- 07	$ 912	$ 987	$ 1,062	$ 1,118	$ 1,173	$ 1,469	$ 1,469
Fuel Cost (s)- 04	$ 360	$ 420	$ 480	$ 480	$ 480	$ 600	$ 600
Three Year Increase/Decrease-Absolute	$ 552	$ 567	$ 582	$ 638	$ 693	$ 869	$ 869
Three Year Increase/Decrease-Percentage	153.33%	135.00%	121.25%	132.81%	144.38%	144.88%	144.88%
Yearly Increase/Decrease-Percentage	0.511111	0.450000	0.404167	0.442708	0.481250	0.482917	0.482917
	51.11%	45.00%	40.42%	44.27%	48.13%	48.29%	48.29%

The data in **Table 8.7** was used to identify percentage increases in vessel operating cost categories that was used to develop update indexes for each of the vessel cost categories, by Great Lakes Vessel class. The percentage increases in 15,000 DWT vessel operating costs were assumed to be representative of increases in vessel operating costs of class 2, 3 and 4 Great Lakes vessels. **Table 8.8** identifies the percentage increases in ocean going vessel operating cost categories that took place between 2004 and 2007.

Table 8.8 Percentage Change by Vessel Cost Category for Great Lakes Vessel Classes
(Based on Ocean Cost Changes Between 2004 – 2007)

Great Lakes Vessel Classes	Class 2 (1)	Class 3 (1)	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9 (2)	Class 10
Vesel Length	400-499'	500-549'	550-599'	600-649'	650-699'	700-730'	731-849'	858-949'	950-1,099'
Great Lakes Vessel Costs									
Construction Costs	59.27%	59.27%	59.27%	69.33%	78.37%	86.53%	93.95%	93.75%	93.75%
Daily Variable Operating Costs									
Wages	-10.61%	-10.61%	-10.61%	-5.95%	-1.37%	1.34%	4.00%	27.12%	27.12%
Subsistence	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Stores, Supplies & Equip	-52.89%	-52.89%	-52.89%	-51.54%	-16.76%	-16.37%	-16.00%	-39.88%	-39.88%
Insurance	-7.35%	-7.35%	-7.35%	-2.14%	2.75%	4.79%	6.71%	6.71%	6.71%
Maintenance & Repair	125.68%	125.68%	125.68%	112.85%	102.74%	94.57%	87.83%	74.27%	74.27%
Fuel costs At Sea	93.15%	93.15%	93.15%	89.86%	86.89%	86.39%	85.92%	81.29%	81.29%
Other	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.

(1). Percentage increases in Class 2 and 3 costs were set equal to percentage increases in Class 4 vessel costs.
(2) Percentage increases in Class 9 costs were set equal to percentage increases in Class 10 vessel costs.

As **Table 8.8** shows, there were dramatic increases in several vessel operating cost components between 2004 and 2007. The two most important were vessel construction costs and vessel fuel costs. Vessel construction costs increased at least 59% for class 2-4 type vessels and almost doubled for class 9 and 10 vessels (93%) during this three year period. Vessel fuel cost increases over this same period were between 81% and 91% for all vessel classes.

A direct application of these percentage increases by vessel cost category to 2005 Great Lakes vessel operating costs would result in Great Lakes vessel operating costs being substantially higher than comparable ocean going bulker vessel operating costs. This did not seem reasonable since the ocean going vessels used in the analysis were either similar in length to various Great Lakes vessel classes (vessel classes 4, 6 and 8), or were adjusted to represent various Great Lakes vessel classes (5, 7, 9 and 10). For example, direct application of the increase in vessel construction costs to a class 4 vessel would result in a Great Lakes class 4 vessel costing $71m while an ocean going bulker of the same length (DWT 15,000) would cost $56m in 2007 prices. The differential became even greater for larger vessel class sizes. Direct application of the increase in vessel construction costs to a class 10 vessel would result in a Great Lakes class 10 vessel costing $206m while an ocean going bulker of the same length (DWT 75,000) would cost $153m. A logic check needed to be implemented when developing update indices that used these percentage cost increases as potential inputs.

The logic check used the estimated ocean going vessel costs in 2007, updated to 2008 costs based on the average yearly increase in ocean going vessel costs by vessel category over the three-year period 2004-2007. Given that the two vessel groups (ocean going and Great Lakes) were similar in size and there were absolute costs for ocean going vessels in

2007 prices, it was assumed that Great Lakes updated 2008 vessel costs by vessel cost category should be similar to updated 2008 ocean going vessel costs by vessel cost category, especially for the major cost categories of vessel replacement, wages and fuel costs.

Consequently, each cost category component was evaluated individually and an appropriate update index was developed. The update index was based on: the percentage increase in ocean going vessel operating costs for the same category, percentage increases in various Bureau of Labor Statistics indexes applicable to the various cost categories for the same three year period (2004-2007), the absolute value of the estimated ocean going cost category in 2008 prices, and historical MARAD data on vessel operating characteristics. The derivation of the indexes by cost component category follows.

8.4.3 Development of Indices

The percentage increase in fixed and variable vessel costs for ocean going vessels provided in **Table 8.8** was the starting point of developing an update index to be applied to 2005 Great Lakes vessel costs (**Table 8.3**). The usage of these percentage increases was tempered by the 2008 absolute value of ocean going vessel costs by cost category, the percentage increase in various applicable Bureau of Labor Statistics update indexes for the same period of 2004-2007, and historical MARAD data on Great Lakes vessel operating characteristics.

8.4.3.1 Fixed Costs - Construction Costs

Table 8.8 indicates that ocean going vessel construction costs increased by 59-93% over the three-year period 2004-2007. However, a straight application of these percentage increases (**Table 8.9**) resulted in Great Lakes Vessel construction costs (2008 prices) being substantially higher than ocean going vessel costs (2008 prices).

Table 8.9 Comparison of Vessel Construction Costs, Great Lakes versus Ocean-going Vessels - 2008 Prices

Rep U.S. G.L. Class	4	5	6	7	8	9	10
		Interpolated		Interpolated		Assumed= 10	Interpolated
Deadweight Tonnage (DWT; metric tonnes)	15,000	20,000	25,000	30,000	35,000		75,000
REPLACEMENT COSTS							
Ocean Replacement Cost (s)- 07	$ 56,085,500	$ 63,000,650	$ 69,915,800	$ 76,830,950	$ 83,746,100	$ 116,724,750	$ 116,724,750
Ocean Average Yearly Increase 04-07	19.76%	23.11%	26.12%	28.84%	31.32%	31.25%	31.25%
2008 Ocean Replacement costs	$ 67,167,057	$ 77,560,904	$ 88,180,204	$ 98,992,826	$ 109,971,611	$ 153,200,962	$ 153,200,962
2005 GL Replacement Costs	$ 44,719,136	$ 59,873,172	$ 66,393,733	$ 75,522,520	$ 91,141,654	$ 106,730,577	$ 106,730,577
Ocean Three Year Increase-Percentage	59%	69%	78%	87%	94%	94%	94%
2008 GL Replacement Costs-Straight % Application	$ 71,226,397	$ 101,385,533	$ 118,426,690	$ 140,875,899	$ 176,766,051	$ 206,789,746	$ 206,789,746

Consequently, the percent change in a number of vessel cost update indices (**Table 8.10**) were calculated for the same period of 2004-2007. The first three vessel cost update indices (Steel Vessel Construction Cost Index, DDG-51 Index and the T-AKE Index) are used by the Navy when developing contracts with shipbuilders to help mitigate the risk of rising material costs shipbuilders could incur (*Using The Steel-Vessel-Material-Cost Index to mitigate Shipbuilder Risk*, By Rand National Defense Research Institute, 2008).

These indices indicate that ship construction costs over the period 2004-2007 increased anywhere between 12 and 18%. The Bureau of Labor Statistics also has a number of indices directly and indirectly related to shipbuilding. The direct indices (“Self Propelled Ships, New, Non-military” and “Self Propelled Ships, New, U.S. Military”) showed that construction costs for new nonmilitary vessels increased at twice the rate of new military vessels. Assuming new non-military vessel construction costs have a larger percentage of total costs in steel, this differential seems reasonable given the 18-25 percent increases in steel mill products and the iron and steel indices.

Table 8.10 Vessel Construction Cost Indexes

Steel Vessel Construction Cost Index						
This is a weighted index of three Bureau of Labor Statistics Indexes						
		Mar 08	Mar 05	change	% Change	Weighted % Change
Iron and Steel index	45%	223.0	178.1	1.25	25%	11%
Gen Purpose Mach & equip	40%	188.9	163.3	1.16	16%	6%
Electrical Machinery & Equipment	15%	113.5	113.3	1.00	0%	0%

DDG-51 Index						18%
This is a weighted index of three Bureau of Labor Statistics Indexes composed for the Navys DDG-51 shipbuilding program. Uses different weights.						
		Mar 08	Mar 05	change	% Change	Weghted % Change
Iron and Steel index	20%	223.0	178.1	1.25	25%	5%
Gen Purpose Mach & equip	43%	188.9	163.3	1.16	16%	7%
Electrical Machinery & Equipment	37%	113.5	113.3	1.00	0%	0%

T-AKE Index						12%
This is a weighted index of three Bureau of Labor Statistics Indexes composed for the Navys T-AKE shipbuilding program. Uses different weights.						
		Mar 08	Mar 05	change	% Change	Weghted % Change
Iron and Steel index	10%	223.0	178.1	1.25	25%	3%
Gen Purpose Mach & equip	60%	188.9	163.3	1.16	16%	9%
Electrical Machinery & Equipment	30%	113.5	113.3	1.00	0%	0%

						12%
Producer Price Index						
Self propelled ships, new, nonmilitary	WPU143103	157.1	124.4	1.26	26%	
Self-propelled ships, new, U.S. military	WPU14310201	138.7	125.3	1.11	11%	
Iron and Steel index-wpu101		223.0	178.1	1.25	25%	
Steel Mill Products-wpu1017		196.6	166.3	1.18	18%	

Based on all of these indices, a reasonable increase in non-military vessel construction costs over the period 2004 to 2007 could range from 12% to 26%. The average percent change per year for ocean going vessels during this same time ranged from 19.76% to 31.25% (**Table 8.7**). Application of these average yearly percentage increases resulted in similar costs for construction of either a Great Lakes vessels or an ocean-going vessel. Consequently, Great Lakes vessel construction cost increases were limited to the average percent change per year of ocean going vessels over the three-year period, 2004-2007.

8.4.3.2 Daily Variable Operating Costs-Wages

Table 8.8 indicates that wages for ocean going vessels showed a decrease in vessel classes 2-6 and increases in remaining vessel classes. However, the Bureau of Labor Statistics shows that wage indices over the same 2004-2007 period showed an increase of wages from 1% to 9 % (**Table 8.11**.)

Table 8.11 Bureau of Labor Statistics - Wage Indexes

Bureau Of Labor Statistics	Mar 08	Mar 05	change	% Change
Total Private Average hourly Earnings-1982 base	$ 8.31	$ 8.21	1.01	1%
Trade Tranport &Util-Avg HtrlyErnings Product Wrkrs	$ 16.11	$ 14.84	1.09	9%
Transprtion & Warehousing-Avg Hrly Erngs Prdctn Wrkrs	$ 18.22	$ 16.62	1.10	10%
TRnsprt&Wrhsing-Marine Cargo Handling	$ 32.81	$ 31.12	1.05	5%
TRnsprt&Wrhsing-Port Oprtns- Wkly Engs Prod Wrkrs	1,138.98	1,069.93	1.06	6%

Given the above indexes, when the percentage increase in ocean vessel wages between 2004 and 2007 was negative, 2005 Great Lakes wages were used. When the percentage increase in ocean vessel wages over the 2004-2007 period was positive, this percentage increase was applied to 2005 Great Lakes vessel wage costs. Class 9 and 10 Great Lakes vessel wages were allowed to increase at 50% of the ocean going vessels percentage increase over the 3 year period 2004-2007 (.5 x 27.12%= 13.56%). This was to keep crew costs for a Great Lakes vessel in line with crew costs of Ocean bulkers of similar size.

8.4.3.3 Daily Variable Operating Costs-Subsistence

Subsistence consists of the costs of all edibles, sales taxes, delivery charges and loading costs. Ocean going bulker costs did not have a "Subsistence" cost category. Consequently, Subsistence costs were kept at 2005 levels for this update.

8.4.3.4 Daily Variable Operating Costs-Stores, Supplies and Equipment

Stores Supplies and Equipment include such items as spare parts, tools, deck and engine room supplies, and all lubes\lubricants and nautical stores or supplies required for operation and basic in-service maintenance while the vessel is operating. Given the components of Stores and Supplies, one would think there would be some increase in these costs between 2004 and 2007. **Table 8.8** shows Stores Supplies and Equipment costs decreasing for all ocean vessel class sizes over the three-year period 2004-2007. **Table 8.8** also shows that Stores Supplies and Equipment costs in 2004 were almost double those in 2007. **Table 8.12** provides some background information on Stores Supplies and Equipment costs and potential update indexes from the Bureau of Labor Statistics.

Table 8.12 Stores, Supplies and Equipment - Absolute Costs

STORES & SUPPLIES-Percent Change							
STORES & SUPPLIES-Yearly							
Ocean Stores & Supplies Cost (s)- 07	$ 80,670	$ 86,050	$ 91,430	$ 96,815	$ 102,200	$ 145,240	$ 145,240
Ocean Stores & Supplies Cost (s)- 04	$ 171,240	$ 177,570	$ 183,900	$ 190,235	$ 196,570	$ 241,573	$ 241,573
Three Year Increase/Decrease-Absolute	$ (90,570)	$ (91,520)	$ (92,470)	$ (93,420)	$ (94,370)	$ (96,333)	$ (96,333)
Three Year Increase/Decrease-Percentage	-52.89%	-51.54%	-50.28%	-49.11%	-48.01%	-39.88%	-39.88%
Yearly Increase/Decrease-Percentage	-0.17630	-0.17180	-0.16761	-0.16369	-0.16003	-0.13292	-0.13292
	-17.63%	-17.18%	-16.76%	-16.37%	-16.00%	-13.29%	-13.29%
STORES & SUPPLIES-Yearly							
Ocean Stores & Supplies Cost (s)- 07	$ 80,670	$ 86,050	$ 91,430	$ 96,815	$ 102,200	$ 145,240	$ 145,240
Days in season-07	348	348	348	348	348	348	348
Cost Per Day- for 07	$ 232	$ 247	$ 263	$ 278	$ 294	$ 417	$ 417
Ocean Stores & SUpplies Cost (s)- 04	$ 171,240	$ 177,570	$ 183,900	$ 190,235	$ 196,570	$ 241,573	$ 241,573
Days in season-04	345	345	345	345	345	345	345
Cost Per Day- for 04	$ 496	$ 515	$ 533	$ 551	$ 570	$ 700	$ 700
Range of Lube and Stores Costs							
Ocean Cost Per Day- for 04	$ 496	$ 515	$ 533	$ 551	$ 570	$ 700	$ 700
Ocean Cost Per Day- for 07	$ 232	$ 247	$ 263	$ 278	$ 294	$ 417	$ 417
2005 Great Lakes Stores & SUpplies	$ 431	$ 674	$ 709	$ 758	$ 896	$ 1,043	$ 1,043
Bureau Of Labor Statistics	Mar 08	Mar 05	change	% Change			
Machinery & Equip-Diesel, Semi Diesel, Non Auto	108.3	101.8	1.06	6%			
Machinery & Equip-Parts and Accessories	166.8	154.2	1.08	8%			
Mach & Equip-Aeronautical, nautical navigational	195.2	192.2	1.02	2%			

Indices from the Bureau of Labor Statistics on diesel engine costs, machinery equipment parts and nautical equipment costs show a 2% to 8% increase in these costs over the three-year period 2004-2007. It is highly unlikely that Stores and Supplies costs for Great Lakes Vessels has decreased over this time period, especially given the average age of Great Lakes vessels. Consequently, Stores and Supplies costs were kept at 2005 levels for this update.

8.4.3.5 Daily Variable Operating Costs-Insurance

Ocean going vessels showed a decrease in insurance costs for classes 2-5 and increases in classes 6 through 10. Previous Great Lakes vessel cost updates provided by MARAD always showed an increase in insurance costs. Consequently, when the percentage increase in Ocean insurance costs between 2004 and 2007 was negative, 2005 Great Lakes insurance costs were used. When the percentage increase in ocean insurance costs over the 2004-2007 period was positive, this percentage increase was applied to 2005 insurance costs.

8.4.3.6 Daily Variable Operating Costs-Maintenance and Repair

Table 8.8 has ocean vessel Maintenance and Repair costs over the three year period 2004-2007 increasing from 174% (class 10) to 225% (Class 4). Given the age of the Great Lakes fleet, these percentage increases were applied to 2005 Great Lakes Maintenance and Repair costs.

8.4.3.7 Daily Variable Operating Costs-Fuel

Table 8.8 had fuel costs increasing over the three-year period 2004-2007 from 181% (class 10) to 193% (Class 4).

Fuel costs were looked at from a number of sources, starting with fuel costs used in the 2003 Soo locks analysis. Ocean going vessels costs of fuel in 2007 were updated to 2008 by using the average increase in fuel costs between 2004 and 2007- 31%. Bunker fuel market prices were obtained for various world ports for the month of April 08 and averaged. These average bunker prices were then used with Great Lakes fuel consumption information by vessel class from MARAD to calculate seasonal and daily fuel costs.

After comparing fuel costs from various sources, the most representative seemed to be the one developed based on current bunkering costs (**Table 8.13**). This is due to the fact that the calculation using current bunkering fuel costs, used actual estimates of fuel consumption provided by MARAD that were representative of Great Lakes vessels when they were either at sea or in port, as well as the type of marine fuel consumed (IFO 180, MGO, MDO). In addition, the calculated costs were in line with IWR estimated daily fuel costs of ocean going vessels, when adjusted to 2008 prices. Consequently, fuel costs for this update are based on current bunkering costs and fuel consumption information provided by MARAD by vessel class.

8.4.3.8 Daily Variable Operating Costs-Other

The category of “Other” variable operating costs includes basically tug charges and lay-up costs. There was no “Other” cost category for Ocean going vessels. Consequently, this update used the 2005 Great Lakes costs associated with the category “Other”.

8.4.3.9 Update Factors Used to bring 2005 Great Lakes Vessel Operating Costs to 2008 Prices

Given all the discussion on various cost categories provided above, **Table 8.14** provides a summary of the percentage increases/indices used to update 2005 vessel costs to reflect 2008 vessel costs.

Table 8.13- Fuel Costs –Comparative Data

DERIVATION OF FUEL COSTS BY VESSEL CLASS- 2008									
Fuel Consumption Per Day Based On 1992 and 1994 Marad Letters.									
Fuel Type by Vessel Class Based On 1992 Marad Letter.									
Number of Operating Days Per Season Based On 1992 Marad Letter.									
Fuel Costs Per Barrel Based On Internet data on fuel costs per barrel.									
Derived Fuel Costs-Based On 92 (Fuel Consumption For 2,3,4,9) And 94 (Fuel Consumption for Vessel Classes 5,6,7,8,10) Marad Letters									
Vessel Class Size	II	III	IV	V	VI	VII	VIII	IX	X
Fuel Consumption:92 And 94 Marad Letters	92	92	92	94	94	94	94	92	94
Barrels Per Day									
At Sea	60	95	125	126	143	160	225	300	305
In Port	25	30	30	27	30	34	36	45	47
Fuel Type- 92 Marad Letter	II	III	IV	V	VI	VII	VIII	IX	X
At Sea	MGO	MGO	MGO	MGO	IFO	IFO	IFO	IFO	IFO
In Port	MDO	MDO	MDO	MDO	MDO	MDO	MDO	MDO	MDO
Assumptions On Operating Days-92 Marad Letter									
	II	III	IV	V	VI	VII	VIII	IX	X
Total	275	275	275	275	275	275	275	275	275
At Sea	179	179	179	179	179	179	179	179	179
In Port	96	96	96	96	96	96	96	96	96
Barrels Consumed Per Season	II	III	IV	V	VI	VII	VIII	IX	X
At Sea	10,740	17,005	22,375	22,554	25,597	28,640	40,275	53,700	54,595
In Port	2,400	2,880	2,880	2,592	2,880	3,264	3,456	4,320	4,512
Total Barrels Consumed	13,140	19,885	25,255	25,146	28,477	31,904	43,731	58,020	59,107
FUEL COSTS BASED ON APRIL 08 BUNKER FUEL COSTS									
	one metric ton equals 348.33 gallons		348.33						
	1 U.S. Gallon =part of Barrel		0.02381						
	US Gallons Per Barrel		41.99916002						
Costs Per Metric Ton-April 08									
		IF0- 380	IF0-180	MGO	MDO				
	New York	$ 513.50	$ 566.50		$ 1,047.50				
	Los Angeles	$ 533.00	$ 554.00		$ 1,075.00				
	Houston	$ 500.00	$ 537.00		$ 1,013.00				
	Singapore	$ 522.00	$ 544.50	$ 1,046.00	$ 1,038.00				
	Rotterdam	$ 495.00	$ 525.50	$ 1,030.00	$ 963.00				
	Fujairah	$ 543.50	$ 565.50	$ 1,105.50	$ 1,140.00				
	Average	$ 517.83	$ 548.83	$ 1,060.50	$ 1,046.08				
	US Gallons Per Metric	348.33	348.33	348.33	348.33				
	Cost Per U.S. gallon	$ 1.49	$ 1.58	$ 3.04	$ 3.00				
	U.S. Gallons Per Barre	42.00	42.00	42.00	42.00				
	Cost Per Barrel	$ 62.44	$ 66.17	$ 127.87	$ 126.13				
	Costs Per Barrel	2008	2008	2008					
		MGO	IFO	MDO					
	Average	$ 127.87	$ 66.17	$ 126.13					
Types Of Fuel Consumed- At Sea, In Port-fuel Costs/Barrel									
Vessel Class	II	III	IV	V	VI	VII	VIII	IX	X
At Sea	MGO	MGO	MGO	MGO	IFO	IFO	IFO	IFO	IFO
In Port	MDO	MDO	MDO	MDO	MDO	MDO	MDO	MDO	MDO
MGO/BBL	$127.87	$127.87	$127.87	$127.87					
IFO/BBL					$66.17	$66.17	$66.17	$66.17	$66.17
MDO/BBL	$126.13	$126.13	$126.13	$126.13	$126.13	$126.13	$126.13	$126.13	$126.13
Barrels Consumed Per Season	II	III	IV	V	VI	VII	VIII	IX	X
At Sea	10,740	17,005	22,375	22,554	25,597	28,640	40,275	53,700	54,595
In Port	2,400	2,880	2,880	2,592	2,880	3,264	3,456	4,320	4,512
Seasonal Cost OF Fuel	II	III	IV	V	VI	VII	VIII	IX	X
At Sea	$1,373,298	$2,174,388	$2,861,037	$2,883,925	$1,693,867	$1,895,236	$2,665,175	$3,553,567	$3,612,793
In Port	$302,710	$363,252	$363,252	$326,927	$363,252	$411,686	$435,903	$544,879	$569,095
Seasonal Fuel Costs	$1,676,008	$2,537,640	$3,224,289	$3,210,852	$2,057,119	$2,306,922	$3,101,078	$4,098,445	$4,181,888
Cost Per Day For Fuel	II	III	IV	V	VI	VII	VIII	IX	X
Seasonal Costs	$1,676,008	$2,537,640	$3,224,289	$3,210,852	$2,057,119	$2,306,922	$3,101,078	$4,098,445	$4,181,888
Days/Season	275	275	275	275	275	275	275	275	275
Fuel Cost/Day	$6,095	$9,228	$11,725	$11,676	$7,480	$8,389	$11,277	$14,903	$15,207
IWR 07 Ocean Fuel Costs			$ 8,696	$ 9,056	$ 9,416	$ 9,757	$ 10,097	$ 12,673	$ 12,673
IWR 08 Ocean Fuel Costs			$10,201	$10,486	$10,774	$11,127	$11,480	$14,240	$14,240
Soo Report 99 Fuel Costs			$8,856	$10,119	$11,012	$12,342	$14,288	$15,725	$15,725

Table 8.14 Percentage Increases/Indices used to bring 2005 Great Lakes Vessel Costs to 2008 Prices

Great Lakes Vessel Classes	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10
Great Lakes Vessel Costs									
Construction Costs	119.76%	119.76%	119.76%	123.11%	126.12%	128.84%	131.32%	131.25%	131.25%
Daily Variable Operating Costs									
Wages	100.00%	100.00%	100.00%	100.00%	100.00%	101.34%	104.00%	113.56%	113.56%
Subsistence	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Stores, Supplies & Equip	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Insurance	100.00%	100.00%	100.00%	100.00%	102.75%	104.79%	106.71%	106.71%	106.71%
Maintenance & Repair	225.68%	225.68%	225.68%	212.85%	202.74%	194.57%	187.83%	174.27%	174.27%
Fuel-Ap 08 Bunker Prices, vessel cnsmptn	*	*	*	*	*	*	*	*	*
Other	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
* Across the board percentage increase in fuel prices was not applicable. Fuel price increases ranged from 204% to 395%									

8.4.4 Development of Fixed and Variable Costs in 2008 Prices

The percentage increases/update factors in **Table 8.14** were applied to 2005 fixed and variable vessel operating costs identified in **Table 8.3**. This resulted in fixed and variable vessel operating costs, by vessel class, in 2008 prices. **Table 8.15** provides data on 2005 vessel costs, the update indices and resulting 2008 vessel costs, by vessel class.

Table 8.15 - Update of Fixed and Variable Vessel Costs from 2005 to 2008 Prices

Great Lakes Vessel Classes	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10
Great Lakes Vessel Costs									
Daily Variable Operating Costs									
Wages									
2005 Wages	$10,238	$10,238	$10,238	$10,385	$10,559	$10,735	$11,193	$11,697	$11,697
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	101.34%	104.00%	113.56%	113.56%
2008 Wages	$10,238	$10,238	$10,238	$10,385	$10,559	$10,878	$11,641	$13,283	$13,283
Subsistence									
2005 Subsistence	$300	$300	$300	$300	$300	$350	$350	$350	$350
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2008 Subsistence	$300	$300	$300	$300	$300	$350	$350	$350	$350
Stores, Supplies & Equip									
2005 Stores, Supplies, Equip	$374	$450	$561	$594	$671	$722	$858	$951	$951
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2008 Stores, Supplies, Equip	$374	$450	$561	$594	$671	$722	$858	$951	$951
Insurance									
2005 Insurance	$960	$1,003	$1,047	$1,194	$1,379	$1,647	$2,113	$2,603	$2,603
Update Factor	100.00%	100.00%	100.00%	100.00%	102.75%	104.79%	106.71%	106.71%	106.71%
2008 Insurance	$960	$1,003	$1,047	$1,194	$1,417	$1,726	$2,255	$2,778	$2,778
Maintenance & Repair									
2005 Maintenance & Repair	$1,624	$1,859	$1,868	$1,972	$2,102	$2,284	$2,470	$2,581	$2,581
Update Factor	225.68%	225.68%	225.68%	212.85%	202.74%	194.57%	187.83%	174.27%	174.27%
2008 Maintenance & Repair	$3,666	$4,196	$4,216	$4,197	$4,262	$4,444	$4,639	$4,498	$4,498
Fuel									
2005 Fuel	$1,543	$2,348	$2,996	$3,364	$3,624	$4,092	$4,760	$5,212	$5,212
Update Factor	395.02%	393.00%	391.38%	347.13%	206.41%	204.99%	236.88%	285.95%	291.77%
2008 Fuel	$6,095	$9,228	$11,725	$11,676	$7,480	$8,389	$11,277	$14,903	$15,207
Other	395.02%	393.00%	391.38%	347.13%	206.41%	204.99%	236.88%	285.95%	291.77%
2005 Other	$918	$1,009	$1,101	$1,120	$1,143	$1,176	$1,215	$1,241	$1,241
Update Factor	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
2008 Other	$918	$1,009	$1,101	$1,120	$1,143	$1,176	$1,215	$1,241	$1,241
Fixed Costs									
Construction Costs									
2005 Construction Costs	$40,484,395	$44,982,661	$49,480,927	$54,338,946	$60,393,266	$68,838,216	$83,230,971	$97,924,955	$97,924,955
Update Factor	119.76%	119.76%	119.76%	123.11%	126.12%	128.84%	131.32%	131.25%	131.25%
2008 Construction Costs	$48,483,434	$53,870,482	$59,257,531	$66,897,369	$76,170,058	$88,694,589	$109,295,167	$128,526,275	$128,526,275

8.4.5 Development of 2008 Great Lakes Vessel Costs

Table 8.15 provides a summary of the update indices used to bring 2005 Great Lakes variable and fixed vessel operating costs to 2008 prices. Profit and Overhead were added to the resulting 2008 fixed and variable costs respectively. A daily cost for fixed and variable vessel costs was then calculated and added together to arrive at total daily vessel operating costs. **Table 8.16** provides a summary of the calculations used to derive 2008 Great Lakes Vessel costs. The costs are provided on a daily and hourly basis, by vessel class.

8.4.5.1 Daily Fixed Vessel Costs

Fixed costs per day were a combination of average annual fixed costs and a profit factor. Average annual fixed costs were derived by converting vessel construction costs to an average annual dollar value, given a 4.875% annual interest rate a 50 year project life, and dividing this average annual dollar value by the Great Lakes Season length: 275 days. A profit factor of 10% was then applied to these fixed costs per day to arrive at total vessel fixed costs. Total daily fixed vessel costs per day ranged from $10,419 for a class 2 vessel to $27,619 for a class 10 vessel.

Table 8.16 - 2008 Great Lakes Vessel Costs - by Vessel Class

Interest rate =	4.8750%	Project Life	50		Profit Factor	10.00%				
1+% Rate	1.048750	PP Factor	0.05372		Overhead Factor	12.00%				
Season Length	275									
Great Lakes Vessel Costs		Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10
Daily Variable Operating Costs										
Wages		$10,238	$10,238	$10,238	$10,385	$10,559	$10,878	$11,641	$13,283	$13,283
Subsistence		$300	$300	$300	$300	$300	$350	$350	$350	$350
Stores, Supplies & Equip		$374	$450	$561	$594	$671	$722	$858	$951	$951
Insurance		$960	$1,003	$1,047	$1,194	$1,417	$1,726	$2,255	$2,778	$2,778
Maintenance & Repair		$3,666	$4,196	$4,216	$4,197	$4,262	$4,444	$4,639	$4,498	$4,498
Fuel		$6,095	$9,228	$11,725	$11,676	$7,480	$8,389	$11,277	$15,207	$15,207
Other		$918	$1,009	$1,101	$1,120	$1,143	$1,176	$1,215	$1,241	$1,241
Total		$22,550	$26,423	$29,188	$29,467	$25,832	$27,685	$32,235	$38,309	$38,309
Construction Costs	4.8750%	$48,483,434	$53,870,482	$59,257,531	$66,897,369	$76,170,058	$88,694,589	$109,295,167	$128,526,275	$128,526,275
Total Daily Fixed Costs										
Construction Costs		$48,483,434	$53,870,482	$59,257,531	$66,897,369	$76,170,058	$88,694,589	$109,295,167	$128,526,275	$128,526,275
Amortization Rate		0.05372	0.05372	0.05372	0.05372	0.05372	0.05372	0.05372	0.05372	0.05372
Annual Fixed Cost/Year		$2,604,641	$2,894,045	$3,183,450	$3,593,879	$4,092,029	$4,764,876	$5,871,586	$6,904,725	$6,904,725
Season Length	275	275	275	275	275	275	275	275	275	275
Fixed Costs Per Day		$9,471	$10,524	$11,576	$13,069	$14,880	$17,327	$21,351	$25,108	$25,108
Profit Factor	10.00%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Total Daily Fixed Costs		$10,419	$11,576	$12,734	$14,376	$16,368	$19,060	$23,486	$27,619	$27,619
Total Daily Variable Costs										
Daily Variable Costs		$22,550	$26,423	$29,188	$29,467	$25,832	$27,685	$32,235	$38,309	$38,309
Overhead Factor	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12.00%	12%
Total Daily Variable Costs		$25,256	$29,594	$32,690	$33,003	$28,932	$31,008	$36,103	$42,906	$42,906
Total Hourly Vessel Costs										
Total Daily Fixed Costs		$10,419	$11,576	$12,734	$14,376	$16,368	$19,060	$23,486	$27,619	$27,619
Total Daily Variable Costs		$25,256	$29,594	$32,690	$33,003	$28,932	$31,008	$36,103	$42,906	$42,906
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Total Daily Vessel Costs		$35,675	$41,170	$45,424	$47,379	$45,300	$50,067	$59,589	$70,525	$70,525
October 2008 Daily Vessel Operating Costs		$35,675	$41,170	$45,424	$47,379	$45,300	$50,067	$59,589	$70,525	$70,525
October 2008 Hourly Vessel Operating Costs		$ 1,486	$ 1,715	$ 1,893	$ 1,974	$ 1,888	$ 2,086	$ 2,483	$ 2,939	$ 2,939

8.4.5.2 Daily Variable Vessel Costs

Variable vessels costs per day are composed of seven cost categories and an overhead factor. The seven variable vessel operating cost categories are: Wages; Subsistence; Stores, Supplies and Equipment; Insurance; Maintenance & Repair; Fuel and Other. The costs associated with each of these categories were summed. An overhead factor of 12% was applied to these summed daily costs to calculate overhead costs. The combination of these daily variable costs and overhead costs resulted in total daily variable costs. Total daily variable costs ranged from $25,256 for a class 2 vessel to $42,906 for a class 10 vessel.

8.4.5.3 Total Daily/Hourly Vessel Costs

Total daily vessel costs are the combination of total daily fixed costs and total daily variable vessel costs. Total Daily vessel costs ranged from $35,675 for a class 2 vessel to $70,525 for a class 10 vessel. Hourly vessel operating costs were developed by dividing total daily vessel costs by the number of hours in a day: 24. Total hourly vessel operating costs ranged from $1,486 for a class 2 vessel to $2,939 for a class 10 vessel.

9.0 Value of Dredging/Deepening the Great Lakes Navigation System

9.1 Introduction

The cost associated with waterborne transportation at federal commercial deep draft harbors on the Great Lakes is highly sensitive to the available channel depths. This is because the carrying capacity of Great Lakes vessels is a function of vessel dimension, the density of the commodity being carried and the available vessel draft. For example, The Stewart J. Cort, a class 10 self-unloader, has a maximum mid-summer capacity of 64,960 tons. When fully loaded, the vessel drafts 27 feet 9 inches. If the vessel was constrained by one inch, (i.e. the maximum available depth for the vessel trip was 27 feet 8 inches) it would need to lightload by 264 tons. Available channel depth changes are the result of three primary elements. The most far-reaching element is the continuous seasonal and annual fluctuation of lake water levels within the system, which impacts large numbers of harbors simultaneously. The second common element is the shoaling that results from sediment transport from sources upstream of federal harbors. Another source of shoal material results from the littoral transport of sand and gravel along the lake coasts into federal channels. Lake storms often contribute to this later process. Shoaling in federal channels reduce the available depth for commercial vessels that call there, restricting the maximum allowable tonnage on a transit. As shoal material fills in navigation channels, the vertical column of water available to a vessel using the channel may restrict the vessel from maximizing the amount of tonnage the vessel can carry, hence raising the cost per ton for the movement. The result of vessel light loading is substantial increases in the transportation cost of a transit. The third element influencing channel depth changes is man's intervention through maintenance dredging and by authorizing new, deeper channel depths. The majority of federal commercial deep draft harbors on the Great Lakes require periodic harbor maintenance dredging.

The purpose of this section is to (1) supplement an analysis that was presented in the Great Lakes Navigation System Reconnaissance Study, Economics Appendix and (2) present the economic value of maintaining (dredging) varying depths at authorized federal navigation channels. To that end, a new model was developed, GL-SAND, Great Lakes Levels System Analysis of Navigation Depths. The model's purpose is to combine the features of two previous models while also enhancing the capabilities provided by both of these models.

9.2 Models used in Estimating Benefits

The primary National Economic Development (NED) benefit associated with harbor improvement plans that consider increased channel depths is transportation cost savings (TCS). Where TCS benefit is a typical benefit for consideration of new authorized depths at a given harbor, TCS benefit is now also being used to help prioritize maintenance dredging work packages for the Great Lakes Navigation Operations and Maintenance budget. The Great Lakes Levels Analysis of Port Operation and Maintenance (GLLAPOM) model was developed to assess the TCS benefit associated with maintaining various harbor depths up to the authorized depth. The Great Lakes Levels Analysis for System Transportation (GLLAST) model was developed to assess the TCS benefit for proposed harbor improvements under the GLNS Reconnaissance Study. A new model, the Great Lakes System Analysis of Navigation Depths (GL-SAND), incorporated the best features of these two predecessor models and did so within a system framework. Model documentation is being finalized and arrangements have been made for model review leading to a recommendation for model certification later this FY. The impetus for this effort was the refinement of Great Lakes transportation cost modeling to support future O&M budget economic metric requirements. Each is discussed below.

9.2.1 Previous Models

9.2.1.1 GLLAST Model

The model developed for the GLNS Reconnaissance Study, GLLAST (Great Lakes Levels Analysis for System Transportation), is a modified version of a costing model used by the Buffalo District in the late 1980s to determine shipping cost effects of proposed lake level control alternatives. It uses a set of input data that describe the types and amounts of commodities being shipped between Great Lakes ports, the dates that the movement begins and ends, the types and costs of the boats that transport the commodities, the depths of the ports and connecting channels that the boats move through, and monthly historic lake levels. Based upon the input data, the model determines the cost of shipping the commodities. It does this by determining, for each movement, the maximum tonnage that can be loaded on the boats that have historically moved the commodity between the origin and destination. Factors that are considered when determining maximum loading include the vessel carrying capacity and tons per inch immersion characteristic, commodity type and density, depths at the ports and connecting channels along the route, the vessel's Coast Guard load line limit by shipping season, and the water levels. The model continues to load commodities onto boats until all commodities have been shipped. It then calculates shipment costs based on the time the vessel is operating and the hourly cost of the vessel. Alternatives can be analyzed by making a change to a key input item, e.g. a port depth, and repeating the model run. The transportation-cost impact can then be determined by comparing the total transportation costs before and after a simulated port deepening alternative. In the GLLAST model, the only factor that affects transportation cost is the number of trips required to move all commodities.

The GLLAST uses several input files to calculate the time required to transport a given amount of commodities in a given fleet of lake vessels for a given set of average monthly water levels and a given set of port/connecting channel depths. Calculations are made on a movement-by-movement basis. That is, if it takes 25 vessel trips to move a given annual commodity tonnage from Port A to Port B, the time required to make each of the 25 movements is calculated separately. This way the seasonal variations in lake levels and vessel load line limits are included in the analysis. The impact of yearly lake level variation is analyzed by running the model several times, each time with a different set of monthly historic lake levels. The average transportation costs are computed based on the transportation costs associated with each of the set of historic years of average monthly water levels.

9.2.1.2 GLLAPOM Model

Where the GLLAST model was developed with the express purpose of evaluating TCS benefit for port channel improvement alternatives, GLLAPOM, (Great Lakes Level Analysis of Port Operation and Maintenance) was designed, using similar logic and input data, to provide the array of transportation costs increases associated with unmitigated harbor shoaling. A TCS benefit can be determined for dredging federally maintained channels to their authorized (and alternative) depths. These transportation cost savings are determined by simulating the shipping costs associated with the most recent representative annual waterborne shipments at varying hypothetical constrained port channel depths. GLLAPOM simulates each vessel movement for a given historical shipment list at a port of interest and determines the maximum tons the vessel can carry given water column constraints. Decreases in available water column lead to light loading and the need to make more round trips to carry a given annual cargo tonnage. This inefficiency results in higher transportation costs. GLLAPOM can be used in making point estimates of net benefits (benefits minus costs), though shoaling rates and dredging costs are needed. Ultimately it can be used in optimizing channel maintenance depths. This framework provides for consistently applied data and tools throughout the Great Lakes system of channels and harbors, an important feature when prioritizing investments throughout the entire system though the focus is still port-centric. The GLLAPOM model's decremental approach allows for an incremental estimation of benefits, which can be compared to an incremental estimate of dredging costs necessary to reclaim these benefits.

9.2.1.3 Model Limitations

Given the complexity and extent of the Great Lakes commercial navigation system, it is extremely difficult to simulate all waterborne movements and corresponding costs for a shipping season. Even more difficult is forecasting shipper/carrier responses to varying depth constraints from shoaling or opportunities from deepening. One implicit assumption in the Great Lakes navigation transportation cost modeling is that the same quantity of goods is moved from origin port to destination port despite increased transportation costs. Though this may not correctly reflect shippers' responses, the resultant increases in calculated transportation costs are used as a proxy for the impacts for production shifts and losses. Another model limitation is holding a particular vessel constant on a route while considering various depth changes (increases or decreases). Considering a specific commodity moved from a given origin port to a given destination port, a specific vessel in the Great Lakes fleet will likely be the most economically efficient one (lowest cost per ton) given a specific depth constraint over the route. Faced with a change in the depth constraint over the trade route, a different vessel may likely be more efficient (lower cost per ton) than the original vessel chosen for that route. Other constraints inherent in these models include, limited number of commodities evaluated, exclusion of detailed foreign vessels movements, non-specific port characteristics (i.e. depths and loading characteristics not at dock level), method for dealing with multiple origin ports or multiple destination ports for a single movement, and port to port distance table with limited pairings.

9.2.2 GL-SAND Model

The existing models, Great Lakes Level Analysis of Port Operation and Maintenance (GLLAPOM) that measures the impacts associated with constrained harbor depths that result from shoaling, and Great Lake Levels Analysis for System Transportation (GLLAST) used to measure the benefits associated with harbor channel improvements have the aforementioned limitations which have lead to the following proposed model improvements:

- incorporate expanded list of bulk commodities modeled;
- combine detailed Canadian shipment list (from Piers) with US domestic shipment list;
- have ability to analyze movements at dock level detail (not just port level);
- incorporate risk analysis for data variability and uncertainty;
- have ability to analyze at GL system level (not just port level);
- have ability to analyze for both depth improvement and shoaling scenarios;
- have ability to enable vessel swapping option to adapt to hypothetical changes in depth to allow for greater economic efficiency;
- have ability to analyze movements that have multiple origin and/or destination ports or docks;
- expand vessel list to include Canadian Lakers (vessel operating characteristics, etc.)
- have ability to analyze and compare alternative mode rate savings and emissions impacts;

A new model, Great Lakes System Analysis of Navigation Depths (GL-SAND) was developed to address these proposed enhancements. The impetus for this effort was the refinement of Great Lakes transportation cost modeling to support future O&M budget economic metric requirements. The idea being that the model should allow for the best practicable measurement of economic metrics to assist in the prioritization of proposed O&M budget dredging work packages for projects at Great Lakes ports.

Ultimately the new model will be risk-based, incorporating the uncertainty associated in input variables including water level variations, vessel class cost variability, safety margins, vessel speeds, etc. while also addressing a "Without Project Condition" (WOPC) for existing federal harbors absent of continued maintenance dredging and evaluating the "With Project Condition" (WPC) under various maintenance dredging scenarios.

The concept of a System based model expands the limited perspective of a harbor-centric based evaluation model. A system based model considers the transportation cost Great Lakes fleet and potential cost reductions (transportation cost savings benefit) for the fleet and also enables analysis in those instances where allowing for a vessel swap to correspond with a proposed port deepening alternative would benefit the system cost.

In developing this model, additional refined input data was required. This included a current (representative) shipment list of detailed domestic and Canadian origin-destination (O-D) movements that is ordered to simulate the exact order of all vessel movements (of the principle GL vessel fleet), updated vessel operating costs by vessel class, updated detailed vessel operating characteristics, and updated port / dock characteristics. Though not part of the model, additional data required to adequately assess a comparison of benefits and costs include: current harbor segment shoaled depths, shoaling rates and associated dredging costs and other related data.

The model was designed to be flexible enough to address specific transportation cost impacts at a dock level of detail as well as addressing the Great Lakes navigation from a system perspective looking at impacts at a total system or lake or commodity basis.

The following paragraphs describe the model inputs, processing, and outputs. Before discussing these in detail, the context for the Great Lakes navigation system in terms of total system benefits is presented.

9.2.2.1 Transportation Rates and System Savings

Transportation rates were derived for the principal origin-destination-commodity movements throughout the Great Lakes. As discussed in Section 3, the Tennessee Valley Authority (TVA) was contracted to measure the rate savings attributable to Great Lakes and St Lawrence Seaway navigation and to measure the transportation cost effect of alternative short term unplanned navigation structure closures. Toward this objective, TVA conducted a study that provided a full range of transportation rates and supplemental costs for 857 waterborne commodity movements made in 2002 that, in total or in part, were routed on the Great Lakes and St Lawrence Seaway. The 857 movements accounted for all moves that exceeded 20,000 net tons annually, representing over 40 individual commodities. These sample moves accounted for 25.0 percent of all U.S. Great Lakes navigation system movements and 93.0 percent of this system's traffic in 2002. Rates estimated for both the existing waterway route and the alternative route are comprised of the cost of loading at origin, charge to transfer point, transfer charge, line haul (overland or waterway) charge, handling at waterway destination, charge ex waterway, and cost of unloading at destination. All computations reflect those rates and fees that were in effect for December 2004.

This rate information, especially the alternative rate and accessorial charges, is input to the current GL-SAND application. This necessitated updating rate estimates reported by TVA in $2005 to current $2008. The method for doing this is described below. With this updated price level, it was also possible to estimate Great Lakes navigation system benefits for U.S. traffic. This system benefit is also presented below.

<u>Price Level Update</u>. The TVA transportation rates were updated to October 2008 price levels using Bureau of Labor Statistics indices. Indices from the Bureau of Labor Statistics were used to develop the update. A BLS website provided access to over 200 indices by industry. Indices that reflect cost increases in the various components of the existing routing transportation costs and the all-land transportation costs were acquired at this site. Once the appropriate category that fit the transportation mode and method and the corresponding index was identified, indices for December 2004 and October 2008 were obtained to develop the update index for that leg of the movement. These update indices were then used to update each commodity handling/line haul cost component associated with each of the sampled 847 commodity movements. Since there were different handling charges based on the mode used,

as well as differing line haul transportation costs by mode for each of the 847 origin destination routes evaluated, update factors were developed for each loading/unloading cost by mode involved, as well as line haul costs by mode.

GLNS System Rate Savings Update. Weighted average rate savings by major commodity group were calculated using the rates estimated by TVA in December 2004. These weighted average rate savings were based upon the 857 movement sample and the calendar year 2002 tonnages for the Great Lakes/St. Lawrence Seaway system. Calendar year 2006 U.S. Great Lakes traffic was aggregated by these same major commodity groupings and the $2008 weighted average rate savings applied to this tonnage in estimating total system benefits for U.S. Great Lakes traffic. The update resulted in a total rate savings benefit of $3.6B as presented in **Table 9.1**

Table 9.1 Great Lakes Rate Savings Benefit

Commodity Group	(Oct 08) $FY09 SPT*	CY 2006 Tonnage	Rate Savings Benefit**
Wheat	$24.02	1,636,000	$39,298,492
Maize	$32.17	1,875,000	$60,326,942
Soybeans	$30.60	1,161,000	$35,531,916
Other grains and seeds	$39.48	2,066,000	$81,570,722
Limestone	$21.78	30,908,000	$673,091,214
Other Minerals	$26.78	7,239,000	$193,848,497
Ores (including iron ore)	$12.89	58,848,000	$758,635,652
Coal	$18.05	44,896,000	$810,365,445
Petroleum Products	$27.43	5,067,000	$139,012,440
Cement	$46.00	7,151,000	$328,946,909
Miscellaneous	$42.73	12,166,000	$519,808,956
	Total	173,013,000	$3,640,437,183

* Savings per ton
** CY 2006 Great Lakes Waterborne Commerce; Oct 08 price level

9.2.2.2 Input Data Development

Shipment List. The GL-SAND model is driven by a list of shipment movements that describe the flow of commodities throughout the Great Lakes system. The list comprised of about 4,200 domestic movements and about 2,500 Canadian movements is based on 2005 data. The model is flexible enough to allow for an updated shipment list and other variable input data however the preparation of data for these changes is not a trivial exercise. **Table 9.2** displays the key data fields that GL-SAND uses from the shipment list. These include: Vessel number, Date of Shipment, Date or Receipt, Commodity Code, Shipping Port Number, Shipping Dock Number, Receiving Port Number, Receiving Dock Number, Trips field, and Number of Short Tons. Canadian movements were obtained from Piers data. Because of data field differences, the Canadian data needed some transformations to be compatible with the domestic shipment list. These transformations include converting vessel names into the appropriate corresponding vessel number and likewise converting Canadian shipping ports and Canadian receiving ports into the appropriate corresponding port code. Dock codes were only available for the US shipping and receiving ports.

Table 9.2 Shipment List: Key Data Fields with Description

Data Field	Description	Domestic Vessels Number of Unique Occurences	Canadian Vessels Number of Unique Occurences
Vessel	Vessel number	53	93
Ship Date	Date of Shipment	349	325
Recv Date	Date or Receipt	346	325
Commodity	Commodity Code	20	22
Loc S	Shipping Port Number	46 *	46 **
Dock S	Shipping Dock Number		
Loc R	Receiving Port Number	66 *	64 **
Dock R	Receiving Dock Number		
Trips	Trips field		
Tons	Number of Short Tons	96,140,909	49,038,490
	Number of records	4,226	2,379
* Number of unique O-D pairs is 347 and unique O-D-C triples is 382			
** Number of unique O-D pairs is 246 and unique O-D-C triples is 339			

<u>Commodities.</u> For each of the commodities modeled, it was necessary to determine their stowage factor in terms of cubic feet per short ton. For GL-SAND the number of commodities modeled is 35, up from the 13 commodities from previous models. **Table 9.3** presents the commodities selected for GL-SAND with their respective stowage factors. For the GL-SAND model, the maximum tons each vessel in the GL fleet can carry was calculated by dividing vessel's cubic capacity by each commodity's stowage factor (cubic feet per net ton). This value is capped by the maximum tons carried by each vessel's mid-Summer draft. Stowage factors were obtained primarily from Greenwood's Guide to Great Lakes Shipping, supplemented by other sources as necessary.

Table 9.3 GL-SAND Commodities and Stowage Factors

Commodity Code	Commodity Name	Stowage Factor
4100	Wheat-Unmilled	42.0
4300	Barley-Unmilled	63.8
4400	Maize-Unmilled	56.0
4510	Rye-Unmilled	56.0
4520	Oats-Unmilled	69.4
22220	Soya Beans	52.4
24700	Wood in the Rough or Roughly Squared	59.0
24820	Wood of Coniferous Species-Sawn	59.0
27322	Limestone Flux & Calcareous Stone	23.0
27323	Gypsum and Anhydrite	18.0
27330	Sands-Natural-(Exc Silica & Quartz)	18.0
27340	Pebbles-Gravel-Crushed Stone	18.0
27420	Iron Pyrites-Unroasted	12.5
27820	Clays and Other Refractory Minerals-NEC	22.0
27830	Sodium Chloride-Pure & Common & Sea Salt	33.0
27840	Asbestos	50.0
27861	Granulated Slar from the Manuf of Iron	33.3
27862	Slag-Dross-Scalings & Iron/Steel Waste	33.3
27869	Slag & Ash-NEC-Incl Seaweed Ash (Kelp)	45.0
27910	Dirt-Soil	22.0
28100	Iron Ore and Concentrates	15.5
28200	Ferrous Waste/Scrap;Remelting Iron Ingot	9.0
28300	Copper Ores & Concentrates;Copper Mattes	15.0
32100	Coal-Pulverized or not-Not Agglo	42.0
32500	Coke-Semi-Coke of Coal-of Lignite	70.0
52210	Carbon (Including Carbon Black)-NEC	14.9
52322	Calcium Chloride	48.0
52363	Other Phosphates	27.0
66120	Cement-Portland-Alum-Slag-Supersulf	22.0
67120	Pig Iron & Spiegeleisen-in Pigs-Blocks	4.1
67140	Ferro-Manganese	19.0
67200	Ingots and Other Primary Forms of Iron	8.9
67300	Flat-Rolled Products of Iron & Steel	4.1
67800	Wire of Iron or Steel	18.7
68400	Aluminum	12.1

Vessel Operating Characteristics. In previous models, commodities moving between U.S. and Canadian ports were evaluated using representative prototype vessels because the Canadian movements in the domestic shipment list did not contain information for the actual vessels making the moves. The operating characteristics for four representative prototype vessels were developed to reflect movements of grain, iron ore, limestone and coal. Because the actual physical characteristics of the vessels for most of the Canadian fleet were previously collected, obtaining the foreign data shipment list (Piers) allowed for the use of detailed Canadian vessel movements based on the actual vessels' operating characteristics instead of a prototype representative vessel. Vessel information was developed for much of the Canadian fleet and added to the corresponding model input files. There are 114 US and Canadian vessels represented in the GL-SAND model. The following four files containing vessel operating characteristics are used in the GL-SAND model.

VesselInfo.csv contains the following data fields: COE Vessel ID, Vessel Class, Vessel Type, Vessel Speed, Midsummer draft, Summer draft, Intermediate draft, Winter draft, Vessel Company, and Vessel Name.

VesLoadRatebyCommodVessel.csv: is a matrix of vessel load rates (tons per hour) by the 114 vessels by the 35 commodities.

MaxTonsbyDepthVessel.csv: is a matrix of the maximum tons by the 114 vessel by depth in 1-inch increments from 14.0 to 34.0 feet.

MaxTonsbyCommodVessel.csv: is a matrix of the maximum tons by the 114 vessels by the 35 commodities.

VesselDefaults.csv organized by vessel class, contains the following data fields many of which are used as defaults when detailed vessel data is unavailable: Tons per Inch Immersion Factor; Maximum draft with dense commodity; Maximum capacity for dense commodity at midsummer draft; Maximum draft for coal; Maximum capacity for Coal at midsummer draft; Maximum draft for Grain; Maximum capacity for grain at midsummer draft; unloading rate for dense commodities; unloading rate for coal and grains; vessel speed; time in minutes through the Soo Locks; time in minutes through the Welland canal; time in minutes through the lower St Lawrence Seaway; hourly vessel operating costs; Maneuvering time for loading in minutes; and Maneuvering time for unloading in minutes. **Table 9.4** presents the number of vessels in each length class.

Table 9.4 Distribution of GL Vessels used in Model by Length Class

Class	Vessel length	Count
1	400' or less	3
2	400' – 499'	5
3	500' – 549'	3
4	550' – 599'	2
5	600' – 649'	18
6	650' – 599'	10
7	700' – 730'	44
8	731' – 849'	14
9	850' – 949'	1
10	950' – 1099'	13
Total		113

Port and Docks. Where previous GL transportation cost models only analyzed movements at the port level, GL-SAND was expanded to analyze movements at the dock level. There are 2,962 unique docks used in the model in the dock database (DockInfo.csv). Fields in the database include port code, port name, dock code, dock name, maximum vessel class accommodated, depth at the dock, maneuvering time once at port, loading rate, unloading rate (when applicable), and minimum underkeel safety factor.

Connecting Channels. The model also utilizes constraint data (ChannelInfo.csv) at the ten connecting channels in the GL system which are St. Lawrence River, Welland Canal, Detroit River, Lake St. Clair, St. Clair River, Straits of Mackinac, St. Mary's River, Sault St. Marie (Soo Locks), and Vidal Shoals. The controlling depth, and underkeel safety clearance factor are the key information used by the model from the connecting channels.

Table 9.5 Connecting Channels and Depths Relative to LWD

Connecting Channel	Depth	Under Keel Clearance
St Lawrence River	27.5 feet	1.0 feet
Welland Canal	27.5 feet	1.0 feet
Detroit River	28.0 feet	1.5 feet
Lake St Clair	28.0 feet	1.5 feet
St Clair River	27.5 feet	1.5 feet
Straits of Mackinac	30.5 feet	1.5 feet
St Mary's River	28.0 feet	1.5 feet
Soo Locks	32.5 feet	1.5 feet
Vidal Shoals	29.0 feet	1.5 feet

Water Level Data. Water level fluctuations on the Great Lakes affect movements of commercial vessels. Changes in water levels affect the cost of delivering bulk commodities. In general, low water levels reduce the water column available to a shipper on a given origin/destination route. This lower water column means that the vessel operator cannot load the vessel to capacity (or the maximum number of tons of cargo it is allowed to hold). Consequently more trips are required to deliver the same amount of tons to the end user. More trips equate to higher transportation costs. Conversely, higher water levels usually allow the vessel operator to load more tons per trip. The vessel operator will load up to the maximum amount of tons that vessel is allowed to carry which may result in fewer trips having to be made to deliver the same amount of tonnage to the end user. Fewer trips equate to lower transportation costs.

Simulated historical mean monthly water levels were generated for the GL-SAND model. Because of existing control works and lake level regulation on Lakes Superior and Ontario and the St. Lawrence River, actual historical levels (which pre-date the construction of the St. Lawrence Seaway and associated control works) would not properly reflect the expected levels of the lakes in the future. Therefore, for the years prior to the control structures and operating plans, lake levels were simulated based on historical supplies and the rules of operation of the existing control works. The regulation plans used include Regulation Plan 77A, (Criteria C) for Lake Superior and Regulation Plan 58D, with deviations on Lake Ontario/ St. Lawrence River. Also existing diversions and consumptive uses were taken into consideration in the development of the simulated levels. Monthly mean levels were developed for the period 1900 – 2005 for the major water bodies on the Great Lakes. The include Lake Superior, Lakes Michigan – Huron (which constitutes one hydraulic lake), Lake St. Clair, Lake Erie, Lake Ontario and the St. Lawrence River.

Table 9.6 Minimum and Maximum Levels (IGLD, 1985) by Lake, 1900-2005

St Lawrence River	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Minimum Level	242.2	242.1	242.6	242.9	243.1	243.4
Maximum Level	246.6	247.0	247.3	248.2	248.5	248.6
Difference	4.4	4.9	4.7	5.3	5.3	5.2
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum Level	243.2	242.8	242.5	242.2	242.0	241.9
Maximum Level	248.2	248.0	247.4	246.8	246.7	246.7
Difference	5.0	5.2	4.9	4.6	4.7	4.8
Ontario	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Minimum Level	242.2	242.1	242.6	242.9	243.1	243.4
Maximum Level	246.6	247.0	247.3	248.2	248.5	248.6
Difference	4.4	4.9	4.7	5.3	5.3	5.2
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum Level	243.2	242.8	242.5	242.2	242.0	241.9
Maximum Level	248.2	248.0	247.4	246.8	246.7	246.7
Difference	5.0	5.2	4.9	4.6	4.7	4.8
Erie	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Minimum Level	568.3	568.2	568.2	568.8	569.0	569.1
Maximum Level	573.7	573.4	573.8	574.1	574.1	574.3
Difference	5.4	5.3	5.5	5.3	5.0	5.2
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum Level	569.1	569.0	568.8	568.6	568.2	568.2
Maximum Level	574.3	574.0	573.6	574.0	573.7	573.8
Difference	5.2	5.0	4.8	5.4	5.4	5.6
Michigan-Huron	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Minimum Level	576.1	576.1	576.1	576.2	576.6	576.6
Maximum Level	581.3	581.1	581.1	581.5	581.6	581.8
Difference	5.2	5.0	5.1	5.3	5.1	5.1
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum Level	576.7	576.7	576.6	576.4	576.3	576.2
Maximum Level	582.0	582.0	582.0	582.4	582.0	581.6
Difference	5.3	5.3	5.3	5.9	5.7	5.4
Superior	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
Minimum Level	599.8	599.6	599.5	599.5	599.6	599.9
Maximum Level	602.7	602.5	602.4	602.6	602.8	602.9
Difference	2.9	2.9	2.9	3.1	3.2	3.0
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Minimum Level	600.3	600.5	600.8	600.7	600.4	600.1
Maximum Level	603.1	603.2	603.2	603.4	603.3	603.1
Difference	2.8	2.8	2.4	2.7	2.9	2.9

Table 9.5 presents the minimum and maximum levels by water body for the period of record, 1900-2005 and **Table 9.7** presents a sample display of the water level data used by the GL-SAND model.

Table 9.7 GL-SAND Sample Water Level Input Data

Water Levels Data

IGLD-1985 Datum = 569.20 ft.

Lake Erie Levels (1900-2005)

Lake Erie

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1900	570.01	570.24	570.6	570.9	571.06	571.13	571	570.96	570.64	570.41	570.14	570.11
1901	570.01	569.65	569.55	569.95	569.98	570.37	570.57	570.44	570.37	569.98	569.82	569.85
1902	569.75	569.29	569.59	570.14	570.51	570.77	571.39	571.38	571.03	570.93	570.67	570.47
1903	570.28	570.34	570.93	571.72	571.75	571.72	571.65	571.42	571.26	570.9	570.44	570.08
1904	569.98	570.08	570.67	571.78	571.98	572.18	572.08	571.75	571.49	571.13	570.77	570.41
1905	570.18	569.88	569.85	570.47	571.13	571.65	571.72	571.52	571.29	570.96	570.6	570.57
1906	570.6	570.6	570.37	570.6	571.06	571.26	571.33	571.33	571.03	570.9	570.87	571.1
1907	571.46	571.16	570.93	571.39	571.56	571.95	571.98	571.72	571.46	571.39	571.1	570.93
1908	571.28	570.87	571.33	571.85	572.18	572.18	571.98	571.82	571.36	571	570.37	570.11
1909	570.11	570.14	570.44	570.73	571.52	571.88	571.69	571.49	571.06	570.44	570.31	570.08
1910	569.95	569.85	570.34	570.77	571.26	571.29	571.1	570.9	570.7	570.57	570.14	570.01
1911	569.69	569.75	569.75	570.28	570.54	570.6	570.41	570.28	570.18	570.18	569.78	570.08
1912	569.95	569.75	569.88	570.93	571.26	571.33	571.23	571.16	571.16	570.8	570.57	570.21
1913	570.9	571.06	571.1	572.7	572.64	572.51	572.21	571.88	571.39	571.06	570.93	570.8
1914	570.7	570.37	570.14	570.83	571.56	571.69	571.49	571.23	570.96	570.73	570.14	570.08
1915	569.75	570.01	570.08	570.11	570.34	570.51	570.67	570.83	570.83	570.6	570.14	570.05
1916	570.34	570.67	570.54	571.13	571.52	571.95	571.88	571.49	570.96	570.57	570.31	570.18
1917	570.24	570.01	570.21	571.26	571.85	572.18	572.51	572.21	571.92	571.49	571.82	571.19
1918	570.54	570.28	570.9	570.93	570.8	571.19	571.26	571.16	571.16	570.93	570.93	570.9
1919	570.87	570.87	571.23	571.69	572.38	572.47	572.15	571.82	571.46	571.13	570.96	570.51
1920	569.95	569.39	569.46	570.24	571	571.16	571.29	571.29	571.06	570.73	570.57	570.64
1921	570.6	570.47	570.77	571.36	571.72	571.65	571.52	571.16	570.87	570.51	570.37	570.41

Display "Setup" Levels

Close

Port Distance Tables. The waterway distance between origin ports and destination ports is a key component in the calculation of transportation costs for waterborne commerce movements. The water mileage distance table from previous Great Lakes transportation cost models was expanded to include distance between each port identified on the combined domestic and Canadian shipment list for CY 2005. There were 208 unique ports identified for which distances between them were determined. This amounts to a total 21,632 distance measurements available for Great Lakes origin – destination movements in the GL-SAND model. It should be noted that distance measurements are occasionally needed for intraport movements. There are several instances where intraport movements and respective distances were measured for dock to dock which were added to the mileage distance table.

Alternative Mode Data. Transportation costs were derived for the principle origin-destination-commodity movements throughout the Great Lakes. The Tennessee Valley Authority (TVA) was contracted to measure the rate savings attributable to Great Lakes & St Lawrence Seaway navigation and to measure the transportation cost effect of alternative short term unplanned navigation structure closures. Toward this objective, the study provided a full range of transportation rates and supplemental costs for 857 waterborne commodity movements in 2002 that, in total or in part, were routed on the Great Lakes & St Lawrence Seaway. Freight rates for each movement are calculated based on the actual water-inclusive routing. All computations reflect those rates and fees that were in effect for December 2004. Results are documented on a movement-by-movement basis, including a separate worksheet for up to the 14-rate scenario observations. These disaggregated data are also integrated into summary and unique observation spreadsheets. Alternative mode costs is comprised of the cost of loading at origin, charge to transfer point, transfer charge, line haul charge, handling at river destination, charge ex river, and cost of unloading at destination.

In order to complete the rate analysis, a field interview of each dock or port on the United States side of the Great Lakes was conducted. Each dock on the Great Lakes was identified, visited, and a summary write-up prepared. Dock-to-dock tonnages over the included origin/destination pairs exceed 20,000 net tons annually, representing over 40 individual commodities. Reported rates for both the water movements and the all-land alternative are based on the actual location of shipment origins and destinations.

9.2.2.3 Water Routings

Because most of the sample movements have off-lake origins and or destinations, a full accounting of all transportation costs for waterborne movements requires the calculation of railroad and/or motor carrier rates for movement to or from the nearest appropriate harbor facility. Additionally, all calculations reflect the loading and unloading costs at origin and destination, all transfer costs to or from barge, and any probable storage costs.

9.2.2.4 Land Routes

As in the case of the barge-inclusive routings, some all-land routes require the use of more than one transport mode. The inclusion of a prior or subsequent truck at a railhead or the use of shuttle vessels to or from islands or captive shippers has been utilized. Therefore, when appropriate, calculations include all requisite transfer charges and/or storage charges.

Based on information collected from shippers, receivers, carriers, lake terminal operators, stevedores, federal agencies, and private trade associations, TVA was able to identify probable origins and destinations for the majority of those movements that originated or terminated at off-lake locations. In the absence of specific shipper/receiver information, it is assumed that the lake origin and destination are the originating and terminating points for both the water and alternative modes of transportation. In every case, an attempt was made to gather information from all shipping harbors.

9.2.2.5 Commodity Assumptions

Commodity specific judgments and assumptions are as follows.

9.2.2.5.1 Grains

The computation of rates for grain is based upon the survey responses of the shippers and receivers throughout the region. These responses reveal considerable information regarding the transportation patterns for corn, soybeans, and wheat. Local/regional consumption and processing demands provide the dominant markets for corn, sorghum, and soybeans in the

United States. By contrast the export market dominates Canadian wheat and oilseed shipping. Local and regional elevators indicate that export shipments occur during those times when local production significantly exceeds local demands. Otherwise, these field crops move by truck or rail directly to domestic use destinations over a distance of as much as 200 miles. Transportation patterns for wheat in the United States are similar, except that the prevalence of local processing is less pronounced.

Also a lake elevator survey was conducted. A response from this survey indicated a pronounced reduction in the drawing area by truck for these elevators. Previous studies indicated that the farthest that trucks would travel to deliver grain to an elevator was 300 miles. Today the maximum distance traveled is 200 miles, and more typically, the drawing area is less than 50 miles, reflecting the dominance of farm direct deliveries to the lake elevators by truck. For those elevators that are rail served on Lake Superior, the use of rail delivery to the lake elevator has increased, but overall elevator tonnages are declining.

9.2.2.5.2 Iron Ore Concentrates

The movement of iron ore concentrates reflects the pattern of a land move to the lake origin, a vessel movement to a lower lake destination, and then either a transfer to rail for movement to an off lake destination or lake port steel mill consumption. Car capacities and train size came from the 2003 Surface Transportation Board Waybill Sample with significant carrier variation in car and train capacities. The distance from the pellet plant to the harbor was also derived from the 2003 Waybill Sample. Likewise the tonnage allocation of traffic to the off lake destinations was taken from the 2003 Waybill Sample.

9.2.2.5.3 Aggregates

All movements within this commodity grouping are either dredged materials, slag or quarried stone materials. With respect to sand and gravel, the waterway serves both as a production facility and a means of local transportation. In the absence of navigation, it was assumed that production would continue under essentially the same mining/transportation techniques employed during the study period.

As for quarried stone materials, these are construction crushed stone and fluxing stone movements from a quarry to a steel or iron ore production site or wholesale construction materials staging area. It is assumed that these materials stop at the harbor destination.

9.2.2.5.4 Coal

The movement of coal starts at a prepping plant and proceeds to an electric power production, coking plant or manufacturing process. All coal origins are off lake with a rail or barge origination, and the lake destinations are constrained by dock size and channel depth in the vessel capacity determination. The 2003 Waybill Sample was used to arrive at the tonnage allocation and average distance to the lake for primary states that were sourced by the lake terminal.

9.2.2.6 GL-SAND Input for Alternative Mode Costs

GL-SAND uses the alternative mode rates for the selected Origin-Destination-Commodity (ODC) combinations to calculate the rate savings benefit for individual Great Lakes ports and channels. The benefit calculation compares the all-land route transportation cost for the each ODC with each corresponding respective water cost. It should be noted that the land portion of the water route transportation cost was added to the transportation cost for water portion to derive the total cost of moving the commodity from its true origin to its final destination. GL-SAND uses the input file, altmode.csv. It contains the following fields of information: Commodity Code, Origin Port Code, Receiving Port Code, All Land Route Rate Per Ton, Land Component Of Water Route Rate Per Ton, All Land Route Rate per ton-mile, Land Component of Water Route Rate per ton-mile, Water Route Truck Miles, Water Route Rail Miles, O-D Water Miles, Total Water Miles, All Land Route Truck Miles, All Land Route Rail Miles, and All Land Route Total Miles. The Rate Savings benefit is calculated by summing all the individual rate savings benefits for each ODC for that port. The rate savings benefits for an individual ODC is calculated as the total tons for the ODC multiplied by the difference in all-land cost per ton and the water route cost per ton for that ODC. The estimated rate savings benefit for each Great Lakes federal commercial port and channel in **Table 9.8**.

Table 9.8 GL-SAND Modeled Rate Savings Benefit by Port and Channel

Port Name	Tons Modeled (2005)	Rate Savings Benefit	Port Name	Tons Modeled (2005)	Rate Savings Benefit
Alpena Harbor, MI	3,243,534	$83,845,642	Manitowoc Harbor	208,576	$16,096,349
Ashland Harbor	98,460	$4,032,219	Marquette Harbor	1,077,218	$17,591,886
Ashtabula Harbor, OH	9,298,577	$166,317,410	Menominee Harbor, MI & Wi	24,112	$0
Buffalo Port, NY	1,092,613	$34,921,276	Milwaukee Harbor, WI	2,950,612	$72,975,706
Burns Harbor, IN	7,945,830	$76,852,623	Monroe Harbor	1,407,242	$4,616,206
Calumet Harbor and River, IL & IN	6,309,052	$129,711,785	Muskegon Harbor	2,032,953	$80,688,800
Charlevoix Harbor	749,414	$50,382,889	Ogdensburg Harbor, NY	174,095	$4,849,837
Cheboygan Harbor, MI	25,346	$0	Ontonagon Harbor	228,629	$8,476,162
Chicago Port, IL	6,309,052	$129,711,785	Oswego Harbor, NY	371,201	$10,084,221
Cleveland Harbor, OH	12,508,505	$223,125,327	Presque Isle Harbor	10,940,784	$125,467,844
Conneaut Harbor, OH	7,243,225	$153,104,753	Rochester Harbor, NY	129,535	$5,294,134
Detroit Port, MI	4,955,553	$55,110,309	Rouge Riv (Dearborn), MI	10,104,703	$160,387,964
Duluth Harbor, MN	20,458,312	$391,588,418	Saginaw River, MI	1,374,766	$19,278,417
Dunkirk Harbor, NY	143,957	$676,662	Sandusky Harbor, OH	3,550,574	$56,000,827
Erie Harbor, PA	885,757	$30,335,030	St. Joseph Harbor, MI	530,615	$14,008,579
Fairport Harbor, OH	2,390,784	$43,154,806	Superior, MN	19,265,211	$183,723,626
Grand Haven Harbor	597,958	$10,189,889	Toledo Harbor, OH	9,304,155	$267,653,793
Green Bay Harbor, WI	2,624,313	$57,288,860	Two Harbors, MN	10,958,982	$86,268,194
Harbor Beach Harbor, MI	209,507	$4,152,428	Waukegan Harbor, IL	640,352	$13,325,680
Holland Harbor, MI	536,229	$15,259,688	Detroit River Channel	62,246,601	$1,193,731,044
Huron Harbor, OH	1,011,458	$24,144,967	Channels in Lake St. Clair	58,583,137	$1,148,905,375
Indiana Harbor, IN	10,969,022	$80,819,831	St. Clair River	68,536,986	$1,257,007,565
Lorain Harbor, OH	2,995,181	$32,382,696	Straits of Mackinac	96,204,692	$1,553,705,995
Ludington Harbor, MI	187,785	$4,391,918	St. Marys River	73,282,800	$1,005,319,780
Manistee Harbor, MI	243,143	$4,146,159	Sault St. Marie (Soo Locks)	66,635,908	$868,540,041

9.2.2.7 Emission-Safety Data

A new analytical component added to the GL-SAND model allowed for the assessment of emissions and safety by comparing water movements and the next least costly alternative mode of transportation. Comparative mileage data and ton-mileage data between modes was obtained from the aforementioned altmode.csv file. Details of the analysis are discussed in another section of this report. **Table 9.9** presents the emission and safety comparative metrics used in this analysis.

Table 9.9 Emission-Safety Metrics Used in GL-SAND (Emission-Safety.csv)

Value	Metric
0.0000362	Water - Emissions (lbs of PM-10) per ton-mile
0.0000406	Truck - Emissions (lbs of PM-10) per ton-mile
0.0000605	Rail - Emissions (lbs of PM-10) per ton-mile
$2.65	Fatal accident cost per rail mile
$3.39	Non-fatal accident cost per rail mile
$0.02	Physical damages from accident cost per rail mile
$0.13572	Fatal accident cost per truck mile
$0.607579	Non-fatal accident cost per truck mile
$0.023129	Physical damages from accident cost per truck mile

9.3 Harbor Improvement Evaluation

The current constraining feature on the GL/SLS is the depth of channels, the most restrictive of these being the St. Lawrence Seaway, the St. Mary's River and the St Clair River-Lake St. Clair-Detroit River. Sill depths at the St. Lawrence Seaway locks are 30'; while channel depths on the Seaway accommodate drafts of 26.5 feet. The St. Marys River has channel depths of 28.0 feet at LWD. The St Clair River-Lake St. Clair-Detroit River has channel depths of 27.5, 28.0 and 28 feet respectively at LWD. Channel and port improvements that would allow depths up to 30' would benefit shippers on the upper lakes and take greater advantage of the existing fleet of vessels.

A number of parameters affect the feasibility of harbor deepening. Some of these factors are: tonnage handled, origin-destination route distance, approach channel length, the existing fleet's capability to draft deeper, the destination port's draft relative to the origin port, and the connecting channel draft. Since benefits are measured as reduced transportation costs, harbors handling large tonnage with fleets that can take advantage of additional draft have the potential to generate enough benefits to justify deepening.

9.3.1 GL-SAND Model- Methodology for Estimating Benefits

The concept of a System based model expands the limited perspective of a harbor-centric based evaluation model. A system based model considers the transportation cost for the entire Great Lakes fleet and potential respective cost reductions (transportation cost savings benefit) from proposed harbor / channel deepening plans. This allows for a true multiport analysis. This is especially important because it eliminates the double counting of benefits that occurs when you analyze proposed improvement plans independently. In a system approach analysis, one may consider an alternative that has the combined measures of deepening say, three receiving ports by two feet each, and deepening a shipping port and perhaps a connecting channel one foot. In this instance, GL-SAND would measure the transportation cost change to the entire Great Lakes system. Previous models would calculate the benefits for each change independently and sum the benefits from each. This previous approach would double count (and possibly triple count) portions of the benefits.

Also, previous models produced results that may have been constrained by vessels not able to fully benefit from the proposed port improvement, because of limitations on vessel operating characteristics. In other words, if the maximum draft of a fully loaded vessel that calls on a port being evaluated is less than or equal to the currently authorized depth at the port, then there would be additional benefit for a port deepening alternative unless a larger more efficient vessel in the fleet was considered to replace the existing vessel. Ideally, in those instances where transportation cost savings are limited due to constraints on the existing fleet that historically served that port, the model should allow for a vessel to be swapped to correspond with a proposed port deepening alternatives that would benefit by increased efficiency. **Table 9.10** presents the base Great Lakes System Transportation Costs by Commodity for the existing system. Total GL system transportation cost for the commodities modeled amount to over $3.5 billion. This is based on approximately 144.6 million tons for 975 unique Origin – Destination movements of the 35 commodities modeled.

Table 9.10 Great Lakes System Transportation Costs by Commodity

Commodity	Number of Unique O-D pairs	Commodity Name	Total Tonnage	Ton-Miles	Total Cost, $
28100	107	Iron Ore and Concentrates	55,325,236	40,365,878,990	$1,362,324,322
32100	182	Coal	38,042,944	18,899,336,492	$1,522,162,777
27322	289	Limestone	30,668,772	9,902,484,188	$279,894,323
66120	63	Cement	5,712,641	2,086,253,598	$81,828,767
27830	93	Salt	5,595,845	2,081,894,683	$56,669,623
32500	36	Coke	1,765,842	1,572,841,825	$30,564,215
27340	48	Crushed Stone	1,472,619	695,171,274	$17,459,848
4100	22	Wheat, Unmilled	1,033,192	1,556,986,170	$66,209,359
27330	29	Sand	999,230	643,027,312	$10,510,795
27861	17	Granulated Slar	715,944	193,635,894	$7,205,365
27862	31	Slag, Dross, & Scalings	703,074	282,515,522	$6,547,828
22220	11	Soya Beans	606,264	800,832,142	$18,255,569
27323	6	Gypsum and Anhydrite	548,095	207,835,911	$9,068,379
27820	13	Clays	476,669	255,135,863	$4,537,323
4400	7	Maize, Unmilled	416,306	226,265,954	$14,857,079
67120	7	Pig Iron	149,175	230,052,449	$10,818,491
4520	5	Oats, Unmilled	122,870	136,072,322	$2,078,215
27869	5	Slag & Ash	109,162	47,728,541	$1,219,941
24820	2	Wood of Coniferous	83,557	93,834,511	$1,085,422
28200	1	Ferrous Waste & Scrap	27,085	4,035,665	$144,634
67200	1	Ingots Iron or Steel	7,163	7,492,498	$218,041
Total	975	Total	144,581,685	80,289,311,804	$3,503,660,316
		Total Time Shipped (hours)			524,191
		Average Weighted Cost per ton			$24.23
		Average Weighted Cost per ton -mile			$0.044

9.3.2 Development of Harbor Improvement Plans

Based upon the above parameters, a number of screening procedures were developed to identify harbors that have potential for deepening. The first screening was by tonnage;

including all ports that ship or receive over 1 million tons annually (see **Table 9.11**). The second consideration was to identify the difference between the depths at the origin and the destination ports.

There were 328 origin-destination pairs that were evaluated with respect to port improvements. The commodity, tons moved, the depth at the origin port, the depth at the destination port and the difference in depth between the origin and destination port was identified for each of these 328 origin destination pairs. **Table 9.12** presents the results of this analysis for all origin destination pairs that had at least 250,000 tons of commodity moved. The table is sorted by tons moved, from highest to lowest. This table was then used to develop a range of potential harbor improvement plans. These plans could be grouped by geographical area: the iron ore and coal- shipping ports of Lake Superior, the iron ore receiving and coal shipping ports located on Lake Erie, and the iron ore movements taking place between ports located on Lake Michigan.

Lake Superior iron ore shipping ports include: Duluth, MN; Presque Isle, MI; Silver Bay, MN; Superior, WI; Taconite Harbor, MN; and Two Harbors, MN. Major Lake Erie ports include Toledo Harbor, Sandusky, Lorain, Cleveland, Ashtabula and Conneaut Harbor, all in Ohio. Finally, a number of ports that have large tonnages moving on the same body of water were identified: iron ore shipments from Escanaba, MI, coal shipments from Sandusky, OH and limestone shipments from various Lake Huron ports. A short list of 25 harbors was developed. These 25 harbors are presented in **Table 9.13**

Preliminary evaluations were performed on these 25 harbors and a range of plans were identified for further evaluation. **Table 9.14** provides the 33 plans that were evaluated in further detail.

Deepening plans were developed for ports on Lake Erie (Sandusky, Ashtabula, Fairport), Lake Huron (Calcite, Stoneport, Drummond Island), Lake Michigan (Indiana Harbor Calumet Harbor), Lake Superior (Presque Isle ,Superior, Two Harbors, six iron ore shipping harbors on Lake Superior), and the St. Clair - Detroit River system (Dearborn Michigan, St. Clair Harbor, Michigan).

The process of developing harbor improvement plans identified a number of harbor pairs where a change in fleet would greatly improve the benefits associated with that plan. Restricting vessel movements to the vessels which moved the tonnages during the 2005 season resulted in underestimating the benefits associated with plans where the main constraint was the existing fleet’s maximum draft. Harbor pairs that had high tonnages, a large differential in channel depth between the two ports, and no node restrictions, but a fleet carrying capacity restriction, were prime candidates for evaluating the plans with vessel optimization. This is especially true when the vessel movements are essentially cross lake movements. Six harbors were identified where vessel optimization would improve plan benefits’ (see **Table 9.15**).

Table 9.11 O-D Screening for Potential Harbor Depth Deepening Measures

O-D	Commodity	Org dock depth	Rec dock depth	depth delta	tons (05)	orgin port	receiving port
O-D-1	28100	29	28	1	5,268,856	Superior Wis	Burns Waterway Harbor Indiana
O-D-2	28100	28	29	1	4,813,198	Two Harbors Minn Agate Bay	Gary Indiana
O-D-3	32100	28	22	6	4,059,858	Duluth Minn	St Clair Michigan
O-D-4	28100	28	25	3	3,668,906	Presque Isle Harbor Michigan	Dearborn Mich
O-D-5	32100	29	27	2	3,355,356	Superior Wis	Marine City Mich
O-D-6	32100	28	27	1	3,022,188	Duluth Minn	Nanticoke Ontario
O-D-7	28100	28	27	1	2,684,748	Presque Isle Harbor Michigan	Sault Ste Marie Ontario
O-D-8	28100	30	28	2	2,341,307	Silver Bay Minn	Cleveland Harbor Ohio
O-D-9	28100	29	25	4	2,210,458	Superior Wis	Detroit Michigan
O-D-10	28100	28	28	0	2,082,934	Two Harbors Minn Agate Bay	Conneaut Harbor Ohio
O-D-11	28100	28	27	1	1,989,424	Duluth Minn	Nanticoke Ontario
O-D-12	28100	28	27	1	1,957,864	Escanaba Michigan Wade Term 778	Indiana Harbor Indiana East Chicago
O-D-13	32100	27	27	0	1,766,661	Ashtabula Harbor Ohio	Nanticoke Ontario
O-D-14	28100	28	27	1	1,603,053	Duluth Minn	Indiana Harbor Indiana East Chicago
O-D-15	28100	29	27	2	1,514,304	Superior Wis	Hamilton Ontario
O-D-16	32100	28	27	1	1,507,451	Conneaut Harbor Ohio	Nanticoke Ontario
O-D-17	32100	27	27	0	1,449,399	Ashtabula Harbor Ohio	Sarnia Ontario
O-D-18	28100	28	25	3	1,360,800	Two Harbors Minn Agate Bay	Detroit Michigan
O-D-19	28100	30	28	2	1,278,589	Silver Bay Minn	Ashtabula Harbor Ohio
O-D-20	32100	29	27	2	1,235,113	Superior Wis	Nanticoke Ontario
O-D-21	32100	29	28	1	1,206,339	Superior Wis	Presque Isle Harbor Michigan
O-D-22	32100	29	28	1	1,206,339	Superior Wis	Presque Isle Harbor Michigan
O-D-23	32100	28	21	7	1,179,790	Duluth Minn	Monroe Harbor Michigan
O-D-24	28100	28	27	1	1,031,828	Escanaba Michigan Wade Term 778	Indiana Harbor Indiana East Chicago
O-D-25	28100	28	27	1	980,580	Two Harbors Minn Agate Bay	Lorain Harbor Ohio
O-D-26	32100	25	27	2	888,226	Sandusky Harbor Ohio	Hamilton Ontario
O-D-27	32100	27	27	0	819,433	Toledo Ohio	Sault Ste Marie Ontario
O-D-28	32100	28	27	1	772,225	Conneaut Harbor Ohio	Sarnia Ontario
O-D-29	27322	26	26	0	750,224	Calcite Michigan	Buffington Harbor Indiana
O-D-30	27322	26	21	5	746,126	Stoneport Mich	Dearborn Mich
O-D-31	32100	29	30	1	713,546	Superior Wis	Taconite Harbor Minn
O-D-32	28100	28	27	1	705,969	Duluth Minn	Indiana Harbor Indiana East Chicago
O-D-33	32100	28	30	2	702,376	Duluth Minn	Muskegon Harbor Michigan
O-D-34	28100	28	28	0	693,808	Duluth Minn	Conneaut Harbor Ohio
O-D-35	28100	30	23	7	672,257	Silver Bay Minn	Cleveland Harbor Ohio
O-D-36	32100	28	23	5	640,360	Duluth Minn	Essexville Michigan
O-D-37	28100	28	28	0	620,532	Presque Isle Harbor Michigan	Ashtabula Harbor Ohio
O-D-38	28100	28	29	1	619,705	Duluth Minn	Gary Indiana
O-D-39	28100	28	27	1	592,706	Two Harbors Minn Agate Bay	Indiana Harbor Indiana East Chicago
O-D-40	32100	27	20	7	591,263	Toledo Ohio	Dearborn Mich
O-D-41	28100	28	27	1	533,909	Escanaba Michigan Wade Term 778	Indiana Harbor Indiana East Chicago
O-D-42	28100	28	27	1	501,126	Escanaba Michigan Wade Term 778	Indiana Harbor Indiana East Chicago
O-D-43	27322	26	29	3	486,871	Calcite Michigan	Superior Wis
O-D-44	27322	26	28	2	479,187	Calcite Michigan	Burns Waterway Harbor Indiana
O-D-45	28100	28	27	1	477,656	Presque Isle Harbor Michigan	Toledo Ohio
O-D-46	32100	28	30	2	474,248	Duluth Minn	Silver Bay Minn
O-D-47	32100	27	28	1	452,930	Ashtabula Harbor Ohio	Presque Isle Harbor Michigan
O-D-48	32100	27	28	1	452,930	Ashtabula Harbor Ohio	Presque Isle Harbor Michigan
O-D-49	28100	28	27	1	443,828	Duluth Minn	Lorain Harbor Ohio
O-D-50	27322	28	27	1	437,267	Port Inland Michigan	Indiana Harbor Indiana East Chicago
O-D-51	32100	27	27	0	430,378	Toledo Ohio	Hamilton Ontario
O-D-52	27322	26	21	5	424,363	Stoneport Mich	Saginaw Michigan
O-D-53	28100	28	27	1	419,226	Presque Isle Harbor Michigan	Nanticoke Ontario
O-D-54	27322	26	28	2	408,989	Stoneport Mich	Burns Waterway Harbor Indiana
O-D-55	27322	26	22	4	400,850	Calcite Michigan	Marine City Mich
O-D-56	28100	28	27	1	398,271	Two Harbors Minn Agate Bay	Indiana Harbor Indiana East Chicago
O-D-57	32100	25	27	2	382,378	Sandusky Harbor Ohio	Sault Ste Marie Ontario
O-D-58	27322	26	28	2	369,830	Calcite Michigan	Duluth Minn
O-D-59	32100	25	20	5	364,915	Sandusky Harbor Ohio	Dearborn Mich
O-D-60	27322	28	28	0	362,665	Port Inland Michigan	Ashtabula Harbor Ohio
O-D-61	27322	26	21	5	361,208	Stoneport Mich	Detroit Michigan
O-D-62	27322	26	28	2	335,388	Stoneport Mich	Huron Harbor Ohio
O-D-63	27322	26	24	2	331,417	Stoneport Mich	Fairport Harbor Ohio Grand River
O-D-64	32100	27	28	1	330,182	Port Of Chicago Ill Calumet Hbr & Ri	Presque Isle Harbor Michigan
O-D-65	28100	29	27	2	329,167	Superior Wis	Indiana Harbor Indiana East Chicago
O-D-66	32100	28	27	1	324,666	Conneaut Harbor Ohio	Hamilton Ontario
O-D-67	32100	27	27.5	0.5	312,188	Ashtabula Harbor Ohio	St Lawrence Riv Above Inter Bdry-Po
O-D-68	27322	28	27	1	312,061	Port Inland Michigan	Sault Ste Marie Ontario
O-D-69	32100	25	23	2	311,452	Sandusky Harbor Ohio	Green Bay Wisconsin
O-D-70	27322	26	24	2	309,619	Stoneport Mich	Fairport Harbor Ohio Grand River
O-D-71	27322	26	30	4	307,422	Stoneport Mich	Marquette Harbor Michigan Check 79
O-D-72	28100	29	29	0	304,978	Superior Wis	Gary Indiana
O-D-73	27322	26	28	2	300,375	Calcite Michigan	Conneaut Harbor Ohio
O-D-74	27322	26	27	1	287,703	Calcite Michigan	Windsor Ontario
O-D-75	27322	26	29	3	284,953	Stoneport Mich	Duluth Minn
O-D-76	27322	26	21	5	280,540	Calcite Michigan	Dearborn Mich
O-D-77	27322	26	23	3	269,771	Calcite Michigan	Cleveland Harbor Ohio
O-D-78	32100	28	28	0	265,498	Duluth Minn	Ashtabula Harbor Ohio
O-D-79	27322	28	25	3	261,469	Port Inland Michigan	Green Bay Wisconsin
O-D-80	28100	29	20	9	253,538	Superior Wis	Dearborn Mich

9.3.3 Harbor Improvement Plan Benefits

The GL-SAND model was used to evaluate the benefits associated with these 33 plans. The GL-SAND model was run with existing harbor channel depths to obtain an “Existing” system wide transportation cost. Then the GL-SAND model was rerun with the Plans new channel depths, resulting in a “With Project” condition system transportation cost. The difference between the systems "Existing" transportation costs and the systems "With Project" transportation costs is the benefit associated with implementing that plan.

The GL-SAND model used the vessel traffic patterns associated with the 2005 commercial navigation season as the basis for calculating the annual benefits accruing to the various improvement plans. The model used 106 years of water levels (1900-2005) in computing "Existing" and "With Project" condition transportation costs. The model calculated transportation costs associated with each water level year, summed them and computed an average transportation cost for the "Existing" condition and each "With Project" condition plan evaluated. Again, plan benefits are the difference between average transportation costs under "Existing" conditions minus average transportation costs under "With Project" conditions associated with each plan. Plan average annual benefits are provided in **Table 9.16**.

9.3.4 Harbor Improvement Plan Project Costs

Deepening costs can be kept to a minimum by choosing harbors that have short approach channels, origin-destination routes where the destination port is deeper than the origin port, harbor pairs that use connecting channels that will not have to be deepened for the fleet to take advantage of the additional water column provided at the origin port, and origin-destination pairs that do not use any connecting channels (are located on the same water body). This means only the origin port needs to be deepened in order to capture the savings in transportation costs associated with the plan.

The level of detail to which the cost estimates were developed varies from port to port and also between the connecting channels. The level of detail was dependent upon availability of existing data from past studies, accessibility of recent condition surveys, and availability of existing data for non-Federal ports. Schedule and funding constraints limited the extent to which previous cost estimates could be refined based on more current data and operational conditions at each port. Where minimal or no data was readily available for a specific port, cost estimates were based on costs for ports in close proximity with similar harbor configuration. As a result, a range of cost estimates was established in order to better reflect these uncertainties. In all cases, however, the same general methodology is employed in estimating the cost of improvements at all GLNS harbors and channels.

Costs for the 33 various harbor deepening plans are provided in **Table 9.16**. All costs reflect October 2008 prices. These costs reflect First Costs of construction and Interest During Construction. These costs were then converted to an average annual cost using the current FY 09 federal discount rate of 4.625%, and a 50 year project evaluation period.

9.3.5 Harbor Improvement Plan - Benefit-to-Cost Comparisons

A benefit-cost analysis identified those plans with positive net benefits, the results of which are presented in **Table 9.16**. **Table 9.16** shows that there are a number of plans with very high net benefits, as well as benefit-to-cost ratios. The top 10 ranked plans with respect to net benefits are:

1- Deepen Dearborn Michigan, 2.5 feet ($6.42M)
2- Deepen St. Clair, MI, 5.0 feet ($2.68M)
3- Deepen Indiana Harbor, 1.0 feet ($0.67M)
4- Deepen Two Harbors, 0.5 feet ($0.49M)
5- Deepen Two Harbors, MN 2.0 feet & St. Mary's River, 1.0 feet ($0.26M)
6- Deepen Calcite, 2.0 feet ($0.19M)
7- Deepen Sandusky, 1.0 feet ($0.17M)
8- Deepen Indiana Harbor, 2.0 feet & Escanaba, 1.0 feet ($0.10M)
9- Deepen Drummond, 2.5 feet ($0.06M)
10- Deepen Presque Isle 0.5 feet ($0.06M)

Table 9.13 presents the key Great Lakes ports. **Table 9.14** presents the harbor improvement plans that were evaluated in detail. **Table 9.15** presents plans that have been identified that could benefit from vessel optimization assuming that a new more efficient vessel provided service to the deepened harbor.

Table 9.12 Port Plans Summary – Comparison of Benefits and Costs

Plan	Description	Oct-08 ($000) First Cost	Oct-08 ($000) IDC	Oct-08 ($000) AAEC		Oct-08 ($) AAEB	Oct-08 ($000) AAEB	Oct-08 ($000) Net Benefit	Oct-08 ($000) BCR
E1	Sandusky 0.5'	$ 984	$ 30	$ 52		$158,196	$ 158	$ 106	3.04
E2	Sandusky 1.0'	$ 2,107	$ 63	$ 112		$285,038	$ 285	$ 173	2.54
E3	Sandusky 1.5'	$ 3,232	$ 97	$ 172		$190,415	$ 190	$ 18	1.10
E4	Sandusky 2.0'	$ 4,612	$ 139	$ 245		$388,531	$ 389	$ 144	1.59
E5	Ashtabula 0.5'	$ 419	$ 12	$ 22		$4,839	$ 5	$ (17)	0.23
E15	* Sandusky 1.0' w/ vessel change	$ 2,107	$ 63	$ 112	**		-	-	-
E16	* Ashtabula 0.5' w/ vessel change	$ 419	$ 12	$ 22	**		-	-	-
E17	* Fairport 1.0' w/ vessel change+1M tons	$ 777	$ 23	$ 41	**		-	-	-
E18	* Fairport 1.0' w/ vessel change	$ 777	$ 23	$ 41	**		-	-	-
H1	Calcite 0.5'	$ 2,365	$ 71	$ 126		$201,594	$ 202	$ 76	1.60
H2	Calcite 1.0'	$ 4,730	$ 143	$ 252		$356,956	$ 357	$ 105	1.42
H3	Calcite 1.5'	$ 4,856	$ 147	$ 258		$439,287	$ 439	$ 181	1.70
H4	Calcite 2.0 '	$ 4,982	$ 151	$ 265		$457,104	$ 457	$ 192	1.72
H5	Stoneport 0.5 '	$ 2,365	$ 71	$ 126		$118,474	$ 118	$ (8)	0.94
H6	Stoneport 1.0 '	$ 4,729	$ 143	$ 252		$205,917	$ 206	$ (46)	0.82
H7	Stoneport 1.5 '	$ 4,856	$ 147	$ 258		$268,828	$ 269	$ 11	1.04
H8	Stoneport 2.0	$ 4,982	$ 151	$ 265		$278,678	$ 279	$ 14	1.05
H9	Drummond 2.5	$ 5,319	$ 160	$ 283		$345,690	$ 346	$ 63	1.22
M1	Indiana Harbor 1.0	$ 3,128	$ 94	$ 166		$839,818	$ 840	$ 674	5.06
M2	Indiana Hrb 2.0 & Escanaba 1.0	$ 15,741	$ 475	$ 837		$934,358	$ 934	$ 97	1.12
M4	* Calumet Harbor 1.0' for coal	$ 26,863	$ 1,658	$ 1,473		$13,034	$ 13	$ (1,460)	0.01
S2	Presque Isle 0.5'	$ 1,111	$ 34	$ 59		$114,863	$ 115	$ 56	1.95
S4	Superior 0.5'	$ 8,382	$ 253	$ 446		$95,282	$ 95	$ (351)	0.21
S6	Two Harbors 0.5'	$ 370	$ 11	$ 20		$514,183	$ 514	$ 494	25.70
S7	Superior 1.0'	$ 16,766	$ 506	$ 892		$117,583	$ 118	$ (774)	0.13
S8	Six Hrbrs 1.5, St. Marys 1.0'	$ 145,151	$ 10,279	$ 8,026		$4,253,627	$ 4,254	$ (3,772)	0.53
S11	Two Harbors, MN 2.0', St. Marys R 1.0'	$ 39,353	$ 2,456	$ 2,159		$2,414,975	$ 2,415	$ 256	1.12
SD 1	Dearborn 0.5'	$ 642	$ 19	$ 34		$5,667,820	$ 5,668	$ 5,634	166.71
SD 2	Dearborn 1.5'	$ 1,927	$ 58	$ 102		$6,427,461	$ 6,427	$ 6,325	63.01
SD 3	Dearborn 2.5'	$ 3,213	$ 97	$ 171		$6,589,703	$ 6,590	$ 6,419	38.54
SD 4	Dearborn 3.0	$ 3,855	$ 116	$ 205		$6,589,703	$ 6,590	$ 6,385	32.15
SD 5	Dearborn 6.0	$ 7,710	$ 233	$ 410		$6,589,703	$ 6,590	$ 6,180	16.07
SD 7	St. Clair, MI- 5.0	$ 7,166	$ 217	$ 381		$3,059,727	$ 3,060	$ 2,679	8.03

* Plan Calls for Vessel swap

** Plan Not Yet Evaluated

Table 9.13 Key Great Lakes Ports

1. Superior, WI	**9. Sandusky Harbor, OH**	**17. Burns Harbor, IN**
2. Indiana Harbor, IN	**10. Detroit, MI**	**18. Calcite, MI**
3. Dearborn, MI	**11. Calumet Harbor, IL**	**19. Alpena, MI**
4. Escanaba, MI	**12. Taconite, MN**	**20 Lorain, OH**
5. St.Clair, MI	**13. Silver Bay, MN**	**21. Cleveland, OH**
6. Duluth, MN	**14. Two Harbors, MN**	**22. Ashtabula, OH**
7. Saginaw, MI	**15. Presque Isle/Marquette, MI**	**23. Conneaut, OH**
8. Monroe Harbor, MI	**16. Gary, IN**	**24. Fairport, OH**
		25. Toledo, OH

Table 9.14 Harbor Improvement Plans Evaluated in Detail

Plan	Description
E1	Deepen Sandusky 0.5'
E2	Deepen Sandusky 1.0'
E3	Deepen Sandusky 1.5'
E4	Deepen Sandusky 2.0'
E5	Ashtabula 0.5'
E15	* Sandusky 1.0’ w/ vessel change
E16	* Ashtabula 0.5’ w/ vessel change
E17	* Fairport 1.0’ w/ vessel change+1M tons
E18	* Fairport 1.0’ w/ vessel change
H1	Deepen Calcite 0.5'
H2	Deepen Calcite 1.0'
H3	Deepen Calcite 1.5'
H4	Deepen Calcite 2.0 '
H5	Deepen Stoneport 0.5 '
H6	Deepen Stoneport 1.0 '
H7	Deepen Stoneport 1.5 '
H8	Deepen Stoneport 2.0
H9	Deepen Drummond 2.5
M1	Deepen Indiana Hrbr 1.0
M2	Deepen Indiana Hrbr 2.0 & Escanaba 1.0
M4	* Calumet Harbor 1.0’ for coal
S2	Deepen Presque Isle 0.5'
S4	Deepen Superior 0.5'
S6	Two Harbors 0.5'
S7	Deepen Superior 1.0'
S8	Deepen Six Hrbrs 1.5, St. Marys 0.5'
S11	Deepen Two Harbors, MN 2.0', St. Marys R 1.0'
SD 1	Deepen Dearborn 0.5'
SD 2	Deepen Dearborn 1.5'
SD 3	Deepen Dearborn 2.5'
SD 4	Deepen Dearborn 3.0'
SD 5	Deepen Dearborn 6.0'
SD 7	Deepen St. Clair, MI- 5.0

Table 9.15 Plans that May Benefit from Vessel Optimization

Harbor	Deepening Plan
1. Sandusky Harbor	1.0 foot deepening for coal- change fleet
2. Calumet Harbor	1.0 foot deepening for coal- change fleet
3. Calumet Harbor	1.0 foot deepening for iron ore l- change fleet
4. Ashtabula Harbor	0.5 foot deepening for coal- change fleet
5. Saginaw Harbor	4.0 foot deepening for limestone
6. Alpena Harbor	2.0 foot deepening for cement

9.4 Harbor Maintenance

The federal ports and channels of Great Lakes Navigation System (GLNS) provide for low cost transportation of bulk commodities. Shipments of iron ore, coal, grain, limestone, salt and petroleum products are among those that are key to the basin's economic stability. The continued viability of the nation's steel industry, the industries that support steel production, and those that use steel, along with the region's electric power suppliers comprising the backbone of the regional manufacturing base, depend on the sustenance of the federal ports and channels of the GLNS.

Although our federal ports and channels have historically provided safe and reliable commercial navigation through the years, recent constrained budgets for navigation channel maintenance have resulted in limitations on vessel draft, vessel maneuverability and harbor access. Recent periods of lower lake levels compound these conditions, particularly in instances where channel and harbor depths have had to be maintained at less than authorized depths due to funding limitations and a resultant dredging backlog. The consequence of a failure at a major port could result in closure of a harbor and production and job losses at the manufacturing facilities it serves.

Constrained funding for O&M makes it essential that the Corps have the appropriate decision tools to prioritize and make sound budget decisions consistent with performance based budgeting that provide for a reliable system.

The ultimate goal is to develop and maintain models and databases capable of providing the scientific basis for decision makers as they address the level of funding essential to provide an efficient and sustainable navigation system. Specific features of the system to be evaluated include: maintenance of navigation channels (width, depth, segments dredged), and short/long term dredged material management activities to include maintenance/construction of confined disposal facilities, Dredged Material Management Plans, habitat restoration, beneficial reuse, etc.).

Growing populations, thriving trade, increasing recreational use and environmental considerations have all intensified the pressures on the Great Lakes. Management of the Great Lakes has thus become an increasingly complex function. By annually preparing accurate, consistent and reliable valuation and performance-based metrics, Navigation Business Line decision makers will be able to prioritize federal investment options for operation and maintenance activities in an effort to provide a sustainable and reliable navigation system.

The reliability of the GLNS is continuously jeopardized by changing depths at federal channels and turning basins. The majority of federal commercial deep draft harbors on the Great Lakes require periodic harbor maintenance dredging. Available depth changes are the result of the continuous seasonal and annual fluctuation of lake water levels within the system, which impacts large numbers of harbors simultaneously. Another common element affecting available depth is the shoaling that results from sediment transport from sources upstream of federal harbors or from the littoral transport of sand and gravel along the lake coasts into federal channels. Lake storms often contribute to this later process. Shoaling in federal channels reduce the available depth for commercial vessels that call there restricting the maximum allowable tonnage on a transit. The result of vessel light loading is substantial increases in the transportation cost of a transit.

9.4.1 Performance Metrics for Budget Use

Performance based budgeting seeks to monitor project performance by tracking a select set of metrics. These metrics should portray the incremental value to the GLNS as compared to the proposed budget expenditure needed to achieve that value. Transportation cost increases that are associated with unchecked shoaling is determined using the GL-SAND model and can be analyzed down to the dock level at a federal port. This is done by calculating the increases in transportation costs that would result with declining available depths at ports as a result of shoaling and comparing the cost of dredging to the authorized depth (or any other depth). Net benefits, calculated as the difference in annual transportation cost savings and average annual maintenance dredging costs, is the economic metric to be used as the basis for prioritizing proposed maintenance dredging work packages. As compared to GLLAPOM model, the GL-SAND model can also provide the rate savings benefit for each harbor as well as the emission and safety impacts for each harbor or channel based on alternative mode comparisons. Also GL-SAND, having expanded commodities, provides a more accurate reflection of impacts. Ports like Cleveland that have significant intraport movements and varying controlling depths are now analyzed properly using GL-SAND. **Table 9.16** presents the potential transportation cost savings benefit by removing varying depths of shoaling from the channel at federal commercial Great Lakes ports.

Table 9.16 Transportation Cost Savings Benefit by Shoal Depth for Federal Commercial Great Lakes Ports

Port Name	Tons (2005)	Total Transportation Costs * (at 0 ft-depth)	1-foot	2-foot	3-foot	4-foot	5-foot	6-foot
Alpena Harbor, MI	3,243,534	$41,777,704	$241,863	$660,821	$1,261,958	$2,633,959	$4,340,900	$6,443,226
Ashland Harbor	98,460	$2,673,099	$13,128	$25,857	$34,920	$86,966	$160,992	$231,363
Ashtabula Harbor, OH	9,298,577	$248,672,559	$207,200	$1,131,091	$2,461,864	$4,189,410	$6,229,594	$8,606,690
Port of Buffalo, NY	1,092,613	$15,577,411	$88,563	$286,869	$582,740	$1,010,278	$1,604,683	$2,400,066
Burns Harbor, IN	7,945,830	$156,893,473	$323,701	$1,119,106	$2,387,119	$4,052,489	$5,922,911	$7,958,507
Calumet Harbor and River, IL & IN	6,309,052	$124,127,267	$109,231	$338,504	$676,436	$1,270,836	$2,050,748	$3,069,335
Charlevoix Harbor	749,414	$8,986,787	$4,326	$32,441	$88,609	$236,355	$474,271	$804,921
Cheboygan Harbor, MI	25,346	$182,395	$6,433	$16,331	$29,068	$44,884	$64,967	$83,455
Port of Chicago, IL	6,309,052	$124,127,267	$109,231	$338,504	$676,436	$1,270,836	$2,050,748	$3,069,335
Cleveland Harbor, OH	12,508,505	$140,113,028	$2,033,995	$5,138,950	$9,237,691	$14,408,243	$20,811,116	$28,742,691
Conneaut Harbor, OH	7,243,225	$164,621,671	$14,560	$706,817	$1,842,072	$3,298,414	$5,069,310	$7,147,797
Port of Detroit, MI	4,955,553	$71,628,214	$1,372,108	$2,980,864	$4,857,251	$7,092,140	$9,803,857	$13,174,832
Duluth Harbor, MN	20,458,312	$573,216,455	$2,412,807	$5,959,267	$10,529,007	$15,854,142	$22,401,151	$30,665,054
Dunkirk Harbor, NY	143,957	$3,072,151	$48,580	$106,641	$181,862	$330,174	$496,667	$598,014
Erie Harbor, PA	885,757	$7,167,043	$181,959	$422,904	$682,519	$963,931	$1,255,284	$1,586,018
Fairport Harbor, OH	2,390,784	$21,505,328	$382,870	$902,572	$1,552,878	$2,355,709	$3,355,908	$4,586,140
Grand Haven Harbor	597,958	$9,708,527	$314,754	$691,769	$1,159,286	$1,723,058	$2,420,832	$3,322,626
Green Bay Harbor	2,624,313	$63,256,051	$452,292	$1,153,099	$2,184,607	$3,613,398	$5,512,396	$7,926,356
Harbor Beach Harbor, MI	209,507	$1,890,902	$0	$0	$0	$487	$17,251	$29,496
Holland Harbor, MI	536,229	$8,301,175	$116,560	$270,588	$462,114	$710,524	$1,016,339	$1,404,861
Huron Harbor, OH	1,011,458	$11,155,649	$2,167	$90,378	$245,074	$465,288	$724,464	$1,029,691
Indiana Harbor, IN	10,969,022	$156,335,825	$1,684,000	$3,897,470	$6,638,436	$9,672,118	$13,129,573	$16,849,724
Lorain Harbor, OH	2,995,181	$43,387,502	$189,966	$649,957	$1,326,592	$2,103,230	$2,963,855	$3,918,928
Ludington Harbor, MI	187,785	$1,819,577	$41,389	$97,908	$178,267	$625,442	$1,086,381	$1,642,906
Manistee Harbor, MI	243,143	$3,778,835	$89,568	$179,238	$291,552	$426,045	$604,340	$839,815
Manitowoc Harbor	208,576	$4,939,056	$39,458	$96,352	$171,190	$266,299	$1,947,870	$3,371,372
Marquette Harbor	1,077,218	$7,612,933	$235	$24,815	$83,933	$166,672	$252,941	$411,833
Menominee Harbor, MI & WI	24,112	$313,510	$4,668	$13,027	$25,622	$38,970	$56,073	$76,463
Milwaukee Harbor, WI	2,950,612	$53,666,505	$293,029	$674,576	$1,256,629	$2,023,369	$3,037,415	$4,353,053
Monroe Harbor	1,407,242	$49,404,697	$468,470	$1,012,619	$1,628,194	$2,289,573	$2,945,260	$3,533,079
Muskegon Harbor	2,032,953	$45,362,580	$89,594	$293,728	$626,819	$1,101,474	$1,760,648	$2,492,791
Ogdensburg Harbor, NY	174,095	$2,084,922	$299	$17,294	$78,917	$160,971	$254,339	$361,357
Ontonagon Harbor	228,629	$8,042,283	$151,149	$349,676	$583,310	$855,982	$1,198,032	$5,058,547
Oswego Harbor, NY	371,201	$3,550,734	$45,852	$144,024	$302,041	$527,033	$828,302	$1,215,746
Presque Isle Harbor	10,940,784	$160,269,941	$588,799	$1,811,307	$3,530,551	$5,798,296	$8,525,692	$11,683,809
Rochester Harbor, NY	129,535	$1,205,932	$77,594	$191,409	$366,317	$1,050,419	$2,588,899	$4,191,073
Rouge Riv (Dearborn), MI	10,104,703	$160,960,912	$3,081,237	$6,815,126	$11,248,966	$16,509,272	$22,863,010	$31,177,687
Saginaw River	1,374,766	$11,804,138	$332,337	$839,650	$1,484,075	$2,282,837	$3,289,277	$4,591,202
Sandusky Harbor, OH	3,550,574	$109,561,017	$247,758	$558,701	$924,105	$1,352,668	$1,919,369	$2,804,159
St. Joseph Harbor, MI	530,615	$6,678,560	$595,207	$1,446,881	$2,284,324	$3,096,423	$4,583,210	$5,761,124
Superior, MN	19,265,211	$439,960,002	$550,559	$2,436,360	$5,724,596	$10,245,797	$15,919,786	$22,127,609
Toledo Harbor, OH	9,304,155	$294,113,418	$381,494	$1,541,052	$3,410,068	$5,798,109	$8,564,948	$11,805,177
Two Harbors, MN	10,958,982	$212,937,696	$1,968,721	$5,018,585	$8,410,875	$12,141,556	$16,109,753	$20,531,909
Waukegan Harbor, IL	640,352	$9,437,948	$517,177	$1,240,865	$2,233,902	$3,194,584	$5,193,360	$6,786,357
Detroit River Channel	62,246,601	$1,277,977,201	$915,907	$5,395,463	$14,331,238	$27,700,542	$44,580,577	$64,993,041
Channels in Lake St. Clair	58,583,137	$1,201,397,433	$1,297,244	$6,551,229	$16,342,775	$29,962,326	$47,072,285	$67,577,816
St. Clair River	68,536,986	$1,495,601,968	$3,845,172	$11,666,686	$24,324,403	$40,334,620	$60,124,794	$84,974,235
Straits of Mackinac	96,204,692	$1,974,821,225	$0	$0	$1,628,024	$10,243,249	$24,498,443	$43,829,093
St. Marys River	73,282,800	$1,594,426,472	$4,849,637	$14,969,982	$29,443,067	$47,692,304	$69,352,439	$94,867,534
Sault St. Marie (Soo Locks)	66,635,908	$1,498,990,433	$0	$4,825,933	$14,830,092	$29,050,741	$46,625,293	$67,067,425

* Oct 08 Price Level

9.4.2 Dredging on the Great Lakes - Placement of Dredged Material

Human development around the Great Lakes tended to occur first at ports and harbors located at the mouth of rivers. The commerce of these cities was serviced by vessel traffic. As vessel sizes increased, the need for and frequency of dredging increased. Natural river channels needed to be deepened as much as 20 feet. These increased channel depths provided a natural area for sediments to settle since the river currents were slower in this area. The Corps involvement with maintaining and improving navigation channels started in 1824 with federal legislations that authorized the Corps to improve safety on the Ohio and Mississippi Rivers and several ports.

Today the Corps of Engineers is authorized to maintain 139 navigation projects and connecting channels around the Great Lakes that serve commercial and recreational users. The system includes 68 deep draft harbors, 71 recreational harbors, 745 miles of navigation channels and 138 miles of breakwater. Great Lakes Harbor and channels are maintained by three corps districts: Buffalo (harbors in New York, Pennsylvania and Ohio) Chicago (Harbors in Indiana and Illinois) and Detroit (harbors and connecting channels in Michigan, Wisconsin and Minnesota).

The disposal of sediments that are removed from federal harbors and channel can be managed in a number of ways, If the sediment is clean it can either be placed in the open lake or used for other purposes such as beach/littoral nourishment, beneficial uses at upland sites (construction fill, landscaping, landfill cover, agricultural amendment, etc). If the sediments contain contaminants in quantities that exceed open lake disposal guidelines, the sediments must be placed in a Confined Disposal Facility (CDF).

The Corps typically dredges about 5.4m cubic yards of sediment annually from federal harbors and channels on the Great Lakes. Approximately 44% (2.4m cubic yards) of these sediments need to be placed in a Confined Disposal Facility. The remaining 56% (3.0m cubic yards) is placed in the open lake.

The passage of Public Law 91-611 in 1970 by Congress established two key programs. The first was the Dike Disposal Program. This program provided funding for the construction of dike disposal facilities that would be used to contain polluted dredged materials. The second program was the Dredged Material Research Program (DMRP). The program was started in 1973 and completed in 1978. The program developed procedures for evaluating the physical, chemical, and biological impacts of a variety of disposal alternatives located in water, on land, and in wetland areas. The research led to guidelines for assessing and minimizing the impacts of conventional disposal alternatives. The research identified two fundamental disposal management conclusions: no disposal method can be precluded based on its inherent characteristics and long range regional planning is required in order to adequately address a variety of environmental factors.

9.4.2.1 Need for Placement

The source of sediments, properties of soil in the watershed, and the hydraulics of the waterway determine the physical characteristics of sediments. Sediments chemical characteristics also vary depending on the watersheds characteristics and the presence, type and number of contaminate sources. Contaminate sources include urban and agricultural runoff , sewer overflows/bypassing, industrial and municipals wastewater discharges, landfill leachate/groundwater discharges, spills of oils or chemicals, air deposition, biological production and naturally occurring mineral deposits.

The rate of sediment deposits in deepened navigation channels can be altered by controlling the source of the sediments through soil conservation practices, wetland protection and restoration, and projects that alleviate shoreline and streambank erosion. Elimination of point and non-point sources of pollution can also reduce the levels of contamination in sediments. Investment in wastewater treatment upgrades, separation of combined sewer systems, air pollution controls, soil conservation and non point pollution prevention have helped to reduce the level of sediments and pollutants discharged into the Great Lakes and its tributaries.

Sediments dredged today at most harbors are significantly cleaner than those dredged 20 or thirty years ago. However, the lag time between implementation of source controls and the appearance of cleaner sediments is substantial. Sediment loads are still substantial given the amount of potentially erodible streambank. Consequently, the need to manage sediments, and especially contaminated sediments, dredged from Great Lakes harbors and channels will continue to be a challenge.

Regulatory Compliance. Any dredging that is performed needs to comply with a wide range of Federal and state regulations. The number of environmental laws and regulations that apply to dredged material management can vary based on the method and location of disposal and the chemical and physical composition of the dredged material. **Table 9.17** provides a listing of major federal regulations that are potentially applicable.

Section 307 of the Clean Water Act directed the USEPA to develop pretreatment standards for industries. Section 401 gave the state authority to issue certification that proposed dredge and fill disposal activities would not violate applicable state water quality standards. There is considerable variation from state to state in the procedures and requirements for 401 certification. Section 402 established the National Pollution Discharge Elimination System (NPDES) program for point source discharges. Section 404 identifies the USACE as the lead agency in the regulation of dredged or fill material into waters of the United States as well as dredge and fill discharges. District offices issue 404 permits. There are regional and nationwide permits that have been issued to cover specific types of discharges.

Section 10 of the Rivers and Harbors Act of 1899 necessitates the permitting of any structures or work that impacts the course, capacity, or condition of a navigable water of the United States. The Coastal Zone Management Act of 1972 requires that federal actions must be consistent with approved state coastal management programs. The National Environment Policy Act (NEPA) calls for a detailed statement on significant federal actions that would impact the quality of the human environment. These take the form of either an environmental assessment (EA) or an environmental impact statement (EIS). Although the USEPA administers the program, the agency that has the lead in the federal action is responsible for preparing and coordinating the NEPA document. The Fish and Wildlife Coordination Act calls for coordination with the U.S. Fish and Wildlife Service and state fish and wildlife agencies when the “waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted …. or otherwise controlled or modified” by any agency under a federal permit or license.

When a new disposal site is proposed, or when there are significant changes in operations, the Corps asks for a letter from the USFWS. The letter identifies any threatened or endangered species within the general area of the dredging and disposal operations and the fish and wildlife resources that might be impacted from these operations. The Endangered Species Act (1973) provides a means of conserving the ecosystems of endangered and threatened species. The Act authorizes a range of actions including: (1) determination and listing of species endangered and threatened, (2) prohibits unauthorized taking, possession, sale and wildlife resources that might be impacted from these operations.

Table 9.17 Potentially Applicable Federal and Environmental Laws and Regulations

Statute	Federal Regulation	Lead Agency	Potentially Applicable Activities
Clean Water Act			
Section 307	40 CFR 403	USEPA[1]	Discharge of CDF effluent to municipal sewer.
Section 401	40 CFR 121	State	Dredged and fill discharges to waters of the U.S.
Section 402	40 CFR 122	USEPA[1]	Discharges of CDF effluent. Stormwater discharges from CDF construction.
Section 404	33 CFR 320-330	USACE[1,3]	Dredged and fill discharges to waters of the U.S.
Rivers & Harbors Act of 1899 Section 10	33 CFR 403	USACE	Construction in waterway and dredging.
Coastal Zone Management Act	15 CFR 923	State	Dredging, disposal in water, construction in the coastal zone.
National Environmental Policy Act	40 CFR 1500-1508	USEPA[2]	Any significant federal action, including federal permit issuance.
Fish & Wildlife Coordination Act	16 CFR 661-667e	USFWS	Federal agency projects as well as Federal permits or licenses.
Endangered Species Act	16 CFR 1531-1544	USFWS	Government and private activities that could impact Federal threatened or endangered species.
Resource Conservation & Recovery Act	40 CFR 257-258	USEPA[1]	Storage, treatment, and disposal of any hazardous materials.
Toxic Substances Control Act	40 CFR 761	USEPA	Transport, handling and disposal of PCB-contaminated sediments.
CERCLA Section 107	43 CFR 11	NOAA, DOI, States	Resolution of natural resource injury liability associated with hazardous substances released as part of the cleanup process or through an assessment of natural resource damages.

1. Program responsibility may be delegated to state.
2 Document preparation the responsibility of proponent or permitting agency.
3. USEPA has the lead in development of Guidelines and implementation guidance, and retains veto authority.

The Endangered Species Act (1973) provides a means of conserving the ecosystems of endangered and threatened species. The Act authorizes a range of actions including: (1) determination and listing of species endangered and threatened, (2) prohibits unauthorized taking, possession, sale and transport of endangered species, (3) provides authority to acquire land for the conservation of listed species, using land and water conservation funds, (4) authorizes the establishment of cooperative agreements and grants-in-aid to states that establish and maintain active and adequate programs for endangered and threatened wild life and plants, (5) and directs the Secretary of the Interior to develop and review recovery plans for listed species without showing preference for any taxonomic group and establishes recovery plan criteria for listed species. The Resource Conservation and Recovery Act (RCRA) defines solid waste, authorizes states to issue solid waste disposal permits, and regulates the storage treatment and disposal of hazardous wastes. The Application of RCRA to sediments, especially contaminated sediments, is unclear since the Corps of Engineers does not consider sediment to be a solid waste. The Toxic Substances Control Act (TSCA) is managed by the U.S. EPA and regulates the manufacture, use distribution, handling, and disposal of a very limited number of materials defined as toxic substances, which includes PCB's (polychlorinated biphenyls). Sediments that contain PCBs are considered "PCB remediation waste" and are managed based on the level of PCB concentration found in the sediments. The Comprehensive Environmental Response, Compensation, and liability Act (CERCLA), Section 107, designates natural resource trustees and authorizes them to address releases of hazardous substances that injure of threaten to injure natural resources. The National Oceanic and Atmospheric Administration (NOAA) is the primary natural resource trustee for waterborne commerce.

9.4.2.2 Great Lakes Dredging Activities - Dredged Material Management Efforts

Given that sediments need to be removed from authorized channels, the final placement of these sediments will depend upon the sediments chemical characteristics. Spoil management/ placement alternatives include: open lake, beach/littoral nourishment, capping, beneficial use, confined disposal and treatment.

<u>Dredged Material Disposal Facilities</u>. Prior to 1960, most dredged sediments were placed in open water. Concerns about the impact of dredging on water quality were first raised in the lower Detroit River. A two year study on the impacts of dredging on Great Lakes water quality was initiated in 1967. The study recommended that sediments from contaminated harbors and channels be confined.

Congress Authorized Section 123 of the Rivers and Harbors Act of 1970 that dealt directly with managing polluted sediments. Section 123 established the Diked Disposal Program which provided funding for the construction of CDFs that would hold polluted sediments dredged from Great Lakes navigation projects. The program authorized the Corps to construct CDFs, in conjunction with a local sponsor, that would accommodate 10 years of dredging. The non-federal partner was typically a state agency, local government or port authority. The local sponsor was responsible for providing all lands, easements and rights of way for the construction of the CDF sites, as well as 25% of the funds for construction of the CDF. The local sponsor was responsible for the long-term maintenance of the CDF facility after it was filled. Under this authority and project specific authorities, 45 CDFs were constructed and/or operated to manage over 90 million cubic yards of contaminated sediments. The Corps built twenty-nine CDFs under the Section 123 authority. The Corps authority to operate and maintain individual navigation projects was the basis for building another 12 CDFs. Four CDFs were provided by non-federal interests. A national program for building new CDFs was created by Congress in 1996 by passage of Section 201 of the Water Resources Development Act of 1996. Uniform cost sharing requirements were identified, based on navigation channel depth. For deep draft channels greater than 18 feet an less than 45 feet, the non-federal sponsor would provided 25% of the CDF construction costs plus an additional 10 percent against which all lands, easements, rights of way and relocations may be credited. Section 217 of WRDA 1996 established guidance on developing CDFs for multiple users.

Table 9.18 provides a summary of information on CDFs constructed around the Great Lakes ranging from year built, to CDF acreage, containment size, construction cost, authority used for construction, current status, etc. Today there are twenty-four active CDFs on the Great Lakes. **Table 9.19** provides background information on these 24 sites such as CDF type, dredging cycle, cubic yards dredged per dredging cycle, years of space left. **Figure 9.1** shows the location of these active CDFs throughout the Great Lakes

Originally PL 91-611 envisioned that CDFs would be needed for a 10 year period. During this 10 year time frame there would be implementation of various pollution controls, especially from municipal and industrial point sources. These new controls would lead to reductions in the sources of contamination, and therefore a reduction in the creation of contaminated sediments, thereby eliminating or reducing the need to use CDFs.

However, the extensive historical accumulation of contaminated bottom sediments, particularly in industrial harbor areas and tributary river reaches, has led to the continued presence of contaminated sediments that require confinement. Increased urbanization and industrialization has led to land use practices that continue to result in erosion. Although there has been a significant reduction to the loading of contaminants in the past 40 years due to pollution prevention and control measures, many navigation channels continue to receive contaminated sediments from channel bottoms, newly uncovered contaminated sediments, adjacent or upstream streambanks and from non-point pollution sources. CDFs continue to be needed at various harbors throughout the Great Lakes for storage of contaminated sediments that are dredged from these harbors and channels.

9.4.2.3 Beneficial Uses - Sample Reuse Projects

The estimated average amount of material dredged per year from all federal projects on the Great Lakes is 5,385,000 cubic yards. It is estimated, on an annual basis that 2,363,000 cubic yards need to be placed into Confined Disposal Facilities. The estimated current remaining storage capacity at all Great Lakes active Federal CDFs is 25,337,000 cubic yards. Given the average amount of sediment dredged annually that needs to be placed into a CDF, and the current storage capacity remaining in Federal CDFs throughout the basin, it would take 10.7 years to fill current remaining capacity assuming no sediment withdrawals from the CDFs.

Since feasible new CDF site locations are at a premium, and new CDF construction costs can be greater than $100m, increasing the capacity at current CDFs has become an alternative to new construction. There are three approaches to increasing current CDF capacities: increased consolidation of dredged material through aggressive dewatering, raise the elevation of the surrounding dikes, and remove material from existing CDFs to make space for new dredging spoils.

Reuse of sediments at currently active CDFs has the greatest potential for extending the useful life of existing CDFs. The Great Lakes Commission, through its Great Lakes Beneficial Use Task Force, created a document titled "Beneficial Use of Great Lakes Dredged Material" in October 2001. This report outlines the need to find and advance the beneficial uses of dredged materials as an alternative to open water disposal and placement in a CDF. The report provides recommendations and strategies that would streamline State and federal initiatives that promote the beneficial use of dredged materials. The report contained 18 specific recommendations, descriptions of selected dredged material treatment technologies for beneficial use, descriptions of selected Great Lakes beneficial use projects, and profiles of each Great Lakes state's regulatory framework for beneficial use of dredged material. Beneficial reuse projects can use the dredged sediments for capping; land creation, topsoil creation, beach/littoral nourishment, and construction fill material and habitat restoration. **Figure 9.2** is a map of selected Great Lakes beneficial use projects. Two examples of beneficial reuse/restoration projects will be discussed: Pointe Mouillee CDF in Lake Erie, and sediment recycling at Duluth Superior.

Table 9.18 CDFs around the Great Lakes

CDF Name[1]	Navigation Projects Served [2]	State	Type[3]	Year Built	Size (Acres)	Initial Design Capacity[4] (Cu Yd)	Percent Filled[5]	Authority[6]	CDF Construction Cost[7]	Existing or Planned Uses After Filling	Status
Bolles Harbor	Bolles Harbor	MI	L	1978	48	335,000	38	Sec 123, PL 91-611	$972,000	marina expansion	**Active**
Buffalo Harbor - Dike 4	Bflo R,Black Rock Chnl,Ton Hrbr	NY	L	1977	107	6,900,000	52	Sec 123, PL 91-611	$15,400,000	wildlife area	**Active**
Buffalo Harbor - Small Boat Harbor	Buffalo Harbor	NY	L	1968	33	1,500,000	100	Project specific O&M	$500,000	small boat harbor parking lot	last used in 1972
Buffalo Harbor - Times Beach	Buffalo Harbor	NY	L	1972	45	1,500,000	20	Project specific O&M	$500,000	wildlife area	last used in 1976
Calumet Harbor - Chicago Area	Chcgo R, Chcgo Hrbr, Cal R, Cal Hrbr	IL	L	1984	42	1,300,000	70	Sec 123, PL 91-611	$7,800,000	port and park expansion	**Active**
Calumet River	Calumet River and Harbor	IL	U	1967	91		100	Project specific O&M		landfill	last used in 1980
Cleveland Harbor - Dike 10B	Cleveland Harbor	OH	L	1998	68	3,840,000	45	Project specific O&M	$32,900,000	airport expansion	**Active**
Cleveland Harbor - Dike 12	Cleveland Harbor	OH	L	1974	56	2,760,000	100	Sec 123, PL 91-611	$6,800,000	airport related use	last used in 1979
Cleveland Harbor - Dike 13	Cuyahoga River	OH	L	1967	10	375,000	100	Project specific O&M		airport expansion	last used in 1968
Cleveland Harbor - Dike 14	Cleveland Harbor	OH	L	1979	88	6,130,000	100	Sec 123, PL 91-611	$28,300,000	under consideration	last used in 1999
Clinton River	Clinton River	MI	U	1989	30	370,000	26	Sec 123, PL 91-611	$2,618,000	recreation	**Active**
Clinton River - Fisheries Site	Clinton River	MI	L	1971	4	21,000	100	Project specific O&M		wildlife area	last used in 1979
Detroit River - Point Mouillee	Detroit River and Rouge River	MI	I	1979	700	18,640,000	45	Sec 123, PL 91-611	$55,856,000	wildlife area	**Active**
Duluth-Superior Harbor - Erie Pier	Duluth-Superior Harbor	MN	L	1979	82	1,000,000	65	Sec 123, PL 91-611	$1,558,000	recreation	**Active**
Erie Harbor	Erie Harbor	PA	L	1979	23	420,000	10	Sec 123, PL 91-611	$2,006,000	recreation	**Active**
Grand Haven Harbor - Harbor Island	Grand Haven Harbor	MI	U	1974	36	310,000	100	Sec 123, PL 91-611	$433,000	recreation	last used in 1995
Grand Haven Harbor - Verplank Site #1	Grand Haven Harbor	MI	U	1974	19	134,000	100	Project specific O&M		aggregate storage	transfer site
Grand Haven Harbor - Verplank Site #2	Grand Haven Harbor	MI	U				100	Project specific O&M		aggregate storage	transfer site
Green Bay Harbor - Bayport	Green Bay Harbor	WI	U	1965	380	650,000		PS O&M, Sec 123, EPA grant	$4,670,000	dewatering/transfer site	turned over to sponsor
Green Bay Harbor - Renard Island	Green Bay Harbor	WI	I	1979	60	1,200,000	72	Sec 123, PL 91-611	$5,564,000	recreation	last used in 1996
Holland Harbor - Holland Township Site	Holland Harbor	MI	U					Provided by sponsor			**Active**
Holland Harbor - Riverview Site	Holland Harbor	MI	L	1978	11	120,000	85	Sec 123, PL 91-611	$1,583,000	recreation/park	last used in 1993
Holland Harbor - Windmill Site	Holland Harbor	MI	U	1978	17	160,000	100	Sec 123, PL 91-611	$1,654,000	recreation/park	last used in 1995
Huron Harbor	Huron Harbor	OH	L	1975	63	2,600,000	65	Sec 123, PL 91-611	$6,400,000	small boat harbor	**Active**
Indiana Harbor	Indiana Harbor & Canal	IN	U	2009-P	96	4,800,000	0	R&HA 1910,30,35,37,60 WRDA 86,96	$118,000,000	recreation/park	**Active**
Inland Route	Inland Route	MI	U	1982	9	19,500	92	Sec 123, PL 91-611	$176,000	wildlife area	**Active**
Kenosha Harbor	Kenosha Harbor	WI	L	1975	32	750,000	40	Sec 123, PL 91-611	$8,270,000	marina	last used in 1987
Kewaunee Harbor	Kewaunee Harbor	WI	L	1982	28	500,000	74	Sec 123, PL 91-611	$2,017,000	recreation	**Active**
Keweenaw Waterway	Keweenaw Waterway	MI	U	1987	50	308,000	50	Sec 123, PL 91-611	$941,000	recreation	**Active**
Lorain Harbor	Lorain Harbor	OH	L	1977	58	1,850,000	56	Sec 123, PL 91-611	$7,900,000	small boat harbor	**Active**
Manitowoc Harbor	Manitowoc Harbor	WI	L	1975	24	800,000	57	Sec 123, PL 91-611	$4,147,000	marina/recreation	**Active**
Michigan City Harbor	Michigan City Harbor	IN	U	1978	3	50,000	100	Sec 123, PL 91-611	$300,000	under consideration	last used in 1988
Milwaukee Harbor	Milwaukee Harbor	WI	L	1975	44	1,600,000	87	Sec 123, PL 91-611	$5,963,000	port expansion	**Active**
Monroe Harbor - Edison Site	Monroe Harbor	MI	L	1974	43		100	Provided by sponsor		private land	last used in 1984
Monroe Harbor - Sterling State Park	Monroe Harbor	MI	L	1983	89	4,300,000	44	Sec 123, PL 91-611	$38,380,000	state park	**Active**
Port Sanilac Harbor	Port Sanilac Harbor	MI	U	1979	13	143,300	100	Project specific O&M		municipal landfill	Site provided by contractor
Rouge River - Grassy Island	Rouge River	MI	U	1960	80	2,500,000	77	Project specific O&M	$747,000	wildlife area	last used in 1983
Saginaw River - Saginaw Bay	Saginaw River	MI	I	1978	283	10,000,000	87	Sec 123, PL 91-611	$14,844,000	wildlife area	**Active**
Saginaw River -Middleground Island	Saginaw River	MI	U	1978	13	150,000	100	Project specific O&M	$3,214,000	recreation	last used in 1983
Sebewaing Harbor	Sebewaing Harbor	MI	U	1979	9	84,000	100	Sec 123, PL 91-611	$1,300,000	airport expansion	last used in 1988
Sebewaing Harbor - Marina Site	Sebewaing Harbor	MI	U		11			Provided by sponsor			**Active**
St, Clair River - Dickinson Island	St. Clair R & L. St. Clair Chnls	MI	U	1975	174	2,000,000	71	Sec 123, PL 91-611	$5,072,000	wildlife area	**Active**
St. Joseph Harbor - Malleable Site	St. Joseph Harbor	MI	U	1978	15	35,000	100		$173,474	private land	material removed from site
St. Joseph Harbor - Whirlpool Site	St. Joseph Harbor	MI	U	1978	14	25,000	100	Project specific O&M	$638,000	tranfer site	last used in 1999
Toledo Harbor - Island 18	Toledo Harbor	OH	I	1961	150	5,000,000	92	Provided by sponsor	$5,000,000	wildlife area	last used in 1978
Toledo Harbor - Riverside Park	Toledo Harbor	OH	U	1961	150		100	Project specific O&M			last used in 1961
Toledo Harbor - Site 3	Toledo Harbor	OH	L	1976	242	11,100,000	98	Sec 123, PL 91-611	$18,400,000	wildlife area	**Active**
Toledo Harbor - Site 3 Extension	Toledo Harbor	OH	L	1994	155	5,300,000	0	Project specific O&M	$4,800,000	wildlife area	**Active**

Legend

1 - CDF name is that most commonly applied, not necessarily a formal title

2 - Federal navigation project from which material was dredged

3 - CDF types (L = in-lake site attached to land; I = in-lake island; U = upland site)

4 - Planned capacity of CDF at time of construction

5 - Percent filled, based on adjusted capacity estimates

6 - Authority for CDF construction. Bayport CDF expanded by non-Federal sponsor with local funding and grant from EPA

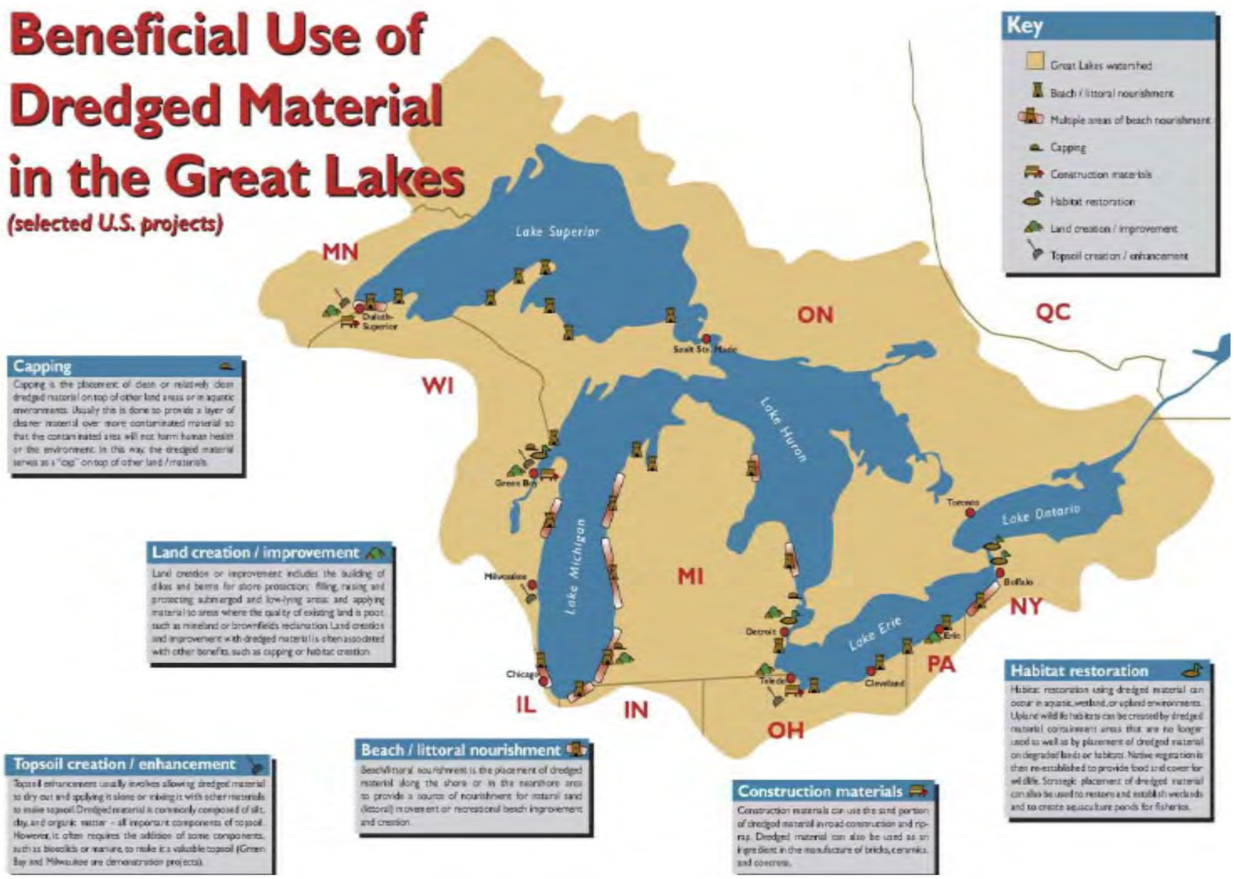
7 - Contract cost for CDF construction, not inflated to current value. Does not include planning and design costs. Some early CDFs were developed by non-Federal interests for limited or one-time use, and construction costs are unknown.

Table 9.19 Active CDFs –Background Information

CDF Name	Type (L,I,U)	Year Built	Construction Authority	CDF Area (Acres)	Total Capacity (Cubic Yards)	Dredging Cycle	Placement Per Dredging Cycle	Years Of Capacity Remaining
Bolles Harbor CDF	L	1978	Section 123	25	335,000	Yearly	4,913	< 5
Buffalo Harbor - Dike 4 CDF	L	1977	Section 123	107	6,900,000	2-3 Years	160,000	> 10
Calumet Harbor - Chicago Area CDF	L	1984	Section 123	42	1,300,000	Yearly	50,000	< 5
Cleveland Harbor - Dike 10B CDF	L	1998	PS O&M	68	2,900,000	Yearly	300,000	< 1
Cleveland Harbor - Dike 12 CDF	L	1974	Section 123	56	2,760,000	Yearly	250,000	< 5
Clinton River CDF	U	1989	Section 123	30	370,000	Yearly	4,674	< 5
Detroit River - Pointe Mouille CDF	I	1981	Section 123	700	18,000,000	Yearly	343,704	> 10
Duluth-Superior Harbor - Erie Pier CDF	L	1979	Section 123	82	2,492,511	Yearly	25,517	< 5
Erie Harbor CDF	L	1979	Section 123	23	420,000	Infrequent	100,000	> 10
Green Bay Harbor - Bayport CDF	L	1977	Section 217	125	2,500,000	Yearly	150,000	> 10
Holland Harbor - Holland Township Site	U	1996	Dredgng Contract	50	400,000	Yearly	30,000	> 10
Huron Harbor CDF	L	1975	Section 123	63	2,600,000	1-2 Years	180,000	> 10
Indiana Harbor CDF	U	2009-P	Multiple R&H Acts	96	4,800,000	Yearly	200,000	30
Inland Route CDF	U	1982	Section 123	9	19,500	Yearly	285	< 5
Kewaunee Harbor CDF	L	1982	Section 123	28	500,000	Yearly	14,231	< 5
Keweenaw Waterway CDF	U	1987	Section 123	21	308,000	Yearly	7,480	< 5
Lorain Harbor CDF	L	1977	Section 123	58	1,850,000	Yearly	150,000	< 5
Manitowoc Harbor CDF	L	1975	Section 123	24	800,000	Yearly	11,879	< 5
Milwaukee Harbor CDF	L	1975	Section 123	44	1,600,000	Yearly	38,303	5-10
Monroe Harbor - Sterling State Park CDF	L	1983	Section 123	89	4,300,000	Yearly	84,280	> 10
Saginaw River - Saginaw Bay CDF	I	1978	Section 123	283	10,849,856	Yearly	320,000	5-10
St. Clair River - Dickinson Island CDF	I	1975	Section 123	174	2,000,000	Yearly	40,606	5-10
Toledo Harbor - Island 18 CDF (Grassy Island)	I	1962	PS O&M	150	5,000,000	Infrequent	-	< 5
Toledo Harbor - Site 3 CDF	L	1976	PS O&M	397	16,400,000	Yearly	200,000	5-10

FIGURE 9.1 - Active CDF Locations

Figure 9.2 Beneficial use of Dredged Material



9.4.2.4 Spoil Management/Placement Alternatives

Open water placement involves the transfer of dredged sediment, usually by bottom-dump barges or scows, to a designated discharge area, located several miles out in the open lake. The discharged dredged material settles to the Lake bottom based on the materials physical properties and the hydrodynamics of the deposit site.

Beach/littoral nourishment typically involves placing the sediment onto a beach or into shallow water. Beach nourishment typically involves fine sand being hydraulically pumped onto a beach. Littoral nourishment typically involves near shore discharge of sediments from bottom-dump scows. Beach and littoral nourishment accounts for about 19% of the sediments dredged yearly. USACE technical guidance on beach/littoral nourishment is provided in EM 1110-2-5026, Engineering and Design - Beneficial Uses of Dredged Material.

Capping involves the placement of contaminated sediment in either a contained aquatic disposal or a level bottom and covering the sediment with a layer of clean material. Capping is used extensively in the ocean in New York and New England, but is not used in the Great Lakes. USACE technical guidance on dredged material capping is provided in Technical Report DOER-1, June 1998.

Beneficial Use includes beach and littoral nourishment as well as a variety of upland applications such as construction fill, landscaping, agricultural applications, and wetland habitat Upland application starts with the dewatering of dredged material, and then the transport of the dewatered sediment (By truck, rail) to the final end use site. The use of dredged material to create islands for wildlife habitat is accomplished by direct placement of dredged material from a pipeline to a pre-developed in water disposal site. USACE technical guidance on Beneficial Use is provided in Technical Report DOER-C2, May 1999.

Confined Disposal is restricted to sediments that cannot be open lake placed or used beneficially due to the chemical composition of the sediments. These sediments are placed in nearshore/inwater/upland Confined Disposal Facilities or commercial landfills. The CDFs vary in size shape, design, and level of complexity based on needed quantities dredged, disposal method, sediment contamination levels, state and local requirements and site characteristics.   USACE technical guidance on Confined Disposals facilities is provided in such documents as Engineer Manual 1110-2-5027 (U.S. Army Corps of Engineers 1987) and ERDC TN-DOER R6, December 2004.

Treatment Methodologies involves the introduction of chemical or biological additives to polluted sediments that result in a physical restructuring of the sediments. Numerous studies have been performed by U.S. EPA (GLNPO 5 year ARCS study 1988-1994) and the Corps of Engineers (ERDC-TN DOER C11, March 2000) on a range of treatment technologies. In general these treatment technologies tend to be several times more expensive that other sediment management options.

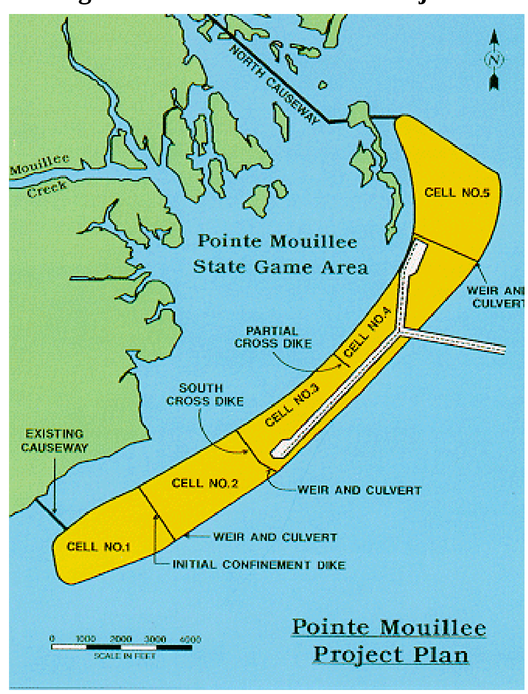
9.4.2.5 Confined Disposal Facility Planning

As identified previously, CDFs have been constructed under the authority of Section 123 of the River and Harbor Act of 1970 (PL 91-611), under Operation and Maintenance authorities, and by local entities. Congress established uniform local cooperation requirements for all new CDFs in 1996.

There is a specific sequence of activities that take place in planning and constructing a CDF. These steps include: site selection, identification of a local sponsor, development of an Environmental Impact Statement, detailed design, signing a Local Cooperation Agreement, obtaining appropriate permits, and construction. There are a number of opportunities for input and comment by the public during this process.

The Corps role with respect to commercial navigation is presented in The Planning Guidance Notebook (ER 1105-2-100, 3-1): “provide safe, reliable, and efficient waterborne transportation systems (channels, harbors, and waterways) for movement of commerce, national security needs, and recreation. The Corps accomplishes this mission through a combination of capital improvements and the operation and maintenance of existing projects”. The Guidance goes on to state (Section 3-4) that dredged material planning will be performed for all federal harbor projects to ensure that maintenance dredging activities are performed in an environmentally acceptable manner, using sound engineering techniques, is economically warranted, and that sufficient confined disposal facilities are available for at least the next 20 years. This is accomplished by performing a Preliminary Assessment. If the Preliminary Assessment finds there is not sufficient storage for 20 years of dredging, a dredged material management study must be performed (E-69). These Dredged Material Management Plan (DMMP) studies follow guidance provided in the Planning Guidance Notebook and Engineer Circular (EC) 1165-2-200. DMMPs develop a range of management strategies (alternatives) for providing future sediment storage needs including: extending the useful life of existing disposal sites, developing new deposal sites, reducing dredging requirements, and beneficial use alternatives. A least-cost alternative is developed (Base Plan) that is consistent with sound engineering practice and meets all Federal Environmental Standards. The Base Plan can include open lake placement as well as beneficial uses of dredged material. All dredging alternatives developed by the DMMP are compared to the "Base Plan". These plans are then evaluated based on their ability to meet specific planning objectives, their environmental impacts, and economic costs and benefits. A tentatively selected plan is then chosen based on the evaluation. The Pointe Mouillee and Erie Pier CDF operations are provided as two examples of beneficial reuse/restoration projects associated with CDF projects. With other CDF's around the Great Lakes reaching capacity, these projects are examples of how new CDF projects can be developed as being multi-purpose in nature. This allows new CDF construction to provide support from multiple stakeholders.

Figure 9.3- Pointe Mouillee Project



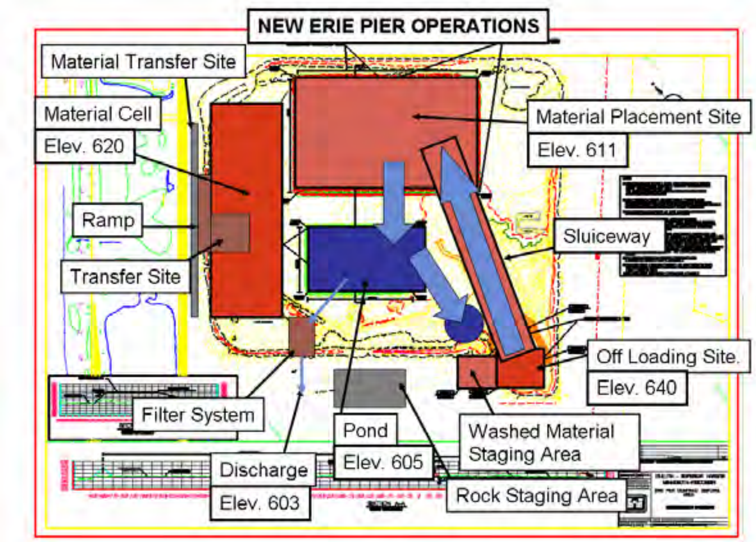
The Pointe Mouillee CDF (**Figure 9.3**) is near the mouth of the Huron River in Lake Erie. The Huron River area has extensive wetlands. Dams built on the river have resulted in a reduction in river sediment flows, which resulted in the erosion of a natural barrier island that protected back barrier marshes. The CDF is a multipurpose 700 acre facility that is 3.5 miles long and 1,400 feet wide. The CDF's primary purpose is to act as a disposal site for contaminated dredged material removed from excising navigation channels in the Detroit and Rouge Rivers. The facility also acts as a protective barrier for the Pointe Mouillee State Game area and marsh. The 18m cubic yard facility was built between 1976 and 1981 at a cost of $45.5m.

The presence of the CDF has allowed the Michigan DNR to plan a marsh restoration and agricultural program for the protected Pointe Mouillee State Game Area. This plan calls for the restoration of 1,900 acres of marsh in three separate compartments by constructing 10,000 linear feet of dikes which will allow water levels to be managed within the marsh. Also envisioned is an agricultural program where 900 acres of farm fields will be developed by constructing/repairing 35,000 lineal feet of low level dikes. This will allow the agricultural acres to be periodically flooded and dewatered using gates and pumps. This land will act as an attractant to waterfowl by providing food for migrating and local waterfowl. This area will be managed as a multipurpose refuge including bird watching, public education programs and public hunting zones.

<u>Duluth Superior Particle Separation at Erie Pier CDF Duluth.</u>

Erie Pier is an 89 acre CDF located in Duluth Superior built in 1978-9 to hold 1.1m cubic yards of dredged material. It had an expected life of 10 years. Approximately 100,000 cubic yards is dredged annually, with 79,000 cubic yards being placed in the CDF.

Figure 9.4 – Erie Pier CDF and Operations



An hydraulic sorting operation is performed where the dredged sediment is sorted into various sediment sizes. Water is pumped over the dredged material in a sloping part of the CDF resulting in the settling out of coarser/cleaner material. This material is then stockpiled in various staging areas where it can be removed and used for construction fill in highways and at building sites. Other potential uses include mine reclamation projects, daily landfill cover, top soil creation enhancement, habitat restoration and habitat creation. The *East Pier Management Plan, June 2007*, calls for the analyzing and evaluating materials being dredged against Minnesota and Wisconsin beneficial reuse guidelines to classify how the material at Erie Pier can be beneficially reused. The Management Plan addresses such issues as material transfer facilities, noxious weed and exotic species managements, material sampling and testing procedures, material marketing and pubic education.

9.5 Summary

The impetus for the development of a new model, Great Lakes - System Analysis of Navigation Depths (GL-SAND), was the refinement of Great Lakes transportation cost modeling to support future operation and maintenance in the prioritization of dredging work. The existing models, Great Lakes Level Analysis of Port Operation and Maintenance (GLLAPOM) and Great Lakes Levels Analysis for System Transportation (GLLAST) presented many limitations that are addressed in the GL-SAND model.

Great Lakes dredged material management efforts have favored methods of dredged disposal material placement other than the traditional construction of new confined disposal facilities given the significant expenditure required to construct new disposal facilities and the inclination to utilize dredged material for beneficial uses.

10.0 Risk Based Analysis of Breakwater Maintenance

10.1 Introduction

The reliability of many USACE structures has degraded and the subsequent risk of failure has increased due to advancing age and insufficient funding for accustomed maintenance and rehabilitation. This has provided additional motivation for more rigorous asset management applications, critical components of which are: knowledge of the structures' condition, their functional reliability, and the risks and consequences of poor performance or failure. The Corps of Engineers is encouraging (and even requiring) greater use of risk-based analytical methods in evaluating the engineering and economic performance of its proposed investments with the intent of improving the quality of its decisions.

The purpose of Section 10 is to present a risk based evaluation framework of proposed maintenance on a selected Great Lakes breakwater. The intent of this section is not to provide an analysis for use in determining the feasibility, timing or sizing of various alternatives that address the problem of breakwater deterioration or failure but rather to offer a framework to conduct such an analysis. This section provides a description of three distinct activities with examples for conducting a detailed risk-based analysis: 1) a coastal analysis as it relates to breakwater failure, 2) identification of the economic consequences associated with various degrees of breakwater deterioration, 3) a risk model that combines the results of these two activities. The level of effort and cost for completing an actual risk-based evaluation for a breakwater on the Great Lakes is outside the scope of this analysis. This evaluation is limited to outlining the steps to perform such an evaluation along with some portions of actual examples for these steps for an actual Great Lakes breakwater.

The site selected to illustrate the steps needed for a risk-based evaluation is a section of the East Breakwater at Cleveland Harbor, Ohio. Cleveland Harbor is located in the city of Cleveland, Cuyahoga County, Ohio on the southern shore of Lake Erie. The length of the East Breakwater is 21,270 feet. It was constructed to a design height of 10.3 feet above Low Water Datum (LWD). The westerly 3,300 feet is composed of a timber crib substructure with stone protection on the lakeside and a stone superstructure. The cribbing was constructed between 1887 and 1900 and the stone superstructure between 1917 and 1926. The easterly 17,970 feet is of laid-up (ashlar) stone construction over a stone core. The easterly section was constructed between 1903 and 1915.

The proposed site is located adjacent to a repair site completed in 2000 and extends from station 84+00 to ~station 106+29. The site selected on the basis of an assessment by the Great Lakes Breakwater Assessment Team (BAT). This team is comprised of subject-matter expert personnel from all three Great Lakes Districts. The BAT oversees annual condition assessment inspections to ensure adequacy and consistency, periodically performs inspections collectively, completes structural Condition Index ratings (with respect to impact on harbor operations) in accordance with ERDC/CERL procedures, and provides long range program management. An attachment to this appendix, *Risk-Based Analysis of Harbor Breakwater*

Repair Using a Section of Cleveland East Breakwater as an Example, discusses data and methods used in the coastal engineering analysis of this breakwater.

10.2 Navigation Structures

10.2.1 General

There are nearly 104 miles of navigation structures that form the 117 federal harbors operating within the Great Lakes Navigation System (GLNS). Over two-thirds of the existing navigation structure components were built prior to World War II. Approximately 58.4 miles of the Great Lakes federal navigation structures have not had a major rehabilitation effort completed within the past 50 years. Of that group, approximately 19 miles have never had any major rehabilitation effort performed. Among the roughly 45.5 miles of “newer” structures, major rehabilitation efforts were completed 40 years ago or more for approximately 30 percent. In general, approximately 70 percent of federal navigation structures are ending their design life, or have been in service for periods long past the design life that was originally anticipated, and their collective deterioration is substantial.

Breakwaters are structures built adjacent to navigation channels that are designed to protect vessels in the channel and harbor from the dangers caused by high waves, such as the danger of collisions. While breakwaters are considered important and have been part of all harbor improvements over the centuries, their importance has been considered self-evident and not subject to detailed risk analysis.

10.2.2 Factors that Affect Breakwater Performance

Two major factors that affect breakwater performance are age, and storm damage. The physical characteristics from storms that affect breakwater performance include high lake levels, and wave heights.

10.2.2.1 Age

Breakwater deterioration occurs through the gradual aging of the structure and/or its components over time. Deterioration can progress slowly, and often goes undetected because the project continues to function as originally intended even in its diminished condition. However, if left uncorrected, continual deterioration can lead to partial or complete failure of the structure. Structure aging is a change to a portion of the structure that affects its function. Examples of structure aging include: settlement or lateral displacement of the structure, loss of slope toe support, partial slope failure, loss of core or backfill material, and loss of armor units. Unit aging is defined as deterioration of individual components which could eventually affect the structure's function. Examples of unit aging for breakwaters include: breakage of concrete armor units and fracturing of armor stone. Because coastal structure aging is a slow process, and the severity of deterioration may be hidden from casual inspection, rehabilitation often is given a low priority and may be postponed if the structure is still functioning at an acceptable level. Saving money by neglecting needed repairs runs the risk of facing a far more expensive (and possibly urgent) repair later.

10.2.2.2 Storm Damage

Over the projected life of a project, the structural components are susceptible to damage and deterioration. Coupled with the continual deterioration resulting from the age of the structure is the damage through structure degradation that occurs over a relatively short period from a single storm event, or even a winter storm season. Damage might be due to storm events that exceed design levels, impacts by vessels, seismic events, unexpected combinations of waves and currents, or some other environmental loading condition.

Low lake levels and low wave heights create a situation of minimum risk to breakwaters function. Conversely, high lake levels and high wave heights create a situation of high risk. The risk levels are exacerbated by deterioration in the structure, which is generally a function of age and original construction techniques. Together these three factors – lake levels, wave heights, and structural integrity – determine the effectiveness of the breakwater structure.

The critical components of rubble-mound and laid-up stone breakwaters that can be adversely affected by age and storm damage are the cross section slope condition and the quality/voids in the core stone, armor stone and toe stone.

10.3 Analytical Framework

The first step in any damage evaluation is to assess the baseline conditions, i.e., the conditions that would likely exist in the absence of any corrective action to address the existing problems in a systematic fashion. In the deterministic approach, which is the traditional approach used by the Corps, point estimates define the physical and economic changes that are expected to occur under the baseline or "without-project" condition. These changes do not take into consideration the uncertainty associated with these point estimates. The development of the "without-project" condition requires assumptions to determine when responses of various types will occur over time. In a risk-based approach to evaluations, the relatively simple definition of the "without-project" condition used in the deterministic methodology is modified to incorporate uncertainties about such factors as storm frequencies, (distribution of wave heights), water levels and the extent of geomorphic changes and property losses produced by storms and waves.

10.3.1 The Model

The economics of the breakwater was evaluated using risk and reliability analysis. This was accomplished by developing a life cycle simulation model that considered the reliability of the project and the expected consequences of unsatisfactory performance. The core logic of the model is based on the possible sequences of events as shown on the event tree. The model is designed to simulate the performance of the project for a fifty year time period, i.e. it performs life-cycle analysis. Excel software with the @Risk add-on feature were used for the programming. Excel and @Risk are both commercial-off-the-shelf software applications with wide use by academic, corporate, and government entities. The model includes embedded formulas developed and/or entered into the @Risk enhanced Excel workbook that are sequentially executed as part of the simulation process. For major rehabilitation evaluations, the model should be documented and reviewed. A brief description of the computations performed by the model follows.

Step 1: generate a random number between 0 and 100%;

Step 2: compare the random number to lake levels and select the lake level whose frequency corresponds to the random number (i.e. a random number of 1% would lead to selection of lake level that occurs once every 100 years;

Step 3: generate a second random number between 0 and 100%;

Step 4: compare the second random number to wave height and select the wave height whose frequency corresponds to the random number (i.e. a random number of 1% would lead to selection of wave height that occurs once every 100 years;

Step 5: lookup the probability of unsatisfactory performance for the simulated lake level and wave height;

Step 6: lookup the probability of unsatisfactory performance due to deterioration over time;

Step 7: multiply the probability of unsatisfactory performance due to lake/wave levels by the probability of unsatisfactory performance due to age to compute the overall probability of unsatisfactory performance;

Step 8: lookup the probability of a major failure given unsatisfactory performance at the simulated lake and wave heights;

Step 9: multiply the probability of a major failure (Step 8) by the probability of unsatisfactory performance (Step 7) to compute the probability of a major failure;

Step 10: performs steps 7 thru 9 for minor failure;

Step 11: express the probability of a minor failure as branch 1 as the range from 0% up to the probability of a minor failure; add the probability of a major failure to the probability of a minor failure to compute the upper value of the probability of a major failure (branch 2); the probability of no failure (branch 3) is the range from the probability of a major failure up to 100%;

Step 12: generate a third random number between 0 and 100%;

Step 13: compare the third random number to the branch probabilities to determine if the project performed satisfactorily or unsatisfactorily, and if unsatisfactorily whether it was a major or minor failure;

Step 14: enter consequences:

14.1 if no unsatisfactory performance then skip to next year and repeat simulation process starting with step 1;

14.2 if yes to unsatisfactory performance, then cross reference degree of failure (major or minor) with the repair costs, navigation delays, damages within the harbor, and other infrastructure damages; and

Step 15: sum the consequences for the simulated year; if satisfactory performance then sum equals zero; if unsatisfactory performance and minor failure then minor cost consequences; if unsatisfactory and major failure then high cost consequences; adjust reliability factor due to repairs;

Step 16: repeat steps 1 thru 15 for the other 49 years in the life cycle;

Step 17: repeat step 16 for all 20,000 iterations;

Step 18: provide results.

A few notes: 1) each year in the fifty year period of evaluation is simulated; this is equal to one life cycle; 2) twenty thousand iterations of the life cycle are simulated; 3) simulated lake levels, wave heights, and damages for values not expressly input are linearly interpolated from the input values; and 4) the values for all iterations are averaged to compute the average values shown as the economic outputs. An example of the operation of the model according to the above steps is shown in **Table 10.1**.

Table 10.1 - Example of Simulation Procedure and Computations

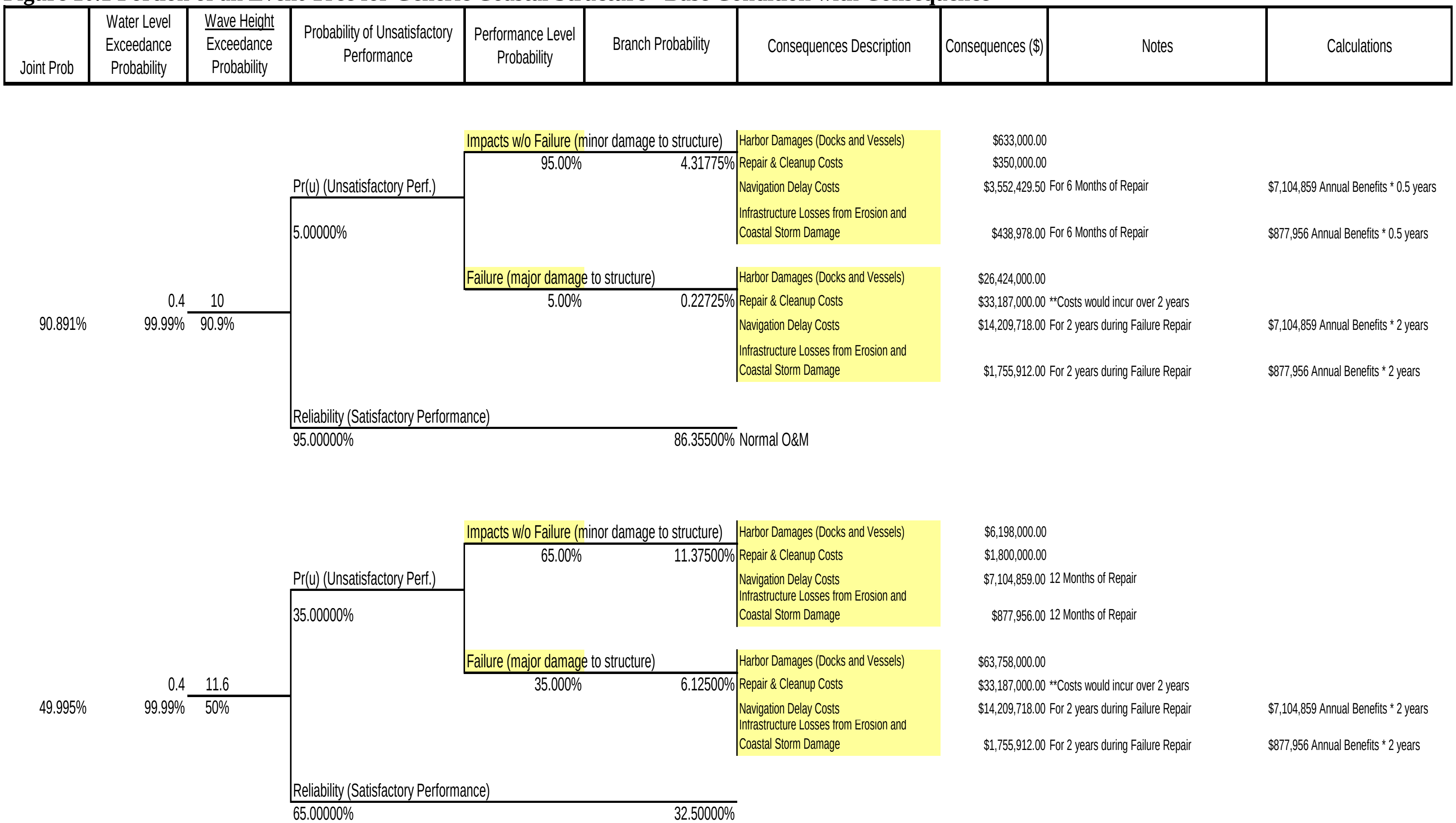
Step	Description	Value	Computation
1	Random number 1	0.33	
2	Lake level of 33% frequency of occurrence	2.3	
3	Random number 2	0.67	
4	Wave height of 67% frequency of occurrence	8.2	
5	Probability of unsatisfactory performance (PUP) due to lake/wave levels	0.15	
6	Probability of unsatisfactory performance (PUP) due to age-induced deterioration	0.05	
7	Overall probability of unsatisfactory performance is computed.		0.15 x (1 + 0.05)
8	Lookup probability failure in major given failure	0.23	
9	Compute probability of major failure	0.04	.15 x .23 x (1+.05)
10	Compute probability of minor failure	0.12	.15 x .77 x (1+.05)
11	Compute probability range for major failure (br 1)	0.00-0.04	
	Compute probability range for minor failure (br 2)	0.05-0.16	.04+.12
	Compute probability range for no failure (br 3)	0.17-1.00	
12	Random number 3	0.05	
13	Determine simulated project performance by comparing random number to probability ranges.		
	Minor failure simulated since r.n. between 0.05 and 0.12		
14	Lookup consequences	$10	$5 for repair; $5 for damages
15	Add up consequences for simulated year	$10	
16	Repeat simulation for all 50 years in life cycle and compute average consequences	$13	
17	Repeat simulation for all 20,000 iterations and average the consequences	$12	
18	Provide results	$12	

10.3.2 Event Tree

For a risk based breakwater evaluation, an event tree can be used to describe the many random factors contributing to major storm event, breakwater damage, and resultant harbor and shoreline impacts. This in turn allows evaluation of the probability of a breakwater failure and the associated distribution of damages and associated impacts. Monte Carlo simulation is used in conjunction with event tree analysis to calculate the actual probability of failure. A portion of an example event tree depicting the factors that could affect the reliability of the Cleveland East breakwater is provided on the next page (Figure 10.1). Each node on the tree represents a situation where two or more mutually exclusive events may occur, given that events leading to the node have already occurred.

For each branch from a node, a conditional probability of occurrence is assigned (conditioned on reaching the node via the preceding events). The set of conditional probability values emanating from each node must total to unity. In accordance with the total probability theorem, multiplying values along any path through the tree gives the probability of the outcome at the end of the path.

Figure 10.1 Portion of an Event Tree for Generic Coastal Structure - Base Condition with Consequence



10.3.3 Verification of Simulation Model

The models should be verified prior to accepting the outputs as correct by comparing the output of the model to the expected value of the consequences for the first year in the simulation period. This method typically works since the reliability factor in year one is a given and has not been changed by repairs or replacements. This method of verification was attempted for this example breakwater model, but the complexity of the expected value calculations required more time than was available for the scope of this effort. However for illustration purposes, an approximate method was used and the results indicated that the model output was in the range of the expected value number. An example of the procedure used in the verification process and corresponding results are provided below.

Step 1: interpolate frequency values for lake level elevations in .1 foot increment 0.0 to 6.8 feet;

Step 2: interpolate frequency values for wave height elevations in .1 foot increment 0.0 to 14.9 feet;

Step 3: interpolate repair costs for major failures given different lake levels and wave heights;

Step 4: interpolate repair costs for minor failures given different lake levels and wave heights;

Step 5: interpolate damage values and other related costs for major failures given different lake levels and wave heights;

Step 6: interpolate damage values and other related costs for minor failures given different lake levels and wave heights;

Step 7: compute matrix listing wave height probabilities for each (interpolated) lake level;

Step 8: compute interval probabilities for wave height/lake level matrix so sum equals 100% (this was unsuccessful) so I did approximation from this point on;

Step 9: compute a normalizing factor by dividing 100% by the computed probability from Step 8 so that recurrence probabilities would equal 100%;

Step 10: apply normalizing factor to expected value of consequences;

Step 11: compare the normalized expected value with the output of the model.

10.3.4 Input Data

Examples of possible economic consequences of unsatisfactory performance include the cost of repairing the project, damages from storm events with the breakwater while in a disrepair state, increased costs of harbor operation resulting from the new wave regime while in a disrepair state, increased dredging costs, and the loss of recreation benefits while the project is under repair. The complexity of the input data requirement is compounded by the fact that there are unique economic consequences of unsatisfactory performance for each condition of breakwater deterioration. Also there are new interior harbor wave regimes with their respective associated probabilities with each new condition of breakwater deterioration.

The inputs to the model are typically the probabilities and values for the factors shown on the event tree. The next two sections (10.4 and 10.5) discuss and present inputs used in the Cleveland East Breakwater example, specifically: 1) describing the probability of a failure and 2) describing the economic consequences of component failure.

10.4 Probability of Failure and Damage Consequence – Cleveland East Breakwater

10.4.1 Structural Reliability and Deterioration of Structure over Time

The deterioration of the original construction materials over time in combination with elisions and harsh weather result in the deterioration of the structural reliability of the breakwater over time. The rate of deterioration over time is illustrated in Figure 10.2 and is listed in **Table 10.2**. The rate was estimated by breakwater engineers based on experience and judgment.

Figure 10.2 Coastal Structure Degradation Curve

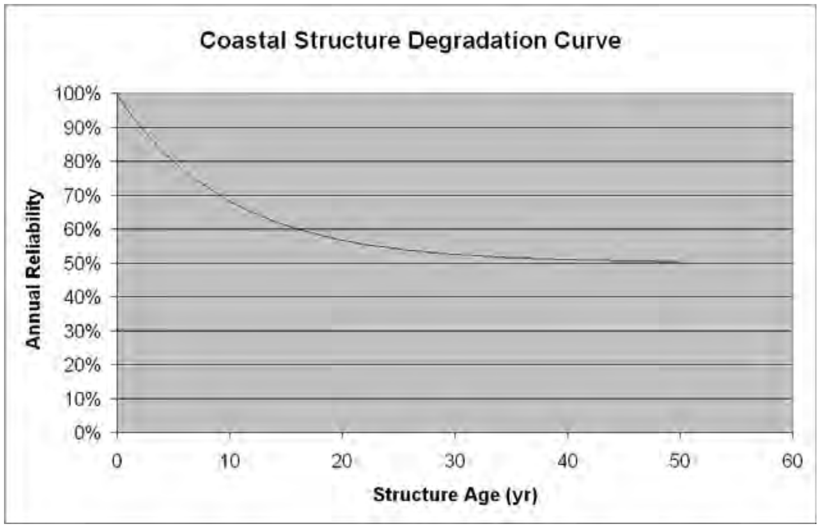


Table 10.2 - Reliability of a Breakwater over Time

Year	Annual Reliability AR = (1-AHR)	Annual Hazard Rate
0	99.50%	0.50%
1	94.79%	5.21%
2	90.53%	9.47%
3	86.67%	13.33%
4	83.18%	16.82%
5	80.02%	19.98%
6	77.17%	22.83%
7	74.58%	25.42%
8	72.24%	27.76%
9	70.13%	29.87%
10	68.21%	31.79%
AR_0	AR_{min}	exponent
99.50%	50%	-0.1 yr

10.4.2 Wave Heights and Lake Levels

High waves combined with high lake levels and deteriorated structures increase the likelihood of some form of failure of the breakwater structures. The probable annual occurrence of specified water levels and wave heights are provided in **Tables 10.3** and **10.4**. The probabilities were provided by Great Lakes water management experts based on historic data.

Table 10.3 - Lake Levels on Lake Erie

Lake level	Frequency in years	Exceedance probability
0.4	1.0001	1.00
3.8	2	0.50
6.8	100	0.01

Table 10.4 - Wave Heights on Lake Erie

Wave height	Frequency in years	Exceedance probability
10.0	1.1	0.91
11.6	2	0.50
14.9	100	0.01

10.4.3 Joint Probabilities and Damage Consequence

It is assumed that lake levels and storm generated wave heights are independent events. Considering the combinations of these two simple three point curves, the estimated affect on breakwater impact was derived with expert elicitation techniques. The results are presented in **Table 10.5**.

Table 10.5 - Damage Consequences from Combination Water Level and Wave Height Events

			Breakwater		
Water Level (above LWD) / Frequency	Wave Ht (ft) / Frequency	Joint Frequency Rank	Damageability Rank[1]	Affect [1] (0-100)	Affect [2] (0-100)
0.4 99.99%	10 90.9%	9	9	10	5
0.4 99.99%	11.6 50%	8	6	40	35
0.4 99.99%	14.9 1%	5	3	90	90
3.8 50%	10 90.9%	7	8	10	10
3.8 50%	11.6 50%	6	5	40	40
3.8 50%	14.9 1%	2	2	95	95
6.8 0.01	10 90.9%	4	7	10	15
6.8 0.01	11.6 50%	3	4	40	45
6.8 0.01	14.9 1%	1	1	100	100

1/ LRB Coastal Engineering (Mike Mohr) initial expert elicitation
2/ LRB Operations Tech Support (Paul Bijhouwer) initial expert elicitation

10.4.4 Different Types of Unsatisfactory Performance

The term failure is often used when a project performs in an unsatisfactory manner. However for simplicity, failure for the purposes of this illustration refers to a nearly catastrophic failure of the project to the point that it is totally ineffective in terms of its purpose. As such, it is one type of unsatisfactory performance albeit the one with the greatest consequences. Another type of unsatisfactory performance might be a localized breach of the breakwater such that the overall structure continues to provide some benefits although less than it was intended. These two types of unsatisfactory performance are considered reflective of what may occur. For the purposes of this example, probabilities were assigned to each type of unsatisfactory performance based on judgment and experience.

10.5 Economic Consequences of Failure – East Cleveland Breakwater

10.5.1 Items Potentially Affected by Failure

The Cleveland Harbor Port Authority assisted in identifying those activities that might be affected and to what degree they would be affected by breakwater failure under varying degrees of potential storm and wave regimes in the inner harbor. Meetings were held in August 2008 with Cleveland Harbor Port authority personnel. The purpose of the meeting was to identify the impacts of a breakwater failure on the operations of the port authority, and vessel operators. The type of impacts discussed ranged from changes in port operational procedures, to additional port based expenditures, additional ship operating expenditures due to delays, need for additional tug assistance, port infrastructure damages, port facility flooding, new dredging at the port facility, additional dredging at port docks, relocation of port activities to different docks, availability/usage of warehouse facilities, etc. Also discussed were current and future commodity movements and cargo handling requirements needed to service these commodity movements, and the impact that a breakwater breach would have on accommodating these tonnages.

One of the goals of the meeting was to obtain information on current vessels entering the affected area, how these vessels are loaded, unloaded, where commodities are staged/stored, how breakwater deterioration would affect these activities and to quantify the cost associated with implementing any operational changes that took place because of the breakwater failure.

Baseline data was obtained on port operations, tonnages received/shipped by commodity, types of vessel involved, average tonnage per vessel, loading/unloading rates in tons/day/, operational changes various vessel types would employ under different wave conditions, and operational changes the port would make with respect to using/not using various docks for loading/unloading purposes.

The port foresees developing a containerized cargo trade, which would be operational by 2012. The trade would be serviced via scheduled weekly port calls by foreign vessels and supplemented by tramp ship steamer. The port has a goal of handling 36,000 TEU’s per year by 2012. In order to accomplish this, all current warehouse space must be usable in 2012, as well as developing additional port facilities/infrastructure/ transportation linkages. This operation would be based around dock 22 and would not be directly affected by a breach in the East Breakwater. However, the breach in the east breakwater could impact the use of warehouses on the Stadium wharf, which is about 33% of the ports total storage capability. Loss of usage of these warehouses would impact potential port throughput since 50% of all steel imported products require warehousing.

Bulk Cargo/steel tonnages moving through the port's docks 20-32 will be 1.2-1.3m tons per year for the next 3 to 5 years (**Table 10.6**). The commodities moved will be stone and semi-finished steel products (coil steel, flat steel, bar steel). Stone traffic is concentrated along dock 20, located on the entrance to the Cuyahoga River. This traffic would not be directly affected by a breach in the east breakwater. Yearly stone tonnages average around 500,000 tons per year. Port activity taking place at docks 24 -32 are basically movements of steel products (shipments/receipts) by ocean going tramp vessels (salties) and barge. Steel traffic moved by foreign vessels is placed at 600,000 tons per year while barge traffic of coiled steel is around 100,000 tons per year. A typical foreign vessel carries around 6,500 tons per trip, and a typical barge carries around 3,000 tons per trip. Tons loaded/unloaded per day are around 2,000 tons.

Table 10.6 - Projected Port Tonnages.

		2008	2009	2010
		Tons	Tons	Tons
Steel-Foreign-Salties		600,000	600,000	600,000
Bulk (stone)		500,000	500,000	500,000
Steel Coils- Barge		100,000	100,000	200,000
		----------------	----------------	----------------
		1,200,000	1,200,000	1,300,000

This information was used to estimate the number of vessel trips per season, the average number of days it takes to load/unload a vessel, and the average number of vessels per day that would be at the ports dock facilities (**Table 10.7**). The data indicate there are 92 port calls by salties and 33 port calls by barges yearly. It takes 3.25 days to load/unload a saltie and 1.5 days to load/unload a barge. Given a 275 day season, there are on average 1.09 salties and .18 barges at a port facility dock on any given day.

Table 10.7 - Vessel Calls per Year, Unloading Time in Days, Vessels per Day at Dock

	Steel Products Foreign Vessels	Steel Products Barges
Yearly Tonnage	600,000	100,000
Tons Per Vessel	6,500	3,000
Vessels	92	33
Unloading Rate	2,000	2,000
Days to Unload a vessel	3.25	1.50
Season Length in Days	275	275
Avg # of Vessels Per Day In Port	1.09	0.18

The ports operation associated with servicing steel commodities would be directly affected by a break in the East Breakwater. Increased wave activity in the channels leading to the normal berthing locations, would affect vessel transit times to/from these docks, as well as affecting the need for tug assistance. Once the vessels are docked, increased wave activities at the dock itself would affect the future usability of that dock, vessel unloading times, the duration and cost of stevedoring services, and the vessel operating costs associated with loading/unloading. The potential for damage to the vessels, the docks fendering system and the docks themselves increases as wave heights encountered by vessels at the docks become larger and more frequent due to the continued deterioration of the breakwaters crest height.

Port/vessel operational changes were grouped into four major cost categories: tug costs, ship dwell time, stevedoring costs, and vessel maneuvering time/costs. The wave regimes that would trigger these operational changes were discussed and found to vary by vessel type (barge versus salty) and the crest elevation of the deteriorated east breakwater. The East Breakwater’s crest elevation has gone from +10 feet LWD to +8 feet LWD. This two foot decrease in breakwater crest elevation has resulted in the transference of waves with a greater wave height and frequency to the port’s main steel product loading and unloading docks. Vessels approaching, leaving or moored at these docks experience this increased wave activity.

Increases in port/vessel operational costs were calculated on a ship type basis for five ranges of wave heights, with range midpoints of 2, 3, 4, 5 and 6 feet. This analysis assumed that various port operational changes with respect to actual dock usage would be implemented once the east breakwater’s crest height was less than +7.5 feet LWD. **Table 10.8** presents a summary of these increased port and vessel operational costs by vessel type by wave height range. Impacts were calculated for two vessel types: salties and barge movements of steel products. A two foot wave affects only barge operations and increases commodity handling costs by between $16,000 and $25,000 per port visit. The majority of this increase is additional vessel dwell time spent at the dock during loading/unloading. Increased wave heights add additional time to loading/unloading operations resulting in increased stevedoring costs. Finally, increased wave heights add additional transit time to vessels maneuvering through the harbor and entering/existing docks. The same set of cost categories was developed for Salties.

Table 10.8 - Increase in Port and Vessel Operational Costs (by Vessel, by Vessel Type, by Wave Height, by East Breakwater Crest Elevation)

Wave Height Range	(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)
Range Midpoint	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet
Salties					
Additional Tug Costs-Current Users	$ -	$ 2,810	$ 3,212	$ 3,613	$ 4,015
Additional Vessel Time At Dock	$ -	$ 48,815	$ 65,087	$ 81,359	$ 131,426
Additional Stevedoring Costs	$ -	$ 19,500	$ 26,000	$ 32,500	$ 32,500
Additional Maneuvering Time	$ -	$ 348	$ 695	$ 1,043	$ 2,086
Operational Costs With E. Breakwater Crest Heights => 7.5 Feet	$ -	$ 51,973	$ 68,994	$ 86,015	$ 137,526
Operational Costs With E. Breakwater Crest Heights Less Than 7.5 Feet	$ -	$ 71,473	$ 94,994	$ 118,515	$ 170,026
Barges					
Additional Tug Costs	$ -	$ -	$ -	$ -	$ -
Additional Vessel Time At Dock	$ 16,054	$ 21,405	$ 26,756	$ 62,431	$ 62,431
Additional Stevedoring Costs	$ 9,000	$ 12,000	$ 15,000	$ 15,000	$ 15,000
Additional Maneuvering Time	$ 248	$ 495	$ 743	$ 1,486	$ 1,486
Operational Costs With E. Breakwater Crest Heights => 7.5 Feet	$ 16,301	$ 21,900	$ 27,499	$ 63,917	$ 63,917
Operational Costs With E. Breakwater Crest Heights Less Than 7.5 Feet	$ 25,301	$ 33,900	$ 42,499	$ 78,917	$ 78,917

This data was then used to develop port/vessel operational costs for various crest height elevations. This analysis assumed the Port Authority would initiate changes in port operations once the east breakwater's crest height was less than 7.5 feet. Port operation changes result in increased stevedoring costs. Thus, **Table 10.8** has vessel operating costs for two sets of east breakwater crest heights: crest heights equal to or greater than 7.5 feet, and crest heights less than 7.5. The difference in port/vessel operating costs for the two sets of breakwater crest heights is stevedoring costs. Additional stevedoring costs are not activated until the East Breakwater's crest height falls below 7.5 feet. The derivation of each of these damage categories follows.

10.5.1.1 Tug Costs

Currently, about 50% of foreign vessels use tug assistance to enter and exit the Ports docks. An increase in waves in the outer harbor could result in a number of these transits requiring two tugs. In addition, foreign vessels that had previously not used tugs would now require tug assistance. The wave height that would trigger this change was estimated between 2 and 4 feet. Consequently, a 3 foot wave was used as the starting point in this analysis. Tug costs are $6,000 per tug usage. Thus to dock is $6,000, and to undock is $6,000.

Foreign vessels that carry steel products are the main users of the tugs. Great Lakes self unloading vessels that bring stone to the Essroc dock do not use tugs. Currently, about 50 percent of foreign vessels use one tug. If waves encountered were 3 feet; these vessels would require two tugs. In addition, tug usage by foreign vessels overall would rise to 70 percent of all foreign vessels. Thus another 20 percent of the foreign fleet would require one-tug assistance given the presence of a three foot wave.

This information was then extrapolated out to identify impacts from larger waves. Each additional foot of wave above 3 feet was assumed to involve 10 percent more of the fleet in using tugs. Thus with a four foot wave, 30 percent of the fleet would be induced to use tugs. A five foot wave would cause 40 percent of the fleet to use a tug. A six foot wave would result in 50 percent of the fleet using a tug when they have never used a tug before. Since 50 percent of the fleet currently uses a tug, these vessels would employ a second tug with waves staring at 3 feet. A six foot wave would result in 50 percent of the foreign vessels using two tugs and the other 50 percent using one tug.

Table 10.9 - Weighted Average Tug Costs per Saltie Vessel

Wave Height Range	(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)
Range Midpoint	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet
Tug Cost-In Out	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000
Percent Of Salties Needing Tugs	0%	70%	80%	90%	100%
Average Cost per Saltie	0	$ 4,200	$ 4,800	$ 5,400	$ 6,000
% of Days Salties Are Entering/exiting	67%	67%	67%	67%	67%
Average Tug costs On a per Day Basis	$0	$ 2,810	$ 3,212	$ 3,613	$ 4,015

In summary, a three foot wave would cause 70% of the foreign vessels to use and additional tug. Correspondingly, a four, five and six foot wave would affect 80%, 90% and 100% of the foreign fleet. Given there are 92 salties that use the harbor over the course of a season, there are 184 days out of the season that a saltie is either entering or existing the port. **Table 10.9** summarizes tug costs by vessel trip, taking into consideration the percent of the foreign fleet that would use an additional tug given various wave heights, and the percent of days over the season a Saltie is either entering or exiting the harbor. A weighted average tug cost per vessel by wave height ranges from $2,800 for a 3 foot wave to $4,015 for a six foot wave.

10.5.1.2 Additional Vessel Time at Dock

Increased wave heights would affect loading/unloading times. A longer cycle time to load/unload a single lift would take place due to the increased movement of the vessel at the dock. The wave height at which this increase in loading/unloading times would start varied by vessel type. A three foot wave would result in foreign vessel loading /unloading times to increase by 30 percent. Loading/unloading of barges would be impacted with a smaller wave. For this analysis a 2 foot wave was used as the starting point for increased loading/unloading times for barges. The barges loading/unloading times would increase by 30 percent with the presence of a two foot wave.

This data was extrapolated out to indicate impacts from even larger waves. A 10 percent increase in loading/unloading time was attached to each foot above the starting wave height of 3 feet for foreign vessels, and 2 feet for barges. This was continued until a 50 percent increase in loading /unloading times were encountered. This meant a 5 foot wave for foreign vessels and a 4 foot wave for barges resulted in a 50 percent increase in loading unloading times. Unloading/loading operations were assumed to stop for at least an additional 24 hours once a foreign docked vessel encountered 6 foot waves and a docked barge encountered 5 foot waves. Basic background information on foreign vessel loads were that a typical vessel load was 6,500 tons and about 2,000 tons per day was either loaded or unloaded from the vessel. Therefore a saltie has a typical loading/unloading time of 3.25 days. Barge loads were placed at 3,000 tons and a loading /unloading rate of 2,000 tons per day. Thus a barge typically is unloaded in 1.5 days.

Given the annual tons of steel products delivered by salties and barges, their typical vessel vessel load, tons loaded/unloaded per day, the number of days it took to load/unload; the additional loading/unloading times per vessel could be calculated by wave height. These additional days of loading/unloading were converted to a dollar impact by using a typical vessel operating cost per day for a saltie vessel and a barge. Saltie daily vessel operating costs were placed at $50,067, the daily vessel operating cost for a Class 7 vessel. Barge daily vessel operating costs were placed at $30,675, the daily vessel operating cost for a Class 2 vessel. **Table 10.10** summarizes the calculations used to evaluate the increase in time vessels spend at the dock from various wave regimes. Additional Saltie vessel operational costs due to increased unloading times, by wave height, vary from $48,815 for a 3 foot wave to $131,426 for a six foot wave or greater. Additional barge vessel operational costs vary from $16,054 for a 2 foot wave to $62,431 for a five foot wave or greater. An additional 24 hours of loading/unloading time was added once a foreign docked vessel encountered 6 foot waves and a docked barge encountered 5 foot waves.

Table 10.10 - Additional Vessel Dock Time Costs

Wave Range Midpoint		2 Feet	3 Feet	4 Feet	5 Feet	6 Feet +
Wave Range		(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)
A. Steel-Foreign Vessels						
	Tonnage	600,000	600,000	600,000	600,000	600,000
	Tons Per Vessel	6,500.00	6,500.00	6,500.00	6,500.00	6,500.00
	Vessels	92.00	92.00	92.00	92.00	92.00
	Days to Unload	3.25	3.25	3.25	3.25	3.25
	Adntl Unldtime/Wave Height	0%	30%	40%	50%	1 Adntl Day Sh
	Addtnl Unlding Days/vsl	-	0.98	1.30	1.63	2.63
	Vessel operating Cost/day	$ 50,067	$ 50,067	$ 50,067	$ 50,067	$ 50,067
	Aditional Unloading Costs/Vsl	$ -	$ 48,815	$ 65,087	$ 81,359	$ 131,426
B. Steel Coils- Barge						
	Tonnage	100,000	100,000	100,000	100,000	100,000
	Tons Per Vessel	3,000	3,000	3,000	3,000	3,000
	Vessels	33.00	33.00	33.00	33.00	33.00
	Days to Unload	1.50	1.50	1.50	1.50	1.50
	Adntl Unldtime/Wave Height	30%	40%	50%	1 Adntl Day Sh	1 Adntl Day Sh
	Addtnl Unlding Days/vsl	0.45	0.60	0.75	1.75	1.75
	Vessel operating Cost/day	$ 35,675	$ 35,675	$ 35,675	$ 35,675	$ 35,675
	Aditional Unloading Costs/Vsl	$ 16,054	$ 21,405	$ 26,756	$ 62,431	$ 62,431

10.5.1.3 Additional Time/Cost for Stevedoring Services

If Cleveland Harbors East Breakwater, opposite the Port Authorities Stadium dock is not maintained, the breakwater's crest height will continue to deteriorate. As the crest height becomes lower, the size and frequency of waves encountered at the ports stadium docks will increase. The increased/continuous wave action on the broad side of the vessel would cause the ships docked there to be pushed into the fendering system adjacent to the dock. This continuous rocking motion would eventually damage the vessel, the fendering system, and or the dock to which the fendering system is attached. Eventually wave conditions would become such that the usage of dock 28 (the north side of the Stadium pier), for loading/unloading would be prohibited.

This dock unloading location is extremely convenient for the Port Authority, since there is large, open storage space just behind the dock and it is conveniently located adjacent to the transit storage sheds. If the north face dockage is no longer available for unloading, due to untenable wave conditions, the Port Authority will have to move the loading /unloading operation to another dock area. Port officials have indicated that their next choice is to use the slip on the west side of the stadium dock and or the north face of pier 24.

Using the north face of pier 24 would call for dredging in this area to bring it to seaway depth. Water depth alongside the dock is currently 18 feet. Dredging would be required for an area 700 feet long by 120 feet wide by 9 feet deep. This converts to 756,000 cubic feet or 28,000 cubic yards. Given a dredging cost per cubic yard of $6.97 and a disposal cost per cubic yard of $8.57, total dredging expenditures needed to make this dock operational are $435,010.

Moving the loading /unloading operations to these other dock areas would also result in additional stevedoring costs, since, the distance the steel products would have to travel in order to be warehoused, would increase significantly. An additional $3 per ton could be added to current stevedoring costs. For discussion purposes, it is assumed the Port Authority would initiate these changes once the East Breakwater's crest height became less than 7.5 feet.

If vessel loading/unloading time increases as shown in **Table 10.10**, the amount of time a stevedoring service is used also increases. A 30 percent increase in unloading time converts to about a $2 to $3 per ton increase for stevedoring costs. The additional stevedoring costs per ton by wave height provided in **Table 10.11** were used for extrapolation purposes.

Table 10.11 - Additional Stevedoring Cost per Ton, by Wave Height

	Additional Stevedoring Costs Per Ton				
Wave Range Midpoint	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet +
Foreign vessel	$0.00	$ 3.00	$ 4.00	$ 5.00	$0.00
Barge	$ 3.00	$ 4.00	$ 5.00	$0.00	$0.00
Wave Range Midpoint	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet +
Wave Range	(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)
A. Steel-Foreign Vessels					
Tonnage	600,000	600,000	600,000	600,000	600,000
Tons Per Vessel	6,500	6,500	6,500	6,500	6,500
Additional Stevedoring Cost/ton	$ -	$ 3.00	$ 4.00	$ 5.00	**STOP**
Additional Stevedoring Costs	-	19,500	26,000	32,500	32,500
B. Steel Coils- Barge					
Tonnage	100,000	100,000	100,000	100,000	100,000
Tons Per Vessel	3,000	3,000	3,000	3,000	3,000
Additional Stevedoring Cost/ton	$ 3.00	$ 4.00	$ 5.00	**STOP**	**STOP**
Additional Stevedoring Costs	$ 9,000	$ 12,000	$ 15,000	15,000	15,000

This data was then used with the number of tons affected by vessel type to calculate increased stevedoring costs. Increased Saltie stevedoring costs ranged from $19,500 for a three foot wave to $32,500 for a five foot wave or greater. Increased barge stevedoring costs ranged from $9,000 for a two foot wave to $15,000 for a four foot wave or greater.

10.5.1.4 Additional Vessel Maneuvering Time/Cost

As the Wave regime behind the breakwater becomes worse, the amount of time it takes vessels to maneuver into/from the dock becomes longer. As some point, vessels will refuse to come in/leave and wait either at the dock or in open water for the waves to subside. Additional maneuvering time was associated with various wave heights. These additional maneuvering times by wave height are provided in **Table 10.12**.

Barges were assumed to be affected by a two foot wave which added an additional 10 minutes maneuvering time. Salties became affected by a three foot wave which added an additional 10 minutes to maneuvering time. These additional times were extrapolated out to a 6 foot wave. Any wave greater than 6 foot, a vessel would not attempt to maneuver into/out of a dock. Thus additional vessel maneuvering times were at least 1 additional hour for any wave greater

Table 10.12 - Additional Vessel Maneuvering Time/Cost

	Additional Vessel Maneuvering Time				
Wave Range Midpoint	2 Feet	3 Feet	4 Feet	5 Feet	6 Feet +
Foreign vessel	0 min delay	10 min delay	20 min delay	30 min delay	1 hr delay
Barge	10 min delay	20 min delay	30 min delay	1 hr delay	1 hr delay
A. Steel-Foreign Vessels					
Additional Maneuvering Time Minutes	0	10	20	30	60
Minutes/Hour	60	60	60	60	60
Additional Maneuvering Time-hours	-	0.17	0.33	0.50	1.00
Vessel operating Costs/hour	$ 2,086	$ 2,086	$ 2,086	$ 2,086	$ 2,086
Additional Saltie Maneuvering Costs/Vsl	$ -	$ 348	$ 695	$ 1,043	$ 2,086
% of Season Saltie is Entrng/Exiting Hrbr	67%	67%	67%	67%	67%
Weighted Additional Maneuvering Time/Vsl	$ -	$ 233	$ 465	$ 698	$ 1,396
B. Steel Coils- Barge					
Additional Maneuvering Time Minutes	10	20	30	60	60
Minutes/Hour	60	60	60	60	60
Additional Maneuvering Time-hours	0.17	0.33	0.50	1.00	1.00
Vessel operating Costs/hour	$ 1,486	$ 1,486	$ 1,486	$ 1,486	$ 1,486
Additional Barge Maneuvering Costs/Vsl	$ 248	$ 495	$ 743	$ 1,486	$ 1,486
% of Season Barge is Entrng/Exiting Hrbr	24%	24%	24%	24%	24%
Weighted Additional Maneuvering Time/Vsl	$ 59	$ 119	$ 178	$ 357	$ 357

than 6 feet for a Saltie and greater than 5 feet for a barge. These additional maneuvering times were converted to costs using an hourly vessel operating cost. Saltie hourly vessel operating costs were placed at $2,086 based on a Class 7 Great Lakes Vessel. Barge hourly vessel operating costs were placed at $1,486 based on a Class 2 Great Lakes Vessel.

These additional maneuvering costs were then adjusted to reflect the percent of time during the season a Saltie or barge would actually be entering /leaving the harbor, based on the number of trips per year by vessel type and the season length (275 days). Saltie additional vessel maneuvering costs ranged from $233 for a three foot wave to $1,396 for a six foot wave. Barge additional vessel maneuvering costs ranged from $59 for a two foot wave to $357 for a five foot wave or greater.

10.5.2 Seasonal Port/Vessel Operating Costs for Various East Breakwater Crest Elevations

Table 10.8 provided a summary of actual changes in port/vessel operating procedures/costs based on interviews with the Cleveland Harbor Port authority, on a per vessel call basis. This data, by individual vessel, can then be extrapolated out to additional port/vessel operational costs per SEASON, if the number of vessels being affected by various wave heights is known for a range of East Breakwater crest heights. This type of information is not available. However, the types of information that would be needed to built such a table would include: range of East Breakwater crest heights that could potentially happen over a specific evaluation period (say 50 years), the resulting wave regimes shippers would experience during the season if that breakwater crest height were reached, and the percent of time during the season these wave heights are encountered.

The range these East Breakwater crest heights could reach would be a function of the current physical condition of the East Breakwater, the amount of natural subsidence the breakwater would experience over time, and the amount of breakwater subsidence that would happen due to accumulated storm damages to the structure. The breakwater has lost, on average, 2 feet of crest height through 2008. It is possible it could lose another 4 feet or more over the next 50 years. Thus the percent of time during the season various wave height ranges would be experienced at port facility docks are needed for a range of East Breakwater crest heights ranging from 8 feet to 4 feet. It would also be necessary to have this information for east breakwater crest heights from 8 feet through 10 feet, the existing breakwater crest height and the repaired crest height elevation.

The resulting wave regimes shippers would experience during the season given a specific breakwater crest height, and the percent of time during the season these wave heights are encountered are a function of many interrelated factors: current condition of the breakwater, amount of fetch the breakwater experiences, depth of water the breakwater is in, lake bathymetry outside the breakwater, inner harbor bathymetry behind the breakwater, the distance from the breakwater to the port authority docks, location and depth of the federal channel, etc. This information could potentially be integrated into a numeric model that would then calculate percent of time over a season that various wave height classes are experienced at specific affected facilities (i.e. Cleveland port authority docks).

Again, this type of data is currently not available; however, for discussion purposes, a "hypothetical" percent of time wave height classes are encountered by breakwater crest height was developed for Cleveland Harbor Port Authority steel docks. "Hypothetical" data was developed for seven East Breakwater crest height elevations above LWD: 4 feet, 5 feet, 6 feet, 7 feet, 7.5 feet, 8 feet and 10 feet (**Table 10.13**).

Table 10.13 - "Hypothetical" Percent of Season Wave Heights are Encountered (by East Breakwater Wave Height)

							Percent Of	Percent Of
Wave Height-Ft			(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)	Season	Season
Range Midpoint			2 Feet	3 Feet	4 Feet	5 Feet	6 Feet	Impacted	No Impact
			Percent of season these wave heights are encountered.						
East Breakwater Crest Height									
	1. 4.0 Ft Above LWD		26.0%	21.0%	16.0%	11.0%	4.5%	78.5%	21.5%
	2. 5.0 Ft Above LWD		21.0%	17.0%	13.0%	9.0%	3.5%	63.5%	36.5%
	3. 6.0 Ft Above LWD		16.0%	13.0%	10.0%	7.0%	2.5%	48.5%	51.5%
	4. 7.0 Ft Above LWD		11.0%	9.0%	7.0%	5.0%	1.5%	33.5%	66.5%
	5. 7.5 Ft Above LWD		8.5%	7.0%	5.5%	4.0%	1.0%	26.0%	74.0%
	6. 8.0 Ft Above LWD		6.0%	5.0%	4.0%	3.0%	0.5%	18.5%	81.5%
	7. 10.0 Ft Above LWD		6.0%	5.0%	4.0%	3.0%	0.5%	18.5%	81.5%

This table exhibits certain characteristics that would be expected in such a table. First of all, the percent of time waves of various heights are encountered increases, as the breakwater crest height decreases. Secondly large wave classes would have very infrequent occurrences. In this table a 6 foot wave would only be experienced 0.5% percent of the season under the current crest height elevation of 8 feet. This results in 1.4 times per season. Finally, the table shows that under current conditions, most of the time, there is no problem with waves. Under an 8.0 foot breakwater crest height, for 82% of the season vessels do not encounter any waves that cause operational changes.

Again, the information in this table is purely “hypothetical”. However, given a table with this type of information, it becomes possible to describe how port/vessel operational costs by vessel (**Table 10.8**), can be used with the percent of time during a season various wave ranges are encountered (**Table 10.13**) to develop seasonal port/vessel operational costs for a range of breakwater elevations.

Table 10.14, Part A, provides seasonal port/vessel operational costs for an 8 foot above LWD East Breakwater crest height elevation. Multiplying the percent of the season various wave height ranges are encountered, by the number of days per season (275), provides the number of days per season various wave height ranges are encountered. This is then multiplied by the number of ships per day, on average, that are at Cleveland Harbor port docks (1.09 salties per day and .18 barges per day- See **Table 10.7** for calculation of vessels per day ay Cleveland port docks). This results in the number of vessel calls that are affected per season by various wave classes. For Salties, the number of vessel calls affected per season by a wave category with an average 3 foot wave height is 14.95 (5% times 275 days=13.75 days waves are encountered times 1.09-average number of salties at a port dock on any given day during the season_= 14.95). This process was repeated for all remaining wave ranges (4,5, and 6) resulting in number of vessel calls affected of 11.96, 8.97 and 1.49 respectively.

Given the East Breakwater crest height elevation being evaluated, **Table 10.8** can be used to identify the daily port/vessel operational cost increases associated with various wave height ranges. For example, for salties, daily port/vessel operational cost increases associated with a wave class with a 3 foot average, for an East Breakwater with an 8 foot crest height elevation, is $51,973. This comes from the row showing Saltie daily operational cost increases when the East Breakwater crest height is equal to or greater than 7.5 feet. Correspondingly Saltie daily port/vessel operational cost increases for wave categories with average wave heights of 4, 5, and 6 feet are $68,994, $86,015 and $137,526 respectively. Cross multiplying these daily port/vessel operation cost increases by wave height category, times the number of vessel calls per season affected, results in seasonal cost increases by wave height category. Saltie seasonal cost increases associated with an 8 foot East Breakwater, are $2,579,324. This process was repeated for barge users and resulted in $270,509 in additional port/vessel operational costs. The total seasonal increase in port/vessel operational cost associated with an East Breakwater with an 8 foot crest elevation is $2,849,833.

The process described above was repeated for an East Breakwater crest elevation of 7.5 feet (**Table 10.14** Part B). Port/vessel daily cost increases was the same as the 8.0 foot breakwater crest elevation. However, since the crest elevation was now .5 feet LOWER, the percent of time during the season these various wave height classes were encountered increased. This resulted in a total seasonal increase in port/vessel operational costs of $4,043,697.

Table 10.14 - Calculation of Seasonal Port/Vessel Operational Costs (by E. Breakwater Height)

A.	Breakwater Crest Height Is 8.0 Feet Above LWD					
	2 Foot Wave	3 Foot Wave	4 Foot Wave	5 Foot Wave	6 Foot Wave	Fleet Costs
	(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)	
%of season wave heights are encountered	6%	5%	4%	3%	1%	
Season Length	275	275	275	275	275	
Days/Season Wave Heights are Encounterd	16.5	13.75	11	8.25	1.375	
A. Steel-Foreign Vessels						
Avge # Of Vessels/Day At Docks	1.09	1.09	1.09	1.09	1.09	
Days/Season Wave Heights are Encounterd	16.5	13.75	11	8.25	1.375	
Number Of Vessel Calls Affected	17.94	14.95	11.96	8.97	1.495	
Average Cost Per Vessel	$ -	$ 51,973	$ 68,994	$ 86,015	$ 137,526	
Fleet Costs	$ -	$ 776,999	$ 825,169	$ 771,554	$ 205,602	$ 2,579,324
B. Steel Coils- Barge						
Avge # Of Vessels/Day At Docks	0.18	0.18	0.18	0.18	0.18	
Days/Season Wave Heights are Encounterd	16.5	13.75	11	8.25	1.375	
Number Of Vessel Calls Affected	3	2.5	2	1.5	0.25	
Average Cost Per Vessel	$ 16,301	$ 21,900	$ 27,499	$ 63,917	$ 63,917	
Fleet Costs	$ 48,904	$ 54,751	$ 54,999	$ 95,876	$ 15,979	$ 270,509
Fleet Summary						
A. Steel-Foreign Vessels	$ -	$ 776,999	$ 825,169	$ 771,554	$ 205,602	
B. Steel Coils- Barge	$ 48,904	$ 54,751	$ 54,999	$ 95,876	$ 15,979	
	$ 48,904	$ 831,750	$ 880,168	$ 867,430	$ 221,581	$ 2,849,833

B.	Breakwater Crest Height Is 7.5 Feet Above LWD					
	2 Foot Wave	3 Foot Wave	4 Foot Wave	5 Foot Wave	6 Foot Wave	Fleet Costs
	(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)	
%of season wave heights are encountered.	9%	7%	6%	4%	1%	
Season Length	275	275	275	275	275	
Days/Season Wave Heights are Encounterd	23.375	19.25	15.125	11	2.75	
A. Steel-Foreign Vessels						
Avge # Of Vessels/Day At Docks	1.09	1.09	1.09	1.09	1.09	
Days/Season Wave Heights are Encounterd	23.375	19.25	15.125	11	2.75	
Number Of Vessel Calls Affected	25.415	20.93	16.445	11.96	2.99	
Average Cost Per Vessel	$ -	$ 51,973	$ 68,994	$ 86,015	$ 137,526	
Fleet Costs	$ -	$ 1,087,799	$ 1,134,607	$ 1,028,739	$ 411,204	$ 3,662,349
B. Steel Coils- Barge						
Avge # Of Vessels/Day At Docks	0.18	0.18	0.18	0.18	0.18	
Days/Season Wave Heights are Encounterd	23.375	19.25	15.125	11	2.75	
Number Of Vessel Calls Affected	4.25	3.5	2.75	2	0.5	
Average Cost Per Vessel	$ 16,301	$ 21,900	$ 27,499	$ 63,917	$ 63,917	
Fleet Costs	$ 69,281	$ 76,651	$ 75,623	$ 127,835	$ 31,959	$ 381,348
Fleet Summary						
A. Steel-Foreign Vessels	$ -	$ 1,087,799	$ 1,134,607	$ 1,028,739	$ 411,204	
B. Steel Coils- Barge	$ 69,281	$ 76,651	$ 75,623	$ 127,835	$ 31,959	
	$ 69,281	$ 1,164,450	$ 1,210,230	$ 1,156,573	$ 443,163	$ 4,043,697

C.	Breakwater Crest Height Is 7.0 Feet Above LWD					
	2 Foot Wave	3 Foot Wave	4 Foot Wave	5 Foot Wave	6 Foot Wave	Fleet Costs
	(1.5-2.4Ft)	(2.5-3.4Ft)	(3.5-4.4Ft)	(4.5-5.4Ft)	(5.5Ft or >)	
%of season wave heights are encountered.	11%	9%	7%	5%	2%	
Season Length	275	275	275	275	275	
Days/Season Wave Heights are Encounterd	30.25	24.75	19.25	13.75	4.125	
A. Steel-Foreign Vessels						
Avge # Of Vessels/Day At Docks	1.09	1.09	1.09	1.09	1.09	
Days/Season Wave Heights are Encounterd	30.25	24.75	19.25	13.75	4.125	
Number Of Vessel Calls Affected	32.89	26.91	20.93	14.95	4.485	
Average Cost Per Vessel	$ -	$ 71,473	$ 94,994	$ 118,515	$ 170,026	
Fleet Costs	$ -	$ 1,923,343	$ 1,988,226	$ 1,771,799	$ 762,568	$ 6,445,936
B. Steel Coils- Barge						
Avge # Of Vessels/Day At Docks	0.18	0.18	0.18	0.18	0.18	
Days/Season Wave Heights are Encounterd	30.25	24.75	19.25	13.75	4.125	
Number Of Vessel Calls Affected	5.5	4.5	3.5	2.5	0.75	
Average Cost Per Vessel	$ 25,301	$ 33,900	$ 42,499	$ 78,917	$ 78,917	
Fleet Costs	$ 139,158	$ 152,552	$ 148,747	$ 197,293	$ 59,188	$ 696,938
Fleet Summary						
A. Steel-Foreign Vessels	$ -	$ 1,923,343	$ 1,988,226	$ 1,771,799	$ 762,568	
B. Steel Coils- Barge	$ 139,158	$ 152,552	$ 148,747	$ 197,293	$ 59,188	
	$ 139,158	$ 2,075,895	$ 2,136,973	$ 1,969,092	$ 821,756	$ 7,142,874

When computing seasonal increases in port/vessel operational costs for breakwater's with a crest elevation less than 7.5 feet, a new set of daily port/vessel operational cost increases is used. This is because at a breakwater crest height of less than 7.5 feet, it is assumed the port authority institutes certain new dock usage operational procedures, wave conditions on the north face of the stadium pier become such that vessels are no longer allowed to moor there, and moved to other dock locations. This results in increased stevedoring costs and port dredging costs associated with making these new locations usable.

For an illustrative purpose, a calculation of the seasonal increase in port/vessel operational costs for a 7.0 foot above LWD East Breakwater is presented in Part C, **Table 10.14**. Again, the percent of time various wave classes are encountered increases since the breakwater is now 1 foot lower than the existing 8 foot crest height. Also, the daily port/vessel operational cost increase has changed to reflect these new stevedoring costs. For example, Saltie daily port/vessel operation cost increases for a 3, 4, 5, and 6 foot average wave category are now $$71,473, $94,994, $118,515 and $170, 026 respectively. Barge daily port/vessel operation cost increases have also increased to $25,301, $33,900, $42, 499 and $78,917 for 2, 3, 4, and 5 foot average wave classes respectively. The total seasonal increase in port/vessel operational cost that is associated with a 7.0 foot crest elevation on the East Breakwater is $7,142.874.

This process was repeated for assumed East Breakwater crest heights of 6, 5 and 4 feet above LWD. **Table 10.15** summarizes these seasonal increases in port/vessel operational costs for an array of crest height of 8.0, 7.5, 7.0, 6.0, 5.0, and 4.0 foot. Seasonal port/vessel operational cost increases range from $2,849, 833 for an East Breakwater with an 8-foot crest elevation to $16,854,454 for an East Breakwater with a 4-foot crest elevation. The increase in seasonal port/vessel operational costs for an East Breakwater crest elevation of 10 feet was made to equal to seasonal operational cost increases associated with an 8-foot crest height.

Table 10.15 - Seasonal Port/Vessel Operational Cost Increases (by East Breakwater Crest Height)

East Breakwater Crest Height Is 10.0 Feet Above LWD	$ 2,849,833
East Breakwater Crest Height Is 8.0 Feet Above LWD	$ 2,849,833
East Breakwater Crest Height Is 7.5 Feet Above LWD	$ 4,043,697
East Breakwater Crest Height Is 7.0 Feet Above LWD	$ 7,142,874
East Breakwater Crest Height Is 6.0 Feet Above LWD	$ 10,380,067
East Breakwater Crest Height Is 5.0 Feet Above LWD	$ 13,617,261
East Breakwater Crest Height Is 4.0 Feet Above LWD	$ 16,854,454

10.5.3 Economic Performance of Various Repair Plans

Table 10.15 provides 7 points that could be used to develop an East Breakwater crest height/operational cost increases cost curve. This curve could then be used with a risk simulation that would provide the resulting East Breakwater crest elevation height for various repair plans over a specific project evaluation period. Given the costs for these various repair plans, and the magnitude of port/vessel operational cost increases, the economic viability of these various plans could be determined.

Repair plans evaluated could range from repair immediately, to repair once the East Breakwater crest height reaches a certain elevation. Benefits for these evaluations equals the difference in port/vessel operational cost increases associated with the Without Project condition and the With Project (Various repair options) condition. Project costs are the difference in East Breakwater repair cost between the WP and WOP condition. Since no repairs are assumed to be made in the WOP condition, repair plan costs equal WP condition repair costs.

Current estimates of East Breakwater repair costs are $9,786,000. It is assumed that this would be expended over a three year period. The occurrence of these repair costs would vary from plan to plan. The "Repair Now Scenario" indicates repair costs will be incurred immediately. If one plan called for a repair of the East breakwater once the crest elevation reached 7.5 feet and it took 16 years before the crest height became 7.5 feet, the model would place the repair cost in project year 16.

Benefits are equal to the difference in port/vessel operational cost increases between the WOP and WP condition. The first step would be to calculate the port/vessel operational cost increases that would occur under the WOP condition. Under the WOP condition, it is assumed no repairs to the East Breakwater are made over the project evaluation period. The East Breakwater's crest elevation is allowed to deteriorate over time, and the associated port/vessel operational costs increase as the breakwater crest height continues to deteriorate. Under WP conditions, port/vessel operational costs would increase until the breakwater is repaired. Then the breakwater crest height would be reset to the repaired breakwater crest height (10.0 feet), which would then experience crest height reductions over the remaining evaluation years.

In this example analysis, a range of repair plans were evaluated: Plan 1-Repair Now, Plan 2- Repair When Crest Height Equals 7.5 feet, Plan 3- Repair When Crest Height Equals 7.0 feet, Plan 4- Repair When Crest Height Equals 6.5 feet. A 50 year project evaluation period was assumed, with a 4.875% annual interest rate. Project year 1 was placed at 2010. The evaluation was performed using present worth values.

The first step is to calculate port/vessel operational cost increases under the WOP condition. One of the key pieces of information needed is the East Breakwater's crest elevation for each year of the 50 year project evaluation period. The East Breakwater's crest height will decrease over the 50 year evaluation period due to natural subsidence, and as the result of storms.

A template was devised (See **Table 10.16** - WOP Condition) that kept tract of construction costs, when they are incurred, as well as East Breakwater crest height, crest height subsidence due to age, crest height subsidence due to storms, and resulting crest height for each project evaluation year. Given the East Breakwater's crest height elevation, port/vessel operational costs associated with these crest heights' could be read off of a port/vessel operational cost curve developed from data provided in **Table 10.15**. For example, in project year 1 the East Breakwater's crest height was 8.0 feet which resulted in a port/vessel operational cost of $2,849, 833. When the breakwater's crest height dropped to 7.9 feet in project year 4, port/vessel operational costs became $3,088,606. This process was repeated for each year of the 50 year project evaluation period. Under WOP conditions the breakwater's crest height fell to 6.3 feet in project year 50 with a corresponding yearly port/vessel operational cost of $9,408,909. These port/vessel operational costs were then converted to a present worth value, and summed. The present worth value of WOP condition port/vessel operational costs are $86,258,950.

There are no costs for breakwater repair under WOP conditions since no repair is made and the breakwater's crest height is allowed to deteriorate. The breakwater's natural subsidence caused the breakwater's crest height elevation to deteriorate 0.5 feet over the 50 year project evaluation period (See column labeled "Deterioration/Subsidence Due To Age"). A nominal 0.1 foot subsidence was allowed to occur once every 10 years. Comparison of this "hypothetical" subsidence rate to an actual breakwater subsidence curve based on breakwater age indicates that natural breakwater subsidence would occur at a much faster rate than 0.1 ft/10 years.

Breakwater crest height deterioration due to storms was placed at 0.1 foot /4 years. Storms resulted in reducing the breakwater's crest height by 1.2 feet over the 50 year evaluation period. These are fully "hypothetical" numbers. Actual deterioration of the breakwater's crest height from storms would normally be the output of a risk model evaluation. The risk model would need to keep track of the number of damaging storms that happened per year, and based on their intensity and duration, determine the impact on the breakwater's crest height elevation. The risk model would then reset the breakwater's crest height elevation for the next year being evaluated, based on the amount of natural subsidence and storm subsidence that had taken place the previous year.

For example, the crest height elevation starts out at 8.0 feet in project year 1. There is no natural subsidence, or storm subsidence for project years 1, 2 and 3. However, in project year 4, storm subsidence causes the breakwater to deteriorate by 0.1 of a foot. Thus in project year 4.0 the breakwater's crest height has become 7.9 feet. Note: this 0.1 foot reduction in crest height in project year 4 is the result the cumulative impacts of damaging storms that have taken place in project years 1, 2, 3 and 4. In reality, as the number of damaging storms the breakwater encounters increases, the actual structural integrity of the structure becomes worse. Thus the next set of storms encounters a weakened structure. Consequently, as the number of storms the breakwater endures increases; it is unlikely that the breakwater's deterioration is linear, as shown in this example.

This process was repeated for various repair plan/ breakwater crest heights. **Table 10.17** shows this same process assuming the breakwater is repaired immediately- starting in 2010. Breakwater repair construction costs are $9,786,000. These costs would be spread evenly over the first 3 years of the project evaluation period. The present worth of these construction costs are $8,904,083.

Port/vessel operational costs under the Fix Immediately scenario results in an East Breakwater crest elevation of 8.0 feet for the first 3 years of the project evaluation period. The breakwater's crest height is then reset to 10.0 in project year four. In addition, since the breakwater is now repaired, it is essentially a new structure.

Table 10.16 - Hypothetical WOP Condition - Port/Vessel Operational Costs

Without Project Condtion

REPAIR COSTS $ -

Harbor Operational Costs Under Without Project Condition

Construction period 3

Yrly Repair costs $ -

Do Repair

Evaluation Year	Project Year	Repair costs	Present worth Factor	Present worth Of Repair costs	Brkwtr Crest Height Above LWD	Deterioration Subsidence Due To Age	Storms	Storms Impact On Crest Height	Resulting Brkwtr Crest Height Above LWD	Tonnage Operational Costs	Port Dredging Costs	Total Operational costs	Present worth Factor	Present worth Of Total Operational costs
1	2010	$ -	0.95352	$ -	8.0	0	4	0	8.0	$ 2,849,833		$ 2,849,833	0.95352	$ 2,717,362
2	2011	$ -	0.90919	$ -	8.0		3	0	8.0	$ 2,849,833		$ 2,849,833	0.90919	$ 2,591,048
3	2012	$ -	0.86693	$ -	8.0		2	0	8.0	$ 2,849,833		$ 2,849,833	0.86693	$ 2,470,606
4	2013		0.82663		8.0		3	0.1	7.9	$ 3,088,606		$ 3,088,606	0.82663	$ 2,553,140
5	2014		0.78821		7.9		4	0	7.9	$ 3,088,606		$ 3,088,606	0.78821	$ 2,434,460
6	2015		0.75157		7.9		3	0	7.9	$ 3,088,606		$ 3,088,606	0.75157	$ 2,321,297
7	2016		0.71663		7.9		2	0	7.9	$ 3,088,606		$ 3,088,606	0.71663	$ 2,213,394
8	2017		0.68332		7.9		3	0.1	7.8	$ 3,327,379		$ 3,327,379	0.68332	$ 2,273,665
9	2018		0.65156		7.8		4	0	7.8	$ 3,327,379		$ 3,327,379	0.65156	$ 2,167,976
10	2019		0.62127		7.8	0.1	3	0	7.7	$ 3,566,152		$ 3,566,152	0.62127	$ 2,215,542
11	2020		0.59239		7.7		2	0	7.7	$ 3,566,152		$ 3,566,152	0.59239	$ 2,112,555
12	2021		0.56485		7.7		3	0.1	7.6	$ 3,804,924		$ 3,804,924	0.56485	$ 2,149,227
13	2022		0.53860		7.6		4	0	7.6	$ 3,804,924		$ 3,804,924	0.53860	$ 2,049,323
14	2023		0.51356		7.6		3	0	7.6	$ 3,804,924		$ 3,804,924	0.51356	$ 1,954,062
15	2024		0.48969		7.6		2	0	7.6	$ 3,804,924		$ 3,804,924	0.48969	$ 1,863,230
16	2025		0.46693		7.6		3	0.1	7.5	$ 4,043,697	$ 435,010	$ 4,478,707	0.46693	$ 2,091,227
17	2026		0.44522		7.5		4	0	7.5	$ 4,043,697		$ 4,043,697	0.44522	$ 1,800,342
18	2027		0.42453		7.5		3	0	7.5	$ 4,043,697		$ 4,043,697	0.42453	$ 1,716,655
19	2028		0.40479		7.5		2	0.1	7.4	$ 4,663,533		$ 4,663,533	0.40479	$ 1,887,763
20	2029		0.38598		7.4	0.1	3	0	7.3	$ 5,283,368		$ 5,283,368	0.38598	$ 2,039,254
21	2030		0.36803		7.3		4	0	7.3	$ 5,283,368		$ 5,283,368	0.36803	$ 1,944,462
22	2031		0.35093		7.3		3	0	7.3	$ 5,283,368		$ 5,283,368	0.35093	$ 1,854,076
23	2032		0.33461		7.3		2	0.1	7.2	$ 5,903,203		$ 5,903,203	0.33461	$ 1,975,297
24	2033		0.31906		7.2		3	0	7.2	$ 5,903,203		$ 5,903,203	0.31906	$ 1,883,477
25	2034		0.30423		7.2		4	0	7.2	$ 5,903,203		$ 5,903,203	0.30423	$ 1,795,926
26	2035		0.29009		7.2		3	0	7.2	$ 5,903,203		$ 5,903,203	0.29009	$ 1,712,444
27	2036		0.27660		7.2		2	0.1	7.1	$ 6,523,039		$ 6,523,039	0.27660	$ 1,804,291
28	2037		0.26375		7.1		3	0	7.1	$ 6,523,039		$ 6,523,039	0.26375	$ 1,720,421
29	2038		0.25149		7.1		4	0	7.1	$ 6,523,039		$ 6,523,039	0.25149	$ 1,640,449
30	2039		0.23980		7.1	0.1	3	0	7.0	$ 7,142,874		$ 7,142,874	0.23980	$ 1,712,828
31	2040		0.22865		7.0		2	0.1	6.9	$ 7,466,593		$ 7,466,593	0.22865	$ 1,707,227
32	2041		0.21802		6.9		3	0	6.9	$ 7,466,593		$ 7,466,593	0.21802	$ 1,627,869
33	2042		0.20789		6.9		4	0	6.9	$ 7,466,593		$ 7,466,593	0.20789	$ 1,552,199
34	2043		0.19822		6.9		3	0	6.9	$ 7,466,593		$ 7,466,593	0.19822	$ 1,480,047
35	2044		0.18901		6.9		2	0.1	6.8	$ 7,790,313		$ 7,790,313	0.18901	$ 1,472,434
36	2045		0.18022		6.8		3	0	6.8	$ 7,790,313		$ 7,790,313	0.18022	$ 1,403,989
37	2046		0.17185		6.8		4	0	6.8	$ 7,790,313		$ 7,790,313	0.17185	$ 1,338,726
38	2047		0.16386		6.8		3	0	6.8	$ 7,790,313		$ 7,790,313	0.16386	$ 1,276,497
39	2048		0.15624		6.8		2	0.1	6.7	$ 8,114,032		$ 8,114,032	0.15624	$ 1,267,739
40	2049		0.14898		6.7	0.1	3	0	6.6	$ 8,437,751		$ 8,437,751	0.14898	$ 1,257,036
41	2050		0.14205		6.6		4	0	6.6	$ 8,437,751		$ 8,437,751	0.14205	$ 1,198,604
42	2051		0.13545		6.6		3	0	6.6	$ 8,437,751		$ 8,437,751	0.13545	$ 1,142,888
43	2052		0.12915		6.6		2	0.1	6.5	$ 8,761,471		$ 8,761,471	0.12915	$ 1,131,572
44	2053		0.12315		6.5		3	0	6.5	$ 8,761,471		$ 8,761,471	0.12315	$ 1,078,972
45	2054		0.11743		6.5		4	0	6.5	$ 8,761,471		$ 8,761,471	0.11743	$ 1,028,817
46	2055		0.11197		6.5		3	0	6.5	$ 8,761,471		$ 8,761,471	0.11197	$ 980,994
47	2056		0.10676		6.5		2	0.1	6.4	$ 9,085,190		$ 9,085,190	0.10676	$ 969,954
48	2057		0.10180		6.4		3	0	6.4	$ 9,085,190		$ 9,085,190	0.10180	$ 924,867
49	2058		0.09707		6.4		4	0	6.4	$ 9,085,190		$ 9,085,190	0.09707	$ 881,876
50	2059		0.09256		6.4	0.1	3	0	6.3	$ 9,408,909		$ 9,408,909	0.09256	$ 870,844
				$ -		0.50		1.20		$ 299,045,483	$ 435,010	$ 299,480,493		$ 86,258,950

Table 10.17 - Hypothetical Plan 1 - Repair Now
– Construction and Port/Vessel Operational Costs

Plan 1- Repair Now

REPAIR COSTS		$ 9,786,000			Harbor Operational Costs Under Repair Now									
Construction period		3												
Yrly Repair costs		$ 3,262,000												
Do Repair		NOW												
Evaluation Year	Project Year	Repair costs	Present worth Factor	Present worth Of Repair costs	Brkwtr Crest Height Above LWD	Deterioration Subsidence Due To Age	Storms	Storms Impact On Crest Height	Resulting Brkwtr Crest Height Above LWD	Tonnage Operational Costs	Port Dredging Costs	Total Operational costs	Present worth Factor	Present worth Of Total Operational costs
1	2010	$ 3,262,000	0.95352	$ 3,110,369	8.0	0	4		8.0	$ 2,849,833		$ 2,849,833	0.95352	$ 2,717,362
2	2011	$ 3,262,000	0.90919	$ 2,965,787	8.0		3		8.0	$ 2,849,833		$ 2,849,833	0.90919	$ 2,591,048
3	2012	$ 3,262,000	0.86693	$ 2,827,926	8.0		2		8.0	$ 2,849,833		$ 2,849,833	0.86693	$ 2,470,606
4	2013		0.82663		10.0		3		10.0	$ 2,849,833		$ 2,849,833	0.82663	$ 2,355,763
5	2014		0.78821		10.0		4		10.0	$ 2,849,833		$ 2,849,833	0.78821	$ 2,246,258
6	2015		0.75157		10.0		3		10.0	$ 2,849,833		$ 2,849,833	0.75157	$ 2,141,843
7	2016		0.71663		10.0		2		10.0	$ 2,849,833		$ 2,849,833	0.71663	$ 2,042,281
8	2017		0.68332		10.0		3		10.0	$ 2,849,833		$ 2,849,833	0.68332	$ 1,947,348
9	2018		0.65156		10.0		4		10.0	$ 2,849,833		$ 2,849,833	0.65156	$ 1,856,828
10	2019		0.62127		10.0	0.1	3		9.9	$ 2,849,833		$ 2,849,833	0.62127	$ 1,770,515
11	2020		0.59239		9.9		2		9.9	$ 2,849,833		$ 2,849,833	0.59239	$ 1,688,215
12	2021		0.56485		9.9		3		9.9	$ 2,849,833		$ 2,849,833	0.56485	$ 1,609,740
13	2022		0.53860		9.9		4		9.9	$ 2,849,833		$ 2,849,833	0.53860	$ 1,534,913
14	2023		0.51356		9.9		3		9.9	$ 2,849,833		$ 2,849,833	0.51356	$ 1,463,564
15	2024		0.48969		9.9		2	0.1	9.8	$ 2,849,833		$ 2,849,833	0.48969	$ 1,395,532
16	2025		0.46693		9.8		3		9.8	$ 2,849,833		$ 2,849,833	0.46693	$ 1,330,662
17	2026		0.44522		9.8		4		9.8	$ 2,849,833		$ 2,849,833	0.44522	$ 1,268,808
18	2027		0.42453		9.8		3		9.8	$ 2,849,833		$ 2,849,833	0.42453	$ 1,209,829
19	2028		0.40479		9.8		2		9.8	$ 2,849,833		$ 2,849,833	0.40479	$ 1,153,591
20	2029		0.38598		9.8	0.1	3		9.7	$ 2,849,833		$ 2,849,833	0.38598	$ 1,099,968
21	2030		0.36803		9.7		4		9.7	$ 2,849,833		$ 2,849,833	0.36803	$ 1,048,837
22	2031		0.35093		9.7		3		9.7	$ 2,849,833		$ 2,849,833	0.35093	$ 1,000,083
23	2032		0.33461		9.7		2		9.7	$ 2,849,833		$ 2,849,833	0.33461	$ 953,595
24	2033		0.31906		9.7		3		9.7	$ 2,849,833		$ 2,849,833	0.31906	$ 909,268
25	2034		0.30423		9.7		4	0.1	9.6	$ 2,849,833		$ 2,849,833	0.30423	$ 867,002
26	2035		0.29009		9.6		3		9.6	$ 2,849,833		$ 2,849,833	0.29009	$ 826,700
27	2036		0.27660		9.6		2		9.6	$ 2,849,833		$ 2,849,833	0.27660	$ 788,272
28	2037		0.26375		9.6		3		9.6	$ 2,849,833		$ 2,849,833	0.26375	$ 751,630
29	2038		0.25149		9.6		4		9.6	$ 2,849,833		$ 2,849,833	0.25149	$ 716,691
30	2039		0.23980		9.6	0.1	3		9.5	$ 2,849,833		$ 2,849,833	0.23980	$ 683,377
31	2040		0.22865		9.5		2		9.5	$ 2,849,833		$ 2,849,833	0.22865	$ 651,611
32	2041		0.21802		9.5		3		9.5	$ 2,849,833		$ 2,849,833	0.21802	$ 621,321
33	2042		0.20789		9.5		4		9.5	$ 2,849,833		$ 2,849,833	0.20789	$ 592,440
34	2043		0.19822		9.5		3		9.5	$ 2,849,833		$ 2,849,833	0.19822	$ 564,901
35	2044		0.18901		9.5		2	0.1	9.4	$ 2,849,833		$ 2,849,833	0.18901	$ 538,642
36	2045		0.18022		9.4		3		9.4	$ 2,849,833		$ 2,849,833	0.18022	$ 513,604
37	2046		0.17185		9.4		4		9.4	$ 2,849,833		$ 2,849,833	0.17185	$ 489,730
38	2047		0.16386		9.4		3		9.4	$ 2,849,833		$ 2,849,833	0.16386	$ 466,965
39	2048		0.15624		9.4		2		9.4	$ 2,849,833		$ 2,849,833	0.15624	$ 445,259
40	2049		0.14898		9.4	0.1	3		9.3	$ 2,849,833		$ 2,849,833	0.14898	$ 424,561
41	2050		0.14205		9.3		4		9.3	$ 2,849,833		$ 2,849,833	0.14205	$ 404,826
42	2051		0.13545		9.3		3		9.3	$ 2,849,833		$ 2,849,833	0.13545	$ 386,008
43	2052		0.12915		9.3		2		9.3	$ 2,849,833		$ 2,849,833	0.12915	$ 368,065
44	2053		0.12315		9.3		3		9.3	$ 2,849,833		$ 2,849,833	0.12315	$ 350,956
45	2054		0.11743		9.3		4	0.1	9.2	$ 2,849,833		$ 2,849,833	0.11743	$ 334,642
46	2055		0.11197		9.2		3		9.2	$ 2,849,833		$ 2,849,833	0.11197	$ 319,087
47	2056		0.10676		9.2		2		9.2	$ 2,849,833		$ 2,849,833	0.10676	$ 304,254
48	2057		0.10180		9.2		3		9.2	$ 2,849,833		$ 2,849,833	0.10180	$ 290,111
49	2058		0.09707		9.2		4		9.2	$ 2,849,833		$ 2,849,833	0.09707	$ 276,626
50	2059		0.09256		9.2	0.1	3		9.1	$ 2,849,833		$ 2,849,833	0.09256	$ 263,767
				$ 8,904,083		0.50		0.40		$ 142,491,652	$ -	$ 142,491,652		$ 53,047,505

Although the breakwater's natural subsidence remains at 0.5 feet over the 50 year project evaluation, the impact on subsidence from storms becomes considerably less. In this "example", storm subsidence reduction was decreased from 0.1 foot/4 years to 0.1 feet//10 years. This resulted in the breakwater's crest height falling to 9.2 feet over the 50 year project evaluation period. Since the breakwater's crest height did not fall below 8 feet any time during the 50 year project evaluation period, port/vessel operational costs for each year was $2,849,833. This resulted in a port/vessel present worth operational cost of $53,047,505.

Table 10.18 provides construction costs and port/vessel operational costs associated with the hypothetical Plan 2- Repair East Breakwater When Crest Height Equals 7.5 feet. The breakwater does not deteriorate to 7.5 feet until project year 16. Breakwater repair construction costs of $9,786,000 are spread evenly over project years 16, 17 and 18. The present worth of these breakwater repairs are $6,322,336. Port/vessel operational costs for Plan 2 are based upon an East Breakwater crest elevation that starts out at 8.0 feet in project year 1, decreases to 7.5 feet in project year 16, then becomes 10.0 feet in project year19, and subsequently is reduced to 9.5 feet by project year 50. Breakwater subsidence due to storms is now reset in project year 19 to reflect that the structure being affected is essentially a new structure. The present worth of this port/vessel operational cost time stream is $58,898,384.

This process was repeated for each of the two remaining repair plans. The present worth of repair costs and port/vessel operational cost were developed for each plan and the WOP condition. Breakwater repair construction costs by plan are simply the present worth of these construction costs based on the project evaluation year in which they are incurred. Benefits associated with each plan are the difference in port/vessel operational costs between the WOP and WP condition. These benefits are calculated in present worth terms.

Table 10.19 provides a summary of plan costs and benefits in present worth terms for the 4 plans evaluated. The results shown here are purely "hypothetical". Plan costs are based on a recent estimate for East Breakwater reconstruction costs of $9,786,000. This reconstruction was assumed to take place over a three year period with equal expenditures in each year. Plan benefits were based on actual port/vessel operational costs associated with various wave heights (**Table 10.8**). Purely "hypothetical" data was developed that provided the percent of season various wave categories were encountered by East Breakwater crest height. (**Table 10.13**). "Hypothetical" breakwater subsidence rates due to age and storm damage were used to generate breakwater crest height elevations by project year.

Given these caveats, **Table 10.19** provides some useful information. This "example" demonstrates that the Repair Now option provides the highest net benefits of any of the plans evaluated. The delaying of repairs into the future does not have enough cost savings to overcome the decrease in port/vessel operational benefits associated with doing so. The longer into the future the repair is delayed, the closer port/vessel operational costs for that plan approach WOP condition port/vessel operational costs. Finally the Repair Now plan results in the highest benefits since increases in port/vessel operational costs under the WP condition are minimized since the breakwater is not allowed to deteriorate. Consequently, the differential between the WOP and WP condition port/vessel operational costs are at its greatest, and is larger than any of the other plans being evaluated.

Table 10.18 - Hypothetical Plan 2 - Repair When Crest Height = 7.5 Feet – Construction and Port/Vessel Operational Costs

Plan 2. - Repair When Crest Height Reaches 7.5

REPAIR COSTS	$ 9,786,000
Construction period	3
Yrly Repair costs	$ 3,262,000
Do Repair Crest=	3.5
RprCsts/ft	$ 978,600
Add Ft Repaired	4.5
Addtnl Crst Rpr Csts	$ 4,403,700
Total Construct Costs	$ 14,189,700
Construct Csts/Year	$ 4,729,900

Harbor Operational Costs For Repair When Breakwater is 7.5 Feet

Evaluation Year	Project Year	Repair costs	Present worth Factor	Present worth Of Repair costs	Brkwtr Crest Height Above LWD	Deterioration Subsidence Due To Age	Storms	Storms Impact On Crest Height	Resulting Brkwtr Crest Height Above LWD	Tonnage Operational Costs	Port Dredging Costs	Total Operational costs	Present worth Factor	Present worth Of Total Operational costs
1	2010		0.95352	$ -	8.0	0	4	0	8.0	$ 2,849,833		$ 2,849,833	0.95352	$ 2,717,362
2	2011		0.90919	$ -	8.0		3	0	8.0	$ 2,849,833		$ 2,849,833	0.90919	$ 2,591,048
3	2012		0.86693	$ -	8.0		2	0	8.0	$ 2,849,833		$ 2,849,833	0.86693	$ 2,470,606
4	2013		0.82663	$ -	8.0		3	0.1	7.9	$ 3,088,606		$ 3,088,606	0.82663	$ 2,553,140
5	2014		0.78821	$ -	7.9		4	0	7.9	$ 3,088,606		$ 3,088,606	0.78821	$ 2,434,460
6	2015		0.75157	$ -	7.9		3	0	7.9	$ 3,088,606		$ 3,088,606	0.75157	$ 2,321,297
7	2016		0.71663	$ -	7.9		2	0	7.9	$ 3,088,606		$ 3,088,606	0.71663	$ 2,213,394
8	2017		0.68332	$ -	7.9		3	0.1	7.8	$ 3,327,379		$ 3,327,379	0.68332	$ 2,273,665
9	2018		0.65156	$ -	7.8		4	0	7.8	$ 3,327,379		$ 3,327,379	0.65156	$ 2,167,976
10	2019		0.62127	$ -	7.8	0.1	3	0	7.7	$ 3,566,152		$ 3,566,152	0.62127	$ 2,215,542
11	2020		0.59239	$ -	7.7		2	0	7.7	$ 3,566,152		$ 3,566,152	0.59239	$ 2,112,555
12	2021		0.56485	$ -	7.7		3	0.1	7.6	$ 3,804,924		$ 3,804,924	0.56485	$ 2,149,227
13	2022		0.53860	$ -	7.6		4	0	7.6	$ 3,804,924		$ 3,804,924	0.53860	$ 2,049,323
14	2023		0.51356	$ -	7.6		3	0	7.6	$ 3,804,924		$ 3,804,924	0.51356	$ 1,954,062
15	2024		0.48969	$ -	7.6		2	0	7.6	$ 3,804,924		$ 3,804,924	0.48969	$ 1,863,230
16	2025	$ 4,729,900	0.46693	$ 2,208,515	7.6		3	0.1	7.5	$ 4,043,697		$ 4,043,697	0.46693	$ 1,888,109
17	2026	$ 4,729,900	0.44522	$ 2,105,855	7.5		4	0	7.5	$ 4,043,697		$ 4,043,697	0.44522	$ 1,800,342
18	2027	$ 4,729,900	0.42453	$ 2,007,966	7.5		3	0	7.5	$ 4,043,697		$ 4,043,697	0.42453	$ 1,716,655
19	2028		0.40479	$ -	10.0		3		10.0	$ 2,849,833		$ 2,849,833	0.40479	$ 1,153,591
20	2029		0.38598	$ -	10.0		4		10.0	$ 2,849,833		$ 2,849,833	0.38598	$ 1,099,968
21	2030		0.36803	$ -	10.0		3		10.0	$ 2,849,833		$ 2,849,833	0.36803	$ 1,048,837
22	2031		0.35093	$ -	10.0		2		10.0	$ 2,849,833		$ 2,849,833	0.35093	$ 1,000,083
23	2032		0.33461	$ -	10.0		3		10.0	$ 2,849,833		$ 2,849,833	0.33461	$ 953,595
24	2033		0.31906	$ -	10.0		4		10.0	$ 2,849,833		$ 2,849,833	0.31906	$ 909,268
25	2034		0.30423	$ -	10.0	0.1	3		9.9	$ 2,849,833		$ 2,849,833	0.30423	$ 867,002
26	2035		0.29009	$ -	9.9		2		9.9	$ 2,849,833		$ 2,849,833	0.29009	$ 826,700
27	2036		0.27660	$ -	9.9		3		9.9	$ 2,849,833		$ 2,849,833	0.27660	$ 788,272
28	2037		0.26375	$ -	9.9		4		9.9	$ 2,849,833		$ 2,849,833	0.26375	$ 751,630
29	2038		0.25149	$ -	9.9		3		9.9	$ 2,849,833		$ 2,849,833	0.25149	$ 716,691
30	2039		0.23980	$ -	9.9		2	0.1	9.8	$ 2,849,833		$ 2,849,833	0.23980	$ 683,377
31	2040		0.22865	$ -	9.8		3		9.8	$ 2,849,833		$ 2,849,833	0.22865	$ 651,611
32	2041		0.21802	$ -	9.8		4		9.8	$ 2,849,833		$ 2,849,833	0.21802	$ 621,321
33	2042		0.20789	$ -	9.8		3		9.8	$ 2,849,833		$ 2,849,833	0.20789	$ 592,440
34	2043		0.19822	$ -	9.8		2		9.8	$ 2,849,833		$ 2,849,833	0.19822	$ 564,901
35	2044		0.18901	$ -	9.8	0.1	3		9.7	$ 2,849,833		$ 2,849,833	0.18901	$ 538,642
36	2045		0.18022	$ -	9.7		4		9.7	$ 2,849,833		$ 2,849,833	0.18022	$ 513,604
37	2046		0.17185	$ -	9.7		3		9.7	$ 2,849,833		$ 2,849,833	0.17185	$ 489,730
38	2047		0.16386	$ -	9.7		2		9.7	$ 2,849,833		$ 2,849,833	0.16386	$ 466,965
39	2048		0.15624	$ -	9.7		3		9.7	$ 2,849,833		$ 2,849,833	0.15624	$ 445,259
40	2049		0.14898	$ -	9.7		4	0.1	9.6	$ 2,849,833		$ 2,849,833	0.14898	$ 424,561
41	2050		0.14205	$ -	9.6		3		9.6	$ 2,849,833		$ 2,849,833	0.14205	$ 404,826
42	2051		0.13545	$ -	9.6		2		9.6	$ 2,849,833		$ 2,849,833	0.13545	$ 386,008
43	2052		0.12915	$ -	9.6		3		9.6	$ 2,849,833		$ 2,849,833	0.12915	$ 368,065
44	2053		0.12315	$ -	9.6		4		9.6	$ 2,849,833		$ 2,849,833	0.12315	$ 350,956
45	2054		0.11743	$ -	9.6	0.1	3		9.5	$ 2,849,833		$ 2,849,833	0.11743	$ 334,642
46	2055		0.11197	$ -	9.5		2		9.5	$ 2,849,833		$ 2,849,833	0.11197	$ 319,087
47	2056		0.10676	$ -	9.5		3		9.5	$ 2,849,833		$ 2,849,833	0.10676	$ 304,254
48	2057		0.10180	$ -	9.5		4		9.5	$ 2,849,833		$ 2,849,833	0.10180	$ 290,111
49	2058		0.09707	$ -	9.5		3		9.5	$ 2,849,833		$ 2,849,833	0.09707	$ 276,626
50	2059		0.09256	$ -	9.5		3	0.1	9.4	$ 2,849,833		$ 2,849,833	0.09256	$ 263,767
				$ 6,322,336		0.40		0.70		$ 153,236,429	$ -	$ 153,236,429		$ 58,898,384

Table 10.19 - Plan Benefits and Costs

	Plan 1	Plan 2	Plan 3	Plan 4
	Repair	Repair	Repair	Repair
	Now	Once	Once	Once
	Crest=	Crest=	Crest=	Crest=
	8	7.5	7	6.5
Port/Vessel Operational Costs/Benefits-Present Worth				
WOP	$ 86,258,950	$ 86,258,950	$ 86,258,950	$ 86,258,950
WP	$ 53,047,505	$ 58,898,384	$ 72,190,743	$ 83,084,260
	------------------	------------------	------------------	------------------
Benefits	$ 33,211,445	$ 27,360,566	$ 14,068,207	$ 3,174,690
Costs	$ 8,904,083	$ 6,322,336	$ 3,358,870	$ 1,869,382
Benefit Cost Ratio- Net Benefits				
BC Ratrio	3.73	4.33	4.19	1.70
Net Benefits	$ 24,307,362	$ 21,038,230	$ 10,709,337	$ 1,305,308

10.6 Risk and Reliability Analysis – An Illustration

10.6.1 Inputs into a Risk Evaluation

Unfortunately, the development of the example consequence relationships for the Cleveland Port Authority was not available at the time the example breakwater repair evaluation was performed using risk analysis. However, the hypothetical data on increases in consequences, by water level and wave height, presented in **Table 10.20**, serve to illustrate how the additional costs associated with storms of a given frequency are evaluated in a risk-based model. These storm frequencies were determined by a combination of wave height and lake levels. The frequency of occurrence of these storms was multiplied by the associated additional consequence data associated with the resulting wave conditions that the port would experience. The event tree depicting these factors that were assumed to affect the reliability of the Cleveland East Breakwater is provided in Figure 10.1.

10.6.2 Model Outputs

The principle output is the dollar value of the consequences for each year in the life cycle given the condition of the project and other factors that affect reliability, as defined by the input factors and the input values. The consequence value represents the average value of each of the fifty years in the life cycle over all twenty thousand iterations of the life cycle. Other outputs, such as the simulated lake level, wave height, etc can be output to provide additional information and as a means of checking the model computations.

The difference in the value of the consequences (disbenefits) between the baseline (which are high) and the scheduled repair alternative (which are low) are designated as the benefits of the scheduled repair alternative. The benefits for each of the fifty years are converted into an annualized equivalent value, similar to a monthly house payment, based on the current interest rate of 4 5/8% and a 50 year period of amortization. The present values for each of the 50 years are added together (cumulative present value or Cum PV as listed below) and the sum is converted into an average annual equivalent value (AAEV). The basic procedure is shown in the table below.

Table 10.20 - Risk Model Benefit Computations - Procedure

Benefit computations				
	Consequences			
Year	Baseline	With scheduled repairs	Reduction (benefits)	Present value
1	2,295	0	2,295	2,243
2	2,295	0	2,295	2,144
3	2,295	0	2,295	2,049
4	2,295	0	2,295	1,959
5	2,295	0	2,295	1,872
50	2,295	0	2,295	245
Cum PV				44,441
AAEB				2,295

10.6.3 Economics of the Scheduled Repair Alternative

The benefits are compared to the costs of a pre-failure schedule repair to determine the economic feasibility of the cost of the scheduled repair. The conversion of the scheduled repair cost into an annualized amount comparable to the annualized benefits is done in the model workbook, but is not part of the model.

Table 10.21 - Risk Model Benefit Computations - Example

Benefit computations				
	Consequences			
Year	Baseline	With scheduled repairs	Reduction (benefits)	Present value
1	2,295	0	2,295	2,243
2	4,000	0	4,000	3,738
3	4,000	0	4,000	3,572
4	2,688	0	2,688	2,295
5	2,688	0	2,688	2,193
50	2,688	0	2,688	287
Cum PV				61,135
AAEB				3,157

10.6.4 Affordability Indicated by the Cost of the Consequences

The annualized cost of the consequences can be capitalized to compute an approximation of the cost of scheduled repairs that is economically justified.

Table 10.22 - Risk Model Computation of Affordable Cost - Example

Computation of affordable cost		
	Lower bound	Upper bound
AAEB	3157	3157
Capitalization factor	10.0	19.4
Affordable cost	31,567	61,135

10.6.5 Baseline Condition - Expected Consequences of Unreliable Service, Construction Costs

The negative economic consequences of the baseline condition were estimated using the simulation model and inputs discussed previously. The quantified values of the negative consequences, including the cost to repair the project, are listed in **Table 10.23**. The values are provided by components and for the project as a whole. The project values are less than the sum of the component values because the values were screened to avoid double counting if both components failed at the same time.

Table 10.23 - Baseline: Repair Costs and Benefits Foregone by Component
Average Annual Equivalent Values
(October 2007 Price Level; Thousands of Dollars; 4 7/8%)

Total Breakwater Repair Cost	($6,573)	Present Value
Repair Cost in Year 1	2,191	$ 1,811
Repair Cost in Year 2	2,191	$ 1,727
Repair Cost in Year 3	2,191	$ 1,647
Sum		$ 5,185
Project AAEV		$ 278.5
*AAEV is average annual equivalent value at 4 7/8% over 50 years.		

10.7 Factors Adding Complexity to Risk Based Analysis for Coastal Breakwater

This hypothetical analysis served to illustrate the complexities involved in performing a risk-based evaluation of a coastal breakwater. By far the primary complexity in the evaluation involves the coastal analysis. The complexity stems from determining the cause effect relationships of such factors as:

- The degradation relationship that relates breakwater crest height and time

- The relationship between lake water levels and storm generated wave heights on the deterioration of a breakwater structure.
- The translated inner harbor wave climate (frequency wave height) for each resultant breakwater crest height that can occur over time.
- Determination of the storm damage deterioration relationship to the breakwater.

GREAT LAKES AND SAINT LAWRENCE SEAWAY SYSTEM

RISK-BASED ANALYSIS OF HARBOR BREAKWATER REPAIR USING A SECTION OF CLEVELAND EAST BREAKWATER AS AN EXAMPLE

COASTAL ENGINEERING APPENDIX

US Army Engineer District Buffalo
1776 Niagara St
Buffalo, NY 14221

November 2008

1. INTRODUCTION

The Corps of Engineers maintains 117 Federal Harbors on the Great Lakes, with 54 of those serving commercial navigation traffic annually, and feature 78.5 miles of navigation structures. A critical maintenance backlog covering approximately 13.2 miles of navigation structures exists within the harbors throughout the Great Lakes navigation system. It is estimated that it would cost approximately $176.7 million to make these critical repairs. The 63 existing Federal recreational harbors, featuring 25.4 miles of navigation structures, also have a significant structural maintenance backlog[1].

Historically, the Corps has successfully maintained the Great Lakes navigation system structures to maintain all critical functions. However, in a constrained budget environment, this capability has been seriously eroded. Reduction in funding has resulted in degradation of the protective functions that navigation structures provide to harbors and coastline areas[2].

A summary of the structure type and maintenance issues follow[3].

- Total navigation structure maintenance budgeting was increased 7.2 percent from FY06 to FY08. This amount is less than 39% of the previous long-term average (1996–2005) of $25.8M for navigation structure maintenance.
- The Great Lakes include 25 of the top 100 harbors in the U.S., and nearly 104 miles of protective Federal navigation structures.
- The Great Lakes navigation structures have been in service for many years. Nearly a quarter of the structures are over 120 years old, 48% are 100 years old or older, and 75% exceed 60 years of age. More than half have not undergone a major rehabilitation effort in the past 50 years.

[1] USACE. 2007. Issue Paper on Great Lakes Navigation Structures, U S Army Corps of Engineers, dated 26 February 2007.
[2] Ibid 1.
[3] Ibid 1.

- The structures were built using cut stone, timber concrete and steel. Their composition reveals the use of stone as either an armor layer or interior filler in all structures, about half employ timber cribs, over 40% use steel sheet pile, a third use timber piling, a quarter use concrete and about 30% use cellular steel piling[4].
- Navigation structure degradation leads to the degradation of the wave climate present within the harbors. This decreases the safety of navigation operations, and can cause vessels to light load to prevent vessel damage when traversing federal project areas.
- Navigation structures also provide coastal storm and flooding protection to a large amount of public infrastructure and property. Structural degradation reduces the effectiveness and reliability of this function.

At present, approximately 13.2 miles of harbor structures are in critical need of repair. The FY07 and FY08 Budget provided for maintenance of one-half mile (4%) and 0.9 miles (7%), respectively, of this total. Total O&M Dollars for 2007 are at 57% (real dollars) of the 1997 amount. In order to maintain channels, more structure maintenance is curtailed[5]. In addition, the low lake water levels that have occurred in Lake Michigan and Lake Huron for the past eight years have accelerated the degradation of the timber crib structures in those lakes. Timber crib breakwater structures located in those lakes represent 21.4 miles of the total maintained structures. Their loss would result in a significant adverse impact on the Great Lakes system functionality and reliability[6].

The Breakwater Assessment Team (BAT) for the Great Lakes region is charged with identifying and prioritizing the most critical navigation structure repair work needed at Great Lakes Federal harbors. The BAT has agreed that a rigorous risk based approach analogous to that employed in assessing

[4] Bottin, R.R. 1988. Case Histories Of Corps Breakwater And Jetty Structures : Report 3, : North Central Division, TR REME-CO-3, Coastal Engineering Research Center, Vicksburg, MS.
[5] USACE. 2006. Great Lakes Navigation System (GLNS) Reliability, Achieving Acceptable Levels of Risk, Presentation given at Coastal Engineering Community of Practice, Vicksburg, MS, June 2006.
[6] Ibid 1.

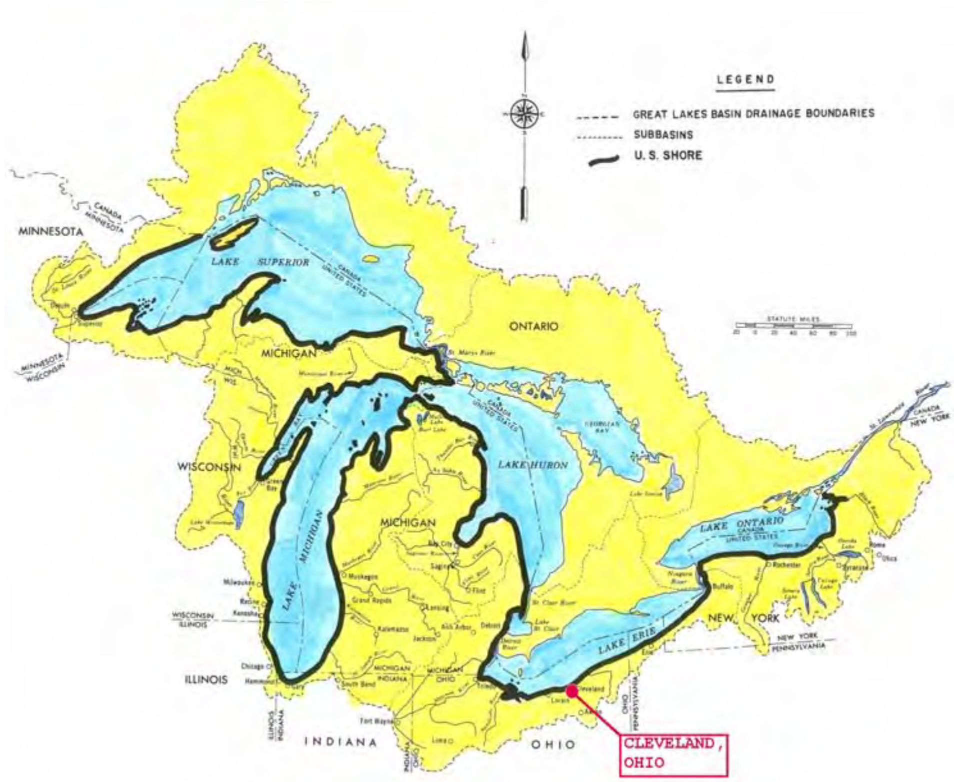
the economic and life-safety benefits of flood control projects is the most appropriate way to prioritize navigation structure work packages. However, it is recognized costs associated with this type of analysis would be prohibited. Hence this limited pilot study is being conducted of a portion of the Cleveland East Breakwater with the hope the some useful simplified metrics may be extracted and serve as a surrogate for a more rigorous analysis for the purposes of work package prioritization[7].

2. LOCATION

Cleveland Harbor is located in the city of Cleveland, Cuyahoga County, Ohio on the southern shore of Lake Erie. The length of the East Breakwater is 21,270 feet and was constructed to a design height of 10.3 feet above Low Water Datum (LWD). The westerly 3,300 feet is composed of a timber crib substructure with stone protection on the lakeside and a stone superstructure. The cribbing was constructed between 1887 and 1900 and the stone superstructure between 1917 and 1926. The easterly 17,970 feet is of laid-up (ashlar) stone construction over a stone core. The easterly section was constructed between 1903 and 1915.

This analysis will focus on the portion of the damaged breakwater from station 84+00 to the old lightblock (~station 106+29). Insert 1 presents the location of Cleveland Harbor within the Great Lakes-Saint Lawrence Seaway System. Figure 1 presents the location of the studied breakwater reach within the harbor.

[7] USACE. 2008. Methodology for Prioritization of Navigation Structure Repairs on the Great Lakes, U S Army Corps of Engineers, Buffalo, NY.



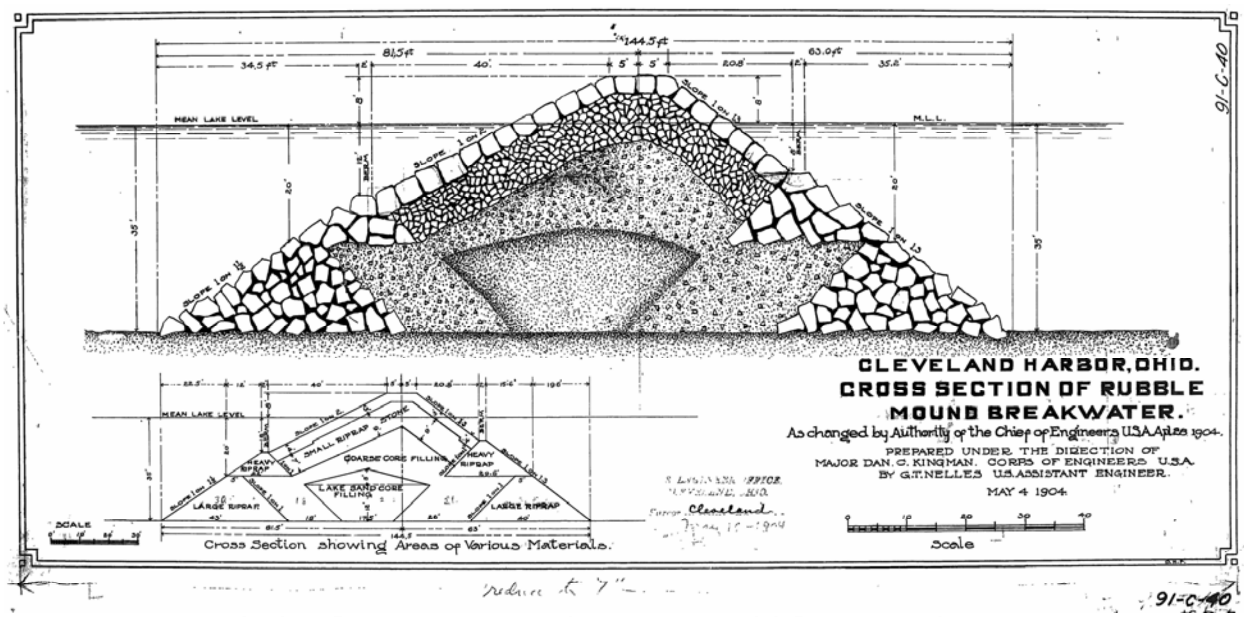
Insert 1. Cleveland Harbor Location map

3. CONSTRUCTION HISTORY: EAST BREAKWATER

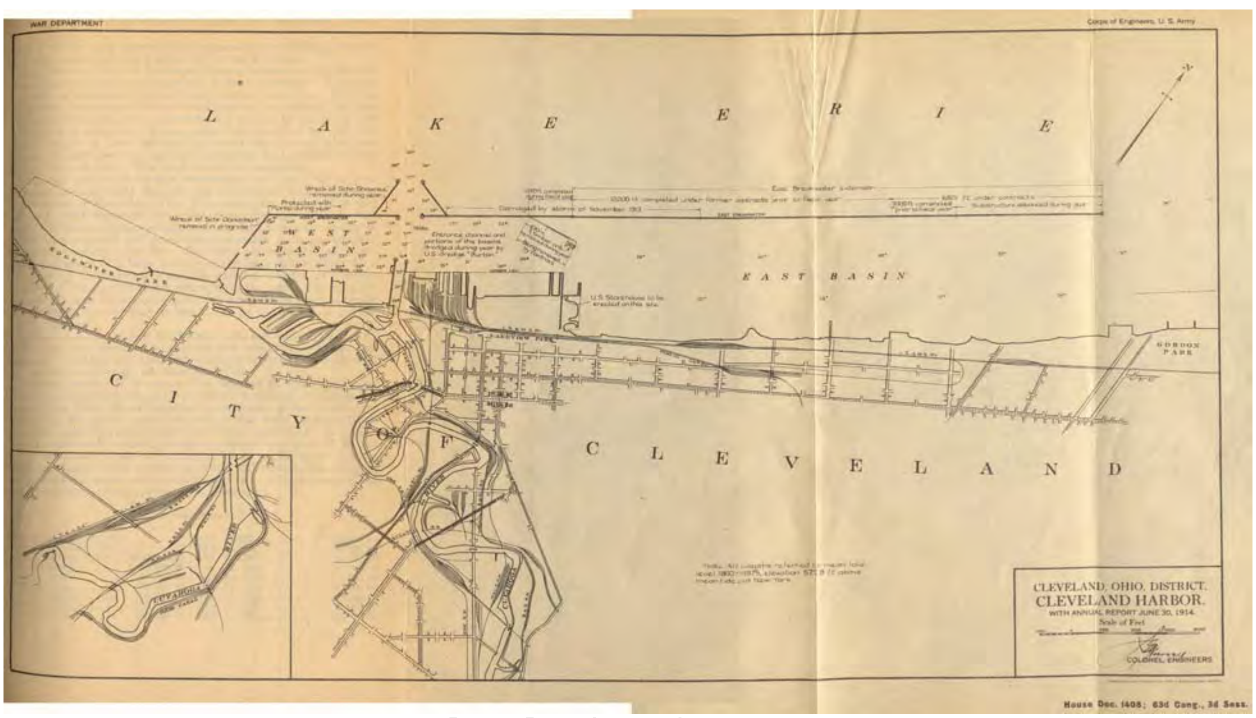
Improvements at the mouth of the Cuyahoga River to facilitate navigation began in 1827. For the next 50 years, work centered on the east and west piers at the river mouth. In 1876 construction began on the West Breakwater, with work beginning on the East Breakwater in 1887. The East Breakwater was a stone-filled timber crib structure with sloping wooden superstructure (Insert 2). The River and Harbor Act of 1902 required “the extension of the East Breakwater to be upon a line in prolongation of the centerline of the main portion of the existing breakwater.” The Act of Congress of that year authorized the construction of a new entrance to the harbor and the extension of the East Breakwater eastward to the city limits. This extension began approximately at the present station 106+29, “beginning with a pierhead 60 ft by 60 ft, 200 feet west of the end of the shore arm of the existing East Breakwater, leaving an entrance 550 feet with in the clear, with the centerline in the prolongation of the main breakwater and extending eastwardly about 10,000 feet." Due to settlement of the completed portion of the rubble mound East Breakwater during the storm of 26 October 1906, Board of Engineer officers recommended to abandon the use of sand and shale as core filler and to complete the structure entirely of quarry run stone (Insert 3). At that time of change, 2,000 feet had been completed and 1,000 feet was nearly completed. The rubble mound extension from the original timber crib portion to the pierhead occurred between 1911 and 1914. Removal of the original breakwater dogleg (deflection arm) was completed in 1915. Insert 4 shows the harbor condition map in 1914. Replacement of the original wooden superstructure with stone occurred between 1917 and 1926 (Insert 4).


CLEVELAND HARBOR, OHIO. EAST BREAKWATER.

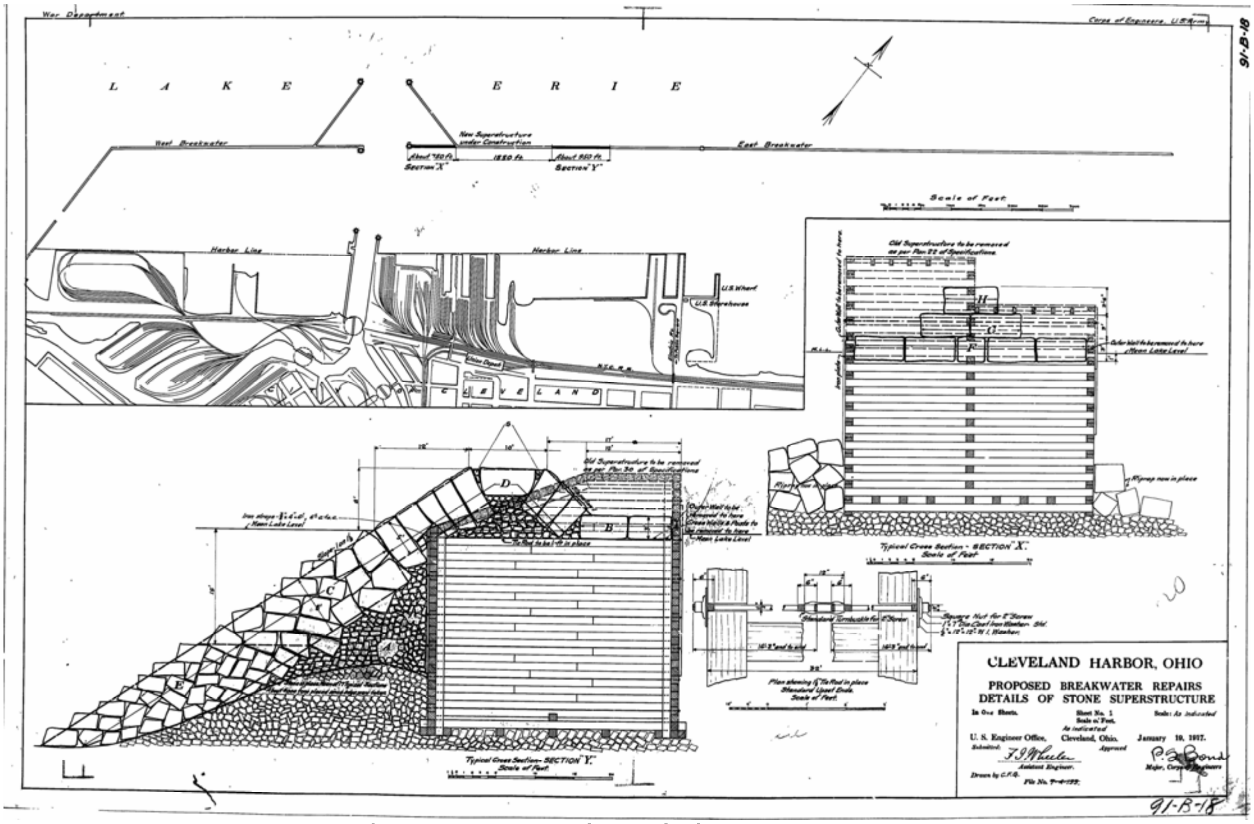
Insert 2. Cleveland Harbor East Breakwater, 1904. Note the Deflection Arm in the background that was removed in 1915.



Insert 3. Original Cross-Section For Rubble Mound Breakwater, Prior To Adopting Quarry Run Stone For Core Instead Of Sand And Shale – Section P (Note, Mean Lake Level = 2.3 ft Low Water Datum (LWD)).



Insert 4. Cleveland Harbor Map, 1914

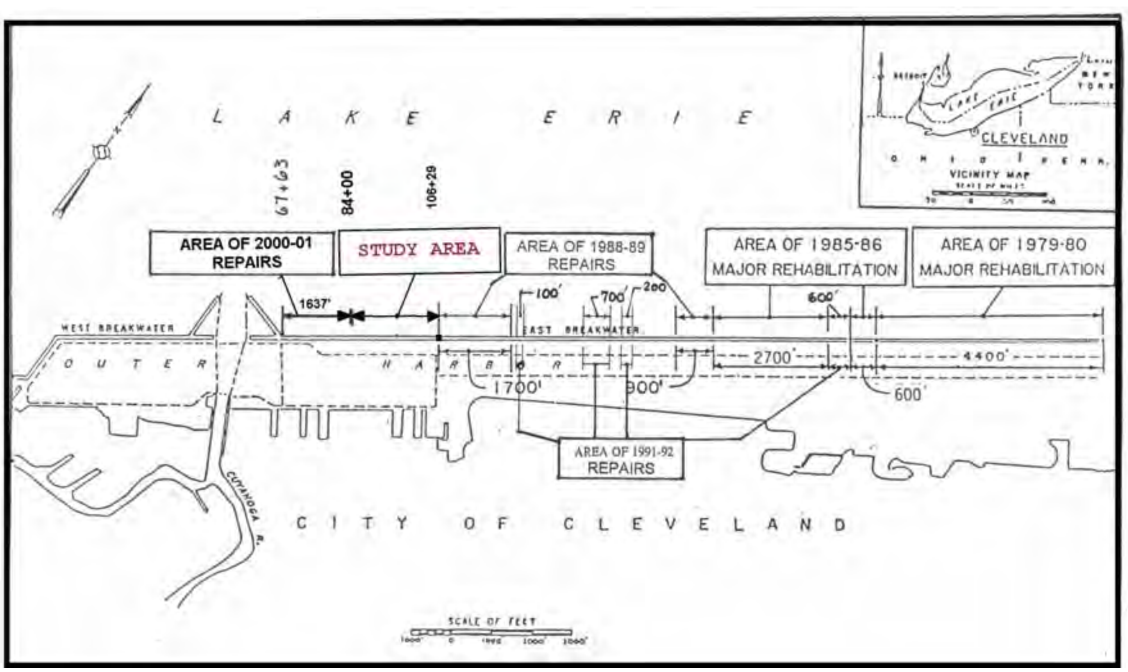


Insert 5. East Breakwater Repair with Stone Superstructure, 1917 – Section Y.

The East Breakwater has had a history of repair (USAED Buffalo 1984[8], 1988[9] & 1990[10]). Storm damage has resulted in the displacement of the laid-up cover stone, especially on the lakeside and consequent unraveling of the breakwater slope in many areas over the years. Some deterioration of the cover stone has also resulted in exposure of the core stone. Subsequent loss of core stone has resulted in the subsidence of the structure. The majority of the damage to the structure is on the lakeside with eventual deformation on the harborside in areas where repairs were not made in a timely manner.

[8] US Army Engineer District Buffalo. 1984. East Breakwater Major Rehabilitation, Cleveland Harbor, Ohio, Phase II GDM.
[9] US Army Engineer District Buffalo. 1988. East Breakwater Repair, Cleveland Harbor, Ohio, Design Analysis.
[10] US Army Engineer District Buffalo. 1990. East Breakwater Repair, Cleveland Harbor, Ohio, Design Analysis.

Most areas needing minor repairs have been done using Corps derrick boats with stone procured under supply contracts. Repairs to the structure were made by rebuilding the damaged portion above -10 feet LWD in a manner similar to the original construction using 3 to 8 ton cut stone. Below -10 feet LWD, additional stone weighing between 10 and 14 tons was been placed in a random manner on the existing cover stone to help prevent further deterioration where it was difficult to rebuild the existing laid-up construction. In addition, two major rehabilitations (1979-1980 and 1985-1986) and three significant repairs occurred during 1988-1989, 1990 and 2000-2001. Except for the 1979 rehabilitation, which used a 2-ton dolosse overlay, these repairs consisted of stone overlays. While the earlier stone repairs used overlays at a 1V:1.5H slope, the latter ones were placed at 1V:2H. Insert 6 presents the areas along the East Breakwater that were repaired during the major rehabilitation and repair projects as well as the present study area. Insert 7 presents a photograph taken during the 2000-01 repairs.



Insert 6. Cleveland East Breakwater Repair Areas

Insert 7. East Breakwater Repair Looking East from East Arrowhead, 11 June 2001

On 27 August 2007, the Great Lakes Breakwater Assessment Team (BAT) inspected the Cleveland Harbor structures by watercraft. A continuous videotape recording and digital still camera record was made of the East Breakwater lakeside. The photographs within the study area have been stitched together and are presented on Figures 2 through 9. The approximate station number is shown and was estimated by the total photograph length and the actual breakwater reach length. It should be noted that since the background city buildings appear to move little in comparison to the breakwater, which is in the immediate foreground, when stitching the photographs, the buildings become repeated. The viewer should ignore this effect and concentrate only on the breakwater stones.

As the stone structure is a laid-up structure, it is comprised of only one layer of cut stone block armor and relies on close contact with adjacent stones for stability. Loss of this contact reduces the structural integrity. It was found within this reach the irregularity in the crest has resulted in at least 2 feet of overall settlement, with up to 4 feet of settlement occurring at some locations (especially between stations 93 to 98). Significant separation between the armor stone is occurring. As the majority of the stones have been displaced or shifted, contact between adjacent stones has been minimized, resulting in uneven stone courses and exposure of the core. The BAT team assessed the overall structural index (SI) for this reach and determined that it was 5.8 (out of 6), indicating that damage was severe and requires repair over the majority of the reach.

4. METHODOLOGY AND RESULTS

With the project development team having developed the basic event tree, the next step was to determine the potential additional damage to the breakwater, associated repair costs and the change in the wave climate behind the breakwater. The basic methodology and results follow. It should be noted that the methodology used did not entail a rigorous analyses, rather one that was tailored to the available time and funding.

A. Water Level – Frequency Relation

The National Oceanic and Atmospheric Administration (NOAA) maintains a water level gage at Cleveland Harbor. The Lake Erie at Cleveland gage has been in operation since 1904. Annual maximum water levels for Cleveland Harbor were obtained for the period, 1904- 2007, ranked, and the exceedence probability determined. The exceedence probability was determined for each annual maximum lake level by the Weibull equation:

$$P = m/(n+1),$$

Where,
- P = Exceedence Probability
- m = Rank
- n = Total Years of Data

Table 1 presents the Lake Erie at Cleveland annual maximum water elevation data and Table 2 presents the water level for the 1.001-year, 2-year and 100-year events. Water elevations are expressed in feet above International Great Lakes Datum 1985 (IGLD 1985) which is 569.2 feet above Low Water Datum (LWD). It should also be noted that the recurrence interval is the reciprocal of probability. Figure 10 presents the water elevation – frequency curve for Lake Erie at Cleveland. A best fit curve was drawn by hand through the data points.

Table 1. Lake Erie at Cleveland, OH Annual Maximum Lake Levels, 1904-2007

Year	Max Lake Level (feet) IGLD 1985	Rank	Exceedence Probability	Recurrence Interval (Years)
1908	576.12	1	0.0095	105.0000
1987	575.33	2	0.0191	52.5000
1986	574.31	3	0.0286	35.0000
1982	575.26	4	0.0381	26.2500
1973	575.08	5	0.0476	21.0000
1985	574.82	6	0.0571	17.5000
1997	574.74	7	0.0667	15.0000
1952	574.63	8	0.0762	13.1250
1974	574.63	9	0.0857	11.6667
1972	574.62	10	0.0952	10.5000
1976	574.59	11	0.1048	9.5455
1947	574.41	12	0.1143	8.7500
1975	574.38	13	0.1238	8.0769
1998	574.38	14	0.1333	7.5000
1946	574.21	15	0.1429	7.0000
1990	574.18	16	0.1524	6.5625
1980	574.08	17	0.1619	6.1765
1945	574.06	18	0.1714	5.8333
1978	574.00	19	0.1809	5.5263
1979	574.00	20	0.1905	5.2500
1983	573.93	21	0.2000	5.0000
1953	573.90	22	0.2095	4.7727
1993	573.88	23	0.2191	4.5652
1992	573.79	24	0.2286	4.3750
1984	573.77	25	0.2381	4.2000
1943	573.71	26	0.2476	4.0385
1913	573.70	27	0.2571	3.8889
1960	573.64	28	0.2667	3.7500
1996	573.62	29	0.2762	3.6207
1969	573.62	30	0.2857	3.5000
1929	573.59	31	0.2952	3.3871
1951	573.55	32	0.3048	3.2813
1977	573.54	33	0.3143	3.1818
1995	573.46	34	0.3238	3.0882
1948	573.45	35	0.3333	3.0000
1961	573.43	36	0.3429	2.9167
1954	573.42	37	0.3524	2.8378
1991	573.41	38	0.3619	2.7632
1988	573.37	39	0.3714	2.6923
1978	573.37	40	0.3809	2.6250

Table 1. Lake Erie at Cleveland, OH Annual Maximum Lake Levels, 1904-2007 continued

Year	Max Lake Level (feet) IGLD 1985	Rank	Exceedence Probability	Recurrence Interval (Years)
1968	573.35	41	0.3905	2.5610
1956	573.33	42	0.4000	2.5000
1944	573.32	43	0.4095	2.4419
1994	573.29	44	0.4191	2.3864
1981	573.19	45	0.4286	2.3333
1930	573.19	46	0.4381	2.2826
2005	573.14	47	0.4476	2.2340
1919	573.13	48	0.4571	2.1875
1989	573.10	49	0.4667	2.1429
1971	573.08	50	0.4762	2.1000
1950	573.07	51	0.4857	2.0588
1917	573.01	52	0.4952	2.0192
1904	572.94	53	0.5048	1.9811
1909	572.94	54	0.5143	1.9444
1921	572.94	55	0.5238	1.9091
1999	572.93	56	0.5333	1.8750
1949	572.91	57	0.5429	1.8421
1970	572.91	58	0.5524	1.8103
1907	572.79	59	0.5619	1.7797
2004	572.78	60	0.5714	1.7500
1967	572.73	61	0.5809	1.7213
1957	572.64	62	0.5905	1.6935
1914	572.61	63	0.6000	1.6667
2002	572.61	64	0.6095	1.6406
2007	572.59	65	0.6191	1.6154
1906	572.53	66	0.6257	1.5909
1920	572.50	67	0.6381	1.5672
1959	572.49	68	0.6476	1.5441
1963	572.47	69	0.6571	1.5217
1910	572.46	70	0.6667	1.5000
2006	572.45	71	0.6762	1.4789
1942	572.41	72	0.6857	1.4583
1922	572.39	73	0.6952	1.4384
1966	572.38	74	0.7048	1.4189
2003	572.37	75	0.7143	1.4000
1911	572.36	76	0.7238	1.3816
1916	572.36	77	0.7333	1.3636
1905	572.33	78	0.7429	1.3462
1924	572.28	79	0.7524	1.3291
1937	572.26	80	0.7619	1.3125

Table 1. Lake Erie at Cleveland, OH Annual Maximum Lake Levels, 1904-2007 continued

Year	Max Lake Level (feet) IGLD 1985	Rank	Exceedence Probability	Recurrence Interval (Years)
1918	572.25	81	0.7714	1.2963
2001	572.23	82	0.7809	1.2805
1912	572.22	83	0.7905	1.2651
2000	572.19	84	0.8000	1.2500
1962	572.16	85	0.8095	1.2353
1928	572.12	86	0.8191	1.2209
1931	572.06	87	0.8286	1.2069
1915	572.02	88	0.8381	1.1932
1939	571.96	89	0.8476	1.1798
1938	571.91	90	0.8571	1.1667
1926	571.88	91	0.8667	1.1538
1958	571.82	92	0.8762	1.1413
1933	571.81	93	0.8857	1.1290
1940	571.80	94	0.8952	1.1170
1927	571.71	95	0.9048	1.1053
1941	571.66	96	0.9143	1.0938
1932	571.64	97	0.9238	1.0825
1923	571.48	98	0.9333	1.0714
1964	571.44	99	0.9429	1.0606
1925	571.32	100	0.9524	1.0500
1965	571.31	101	0.9619	1.0396
1936	571.19	102	0.9714	1.0294
1935	571.11	103	0.9809	1.0194
1934	570.94	104	0.9905	1.0096

Table 2. Lake Erie at Cleveland Water Elevation – Recurrence Interval

Recurrence Interval	Water Level	
	Feet – IGLD (1985)	Feet- LWD
1.001- Year	570.0	0.8
2-Year	573.0	3.8
100-Year	576.0	6.8

B. Offshore Wave Height

A wave hindcast was developed for 53 stations along the Lake Erie shore based upon thirty-two years (1956-1987) of meteorological data at three-hour intervals (Driver, et.

al., 1991)[11]. The nearest wave hindcast station (Driver, et. al., 1991) to Cleveland Harbor is WIS Station 10 at 81.72W and 41.58N and is shown on Figure 11. The shore normal at this location has been established as 329 degrees azimuth. Waves approaching Cleveland Harbor approach from 275 degrees to 48 degrees azimuth and only those waves were considered during the wave analysis.

a. Offshore Wave Height – Duration Relation

Wave data was obtained from the Wind Information System (WIS) Lake Erie Station 10, for waves propagating toward Cleveland Harbor between 275 and 48 degrees Azimuth[12]. Offshore wave height, time of occurrence, wave period and offshore wave angle for the 32-year period of record were tabulated in an excel spreadsheet. The wave data (31,976 waves total) was ranked in ascending order by wave height. The percent of time the wave height was exceeded was calculated for each wave:

Percent of Time Wave Height Exceeded = Rank/(Total Number of Waves) * 100 Percent

The percent of time wave height exceeded versus wave height is presented in Figure 12. The best fit curve shown was drawn by hand.

b. Offshore Wave Height – Frequency Relation

For this analysis, the wave height-frequency relation was developed using the annual maximum significant wave height for all waves approaching the Cleveland East Breakwater within the considered wave angle band. The respective frequency of occurrence of the annual maximum waves was determined using the Weibull relation:

$P = m/(n+1)$
Where:
P = probability
M = rank
N = number of years of record

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[11] Driver, D.B., Reinhard, R.D. and Hubertz, J.M. 1991. Hindcast Wave Information For The Great Lakes: Lake Erie, WIS RPT 22, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

[12] All degrees are Azimuth True North

Table 3 presents a summary of the annual maximum wave heights and Figure 13 presents the plotted annual maximum wave height-frequency curve.

Table 3. Annual Maximum Wave Heights, WIS Station LE10, $275^0 - 48^0$

Date	H - Feet	T - sec	Direction	RANK	Probability Percent
1982040612	14.8	10	6	1	3.03
1962111012	12.8	9	43	2	6.06
1975040321	12.8	8	322	3	9.09
1969041900	12.5	8	43	4	12.12
1974040900	12.5	9	43	5	15.15
1979040621	12.5	8	278	6	18.18
1980011209	12.5	8	277	7	21.21
1956022603	12.1	8	293	8	24.24
1957040900	12.1	9	41	9	27.27
1978011003	12.1	8	276	10	30.30
1984032906	12.1	8	44	11	33.33
1970040300	11.8	8	289	12	36.36
1963050103	11.5	8	330	13	39.39
1967111909	11.5	8	294	14	42.42
1971012621	11.5	8	281	15	45.45
1983042421	11.5	8	5	16	48.48
1987042421	11.5	8	42	17	51.52
1973031800	11.2	8	293	18	54.55
1964011312	10.8	8	43	19	57.58
1968031221	10.8	8	43	20	60.61
1986031109	10.8	8	275	21	63.64
1960121206	10.5	8	43	22	66.67
1966110300	10.5	8	26	23	69.70
1972040718	10.5	8	43	24	72.73
1965011618	10.2	8	44	25	75.76
1958042503	9.8	7	294	26	78.79
1976040418	9.8	8	41	27	81.82
1981042018	9.8	7	4	28	84.85
1959032800	9.5	8	5	29	87.88
1961031000	9.5	7	323	30	90.91
1977112615	9.2	7	313	31	93.94
1985031218	9.2	7	288	32	96.97

The directionality of all of the waves considered during the hindcast period was determined by sorting the waves into 10-degree angle bands and counting the number of waves in each band. Table 4 presents the number of waves within each band and Figure 14 presents a plot of the wave direction distribution.

Table 4. WIS LE10 Wave Direction Distribution, 275^0 - 45^0

Angle Band[1]	1955-1965	1966-1977	1978-1987	Total	Percent Total
275 - 284	1076	1247	1162	3485	11.2
285 - 294	1335	1219	952	3506	11.3
295 - 304	1100	1015	873	2988	9.6
305 - 314	941	932	850	2723	8.8
315 - 324	482	518	507	1507	4.8
325 - 334	534	509	443	1486	4.8
335 - 344	652	732	587	1971	6.3
345 - 354	573	657	558	1788	5.7
355 - 4	1130	978	1807	3915	12.6
5 - 14	463	534	587	1584	5.1
15 - 24	684	650	654	1988	6.4
25 - 34	508	570	588	1666	5.4
35 - 44	946	807	752	2505	8.1
SUM	10424	10368	10320	31112	100

1. Note that since 10-degree angle bands were used, waves from 46^0 to 48^0 were not included.

Due to the limited time and budget constraints, waves from multiple directions were not determined during this analysis. Rather, the selected waves were considered to approach the East Breakwater along the shore normal. Table 5 presents the offshore waves used for the risk analysis.

Table 5. Offshore Wave Parameters

Wave Recurrence Interval	H_{mo} - Feet	T_p - sec	Direction
100-year	14.7 FT	10 Seconds	329 degrees
10-Year	13.0 FT	9 Seconds	329 degrees
2-year	11.2 FT	8 Seconds	329 degrees
1.1-year	9.4 FT	7 Seconds	329 degrees

The following storms were used to develop the pattern storm hydrograph, based upon the peak significant wave height being similar to the computed offshore wave height for the given recurrence interval storm waves: April 1982 for the 100-year, November 1962 for the 10-year and the March 1973 for the 2-year. No damage results from the 2-

and 1.001-year waves. The 100-year and 10-year offshore storm wave height graphs are shown on Figures 15 and 16.

C. Incident Waves at Breakwater

Waves are irregular in height, period and direction. The methodology to compute the transformation and attenuation of irregular waves propagating from deep water based upon work done by Goda has been summarized in Seelig and Ahrens (1980)[13] and is intended for open sections of the coast with continuously shallowing depth contours. Design curves were developed to compute refraction coefficients and nearshore wave breaking. Refraction calculations are based on the energy-weighted superposition of refraction coefficients obtained from linear theory and include directional spreading of wave energy. The method is intended for the case of straight parallel bottom contours. Calculation of refraction coefficients, K_R, and nearshore wave direction angle, α, using the design curves in Seelig and Ahrens (1980) require the dominant deepwater wave direction angle, α_0, an estimate of the variation of energy level with wave direction parameter, S^*, and the peak wave period, T_p. The recommended value for S^* is 4.0 (wind waves). The estimation of the refraction coefficient allows the calculation of the equivalent deepwater wave height, H_0', which is determined from

$$H_0' = K_R H_0$$

where H_0 (also labelled as H_{mo} in this report) is defined as the deepwater significant wave height.

The nearshore wave height prediction model for irregular waves accounts for wave breaking, nonlinear wave shoaling, irregular wave setup and surf beat. Goda's approach allows broken waves to reform at a lower height. The significant wave height at the structure, H_{sig}, is calculated using H_0', T_p, the offshore bottom slope, m, and the water depth, d.

Goda’s algorithm has been incorporated into the Coastal Engineering Design and Analysis System[14] and was

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[13] Seelig, W.M. and Ahrens, J.P. 1980. "Estimating Nearshore Conditions for Irregular Waves," Technical Paper No. 80-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

[14] USACE. 2008. Computer Program, Coastal Engineering Design and Analysis System, CEDAS, US Army Engineer Research and Development Center, Vicksburg, MS.

used to estimate incident waves at the Cleveland East Breakwater

a. Incident Waves at Breakwater – Period of Record

Incident waves at the Cleveland East Breakwater were calculated for the entire hindcast data set with an deep water wave angle, α_0, between 275 and 48 degrees Azimuth[15]. Due to the large record of waves for this time period, a generalized method was developed to determine the incident wave height for all offshore waves, excluding storm events. Incident waves for storm events were calculated using the Coastal Engineering Design and Analysis System(CEDAS).

The generalized method for calculating offshore wave heights, began with plotting all the deep water waves versus (vs.) wave period for the 32-year period of record (Figure 17). Next, nine individual wave heights were selected from this data. The nine offshore wave heights were combined with three water levels: +0.8 feet Low Water Datum (LWD)[16] (1.001-year water level return period), +3.8 feet LWD (2-year water level return period), and +6.8 feet LWD (100-year water level return period) and two offshore wave directions, α_0: 0 degrees and 60 degrees. CEDAS was used to calculate the incident wave heights for these 54 offshore wave cases. The incident wave heights vs. offshore wave heights are presented in Inserts 8 and 9. The 2-year water level return period (+3.8 feet LWD) was used to establish a relationship between the incident wave height and offshore wave height for determining generalized incident wave heights, Inserts 10 and 11. Values for the incident waves were calculated based upon the best fit line equations found in Inserts 10 and 11.

The following is a summary of the equations from Inserts 10 and 11:

For deepwater wave directions between 330 degrees and 30 degrees and for deep water wave heights less than 10 feet:
Y = 0.9407X
Where:
Y = Incident Wave Height (FT)
X = Deep Water Wave height (FT)

[15] All degrees are Azimuth True North
[16] All depths are in relation LWD (Low Water Datum) 569.2 feet International Great Lakes Datum (IGLD 1985)

For deepwater wave directions between 330 degrees and 30 degrees and for deep water wave heights greater than 10 feet:

$Y = 0.8274X + 1.136$

For deepwater wave directions between 270 degrees and 300 degrees or between 30 degrees and 90 degrees and for deep water wave heights less than 10 feet:

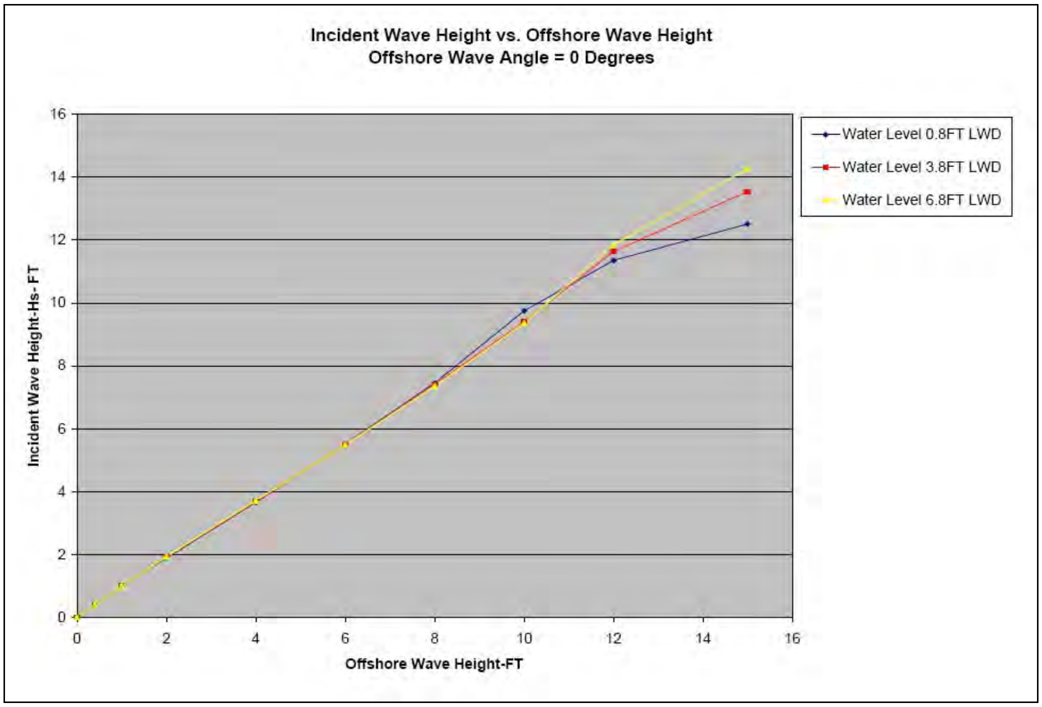
$Y = 0.9241X$

For deepwater wave directions between 270 degrees and 300 degrees or between 30 degrees and 90 degrees and for deep water wave heights greater than 10 feet:

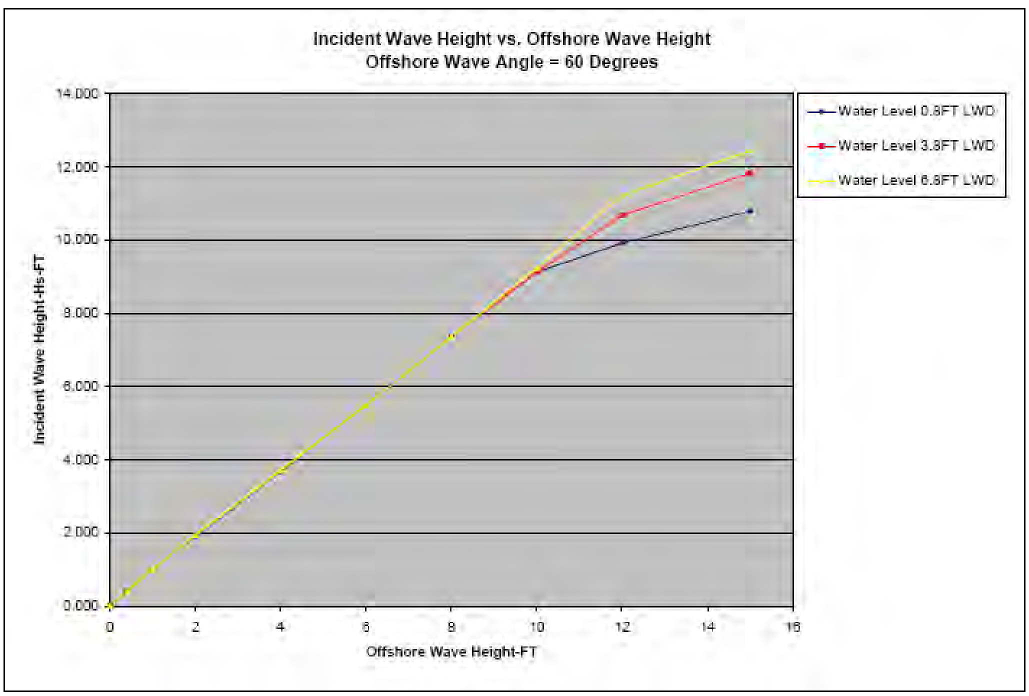
$Y = 0.5194X + 4.04$

Note, a 0 degree offshore wave angle was assumed for deepwater wave directions between 330 degrees and 30 degrees toward the foreshore. A 60 degree offshore wave direction was used for all waves propagating between 270 degrees and 300 degrees or between 30 degrees and 90 degrees toward the foreshore. Employing the above equations and wave parameters, the generalized incident wave heights were calculated for all offshore waves for the study time period, excluding storm events.

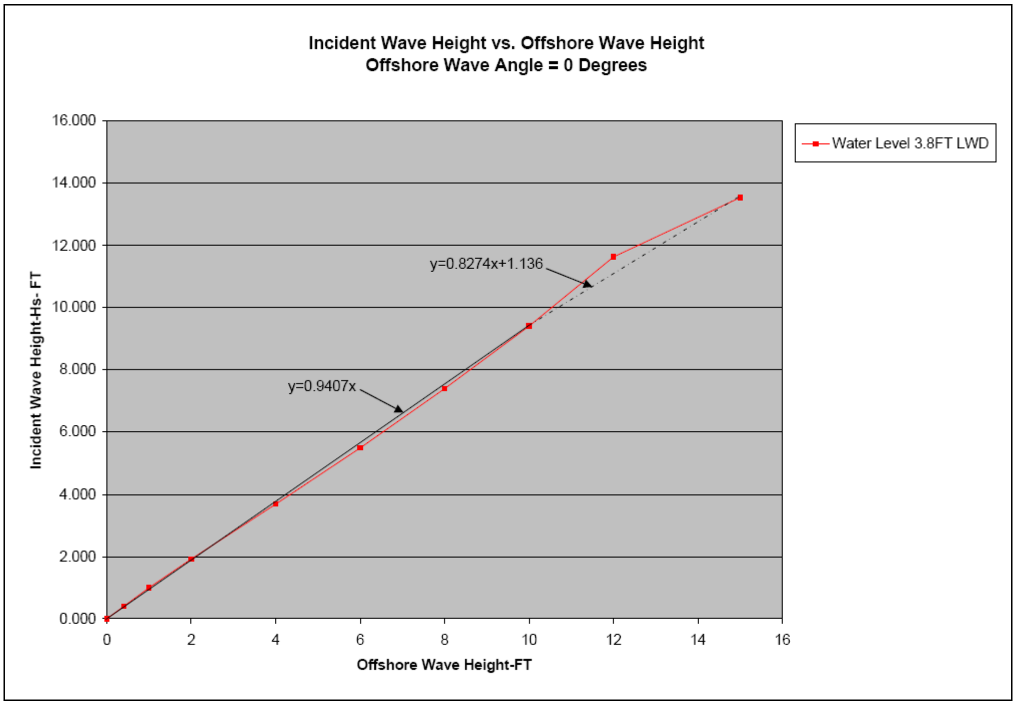
The largest storm events occurred in November 1962, April 1969, April 1975, and April 1982. The incident waves during storm events were calculated using CEDAS. The incident waves during storm events and generalized incident waves were applied to estimate historic damage to the breakwater in report Section 4.E.b.



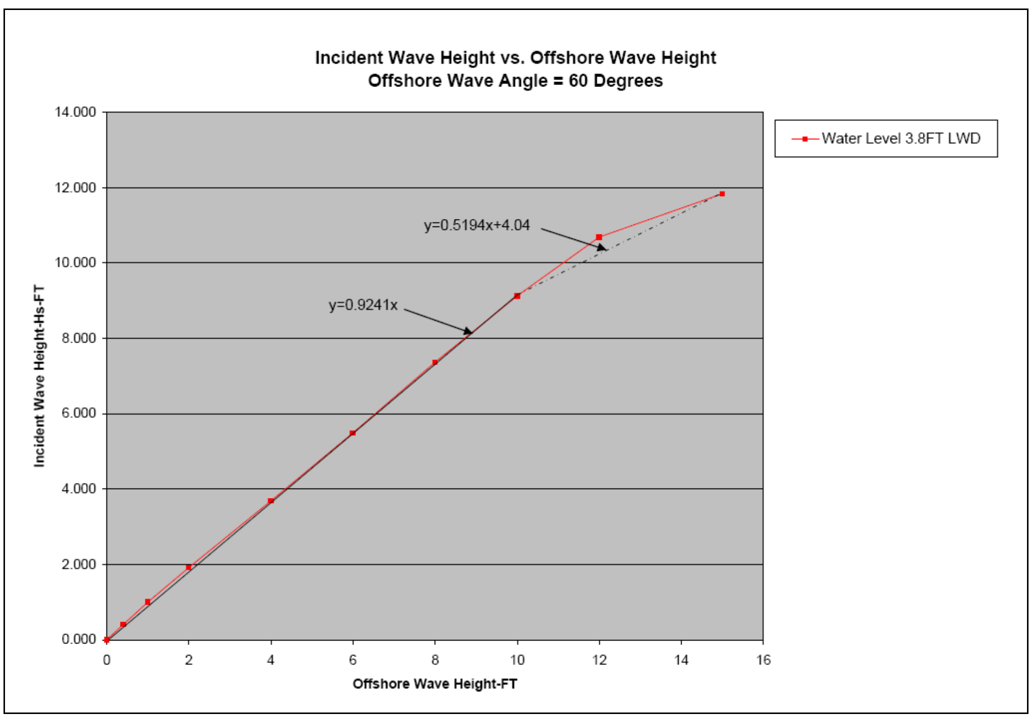
Insert 8. Wave Height versus Wave Period, 275 to 48 Degrees



Insert 9. Incident Wave Height vs. Offshore Wave Height, Offshore Wave Angle = 0 Degrees



Insert 10. Incident Wave Height vs. Offshore Wave Height
Offshore Wave Angle = 0 Degrees



Insert 11. Incident Wave Height vs. Offshore Wave Height
Offshore Wave Angle = 60 Degrees

b. Incident Waves at Breakwater – Storm Events

The incident wave height storm hydrograph was estimated for the three water levels (100-, 2- and 1.001-year) using the Goda algorithm in CEDAS as described previously. For these hypothetical storms, the waves were assumed to be approaching the breakwater along the shore normal. The incident wave height at the breakwater for the 100- and 10-year waves are presented in the damage tables presented in Section 4.E.c and the 2- and 1.001-year incident waves are presented in the table presented in Section 4.G.b., respectively.

D. Basic Existing Cross-section

Above and below water surveys of the structure and lake bottom in the vicinity of the breakwater reach under investigation were obtained during Winter/Spring 2008. Structure cross-sections were made using Microstation InRoads™ at 25-foot intervals (Figures 18 - 21 present sections at 100-ft intervals). This data was used to plot the crest elevation, crest width and armor slope versus station and are shown on Figures 22 - 24, respectively. This suggests a mean crest elevation of +7.1 ft LWD that varies from a minimum of +5 ft LWD to a maximum of +8 ft LWD and a mean crest width of 9.1 feet that varies from a minimum of 4 feet to a maximum of 16 feet. This information was used to estimate a typical section for the entire reach under investigation. Figure 25 presents the typical existing section, with the assumed original section shown for comparison (variables are described in next section).

E. Additional Damage to Breakwater

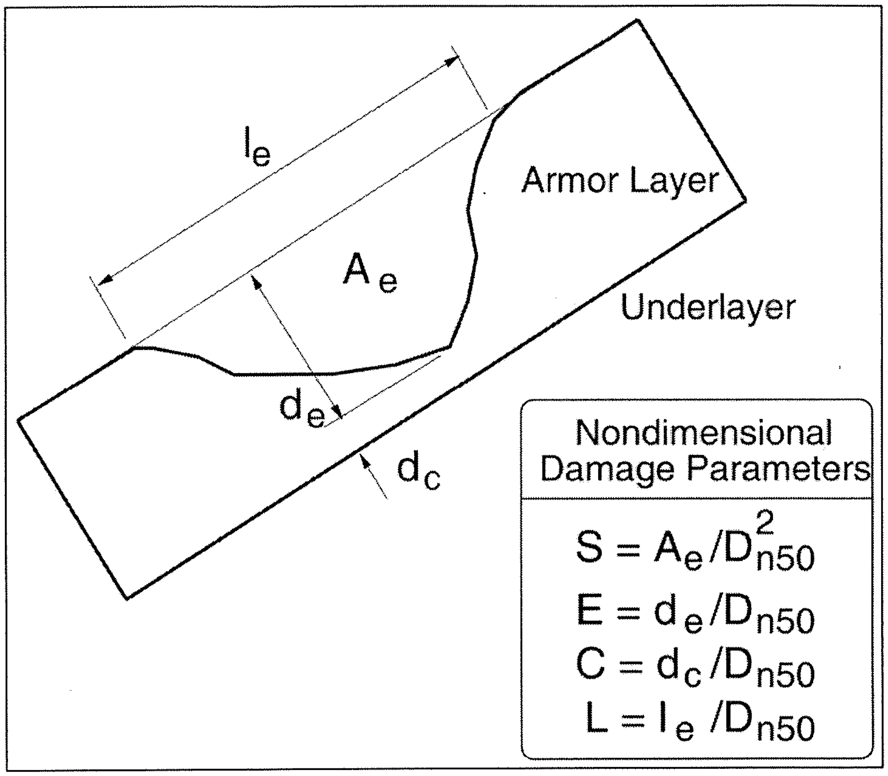
a. Damage Equations

The damage progression on a rubble mound breakwater caused by wave action has been summarized by Melby (1999)[17]. While the section of the Cleveland East Breakwater under investigation has a single-layer of cut stone armor, it has been severely damaged and is no longer functioning as a breakwater with ashlar armor. It is noted that damage progression is not the same for a single-layer of cut stone armor as for a rubble-mound breakwater since there is only one layer of armor, the armor is not irregularly shaped which allows it more readily interlocked after some

[17] Melby, J.A. 1999. Damage Progression on Rubble-Mound Breakwaters, TR CHL-99-17, US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

movement and the stone 'underlayer" is much smaller and hence can more readily be lost through the armor voids. Nevertheless, this is the only formulation for wave-induced damage and will be applied with recognition of the limitations.

The basic wave induced damage equations, as illustrated in Insert 12, are:



Insert 12. Rubble-mound Damage

$$S(t) = 0.011N_s^5(N_e + \delta N)^{0.25}$$

Where,

$S(t)$ = accumulated damage expressed as eroded cross-sectional area/square of armor width.

N_s = dimensionless stability number

$= H_s/(\Delta D_{n50})$

H_s = incident wave height (FT)

$\Delta = S_a - 1$

S_a = specific gravity of armor unit material

D_{n50} = Average armor stone dimension (FT)

$N_e = (S(t_n)/(0.011N_s^5))^4$

$\delta N = (t-t_n)/T_m$ for $t_n \leq t \leq t_{n+1}$

t = time (seconds)

T_m = mean wave period - seconds

= 0.8 * Peak wave period

As an equation for crest loss is unavailable, it was assumed that the crest loss is proportional to the additional armor loss. Based upon Figure 25, the average existing armor damage, A_e, is 60.75 FT^2, and the existing average crest height reduction, d_{cr}, is 3.2 feet. Using these values, the crest elevation resulting from additional armor damage, $Elev_{cr}(t)$, was determined by:

$$Elev_{cr}(t) = 10.3 - 3.2(A_e(t)/60.75)$$

Similarly, the crest width, $Width_{cr}(t)$, was determined based upon the existing crest reduction of 0.9 feet from the original by:

$$Width_{cr}(t) = 10 - 0.9(A_e(t)/60.75)$$

Additional data required to perform the analysis is the original armor layer thickness, D_{n50}, and original stone specific gravity, S_a. Based upon original drawings, the average cut stone block created a layer 5 feet thick and the stone used was Berea sandstone. A specific gravity of 2.24 will be assumed for this stone.

b. Confirm Damage Equations Using Period 1956-2007

In order to gain confidence in the methodology and values used to compute hypothetical damage from design storms, the existing damage was modeled. The WIS 3-hour wave information was used (1956-1987) and extended to 2007 by repeating the wave record. Incident waves at the breakwater were determined as previously discussed in the section titled, Incident Waves at Breakwater – Period of Record, Section 4.C.a. It was assumed that there was no damage to the breakwater at the time of the simulation (1956) and that no repairs or modifications were made to the stone slope since the original construction. Using the period of record incident waves and damage equations, the total armor damage, S, and total eroded area, A_e, were calculated for the study period. This analysis resulted in a total armor stone damage, S, of 3.8 and a total eroded area of the lakeside stone slope, A_e, of 94.5 square feet. It is noted that the actual average eroded area of the lakeside stone slope, A_e, is 60.75 square feet, suggesting potential overestimation of the damage during the hypothetical storms analysis. As expected, most of the damage to the Cleveland East Breakwater occurred during storm events, as presented in Figure 26.

c. Estimate Additional Damage from Individual Storms

Additional damage to the breakwater was estimated using the damage equations and the hypothetical storms for the 100-year and 10-year waves occurring with the 100-year, 2-year, and 1.001-year water levels. No additional damage occurs from 2-year or 1.001-year waves. Tables 6 – 11 present the additional damage from those aforementioned storms and are summarized in Table 12.

Using the results from Table 12, the breakwater cross-section incorporating the additional damage was developed by modifying the crest elevation, crest width and adopting a crest slope line that reflects the damage area, A_e.

A typical section for a rubblemound repair alternative was also drawn on the damaged sections to reflect a potential repair[18] (Figure 27). The proposed repair consists of placing cover stone weighing 4.1 to 9.0 tons on the crest and the lakeside face at a 1 vertical to 2 horizontal slope, with a maximum 2-layer thickness of 8.5 feet. Underlayer stone ranging from 540 to 1800 pounds would be placed between the existing damaged breakwater surface and the cover stone to achieve the desired grade. Underlayer stone would also be placed as a 10-foot wide berm at the toe and covered with a single layer of armor to provide adequate slope stability. Bedding stone consisting of graded stone ranging from chips to 100 pounds would be placed on the lake bottom soils under the underlayer to reduce settlement of the stability berm.

Figures 28 to 33 present the typical cross-sections of the breakwater showing the original, Jan/Mar 2008 condition, the additional damage for the six damage scenarios and the typical repair section.

[18] USAED 2003. East Breakwater Cleveland Harbor, Ohio Design Documentation Report, US Army Corps of Engineers, Buffalo NY.

Table 6. Damage from 100-year Waves and 100-Year Water Level

Time - Hours	Wave Height at Breakwater FT	Wave Period Seconds	Mean Wave Period Seconds	Wave Direction	δN	N_s	N_s^5	N_e	S	A_e	Crest Elevation - FT LWD	Crest Width Feet	l_e Feet
0	0.98	3	2.4	329	4500.00	0.158065	9.8667E-05	2.51285E+25	2.43	60.75	7.1	9.1	34.3
3	1.97	3	2.4	329	4500.00	0.317742	0.00323871	2.16453E+19	2.43	60.75	7.1	9.1	34.3
6	3.17	4	3.2	329	3375.00	0.51129	0.0349412	1.59773E+15	2.43	60.75	7.1	9.1	34.3
9	4.26	5	4.0	329	2700.00	0.687097	0.15314032	4.33008E+12	2.43	60.75	7.1	9.1	34.3
12	4.87	5	4.0	329	2700.00	0.785484	0.29901044	2.97926E+11	2.43	60.75	7.1	9.1	34.3
15	4.57	5	4.0	329	2700.00	0.737097	0.21758179	1.06259E+12	2.43	60.75	7.1	9.1	34.3
18	4.57	5	4.0	329	2700.00	0.737097	0.21758179	1.06259E+12	2.43	60.75	7.1	9.1	34.3
21	5.40	6	4.8	329	2250.00	0.870968	0.50119918	37740960935	2.43	60.75	7.1	9.1	34.3
24	6.38	6	4.8	329	2250.00	1.029032	1.15383829	1343614251	2.430001	60.75003	7.1	9.1	34.3
27	6.60	6	4.8	329	2250.00	1.064516	1.36697707	682040544.5	2.430003	60.75008	7.1	9.1	34.3
30	5.70	6	4.8	329	2250.00	0.919355	0.65677382	12799506421	2.430003	60.75008	7.1	9.1	34.3
33	5.40	6	4.8	329	2250.00	0.870968	0.50119918	37741157524	2.430003	60.75008	7.1	9.1	34.3
36	5.70	6	4.8	329	2250.00	0.919355	0.65677382	12799509434	2.430003	60.75008	7.1	9.1	34.3
39	5.40	6	4.8	329	2250.00	0.870968	0.50119918	37741166409	2.430003	60.75008	7.1	9.1	34.3
42	6.38	6	4.8	329	2250.00	1.029032	1.15383829	1343621566	2.430004	60.75011	7.1	9.1	34.3
45	6.38	6	4.8	329	2250.00	1.029032	1.15383829	1343623816	2.430005	60.75013	7.1	9.1	34.3
48	5.70	6	4.8	329	2250.00	0.919355	0.65677382	12799555314	2.430005	60.75014	7.1	9.1	34.3
51	3.96	5	4.0	329	2700.00	0.63871	0.10629614	1.86547E+13	2.430005	60.75014	7.1	9.1	34.3
54	1.64	3	2.4	329	4500.00	0.264516	0.00129497	8.46867E+20	2.430005	60.75014	7.1	9.1	34.3
57	0.66	3	2.4	329	4500.00	0.106452	1.367E-05	6.82046E+28	2.430005	60.75014	7.1	9.1	34.3
60	10.72	8	6.4	329	1687.50	1.729032	15.4530952	41763.44967	2.454189	61.35472	7.1	9.1	34.5
63	9.35	7	5.6	329	1928.57	1.508065	7.80008988	669364.6339	2.455955	61.39887	7.1	9.1	34.5
66	9.35	7	5.6	329	1928.57	1.508065	7.80008988	671293.2053	2.457717	61.44292	7.1	9.1	34.5
69	7.57	7	5.6	329	1928.57	1.220968	2.71344454	45969817.87	2.457743	61.44356	7.1	9.1	34.5
72	5.10	6	4.8	329	2250.00	0.822581	0.37661051	1.23881E+11	2.457743	61.44356	7.1	9.1	34.5
75	4.87	5	4.0	329	2700.00	0.785484	0.29901044	3.11766E+11	2.457743	61.44356	7.1	9.1	34.5
78	4.26	5	4.0	329	2700.00	0.687097	0.15314032	4.53124E+12	2.457743	61.44356	7.1	9.1	34.5
81	11.00	8	6.4	329	1687.50	1.774194	17.5794377	26094.85581	2.496548	62.4137	7.0	9.1	34.8
84	11.75	8	6.4	329	1687.50	1.895161	24.4472991	7427.889597	2.627649	65.69123	6.8	9.0	35.7
87	10.72	8	6.4	329	1687.50	1.729032	15.4530952	57100.09889	2.646852	66.17129	6.8	9.0	35.8
90	10.45	8	6.4	329	1687.50	1.685484	13.6026337	97916.44119	2.658183	66.45457	6.8	9.0	35.9
93	10.17	8	6.4	329	1687.50	1.640323	11.8753472	171468.0756	2.664699	66.61747	6.8	9.0	35.9
96	10.17	8	6.4	329	1687.50	1.640323	11.8753472	173155.5756	2.671167	66.77919	6.8	9.0	36.0
99	6.00	6	4.8	329	2250.00	0.967742	0.84878521	6699501491	2.671168	66.77919	6.8	9.0	36.0
102	4.26	5	4.0	329	2700.00	0.687097	0.15314032	6.32231E+12	2.671168	66.77919	6.8	9.0	36.0
105	2.43	5	4.0	329	2700.00	0.391935	0.00924853	4.75272E+17	2.671168	66.77919	6.8	9.0	36.0
108	2.86	4	3.2	329	3375.00	0.46129	0.02088679	1.82704E+16	2.671168	66.77919	6.8	9.0	36.0
111	7.80	6	4.8	329	2250.00	1.258065	3.15148008	35251336.56	2.67121	66.78026	6.8	9.0	36.0
114	8.97	8	6.4	329	1687.50	1.446774	6.3387521	2154003.973	2.671733	66.79333	6.8	9.0	36.0
117	10.17	8	6.4	329	1687.50	1.640323	11.8753472	174991.2793	2.678151	66.95378	6.8	9.0	36.0
120	11.75	9	7.2	329	1500.00	1.895161	24.4472991	9836.625027	2.774882	69.37205	6.6	9.0	36.6
123	14.20	10	8.0	329	1350.00	2.290323	63.0207075	256.7285846	4.38896	109.724	4.5	8.4	46.1
126	11.00	8	6.4	329	1687.50	1.774194	17.5794377	265372.3709	4.39592	109.898	4.5	8.4	46.1
129	10.17	8	6.4	329	1687.50	1.640323	11.8753472	1282458.379	4.397366	109.9341	4.5	8.4	46.1
132	8.18	7	5.6	329	1928.57	1.319355	3.9976804	99992481.77	4.397387	109.9347	4.5	8.4	46.1
135	6.60	6	4.8	329	2250.00	1.064516	1.36697707	7314136925	4.397387	109.9347	4.5	8.4	46.1
138	6.91	6	4.8	329	2250.00	1.114516	1.71961724	2920659869	4.397388	109.9347	4.5	8.4	46.1
141	5.10	6	4.8	329	2250.00	0.822581	0.37661051	1.26952E+12	4.397388	109.9347	4.5	8.4	46.1
144	5.18	5	4.0	329	2700.00	0.835484	0.40708992	9.29923E+11	4.397388	109.9347	4.5	8.4	46.1
147	5.40	6	4.8	329	2250.00	0.870968	0.50119918	4.04732E+11	4.397388	109.9347	4.5	8.4	46.1
150	6.00	6	4.8	329	2250.00	0.967742	0.84878521	49205909341	4.397388	109.9347	4.5	8.4	46.1
153	5.10	6	4.8	329	2250.00	0.822581	0.37661051	1.26952E+12	4.397388	109.9347	4.5	8.4	46.1
156	4.57	5	4.0	329	2700.00	0.737097	0.21758179	1.13951E+13	4.397388	109.9347	4.5	8.4	46.1
159	3.17	4	3.2	329	3375.00	0.51129	0.0349412	1.71339E+16	4.397388	109.9347	4.5	8.4	46.1
162	1.97	4	3.2	329	3375.00	0.317742	0.00323871	2.32123E+20	4.397388	109.9347	4.5	8.4	46.1
165	0.98	3	2.4	329	4500.00	0.158065	9.8667E-05	2.69476E+26	4.397388	109.9347	4.5	8.4	46.1

Table 7. Damage from 100-year Waves and 2-Year Water Level

Time - Hours	Wave Height at Breakwater FT	Wave Period Seconds	Mean Wave Period Seconds	Wave Direction	δN	N_s	N_s^5	N_e	S	A_e	Crest Elevation - FT LWD	Crest Width Feet	l_e Feet
0	0.98	3	2.4	329	4500.00	0.158065	9.87E-05	2.51E+25	2.43	60.75	7.1	9.1	34.3
3	1.97	3	2.4	329	4500.00	0.317742	0.003239	2.16E+19	2.43	60.75	7.1	9.1	34.3
6	3.14	4	3.2	329	3375.00	0.506452	0.033319	1.93E+15	2.43	60.75	7.1	9.1	34.3
9	4.22	5	4.0	329	2700.00	0.680645	0.146084	5.23E+12	2.43	60.75	7.1	9.1	34.3
12	4.84	5	4.0	329	2700.00	0.780645	0.289913	3.37E+11	2.43	60.75	7.1	9.1	34.3
15	4.53	5	4.0	329	2700.00	0.730645	0.208225	1.27E+12	2.43	60.75	7.1	9.1	34.3
18	4.53	5	4.0	329	2700.00	0.730645	0.208225	1.27E+12	2.43	60.75	7.1	9.1	34.3
21	5.41	6	4.8	329	2250.00	0.872581	0.505857	3.64E+10	2.43	60.75	7.1	9.1	34.3
24	6.40	6	4.8	329	2250.00	1.032258	1.172037	1.26E+09	2.430001	60.75003	7.1	9.1	34.3
27	6.61	6	4.8	329	2250.00	1.066129	1.377364	6.62E+08	2.430003	60.75008	7.1	9.1	34.3
30	5.71	6	4.8	329	2250.00	0.920968	0.662555	1.24E+10	2.430003	60.75008	7.1	9.1	34.3
33	5.41	6	4.8	329	2250.00	0.872581	0.505857	3.64E+10	2.430003	60.75008	7.1	9.1	34.3
36	5.71	6	4.8	329	2250.00	0.920968	0.662555	1.24E+10	2.430003	60.75009	7.1	9.1	34.3
39	5.41	6	4.8	329	2250.00	0.872581	0.505857	3.64E+10	2.430003	60.75009	7.1	9.1	34.3
42	6.40	6	4.8	329	2250.00	1.032258	1.172037	1.26E+09	2.430005	60.75011	7.1	9.1	34.3
45	6.40	6	4.8	329	2250.00	1.032258	1.172037	1.26E+09	2.430006	60.75014	7.1	9.1	34.3
48	5.07	6	4.8	329	2250.00	0.817903	0.366024	1.33E+11	2.430006	60.75014	7.1	9.1	34.3
51	5.93	5	4.0	329	2700.00	0.956452	0.800415	5.8E+09	2.430006	60.75015	7.1	9.1	34.3
54	1.64	3	2.4	329	4500.00	0.264516	0.001295	8.47E+20	2.430006	60.75015	7.1	9.1	34.3
57	0.66	3	2.4	329	4500.00	0.106452	1.37E-05	6.82E+28	2.430006	60.75015	7.1	9.1	34.3
60	11.09	8	6.4	329	1687.50	1.78871	18.31046	21186.61	2.477011	61.92529	7.0	9.1	34.6
63	9.36	7	5.6	329	1928.57	1.509677	7.841891	679920.5	2.478766	61.96915	7.0	9.1	34.6
66	9.36	7	5.6	329	1928.57	1.509677	7.841891	681849.1	2.480517	62.01293	7.0	9.1	34.6
69	7.62	7	5.6	329	1928.57	1.229032	2.804248	41815035	2.480546	62.01364	7.0	9.1	34.6
72	5.10	6	4.8	329	2250.00	0.822581	0.376611	1.29E+11	2.480546	62.01364	7.0	9.1	34.6
75	4.84	5	4.0	329	2700.00	0.780645	0.289913	3.66E+11	2.480546	62.01364	7.0	9.1	34.6
78	4.23	5	4.0	329	2700.00	0.682258	0.147823	5.42E+12	2.480546	62.01364	7.0	9.1	34.6
81	11.36	8	6.4	329	1687.50	1.832258	20.65063	14219.53	2.551075	63.77687	6.9	9.1	35.1
84	11.60	8	6.4	329	1687.50	1.870968	22.92617	10471.19	2.64817	66.20425	6.8	9.0	35.8
87	11.09	8	6.4	329	1687.50	1.78871	18.31046	29882.41	2.68479	67.11975	6.8	9.0	36.0
90	10.43	8	6.4	329	1687.50	1.682258	13.47296	107700.6	2.695245	67.38113	6.8	9.0	36.1
93	10.19	8	6.4	329	1687.50	1.643548	11.99258	174249.9	2.701747	67.54368	6.7	9.0	36.2
96	10.19	8	6.4	329	1687.50	1.643548	11.99258	175937.4	2.708202	67.70506	6.7	9.0	36.2
99	6.00	6	4.8	329	2250.00	0.967742	0.848785	7.08E+09	2.708203	67.70507	6.7	9.0	36.2
102	4.23	5	4.0	329	2700.00	0.682258	0.147823	7.69E+12	2.708203	67.70507	6.7	9.0	36.2
105	2.42	5	4.0	329	2700.00	0.390323	0.00906	5.45E+17	2.708203	67.70507	6.7	9.0	36.2
108	2.83	4	3.2	329	3375.00	0.456452	0.019814	2.38E+16	2.708203	67.70507	6.7	9.0	36.2
111	7.08	6	4.8	329	2250.00	1.141774	1.940444	2.59E+08	2.708208	67.70521	6.7	9.0	36.2
114	9.06	8	6.4	329	1687.50	1.46129	6.663195	1863921	2.708821	67.72053	6.7	9.0	36.2
117	10.19	8	6.4	329	1687.50	1.643548	11.99258	177787.3	2.715226	67.88066	6.7	9.0	36.3
120	11.60	9	7.2	329	1500.00	1.870968	22.92617	13437.78	2.788019	69.70047	6.6	9.0	36.7
123	13.52	10	8.0	329	1350.00	2.180645	49.30887	698.0908	3.648841	91.22104	5.5	8.6	42.0
126	11.36	8	6.4	329	1687.50	1.832258	20.65063	66575.8	3.671747	91.79367	5.5	8.6	42.2
129	10.19	8	6.4	329	1687.50	1.643548	11.99258	600164.4	3.674325	91.85813	5.5	8.6	42.2
132	8.23	7	5.6	329	1928.57	1.327419	4.121362	43149585	3.674366	91.85915	5.5	8.6	42.2
135	6.61	6	4.8	329	2250.00	1.066129	1.377364	3.46E+09	3.674367	91.85917	5.5	8.6	42.2
138	6.92	6	4.8	329	2250.00	1.116129	1.732096	1.38E+09	3.674368	91.8592	5.5	8.6	42.2
141	5.11	6	4.8	329	2250.00	0.824194	0.380317	5.95E+11	3.674368	91.8592	5.5	8.6	42.2
144	5.14	5	4.0	329	2700.00	0.829032	0.391613	5.29E+11	3.674368	91.8592	5.5	8.6	42.2
147	5.41	6	4.8	329	2250.00	0.872581	0.505857	1.9E+11	3.674368	91.8592	5.5	8.6	42.2
150	6.00	6	4.8	329	2250.00	0.967742	0.848785	2.4E+10	3.674368	91.85921	5.5	8.6	42.2
153	5.11	6	4.8	329	2250.00	0.824194	0.380317	5.95E+11	3.674368	91.85921	5.5	8.6	42.2
156	4.53	5	4.0	329	2700.00	0.730645	0.208225	6.62E+12	3.674368	91.85921	5.5	8.6	42.2
159	3.14	4	3.2	329	3375.00	0.506452	0.033319	1.01E+16	3.674368	91.85921	5.5	8.6	42.2
162	1.97	4	3.2	329	3375.00	0.317742	0.003239	1.13E+20	3.674368	91.85921	5.5	8.6	42.2
165	0.98	3	2.4	329	4500.00	0.158065	9.87E-05	1.31E+26	3.674368	91.85921	5.5	8.6	42.2

Table 8. Damage from 100-year Waves and 1.001-Year Water Level

Time - Hours	Wave Height at Breakwater FT	Wave Period Seconds	Mean Wave Period Seconds	Wave Direction	δN	N_s	N_s^5	N_e	S	A_e	Crest Elevation - FT LWD	Crest Width Feet	l_e Feet
0	0.98	3	2.4	329	4500.00	0.158065	9.87E-05	2.51E+25	2.43	60.75	7.1	9.1	34.3
3	1.97	3	2.4	329	4500.00	0.317742	0.003239	2.16E+19	2.43	60.75	7.1	9.1	34.3
6	3.11	4	3.2	329	3375.00	0.501613	0.031757	2.34E+15	2.43	60.75	7.1	9.1	34.3
9	4.21	5	4.0	329	2700.00	0.679032	0.144362	5.48E+12	2.43	60.75	7.1	9.1	34.3
12	4.82	5	4.0	329	2700.00	0.777419	0.283973	3.66E+11	2.43	60.75	7.1	9.1	34.3
15	4.51	5	4.0	329	2700.00	0.727419	0.203669	1.38E+12	2.43	60.75	7.1	9.1	34.3
18	4.51	5	4.0	329	2700.00	0.727419	0.203669	1.38E+12	2.43	60.75	7.1	9.1	34.3
21	5.43	6	4.8	329	2250.00	0.875806	0.515277	3.38E+10	2.43	60.75	7.1	9.1	34.3
24	6.41	6	4.8	329	2250.00	1.033871	1.181222	1.22E+09	2.430001	60.75003	7.1	9.1	34.3
27	6.63	6	4.8	329	2250.00	1.069355	1.398328	6.23E+08	2.430003	60.75008	7.1	9.1	34.3
30	5.73	6	4.8	329	2250.00	0.924194	0.67424	1.15E+10	2.430003	60.75009	7.1	9.1	34.3
33	5.43	6	4.8	329	2250.00	0.875806	0.515277	3.38E+10	2.430004	60.75009	7.1	9.1	34.3
36	5.73	6	4.8	329	2250.00	0.924194	0.67424	1.15E+10	2.430004	60.75009	7.1	9.1	34.3
39	5.43	6	4.8	329	2250.00	0.875806	0.515277	3.38E+10	2.430004	60.75009	7.1	9.1	34.3
42	6.41	6	4.8	329	2250.00	1.033871	1.181222	1.22E+09	2.430005	60.75012	7.1	9.1	34.3
45	6.41	6	4.8	329	2250.00	1.033871	1.181222	1.22E+09	2.430006	60.75015	7.1	9.1	34.3
48	5.73	6	4.8	329	2250.00	0.924194	0.67424	1.15E+10	2.430006	60.75015	7.1	9.1	34.3
51	3.91	5	4.0	329	2700.00	0.630645	0.099753	2.41E+13	2.430006	60.75015	7.1	9.1	34.3
54	1.64	3	2.4	329	4500.00	0.264516	0.001295	8.47E+20	2.430006	60.75015	7.1	9.1	34.3
57	0.66	3	2.4	329	4500.00	0.106452	1.37E-05	6.82E+28	2.430006	60.75015	7.1	9.1	34.3
60	10.77	8	6.4	329	1687.50	1.737097	15.81685	38052.08	2.45651	61.41275	7.1	9.1	34.5
63	9.30	7	5.6	329	1928.57	1.5	7.59375	747960	2.458092	61.4523	7.1	9.1	34.5
66	9.30	7	5.6	329	1928.57	1.5	7.59375	749888.5	2.459671	61.49178	7.1	9.1	34.5
69	7.69	7	5.6	329	1928.57	1.240323	2.93544	33670098	2.459706	61.49266	7.1	9.1	34.5
72	5.13	6	4.8	329	2250.00	0.827419	0.387818	1.11E+11	2.459706	61.49266	7.1	9.1	34.5
75	4.81	5	4.0	329	2700.00	0.775806	0.281039	4.01E+11	2.459706	61.49266	7.1	9.1	34.5
78	4.21	5	4.0	329	2700.00	0.679032	0.144362	5.76E+12	2.459706	61.49266	7.1	9.1	34.5
81	10.60	8	6.4	329	1687.50	1.709677	14.60733	54913.45	2.478389	61.95973	7.0	9.1	34.6
84	11.29	8	6.4	329	1687.50	1.820968	20.02218	16034.75	2.54117	63.52924	7.0	9.1	35.1
87	10.77	8	6.4	329	1687.50	1.737097	15.81685	45507.57	2.564407	64.11017	6.9	9.1	35.2
90	10.29	8	6.4	329	1687.50	1.659677	12.59269	117463.6	2.573568	64.33919	6.9	9.0	35.3
93	10.05	8	6.4	329	1687.50	1.620968	11.19108	191022.4	2.579233	64.48082	6.9	9.0	35.3
96	10.05	8	6.4	329	1687.50	1.620968	11.19108	192709.9	2.584861	64.62152	6.9	9.0	35.4
99	6.03	6	4.8	329	2250.00	0.972581	0.870218	5.32E+09	2.584861	64.62152	6.9	9.0	35.4
102	4.20	5	4.0	329	2700.00	0.677419	0.142655	7.36E+12	2.584861	64.62152	6.9	9.0	35.4
105	2.40	5	4.0	329	2700.00	0.387097	0.008692	5.34E+17	2.584861	64.62152	6.9	9.0	35.4
108	2.79	4	3.2	329	3375.00	0.45	0.018453	2.63E+16	2.584861	64.62152	6.9	9.0	35.4
111	7.78	6	4.8	329	2250.00	1.254839	3.111283	32540173	2.584906	64.62264	6.9	9.0	35.4
114	9.10	8	6.4	329	1687.50	1.467742	6.81159	1416492	2.585675	64.64188	6.9	9.0	35.4
117	10.05	8	6.4	329	1687.50	1.620968	11.19108	194642.5	2.591261	64.78153	6.9	9.0	35.4
120	11.29	9	7.2	329	1500.00	1.820968	20.02218	19161.48	2.640549	66.01374	6.8	9.0	35.7
123	12.53	10	8.0	329	1350.00	2.020968	33.71296	2570.507	2.93444	73.36099	6.4	8.9	37.7
126	10.60	8	6.4	329	1687.50	1.709677	14.60733	111236.3	2.945506	73.63765	6.4	8.9	37.8
129	10.05	8	6.4	329	1687.50	1.620968	11.19108	327779.2	2.94929	73.73224	6.4	8.9	37.8
132	8.27	7	5.6	329	1928.57	1.333871	4.222495	16256333	2.949377	73.73443	6.4	8.9	37.8
135	6.63	6	4.8	329	2250.00	1.069355	1.398328	1.35E+09	2.949378	73.73446	6.4	8.9	37.8
138	6.93	6	4.8	329	2250.00	1.117742	1.744648	5.58E+08	2.949381	73.73453	6.4	8.9	37.8
141	5.13	6	4.8	329	2250.00	0.827419	0.387818	2.28E+11	2.949381	73.73453	6.4	8.9	37.8
144	5.11	5	4.0	329	2700.00	0.824194	0.380317	2.47E+11	2.949381	73.73453	6.4	8.9	37.8
147	5.43	6	4.8	329	2250.00	0.875806	0.515277	7.33E+10	2.949381	73.73453	6.4	8.9	37.8
150	6.03	6	4.8	329	2250.00	0.972581	0.870218	9.01E+09	2.949382	73.73454	6.4	8.9	37.8
153	5.13	6	4.8	329	2250.00	0.827419	0.387818	2.28E+11	2.949382	73.73454	6.4	8.9	37.8
156	4.51	5	4.0	329	2700.00	0.727419	0.203669	3E+12	2.949382	73.73454	6.4	8.9	37.8
159	3.11	4	3.2	329	3375.00	0.501613	0.031757	5.08E+15	2.949382	73.73454	6.4	8.9	37.8
162	1.97	4	3.2	329	3375.00	0.317742	0.003239	4.7E+19	2.949382	73.73454	6.4	8.9	37.8
165	0.98	3	2.4	329	4500.00	0.158065	9.87E-05	5.45E+25	2.949382	73.73454	6.4	8.9	37.8

Table 9. Damage from 10-Year Waves and 100-Yr Water Level

Time	Wave Height Feet	Wave Period - Seconds	Wave Direction Degrees	Water Level FT LWD	Wave Height at Breakwater FT	Mean Wave Period Seconds	δN	N_s	N_s^5	N_e	S	A_e	Crest Elevation - FT LWD	Crest Width Feet	l_e Feet
0	5.0	5	329	6.8	4.6	4	2700.00	0.748387	0.234764	7.84023E+11	2.43	60.75	7.1	9.1	34.3
3	8.0	6	329	6.8	7.3	4.8	2250.00	1.180645	2.294019	85993677.94	2.430016	60.7504	7.1	9.1	34.3
6	11.3	8	329	6.8	10.6	6.4	1687.50	1.706452	14.47005	54323.30124	2.448671	61.21679	7.1	9.1	34.4
9	13.0	9	329	6.8	12.7	7.2	1500.00	2.048387	36.06286	1451.813131	2.923984	73.09961	6.4	8.9	37.6
12	11.3	8	329	6.8	10.6	6.4	1687.50	1.706452	14.47005	113880.6469	2.934757	73.36892	6.4	8.9	37.7
15	8.7	8	329	6.8	8.2	6.4	1687.50	1.325806	4.096384	17993479.47	2.934826	73.37064	6.4	8.9	37.7
18	8.3	7	329	6.8	7.7	5.6	1928.57	1.235484	2.878627	73793284.14	2.934845	73.37112	6.4	8.9	37.7
21	7.0	6	329	6.8	6.4	4.8	2250.00	1.032258	1.172037	2685369809	2.934845	73.37113	6.4	8.9	37.7
24	6.3	6	329	6.8	5.8	4.8	2250.00	0.930645	0.698105	21334756101	2.934845	73.37114	6.4	8.9	37.7
27	6.3	6	329	6.8	5.8	4.8	2250.00	0.930645	0.698105	21334758351	2.934846	73.37114	6.4	8.9	37.7
30	5.3	6	329	6.8	4.8	4.8	2250.00	0.780645	0.289913	7.17293E+11	2.934846	73.37114	6.4	8.9	37.7
33	4.0	5	329	6.8	3.7	4	2700.00	0.6	0.07776	1.38594E+14	2.934846	73.37114	6.4	8.9	37.7
36	3.3	5	329	6.8	3.1	4	2700.00	0.493548	0.029285	6.88931E+15	2.934846	73.37114	6.4	8.9	37.7
39	2.7	5	329	6.8	2.5	4	2700.00	0.404839	0.010875	3.62351E+17	2.934846	73.37114	6.4	8.9	37.7
42	2.0	4	329	6.8	2.0	3.2	3375.00	0.322581	0.003493	3.40411E+19	2.934846	73.37114	6.4	8.9	37.7

Table 10. Damage from 10-Year Waves and 2-Yr Water Level

Time	Wave Height Feet	Wave Period - Seconds	Wave Direction Degrees	Water Level FT LWD	Wave Height at Breakwater FT	Mean Wave Period Seconds	δN	N_s	N_s^5	N_e	S	A_e	Crest Elevation - FT LWD	Crest Width Feet	l_e Feet
0	5.0	5	329	6.8	4.6	4	2700.00	0.743548	0.227272	8.93E+11	2.43	60.75	7.1	9.1	34.3
3	8.0	6	329	6.8	7.3	4.8	2250.00	1.180645	2.294019	85993678	2.430016	60.7504	7.1	9.1	34.3
6	11.3	8	329	6.8	11.0	6.4	1687.50	1.774194	17.57944	24937.09	2.470122	61.75305	7.0	9.1	34.6
9	13.0	9	329	6.8	12.3	7.2	1500.00	1.977419	30.23388	3043.177	2.730401	68.26004	6.7	9.0	36.4
12	11.3	8	329	6.8	11.0	6.4	1687.50	1.774194	17.57944	39748.01	2.758931	68.97327	6.7	9.0	36.5
15	8.7	8	329	6.8	8.3	6.4	1687.50	1.33871	4.299639	11578826	2.759031	68.97579	6.7	9.0	36.5
18	8.3	7	329	6.8	7.7	5.6	1928.57	1.245161	2.993147	49310984	2.759058	68.97646	6.7	9.0	36.5
21	7.0	6	329	6.8	6.4	4.8	2250.00	1.033871	1.181222	2.03E+09	2.759059	68.97648	6.7	9.0	36.5
24	6.3	6	329	6.8	5.8	4.8	2250.00	0.930645	0.698105	1.67E+10	2.759059	68.97648	6.7	9.0	36.5
27	6.3	6	329	6.8	5.8	4.8	2250.00	0.935484	0.716443	1.5E+10	2.759059	68.97649	6.7	9.0	36.5
30	5.3	6	329	6.8	4.9	4.8	2250.00	0.782258	0.292921	5.38E+11	2.759059	68.97649	6.7	9.0	36.5
33	4.0	5	329	6.8	3.7	4	2700.00	0.595161	0.074675	1.27E+14	2.759059	68.97649	6.7	9.0	36.5
36	3.3	5	329	6.8	3.0	4	2700.00	0.490323	0.028341	6.14E+15	2.759059	68.97649	6.7	9.0	36.5
39	2.7	5	329	6.8	2.5	4	2700.00	0.401613	0.010448	3.32E+17	2.759059	68.97649	6.7	9.0	36.5
42	2.0	4	329	6.8	2.0	3.2	3375.00	0.322581	0.003493	2.66E+19	2.759059	68.97649	6.7	9.0	36.5

Table 11. Damage from 10-Year Waves and 1.001-Yr Water Level

Time	Wave Height Feet	Wave Period - Seconds	Wave Direction Degrees	Water Level FT LWD	Wave Height at Breakwater FT	Mean Wave Period Seconds	δN	N_s	N_s^5	N_e	S	A_e	Crest Elevation - FT LWD	Crest Width Feet	l_e Feet
0	5.0	5	329	6.8	4.6	4	2700.00	0.73871	0.219973	1.02E+12	2.43	60.75	7.1	9.1	34.3
3	8.0	6	329	6.8	7.3	4.8	2250.00	1.182258	2.309731	83677491	2.430016	60.75041	7.1	9.1	34.3
6	11.3	8	329	6.8	10.7	6.4	1687.50	1.725806	15.30948	43353.51	2.453325	61.33314	7.1	9.1	34.5
9	13.0	9	329	6.8	11.8	7.2	1500.00	1.906452	25.18424	6150.836	2.590889	64.77223	6.9	9.0	35.4
12	11.3	8	329	6.8	10.7	6.4	1687.50	1.725806	15.30948	56025.13	2.610182	65.25456	6.9	9.0	35.5
15	8.7	8	329	6.8	8.7	6.4	1687.50	1.403226	5.440487	3618773	2.610487	65.26216	6.9	9.0	35.5
18	8.3	7	329	6.8	7.8	5.6	1928.57	1.256452	3.13133	32991323	2.610525	65.26312	6.9	9.0	35.5
21	7.0	6	329	6.8	6.4	4.8	2250.00	1.037097	1.199766	1.53E+09	2.610526	65.26314	6.9	9.0	35.5
24	6.3	6	329	6.8	5.8	4.8	2250.00	0.933871	0.710288	1.25E+10	2.610526	65.26314	6.9	9.0	35.5
27	6.3	6	329	6.8	5.8	4.8	2250.00	0.933871	0.710288	1.25E+10	2.610526	65.26315	6.9	9.0	35.5
30	5.3	6	329	6.8	4.9	4.8	2250.00	0.787097	0.302093	3.81E+11	2.610526	65.26315	6.9	9.0	35.5
33	4.0	5	329	6.8	3.7	4	2700.00	0.591935	0.072673	1.14E+14	2.610526	65.26315	6.9	9.0	35.5
36	3.3	5	329	6.8	3.0	4	2700.00	0.487097	0.027421	5.61E+15	2.610526	65.26315	6.9	9.0	35.5
39	2.7	5	329	6.8	2.5	4	2700.00	0.398387	0.010035	3.13E+17	2.610526	65.26315	6.9	9.0	35.5
42	2.0	4	329	6.8	1.9	3.2	3375.00	0.304839	0.002632	6.61E+19	2.610526	65.26315	6.9	9.0	35.5

Table 12. Summary of Computed Breakwater Damage from Individual Storm Event

Condition		Resulting Values				
Wave Recurrence Interval	Water Level Recurrence Interval	S	A_e SQ FT	Crest Elevation - FT LWD	Crest Width Feet	l_e Feet
100-year	100-year	4.397388	109.9347	4.5	8.4	46.1
	2-year	3.674368	91.85921	5.5	8.6	42.2
	1.001-year	2.949382	73.73454	6.4	8.9	37.8
10-year	100-year	2.934846	73.37114	6.4	8.9	37.7
	2-year	2.759059	68.97649	6.7	9.0	36.5
	1.001-year	2.610526	65.26315	6.9	9.0	35.5

F. Repair Costs

Based upon the typical existing or additionally damaged section and the proposed repair, stone quantity estimates were made. A specific gravity of 2.65 and porosity of 0.37 for the repair stone was used. Repair costs (2002) were updated to the year 2008 using the Engineering News Record construction cost index[19]. Tables 13-19 present the repair costs the existing conditions and for the varying damaging wave/ water levels[20]. Table 20 summarizes these costs.

Table 13. Cost to Repair Study Reach – Existing Conditions (2008)

Item	Cost Fall 2002	Cost Fall 2008	Unit	Quantity	Cost
Mob and Demob	111535	144850.50	EA	1	144851
As-Built Drawings	13010	16896.09	EA	1	16896
Armor Stone	52.32	67.95	Ton	69210	4702680
Underlayer Stone	45.26	58.78	Ton	14053	826024
Bedding Stone	35.65	46.30	Ton	5279	244411
Construction Cost					5934861
Contingency (10%)					593486
Const Cost + Contingency					6528347
E&D					250000
S&I					250000
Total Cost for Repair					7028347

Table 14. Repair Costs Resulting from Damage from 100-Year Wave and 100-Year Water Level

Item	Cost Fall 2002	Cost Fall 2008	Unit	Quantity	Cost
Mob and Demob	111535	144850.50	EA	1	144851
As-Built Drawings	13010	16896.09	EA	1	16896
Armor Stone	52.32	67.95	Ton	77354	5256048
Underlayer Stone	45.26	58.78	Ton	27530	1618190
Bedding Stone	35.65	46.30	Ton	6847	317007
Construction Cost					7352992
Contingency (10%)					735299
Const Cost + Contingency					8088291
E&D					250000
S&I					250000
Total Cost for Repair					8588291

[19] ENR 2008. Engineering News Record Construction Cost Index History (1908-2008), http://enr.ecnext.com/

[20] It must be emphatically stated that these costs are based upon a single cross-section over the 2229-foot long study reach and shall not be used for any other purpose than this investigation.

Table 15. Repair Costs Resulting from Damage from 100-Year Wave and 2-Year Water Level

Item	Cost Fall 2002	Cost Fall 2008	Unit	Quantity	Cost
Mob and Demob	111535	144850.50	EA	1	144851
As-Built Drawings	13010	16896.09	EA	1	16896
Armor Stone	52.32	67.95	Ton	75211	5110436
Underlayer Stone	45.26	58.78	Ton	23008	1352391
Bedding Stone	35.65	46.30	Ton	6140	284274
Construction Cost					6908847
Contingency (10%)					690885
Const Cost + Contingency					7599732
E&D					250000
S&I					250000
Total Cost for Repair					8099732

Table 16. Repair Costs Resulting from Damage from 100-Year Wave and 1.001-Year Water Level

Item	Cost Fall 2002	Cost Fall 2008	Unit	Quantity	Cost
Mob and Demob	111535	144850.50	EA	1	144851
As-Built Drawings	13010	16896.09	EA	1	16896
Armor Stone	52.32	67.95	Ton	72524	4927860
Underlayer Stone	45.26	58.78	Ton	16510	970444
Bedding Stone	35.65	46.30	Ton	5839	270338
Construction Cost					6330388
Contingency (10%)					633039
Const Cost + Contingency					6963427
E&D					250000
S&I					250000
Total Cost for Repair					7463427

Table 17. Repair Costs Resulting from Damage from 10-Year Wave and 100-Year Water Level

Item	Cost Fall 2002	Cost Fall 2008	Unit	Quantity	Cost
Mob and Demob	111535	144850.50	EA	1	144851
As-Built Drawings	13010	16896.09	EA	1	16896
Armor Stone	52.32	67.95	Ton	72524	4927860
Underlayer Stone	45.26	58.78	Ton	16510	970444
Bedding Stone	35.65	46.30	Ton	5839	270338
Construction Cost					6330388
Contingency (10%)					633039
Const Cost + Contingency					6963427
E&D					250000
S&I					250000
Total Cost for Repair					7463427

Table 18. Repair Costs Resulting from Damage from 10-Year Wave and 2-Year Water Level

Item	Cost Fall 2002	Cost Fall 2008	Unit	Quantity	Cost
Mob and Demob	111535	144850.50	EA	1	144851
As-Built Drawings	13010	16896.09	EA	1	16896
Armor Stone	52.32	67.95	Ton	70961	4821657
Underlayer Stone	45.26	58.78	Ton	14736	866170
Bedding Stone	35.65	46.30	Ton	5698	263810
Construction Cost					6113383
Contingency (10%)					611338
Const Cost + Contingency					6724721
E&D					250000
S&I					250000
Total Cost for Repair					7224721

Table 19. Repair Costs Resulting from Damage from 10-Year Wave and 1.001-Year Water Level

Item	Cost Fall 2002	Cost Fall 2008	Unit	Quantity	Cost
Mob and Demob	111535	144850.50	EA	1	144851
As-Built Drawings	13010	16896.09	EA	1	16896
Armor Stone	52.32	67.95	Ton	70116	4764241
Underlayer Stone	45.26	58.78	Ton	14258	838073
Bedding Stone	35.65	46.30	Ton	5410	250476
Construction Cost					6014536
Contingency (10%)					601454
Const Cost + Contingency					6615990
E&D					250000
S&I					250000
Total Cost for Repair					7115990

Table 20. Summary of Repair Costs

Condition	Repair Cost (2008 $)	Additional Cost above Existing Conditions
Existing	7028347	0
1.001-YR Wave and 1.001-YR Water Level	7028347	0
1.001-YR Wave and 2-YR Water Level	7028347	0
1.001-YR Wave and 100-YR Water Level	7028347	0
2-YR Wave and 1.001-YR Water Level	7028347	0
2-YR Wave and 2-YR Water Level	7028347	0
2-YR Wave and 100-YR Water Level	7028347	0
10-YR Wave and 1.001-YR Water Level	7115990	87643
10-YR Wave and 2-YR Water Level	7224721	196374
10-YR Wave and 100-YR Water Level	7463427	435080
100-YR Wave and 1.001-YR Water Level	7463427	435080
100-YR Wave and 2-YR Water Level	8099732	1071385
100-YR Wave and 100-YR Water Level	8588291	1559944

G. Transmitted Waves

a. Transmitted Waves over Breakwater – Duration Relation

Wave runup and transmission over the Cleveland East Breakwater was determined for the period of record (1956-1986) set of incident waves described previously. These waves approached the study reach from 275 to 48 degrees Azimuth[21]. Wave runup and transmission was determined for four breakwater conditions: original condition, 2008 condition, additional damage condition, and repaired condition.

Wave run-up is defined as the maximum vertical distance of wave uprush on a beach or structure above the still water level (SWL). As waves interact with the breakwater, a portion of the energy is reflected, dissipated or may be transmitted past the structure. For the latter condition, each wave may either generate a flow of water overtopping the breakwater and/or a flow of water passing through a sufficiently permeable structure. In turn, this process generates waves in the lee of the structure and is known as wave transmission. For this analysis the breakwater was considered impermeable and hence only wave transmission over the structure was considered.

Wave run-up and overtopping are dependent upon the incident wave characteristics, water depth and structure configuration. The runup and transmitted wave height were determined for the period of record waves for the 100-, 2- and 1.001-year water levels and the four possible breakwater conditions(original condition, 2008 condition, additional damage condition, and repaired condition) using the Coastal Engineering Design and Analysis System (CEDAS)[22]. Sample CEDAS calculations are presented in Inserts 13 and 14.

Tables 21 to 24 present a summary of transmitted waves versus the percent time exceeded for the 100-, 2- and 1.001-year water levels and the four breakwater configurations, respectively. This information is also presented graphically in Figures 33 to 36.

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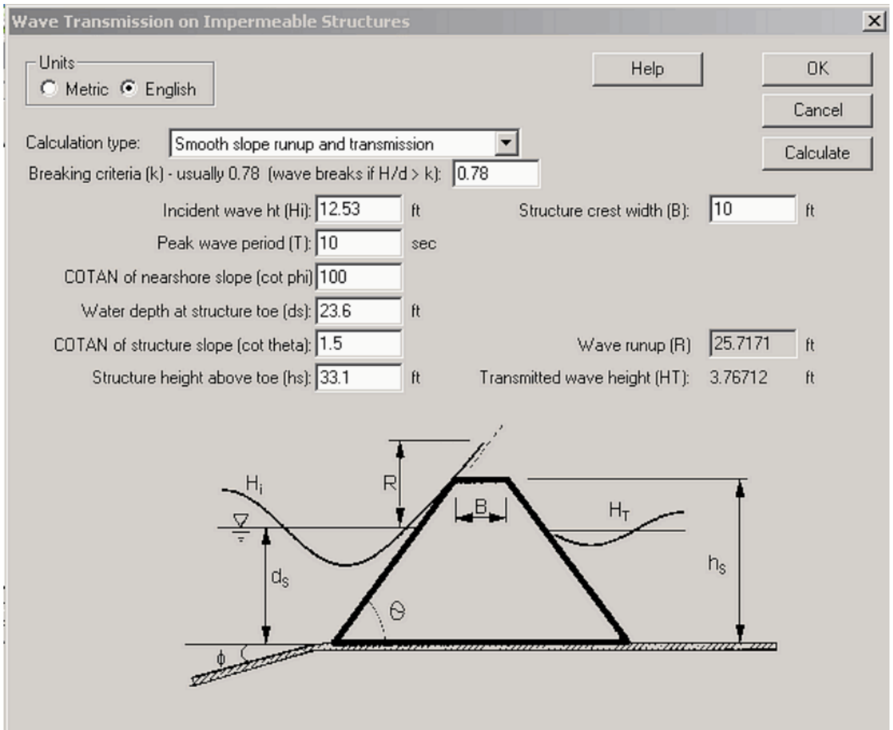
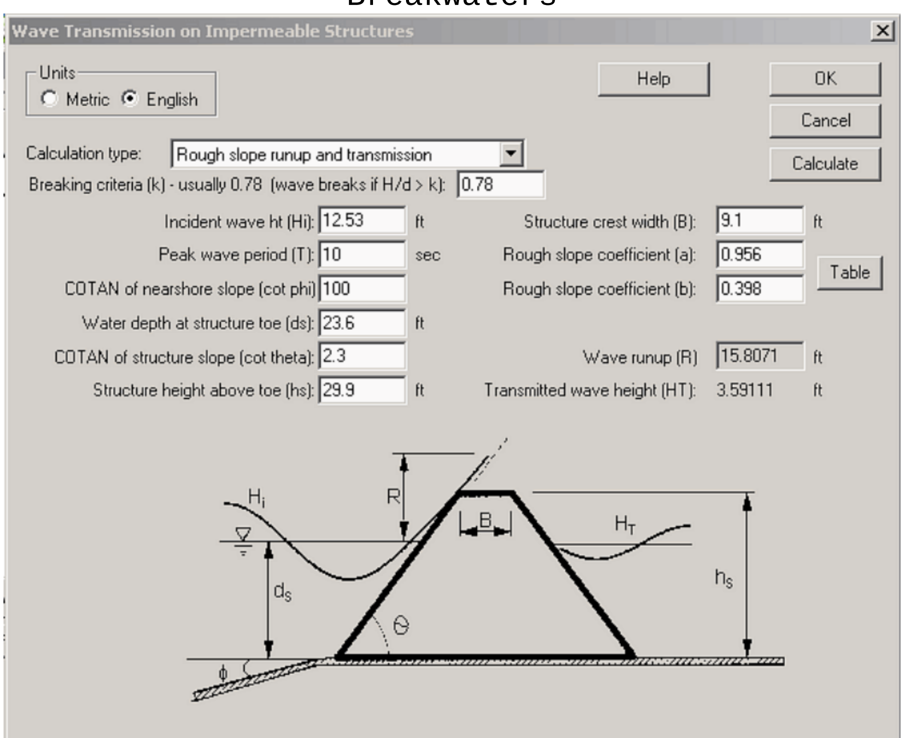
[21] All degrees are True North Azimuth

[22] USACE. Computer Program, Coastal Engineering Design and Analysis System, CEDAS, Version 4.0, U S Army Engineer Research and Development Center, Vicksburg, MS.



Insert 13. CEDAS Screen Capture: Example of Smooth Slope Irregular Wave Runup and Transmission for Impermeable Breakwaters



Insert 14. CEDAS Screen Capture: Example of Smooth Slope Irregular Wave Runup and Transmission for Impermeable Breakwaters

Table 21. Transmitted Wave Height Duration Data for Original Condition

Offshore Wave Height Feet	Wave Period Seconds	Percent Time Wave Exceeded	Water Level Return Period	Water Level FT LWD	Water Depth Feet	Incident Wave Height Feet	Crest Elevation FT LWD	Structure Height above Toe Feet	COTAN of Armor Slope	Structure Crest Width Feet	Slope Type	Wave Runup FEET	Transmitted Wave Height Feet
0.0	0.0	100.00	1.001-YR	0.8	23.6	0.00	10.3	33.1	1.5	10	Smooth	0.00	0.00
0.4	2.0	99.60	1.001-YR	0.8	23.6	0.40	10.3	33.1	1.5	10	Smooth	0.72	0.00
1.0	3.0	94.50	1.001-YR	0.8	23.6	1.00	10.3	33.1	1.5	10	Smooth	1.79	0.00
2.0	4.0	71.00	1.001-YR	0.8	23.6	2.00	10.3	33.1	1.5	10	Smooth	4.22	0.00
4.0	5.0	30.00	1.001-YR	0.8	23.6	3.67	10.3	33.1	1.5	10	Smooth	6.65	0.00
6.0	5.9	8.50	1.001-YR	0.8	23.6	5.51	10.3	33.1	1.5	10	Smooth	10.14	0.17
8.0	6.7	1.30	1.001-YR	0.8	23.6	7.45	10.3	33.1	1.5	10	Smooth	13.94	1.13
10.0	7.7	0.25	1.001-YR	0.8	23.6	9.75	10.3	33.1	1.5	10	Smooth	18.76	2.29
12.0	8.7	0.01	1.001-YR	0.8	23.6	11.35	10.3	33.1	1.5	10	Smooth	22.46	3.12
15.0	10.0	0.00	1.001-YR	0.8	23.6	12.51	10.3	33.1	1.5	10	Smooth	25.67	3.76
0.0	0.0	100.00	2-YR	3.8	26.6	0.00	10.3	33.1	1.5	10	Smooth	0.00	0.00
0.4	2.0	99.60	2-YR	3.8	26.6	0.40	10.3	33.1	1.5	10	Smooth	0.72	0.00
1.0	3.0	94.50	2-YR	3.8	26.6	1.00	10.3	33.1	1.5	10	Smooth	1.79	0.00
2.0	4.0	71.00	2-YR	3.8	26.6	1.92	10.3	33.1	1.5	10	Smooth	3.45	0.00
4.0	5.0	30.00	2-YR	3.8	26.6	3.69	10.3	33.1	1.5	10	Smooth	6.68	0.05
6.0	5.9	8.50	2-YR	3.8	26.6	5.49	10.3	33.1	1.5	10	Smooth	10.05	0.92
8.0	6.7	1.30	2-YR	3.8	26.6	7.40	10.3	33.1	1.5	10	Smooth	13.73	1.86
10.0	7.7	0.25	2-YR	3.8	26.6	9.41	10.3	33.1	1.5	10	Smooth	17.81	2.85
12.0	8.7	0.01	2-YR	3.8	26.6	11.63	10.3	33.1	1.5	10	Smooth	22.63	3.95
15.0	10.0	0.00	2-YR	3.8	26.6	13.54	10.3	33.1	1.5	10	Smooth	27.33	4.92
0.0	0.0	100.00	100-YR	6.8	29.6	0.00	10.3	33.1	1.5	10	Smooth	0.00	0.00
0.4	2.0	99.60	100-YR	6.8	29.6	0.40	10.3	33.1	1.5	10	Smooth	0.72	0.00
1.0	3.0	94.50	100-YR	6.8	29.6	1.00	10.3	33.1	1.5	10	Smooth	1.79	0.00
2.0	4.0	71.00	100-YR	6.8	29.6	1.94	10.3	33.1	1.5	10	Smooth	3.48	0.00
4.0	5.0	30.00	100-YR	6.8	29.6	3.72	10.3	33.1	1.5	10	Smooth	6.72	0.85
6.0	5.9	8.50	100-YR	6.8	29.6	5.49	10.3	33.1	1.5	10	Smooth	10.01	1.70
8.0	6.7	1.30	100-YR	6.8	29.6	7.36	10.3	33.1	1.5	10	Smooth	13.57	2.60
10.0	7.7	0.25	100-YR	6.8	29.6	9.35	10.3	33.1	1.5	10	Smooth	17.54	3.57
12.0	8.7	0.01	100-YR	6.8	29.6	11.84	10.3	33.1	1.5	10	Smooth	22.74	4.78
15.0	10.0	0.00	100-YR	6.8	29.6	14.27	10.3	33.1	1.5	10	Smooth	28.36	5.96

Table 22. Transmitted Wave Height Duration Data for 2008 Condition

Offshore Wave Height Feet	Wave Period Seconds	Percent Time Wave Exceeded	Water Level Return Period	Water Level FT LWD	Water Depth Feet	Incident Wave Height Feet	Crest Elevation FT LWD	Structure Height above Toe Feet	COTAN of Armor Slope	Structure Crest Width Feet	Slope Type	Wave Runup FEET	Transmitted Wave Height Feet
0.0	0.0	100.00	1.001-YR	0.8	23.6	0.00	7.1	29.9	2.3	9.1	Rough	0.00	0.00
0.4	2.0	99.60	1.001-YR	0.8	23.6	0.40	7.1	29.9	2.3	9.1	Rough	0.53	0.00
1.0	3.0	94.50	1.001-YR	0.8	23.6	1.00	7.1	29.9	2.3	9.1	Rough	1.30	0.00
2.0	4.0	71.00	1.001-YR	0.8	23.6	2.00	7.1	29.9	2.3	9.1	Rough	2.52	0.00
4.0	5.0	30.00	1.001-YR	0.8	23.6	3.67	7.1	29.9	2.3	9.1	Rough	4.45	0.00
6.0	5.9	8.50	1.001-YR	0.8	23.6	5.51	7.1	29.9	2.3	9.1	Rough	6.57	0.11
8.0	6.7	1.30	1.001-YR	0.8	23.6	7.45	7.1	29.9	2.3	9.1	Rough	8.77	1.00
10.0	7.7	0.25	1.001-YR	0.8	23.6	9.75	7.1	29.9	2.3	9.1	Rough	11.51	2.10
12.0	8.7	0.01	1.001-YR	0.8	23.6	11.35	7.1	29.9	2.3	9.1	Rough	13.71	2.92
15.0	10.0	0.00	1.001-YR	0.8	23.6	12.51	7.1	29.9	2.3	9.1	Rough	15.79	3.58
0.0	0.0	100.00	2-YR	3.8	26.6	0.00	7.1	29.9	2.3	9.1	Rough	0.00	0.00
0.4	2.0	99.60	2-YR	3.8	26.6	0.40	7.1	29.9	2.3	9.1	Rough	0.53	0.00
1.0	3.0	94.50	2-YR	3.8	26.6	1.00	7.1	29.9	2.3	9.1	Rough	1.30	0.00
2.0	4.0	71.00	2-YR	3.8	26.6	1.92	7.1	29.9	2.3	9.1	Rough	2.44	0.00
4.0	5.0	30.00	2-YR	3.8	26.6	3.69	7.1	29.9	2.3	9.1	Rough	4.47	0.46
6.0	5.9	8.50	2-YR	3.8	26.6	5.49	7.1	29.9	2.3	9.1	Rough	6.55	1.30
8.0	6.7	1.30	2-YR	3.8	26.6	7.40	7.1	29.9	2.3	9.1	Rough	8.72	2.19
10.0	7.7	0.25	2-YR	3.8	26.6	9.41	7.1	29.9	2.3	9.1	Rough	11.20	3.16
12.0	8.7	0.01	2-YR	3.8	26.6	11.63	7.1	29.9	2.3	9.1	Rough	13.96	4.23
15.0	10.0	0.00	2-YR	3.8	26.6	13.54	7.1	29.9	2.3	9.1	Rough	16.77	5.18
0.0	0.0	100.00	100-YR	6.8	29.6	0.00	7.1	29.9	2.3	9.1	Rough	0.00	0.00
0.4	2.0	99.60	100-YR	6.8	29.6	0.40	7.1	29.9	2.3	9.1	Rough	0.53	0.08
1.0	3.0	94.50	100-YR	6.8	29.6	1.00	7.1	29.9	2.3	9.1	Rough	1.30	0.37
2.0	4.0	71.00	100-YR	6.8	29.6	1.94	7.1	29.9	2.3	9.1	Rough	2.46	0.81
4.0	5.0	30.00	100-YR	6.8	29.6	3.72	7.1	29.9	2.3	9.1	Rough	4.50	1.65
6.0	5.9	8.50	100-YR	6.8	29.6	5.49	7.1	29.9	2.3	9.1	Rough	6.55	2.50
8.0	6.7	1.30	100-YR	6.8	29.6	7.36	7.1	29.9	2.3	9.1	Rough	8.69	3.38
10.0	7.7	0.25	100-YR	6.8	29.6	9.35	7.1	29.9	2.3	9.1	Rough	11.15	4.33
12.0	8.7	0.01	100-YR	6.8	29.6	11.84	7.1	29.9	2.3	9.1	Rough	14.15	5.52
15.0	10.0	0.00	100-YR	6.8	29.6	14.27	7.1	29.9	2.3	9.1	Rough	17.45	6.68

Table 23. Transmitted Wave Height Duration Data for Additional Damage State

Offshore Wave Height Feet	Wave Period Seconds	Percent Time Wave Exceeded	Water Level Return Period	Water Level FT LWD	Water Depth Feet	Incident Wave Height Feet	Crest Elevation FT LWD	Structure Height above Toe Feet	COTAN of Armor Slope	Structure Crest Width Feet	Slope Type	Wave Runup FEET	Transmitted Wave Height Feet
0.0	0.0	100.00	1.001-YR	0.8	23.6	0.00	7.1	29.9	2.3	9.1	Rough	0.00	0.00
0.4	2.0	99.60	1.001-YR	0.8	23.6	0.40	7.1	29.9	2.3	9.1	Rough	0.53	0.00
1.0	3.0	94.50	1.001-YR	0.8	23.6	1.00	7.1	29.9	2.3	9.1	Rough	1.30	0.00
2.0	4.0	71.00	1.001-YR	0.8	23.6	2.00	7.1	29.9	2.3	9.1	Rough	2.52	0.00
4.0	5.0	30.00	1.001-YR	0.8	23.6	3.67	7.1	29.9	2.3	9.1	Rough	4.45	0.00
6.0	5.9	8.50	1.001-YR	0.8	23.6	5.51	7.1	29.9	2.3	9.1	Rough	6.57	0.11
8.0	6.7	1.30	1.001-YR	0.8	23.6	7.45	7.1	29.9	2.3	9.1	Rough	8.77	1.00
10.0	7.7	0.25	1.001-YR	0.8	23.6	9.75	7.1	29.9	2.3	9.1	Rough	11.51	2.10
12.0	8.7	0.01	1.001-YR	0.8	23.6	11.35	7.0	29.8	2.2	9.1	Rough	14.11	3.19
15.0	10.0	0.00	1.001-YR	0.8	23.6	12.51	6.4	29.2	1.9	8.9	Rough	17.21	4.02
0.0	0.0	100.00	2-YR	3.8	26.6	0.00	7.1	29.9	2.3	9.1	Rough	0.00	0.00
0.4	2.0	99.60	2-YR	3.8	26.6	0.40	7.1	29.9	2.3	9.1	Rough	0.53	0.00
1.0	3.0	94.50	2-YR	3.8	26.6	1.00	7.1	29.9	2.3	9.1	Rough	1.30	0.00
2.0	4.0	71.00	2-YR	3.8	26.6	1.92	7.1	29.9	2.3	9.1	Rough	2.44	0.00
4.0	5.0	30.00	2-YR	3.8	26.6	3.69	7.1	29.9	2.3	9.1	Rough	4.47	0.46
6.0	5.9	8.50	2-YR	3.8	26.6	5.49	7.1	29.9	2.3	9.1	Rough	6.55	1.30
8.0	6.7	1.30	2-YR	3.8	26.6	7.40	7.1	29.9	2.3	9.1	Rough	8.72	2.19
10.0	7.7	0.25	2-YR	3.8	26.6	9.41	7.1	29.9	2.3	9.1	Rough	11.20	3.16
12.0	8.7	0.01	2-YR	3.8	26.6	11.63	6.9	29.7	2.2	9.1	Rough	14.38	4.35
15.0	10.0	0.00	2-YR	3.8	26.6	13.54	5.5	28.3	1.9	8.6	Rough	18.31	5.86
0.0	0.0	100.00	100-YR	6.8	29.6	0.00	7.1	29.9	2.3	9.1	Rough	0.00	0.00
0.4	2.0	99.60	100-YR	6.8	29.6	0.40	7.1	29.9	2.3	9.1	Rough	0.53	0.08
1.0	3.0	94.50	100-YR	6.8	29.6	1.00	7.1	29.9	2.3	9.1	Rough	1.30	0.37
2.0	4.0	71.00	100-YR	6.8	29.6	1.94	7.1	29.9	2.3	9.1	Rough	2.46	0.81
4.0	5.0	30.00	100-YR	6.8	29.6	3.72	7.1	29.9	2.3	9.1	Rough	4.50	1.65
6.0	5.9	8.50	100-YR	6.8	29.6	5.49	7.1	29.9	2.3	9.1	Rough	6.55	2.50
8.0	6.7	1.30	100-YR	6.8	29.6	7.36	7.1	29.9	2.3	9.1	Rough	8.69	3.38
10.0	7.7	0.25	100-YR	6.8	29.6	9.35	7.1	29.9	2.3	9.1	Rough	11.15	4.33
12.0	8.7	0.01	100-YR	6.8	29.6	11.84	6.8	29.6	2.2	9.0	Rough	14.57	5.64
15.0	10.0	0.00	100-YR	6.8	29.6	14.27	4.5	27.3	2.0	8.4	Rough	18.64	7.65

Table 24. Transmitted Wave Height Duration Data for Repaired

Offshore Wave Height Feet	Wave Period Seconds	Percent Time Wave Exceeded	Water Level Return Period	Water Level FT LWD	Water Depth Feet	Incident Wave Height Feet	Crest Elevation FT LWD	Structure Height above Toe Feet	COTAN of Armor Slope	Structure Crest Width Feet	Slope Type	Wave Runup FEET	Transmitted Wave Height Feet
0.0	0.0	100.00	1.001-YR	0.8	23.6	0.00	10.3	33.1	2	10	Rough	0.00	0.00
0.4	2.0	99.60	1.001-YR	0.8	23.6	0.40	10.3	33.1	2	10	Rough	0.56	0.00
1.0	3.0	94.50	1.001-YR	0.8	23.6	1.00	10.3	33.1	2	10	Rough	1.38	0.00
2.0	4.0	71.00	1.001-YR	0.8	23.6	2.00	10.3	33.1	2	10	Rough	2.69	0.00
4.0	5.0	30.00	1.001-YR	0.8	23.6	3.67	10.3	33.1	2	10	Rough	4.76	0.00
6.0	5.9	8.50	1.001-YR	0.8	23.6	5.51	10.3	33.1	2	10	Rough	7.03	0.00
8.0	6.7	1.30	1.001-YR	0.8	23.6	7.45	10.3	33.1	2	10	Rough	9.39	0.00
10.0	7.7	0.25	1.001-YR	0.8	23.6	9.75	10.3	33.1	2	10	Rough	12.32	1.07
12.0	8.7	0.01	1.001-YR	0.8	23.6	11.35	10.3	33.1	2	10	Rough	14.66	1.90
15.0	10.0	0.00	1.001-YR	0.8	23.6	12.51	10.3	33.1	2	10	Rough	16.83	2.60
0.0	0.0	100.00	2-YR	3.8	26.6	0.00	10.3	33.1	2	10	Rough	0.00	0.00
0.4	2.0	99.60	2-YR	3.8	26.6	0.40	10.3	33.1	2	10	Rough	0.56	0.00
1.0	3.0	94.50	2-YR	3.8	26.6	1.00	10.3	33.1	2	10	Rough	1.38	0.00
2.0	4.0	71.00	2-YR	3.8	26.6	1.92	10.3	33.1	2	10	Rough	2.60	0.00
4.0	5.0	30.00	2-YR	3.8	26.6	3.69	10.3	33.1	2	10	Rough	4.78	0.00
6.0	5.9	8.50	2-YR	3.8	26.6	5.49	10.3	33.1	2	10	Rough	7.01	0.19
8.0	6.7	1.30	2-YR	3.8	26.6	7.40	10.3	33.1	2	10	Rough	9.34	1.07
10.0	7.7	0.25	2-YR	3.8	26.6	9.41	10.3	33.1	2	10	Rough	11.99	2.05
12.0	8.7	0.01	2-YR	3.8	26.6	11.63	10.3	33.1	2	10	Rough	14.94	3.13
15.0	10.0	0.00	2-YR	3.8	26.6	13.54	10.3	33.1	2	10	Rough	17.90	4.11
0.0	0.0	100.00	100-YR	6.8	29.6	0.00	10.3	33.1	2	10	Rough	0.00	0.00
0.4	2.0	99.60	100-YR	6.8	29.6	0.40	10.3	33.1	2	10	Rough	0.56	0.00
1.0	3.0	94.50	100-YR	6.8	29.6	1.00	10.3	33.1	2	10	Rough	1.38	0.00
2.0	4.0	71.00	100-YR	6.8	29.6	1.94	10.3	33.1	2	10	Rough	2.62	0.00
4.0	5.0	30.00	100-YR	6.8	29.6	3.72	10.3	33.1	2	10	Rough	4.81	0.48
6.0	5.9	8.50	100-YR	6.8	29.6	5.49	10.3	33.1	2	10	Rough	7.01	1.31
8.0	6.7	1.30	100-YR	6.8	29.6	7.36	10.3	33.1	2	10	Rough	9.30	2.19
10.0	7.7	0.25	100-YR	6.8	29.6	9.35	10.3	33.1	2	10	Rough	11.93	3.15
12.0	8.7	0.01	100-YR	6.8	29.6	11.84	10.3	33.1	2	10	Rough	15.14	4.34
15.0	10.0	0.00	100-YR	6.8	29.6	14.27	10.3	33.1	2	10	Rough	18.64	5.53

b. Transmitted Waves over Breakwater – Frequency Relation

The wave runup and transmission for the four breakwater conditions (original condition, 2008 condition, additional damage condition, and repaired condition), the 100-, 10-, 2-, and 1.001-year waves, and the 100-, 2- and 1.001-year water levels were also determined using CEDAS. Table 25 presents the results in tabular form and Figures 37 to 39 present the results graphically.

Table 25. Wave Runup and Transmission – Frequency Relation

Condition	Wave Return Period	Offshore Wave Height Feet	Wave Period Seconds	Incident Wave Height Feet	Water Level Return Period	Water Level FT LWD	Crest Elevation FT LWD	Structure Height above Toe Feet	Water Depth Feet	COTAN of Armor Slope	Structure Crest Width Feet	Slope Type	Wave Runup FEET	Transmitted Wave Height
Original	100-YR	14.7	10.0	12.53	1.001-YR	0.8	10.3	33.1	23.6	1.5	10	Smooth	25.72	3.77
Original	100-YR	14.7	10.0	13.52	2-YR	3.8	10.3	33.1	26.6	1.5	10	Smooth	27.27	4.91
Original	100-YR	14.7	10.0	14.2	100-YR	6.8	10.3	33.1	29.6	1.5	10	Smooth	28.20	5.93
Existing	100-YR	14.7	10.0	12.53	1.001-YR	0.8	7.1	29.9	23.6	2.3	9.1	Rough	15.81	3.59
Existing	100-YR	14.7	10.0	13.52	2-YR	3.8	7.1	29.9	26.6	2.3	9.1	Rough	16.75	5.17
Existing	100-YR	14.7	10.0	14.2	100-YR	6.8	7.1	29.9	29.6	2.3	9.1	Rough	17.38	6.65
Additional Damaged State	100-YR	14.7	10.0	12.53	1.001-YR	0.8	6.4	29.2	23.6	1.9	8.9	Rough	17.23	4.03
Additional Damaged State	100-YR	14.7	10.0	13.52	2-YR	3.8	5.5	28.3	26.6	1.9	8.6	Rough	18.29	5.84
Additional Damaged State	100-YR	14.7	10.0	14.2	100-YR	6.8	4.5	27.3	29.6	2	8.4	Rough	18.57	7.60
Repaired	100-YR	14.7	10.0	12.53	1.001-YR	0.8	10.3	33.1	23.6	2	10	Rough	16.85	2.55
Repaired	100-YR	14.7	10.0	13.52	2-YR	3.8	10.3	33.1	26.6	2	10	Rough	17.88	4.02
Repaired	100-YR	14.7	10.0	14.2	100-YR	6.8	10.3	33.1	29.6	2	10	Rough	18.57	5.38
Original	10-YR	13.0	9.0	11.82	1.001-YR	0.8	10.3	33.1	23.6	1.5	10	Smooth	23.61	3.37
Original	10-YR	13.0	9.0	12.3	2-YR	3.8	10.3	33.1	26.6	1.5	10	Smooth	24.15	4.29
Original	10-YR	13.0	9.0	12.7	100-YR	6.8	10.3	33.1	29.6	1.5	10	Smooth	24.61	5.19
Existing	10-YR	13.0	9.0	11.82	1.001-YR	0.8	7.1	29.9	23.6	2.3	9.1	Rough	14.37	3.14
Existing	10-YR	13.0	9.0	12.3	2-YR	3.8	7.1	29.9	26.6	2.3	9.1	Rough	14.81	4.56
Existing	10-YR	13.0	9.0	12.7	100-YR	6.8	7.1	29.9	29.6	2.3	9.1	Rough	15.17	5.93
Additional Damaged State	10-YR	13.0	9.0	11.82	1.001-YR	0.8	6.9	29.7	23.6	2	9.0	Rough	15.36	3.40
Additional Damaged State	10-YR	13.0	9.0	12.3	2-YR	3.8	6.7	29.5	26.6	2	9.0	Rough	15.84	4.79
Additional Damaged State	10-YR	13.0	9.0	12.7	100-YR	6.8	6.4	29.2	29.6	2	8.9	Rough	16.23	6.20
Repaired	10-YR	13.0	9.0	11.82	1.001-YR	0.8	10.3	33.1	23.6	2	10	Rough	15.36	2.15
Repaired	10-YR	13.0	9.0	12.3	2-YR	3.8	10.3	33.1	26.6	2	10	Rough	15.38	3.46
Repaired	10-YR	13.0	9.0	12.7	100-YR	6.8	10.3	33.1	29.6	2	10	Rough	16.23	4.75
Original	2-YR	11.2	8.0	10.32	1.001-YR	0.8	10.3	33.1	23.6	1.5	10	Smooth	20.02	2.59
Original	2-YR	11.2	8.0	10.47	2-YR	3.8	10.3	33.1	26.6	1.5	10	Smooth	20.02	3.38
Original	2-YR	11.2	8.0	10.49	100-YR	6.8	10.3	33.1	29.6	1.5	10	Smooth	19.84	4.12
Existing	2-YR	11.2	8.0	10.32	1.001-YR	0.8	7.1	29.9	23.6	2.3	9.1	Rough	12.24	2.39
Existing	2-YR	11.2	8.0	10.47	2-YR	3.8	7.1	29.9	26.6	2.3	9.1	Rough	12.37	3.66
Existing	2-YR	11.2	8.0	10.49	100-YR	6.8	7.1	29.9	29.6	2.3	9.1	Rough	12.39	4.88
Additional Damaged State	2-YR	11.2	8.0	10.32	1.001-YR	0.8	7.1	29.9	23.6	2.3	9.1	Rough	12.24	2.39
Additional Damaged State	2-YR	11.2	8.0	10.47	2-YR	3.8	7.1	29.9	26.6	2.3	9.1	Rough	12.37	3.66
Additional Damaged State	2-YR	11.2	8.0	10.49	100-YR	6.8	7.1	29.9	29.6	2.3	9.1	Rough	12.39	4.88
Repaired	2-YR	11.2	8.0	10.32	1.001-YR	0.8	10.3	33.1	23.6	2	10	Rough	13.10	1.35
Repaired	2-YR	11.2	8.0	10.47	2-YR	3.8	10.3	33.1	26.6	2	10	Rough	13.25	2.54
Repaired	2-YR	11.2	8.0	10.49	100-YR	6.8	10.3	33.1	29.6	2	10	Rough	13.27	3.68
Original	1.001-YR	9.4	7.0	8.71	1.001-YR	0.8	10.3	33.1	23.6	1.5	10	Smooth	16.49	1.76
Original	1.001-YR	9.4	7.0	8.71	2-YR	3.8	10.3	33.1	26.6	1.5	10	Smooth	16.32	2.50
Original	1.001-YR	9.4	7.0	8.67	100-YR	6.8	10.3	33.1	29.6	1.5	10	Smooth	16.12	3.23
Existing	1.001-YR	9.4	7.0	8.71	1.001-YR	0.8	7.1	29.9	23.6	2.3	9.1	Rough	10.07	1.55
Existing	1.001-YR	9.4	7.0	8.71	2-YR	3.8	7.1	29.9	26.6	2.3	9.1	Rough	10.07	2.79
Existing	1.001-YR	9.4	7.0	8.67	100-YR	6.8	7.1	29.9	29.6	2.3	9.1	Rough	10.04	4.01
Additional Damaged State	1.001-YR	9.4	7.0	8.71	1.001-YR	0.8	7.1	29.9	23.6	2.3	9.1	Rough	10.07	1.55
Additional Damaged State	1.001-YR	9.4	7.0	8.71	2-YR	3.8	7.1	29.9	26.6	2.3	9.1	Rough	10.07	2.79
Additional Damaged State	1.001-YR	9.4	7.0	8.67	100-YR	6.8	7.1	29.9	29.6	2.3	9.1	Rough	10.04	4.01
Repaired	1.001-YR	9.4	7.0	8.71	1.001-YR	0.8	10.3	33.1	23.6	2	10	Rough	10.80	0.50
Repaired	1.001-YR	9.4	7.0	8.71	2-YR	3.8	10.3	33.1	26.6	2	10	Rough	10.80	1.65
Repaired	1.001-YR	9.4	7.0	8.67	100-YR	6.8	10.3	33.1	29.6	2	10	Rough	10.77	2.79

5. CONCLUSIONS

This appendix presented wave and damage information for a portion of the Cleveland East Breakwater, station 84+00 to 106+29, to assist in the completion of a risk-based analysis. A summary of conclusions follow.

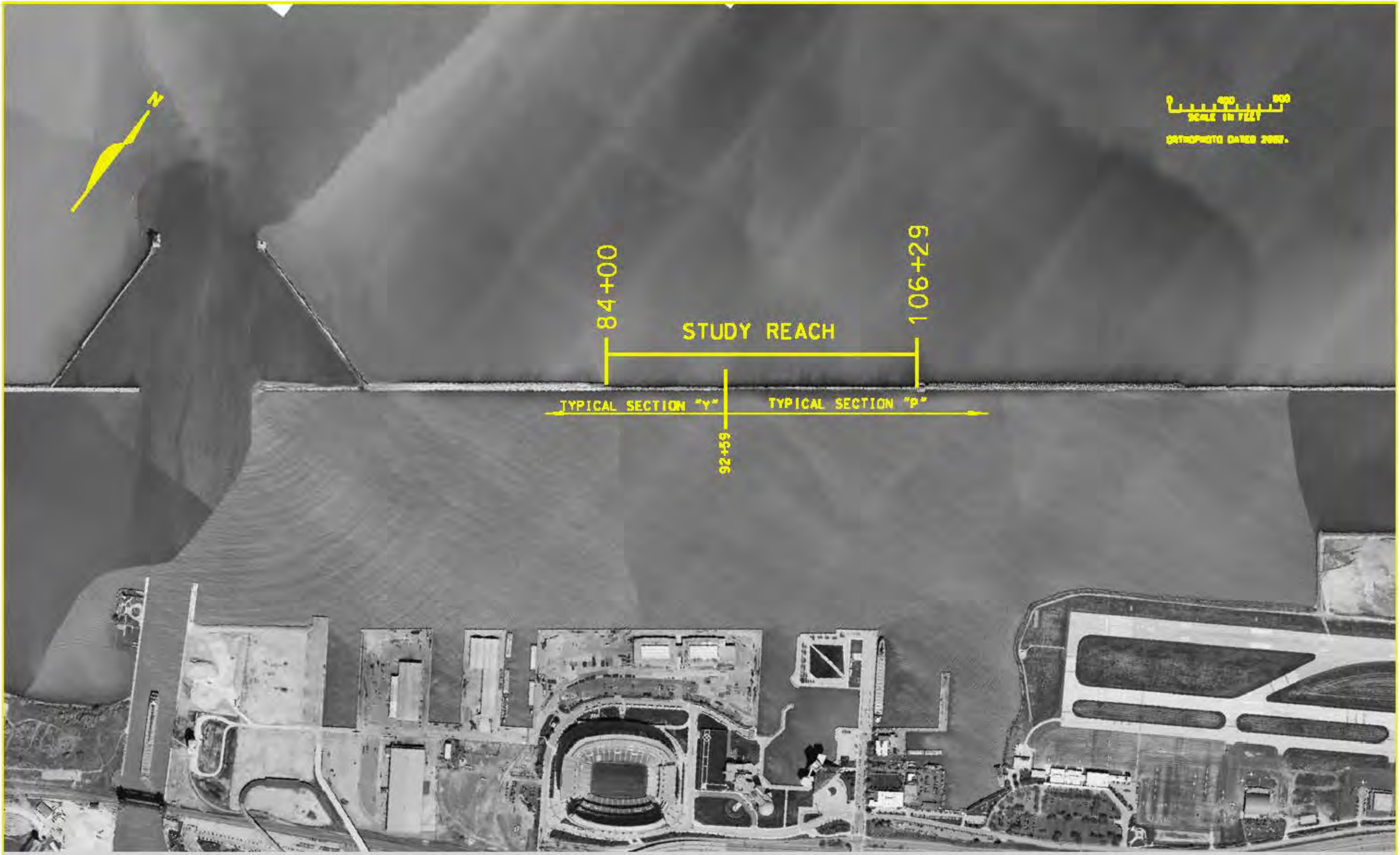
- An average cross-section for the entire reach was developed resulting in an average existing armor loss of 60.75 SQ FT.
- A simple wave transformation technique allowed the creation of a period of record (1956-2007) set of waves incident to the breakwater. Assuming that the breakwater was in good condition at the beginning of this period, wave damage equations were applied to the structure. This analysis resulted in an average armor area loss of 94.5 SQ FT. This is about 56% greater than the actual existing damage. The result lends some credibility to the subsequent computed damage from hypothetical storms, but suggests that the average estimated damage may be overestimated. Experience with other laid-up structures in the Great Lakes indicate other causes (settlement, stone durability) may initiate damage with waves potentially causing subsequent damage.
- Additional lakeside armor area loss (damage) to the breakwater resulting from hypothetical storms ranged from 4.5 SQ FT from the 10-year wave with 1.001-year water level storm to 49.2 SQ FT from the 100-year wave with 100-year water level storm. The crest elevation would reduce from the average existing elevation of +7.1 ft LWD to 6.9 FT LWD from the 10-year wave with 1.001-year water level storm down to +4.5 ft LWD from the 100-year wave with 100-year water level storm.
- The cost to repair the existing structure was estimated to be approximately $7 million. The additional cost to repair damage to the breakwater resulting from hypothetical storms ranged from $88,000 from the 10-year wave with 1.001-year water level storm to $1.6 million for the 100-year wave with 100-year water level storm.
- Transmitted significant wave heights from the 1.001-year wave and 1.001-year water level storm were 1.8 ft, 1.6 ft, 1.6 ft and 0.5 ft for the original, existing, additional and repaired condition, respectively. Transmitted significant wave heights from the 100-year wave and 100-year water level storm were 5.9 ft, 6.7 ft, 7.6 ft and 5.4 ft for the

original, existing, additional damage and repaired condition, respectively.

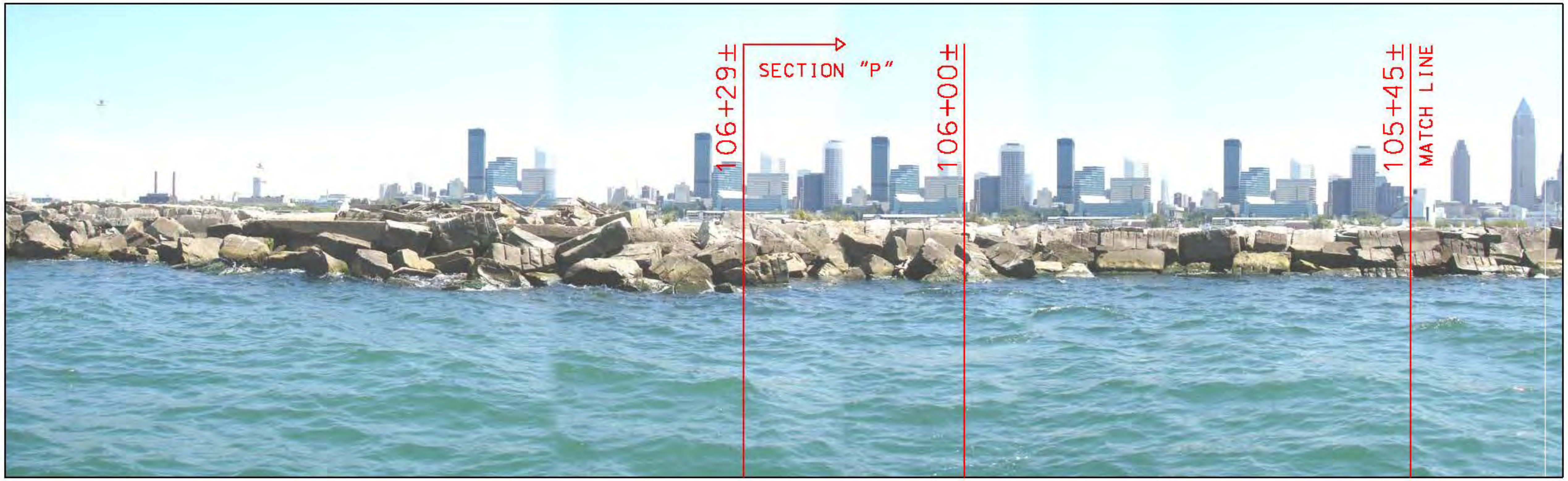
6. FURTHER STUDY NEEDS

This study attempted to estimate future wave-induced damage to the Cleveland East Breakwater. During the course of the analysis some potential improvements were noted.

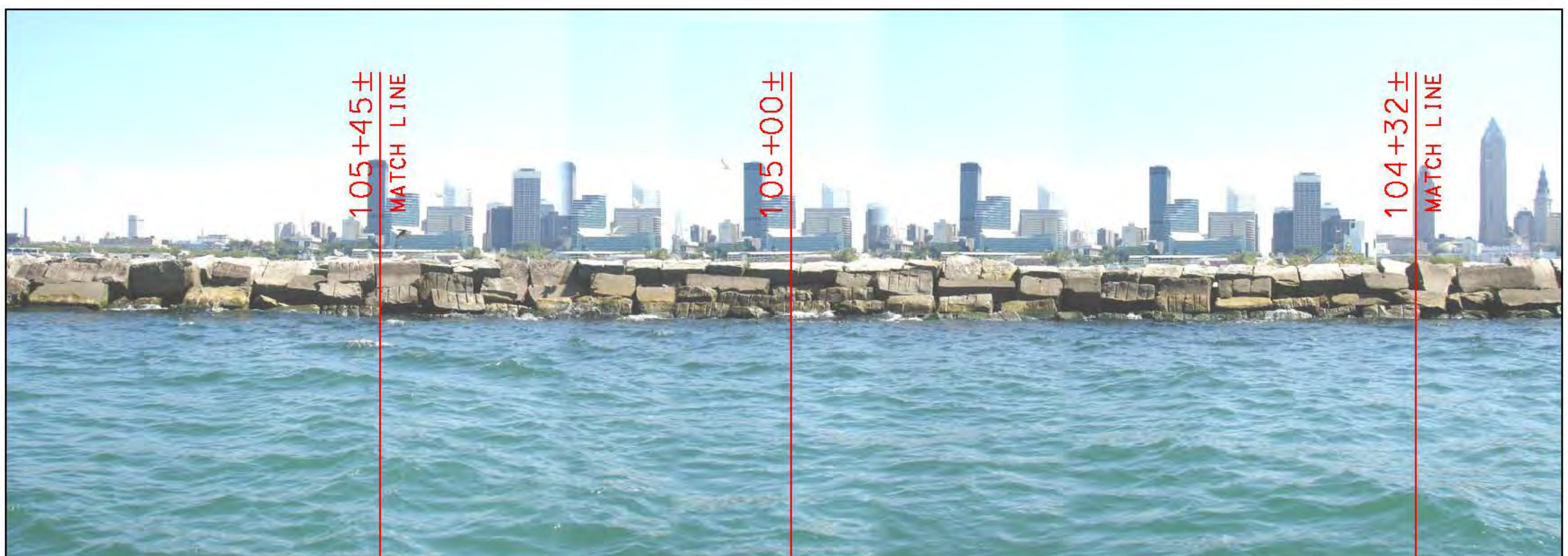
- Simplified techniques were used to estimate incident waves and hypothetical storms were assumed to approach perpendicular to the breakwater. A more rigorous approach may result in an improved incident wave data set.
- Damage to the structure was determined using rubble mound wave-induced damage equations. The Cleveland East Breakwater was originally constructed using a single layer of cut stone. While in its present disheveled state the armor demonstrates some characteristics of a single-layer rubble mound, there are differences such as having a much smaller underlayer and the blocky stone does not interlock as well as randomly-shaped stone. Additional study of the failure of single-layer cut stone would improve the damage results.
- Most of the breakwaters in the Great Lakes are composed of multiple materials (timber cribs, concrete caps, steel-sheet pile, and laid-up stone). Damage equations for these types of structures are required in order that risk-based techniques may be applied.
- The event tree did not account for multiple storms in a year (additional storms until repaired).
- The analysis considered the entire year and did not estimate transmitted waves during the navigation season.



CLEVELAND HARBOR RISK ANALYSIS STUDY AREA



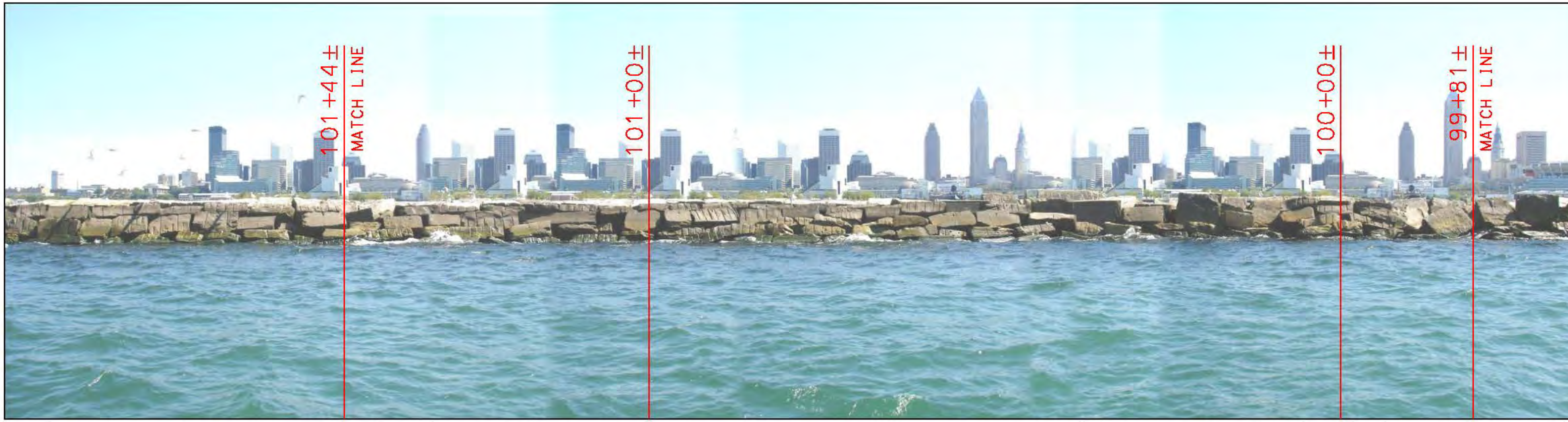
CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 106+29± TO 105+45±



CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 105+45± TO 104+32±

CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 104+32± TO 102+75±

CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 102+75± TO 101+44±

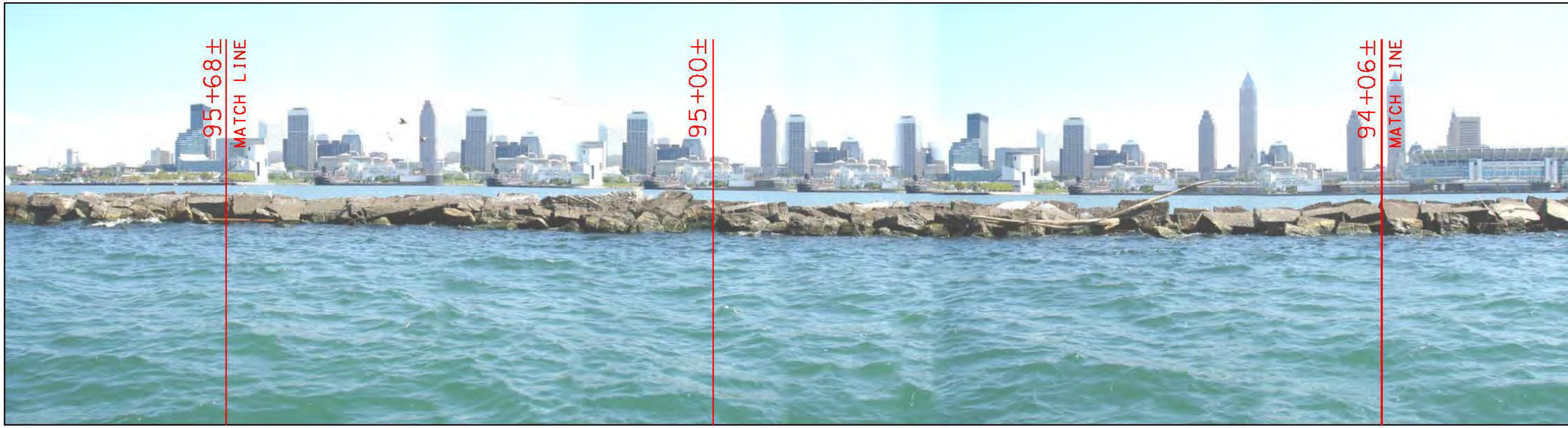


CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 101+44± TO 99+81±

CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 99+81± TO 98+35±

CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 98+35 TO 97+08

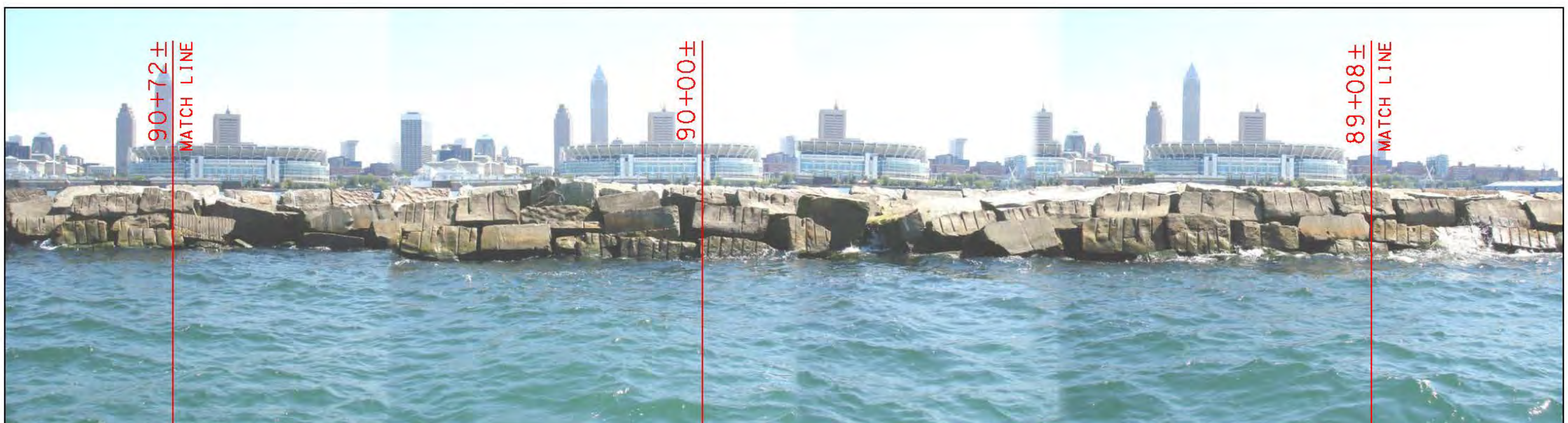
CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 97+08± TO 95+68±



CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 95+68± TO 94+06±

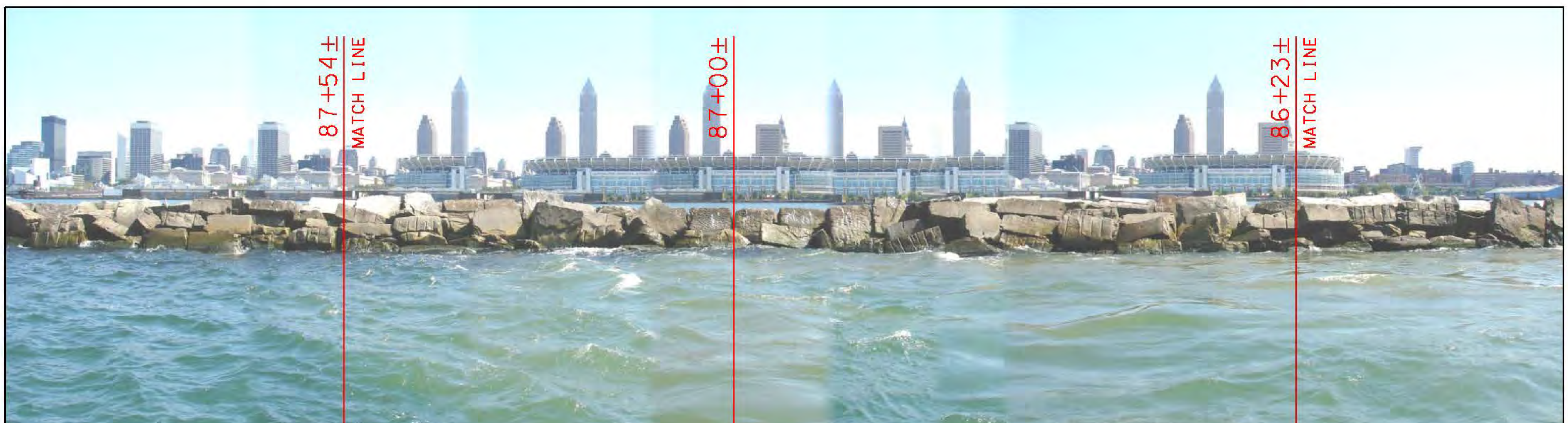
CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 94+06± TO 92+40±

CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 92+40± TO 90+72±



CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 90+72± TO 89+08±

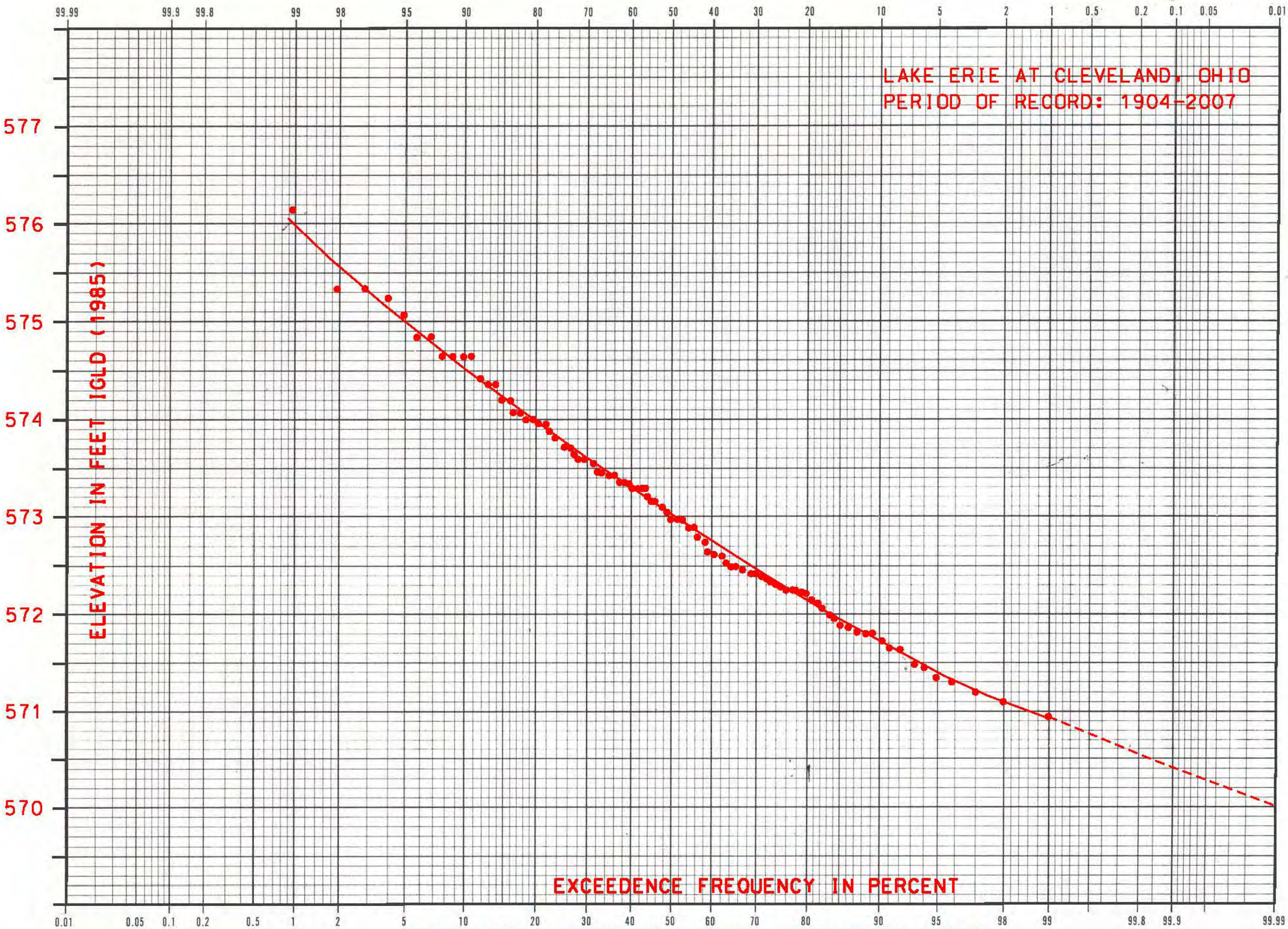
CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 89+08± TO 87+54±



CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 87+54± TO 86+23±

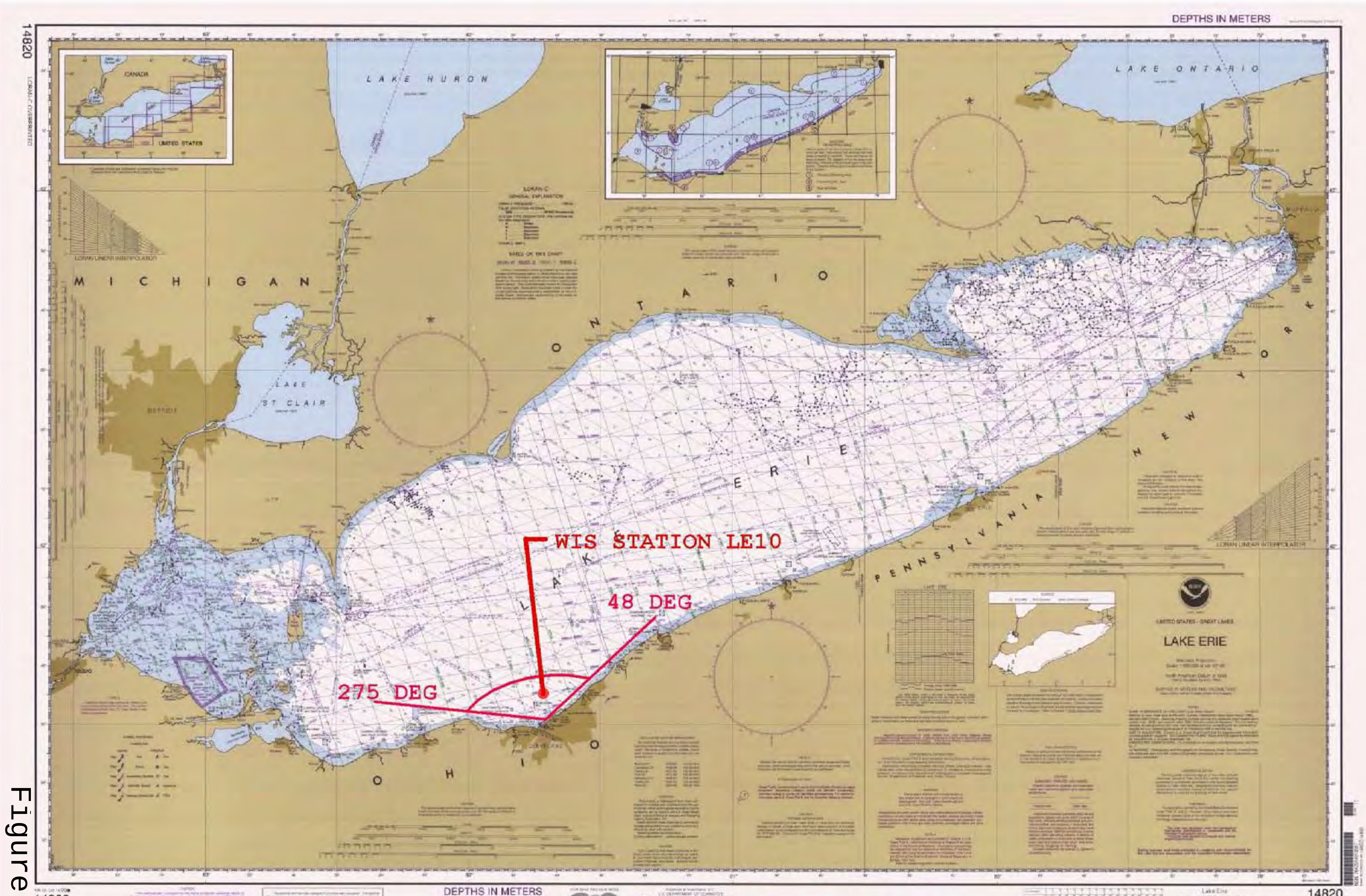
CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 86+23± TO 84+77±

CLEVELAND EAST BREAKWATER LAKESIDE PANORAMIC PHOTO, 27 AUGUST 2007,
APPROXIMATE STATION 84+77± TO 84+00±



LAKE LEVEL- FREQUENCY CURVE: CLEVELAND, OHIO

CLEVELAND WATER LEVEL-PROBABILITY.DGN
Reference: Probability Paper.JPG



DEEPWATER WAVE DIRECTIONS AT CLEVELAND, OHIO

Figure 11

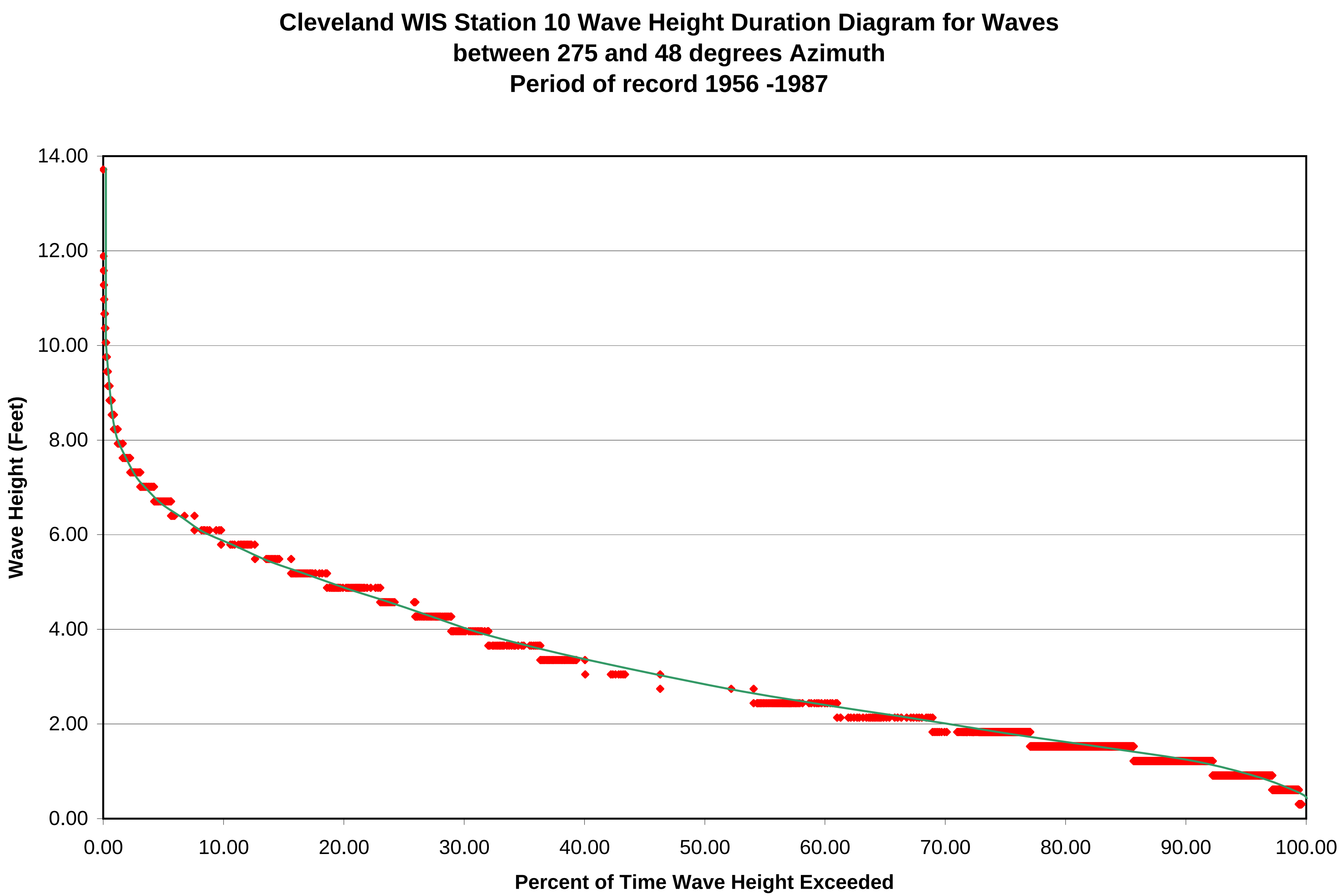
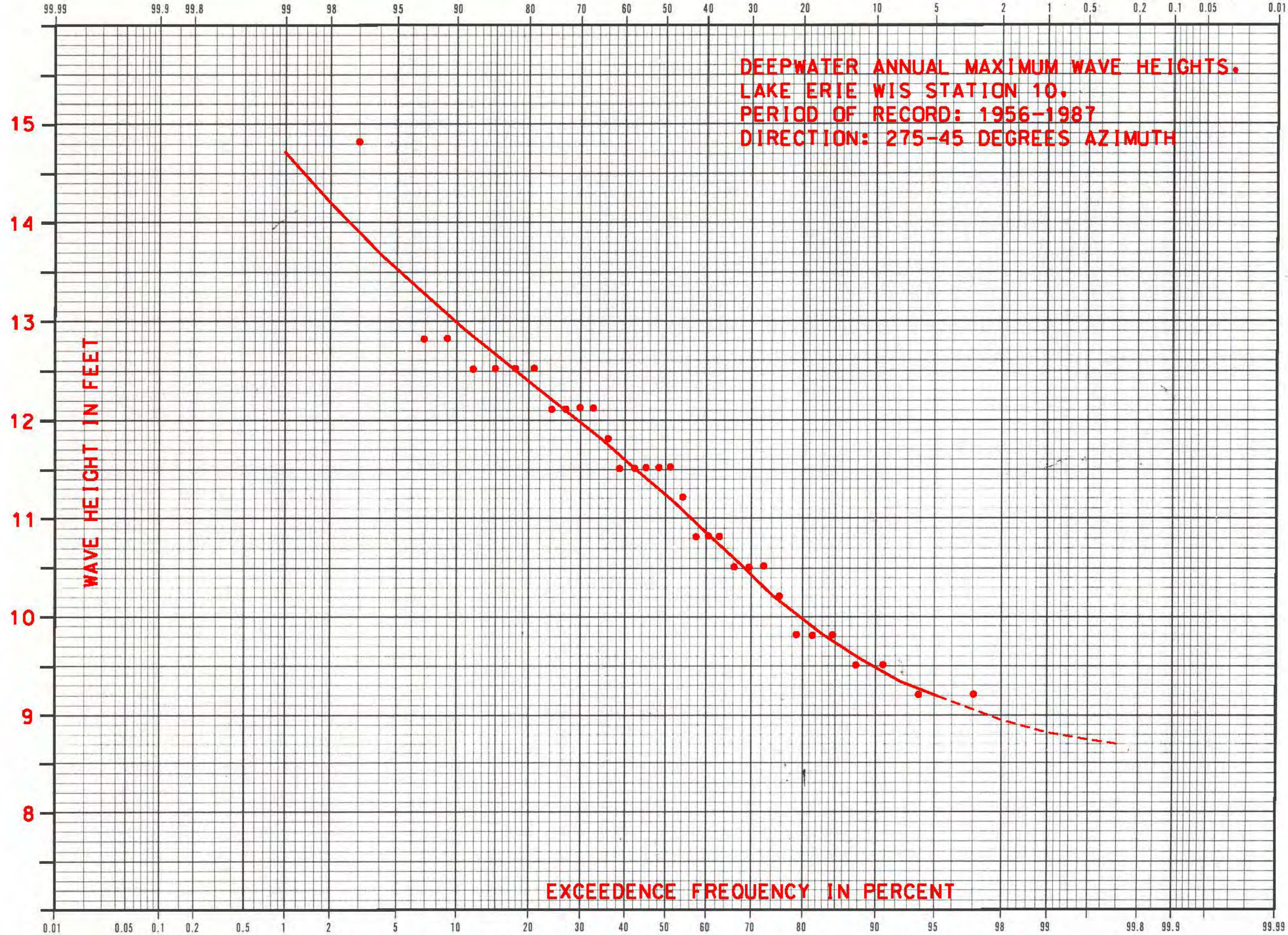
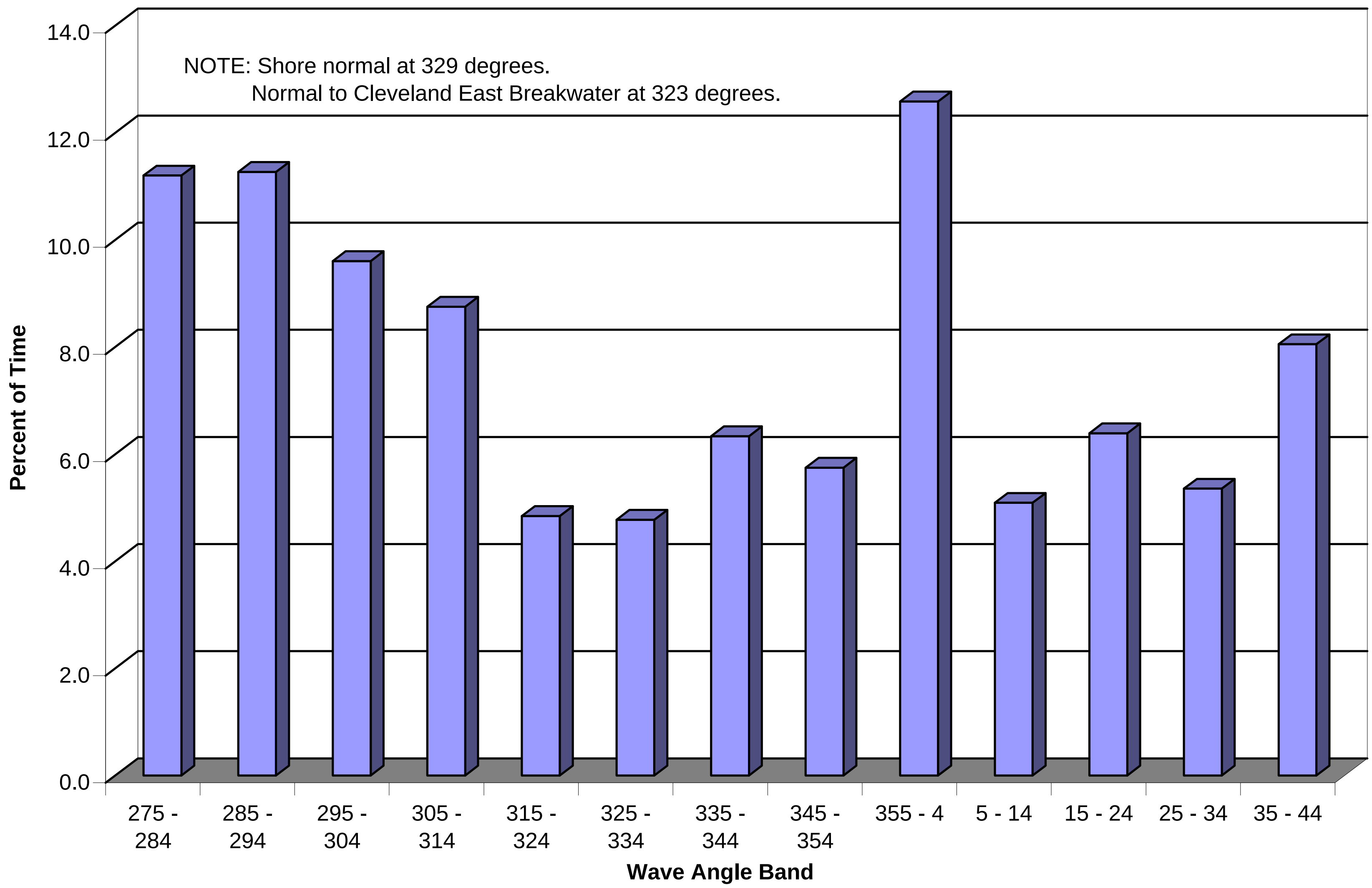

Cleveland WIS Station 10 Wave Height Duration Diagram for Waves
between 275 and 48 degrees Azimuth
Period of record 1956 -1987
Wave Height (Feet)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Percent of Time Wave Height Exceeded

Figure 12

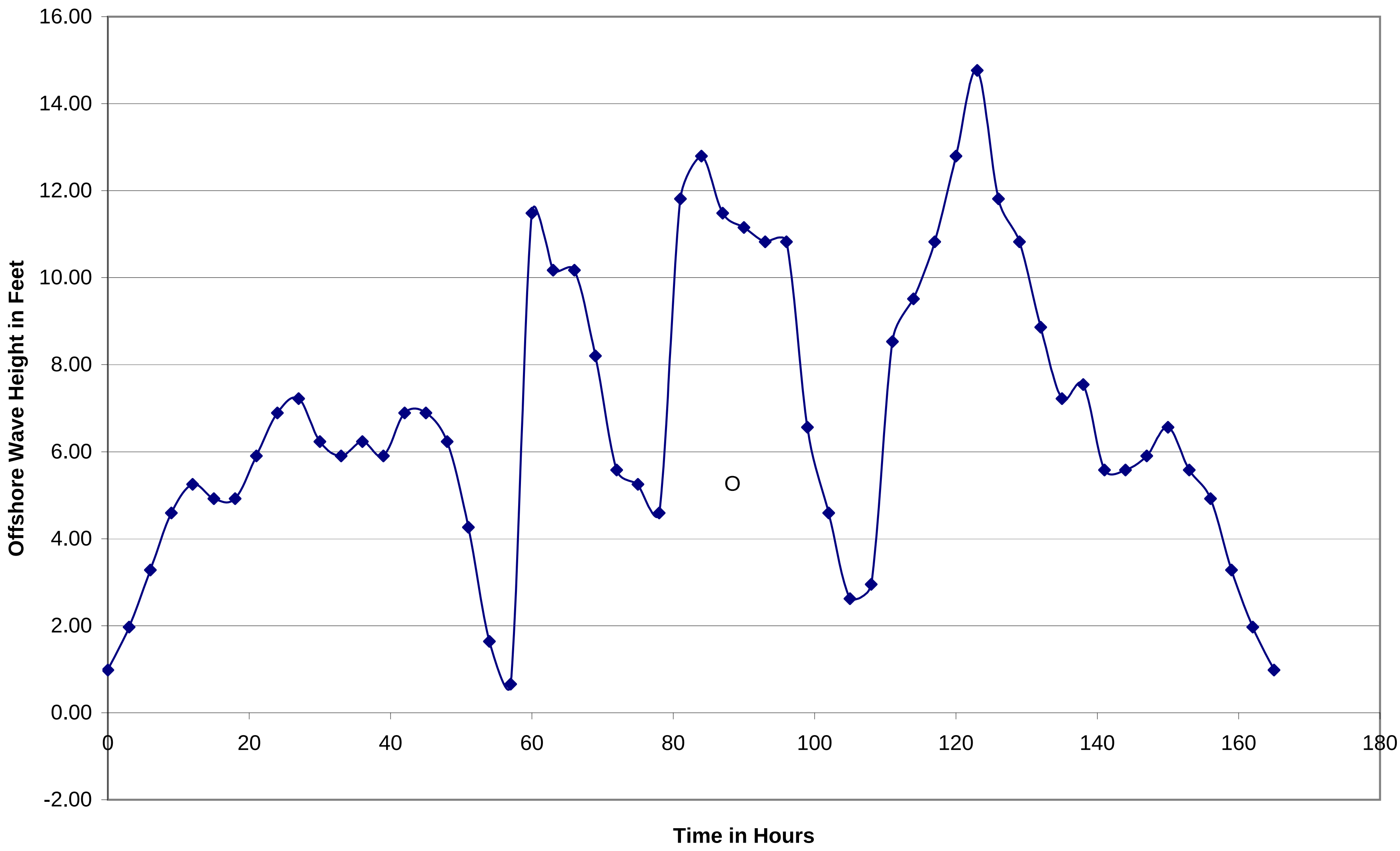


ANNUAL MAXIMUM WAVE HEIGHT - FREQUENCY: CLEVELAND, OHIO



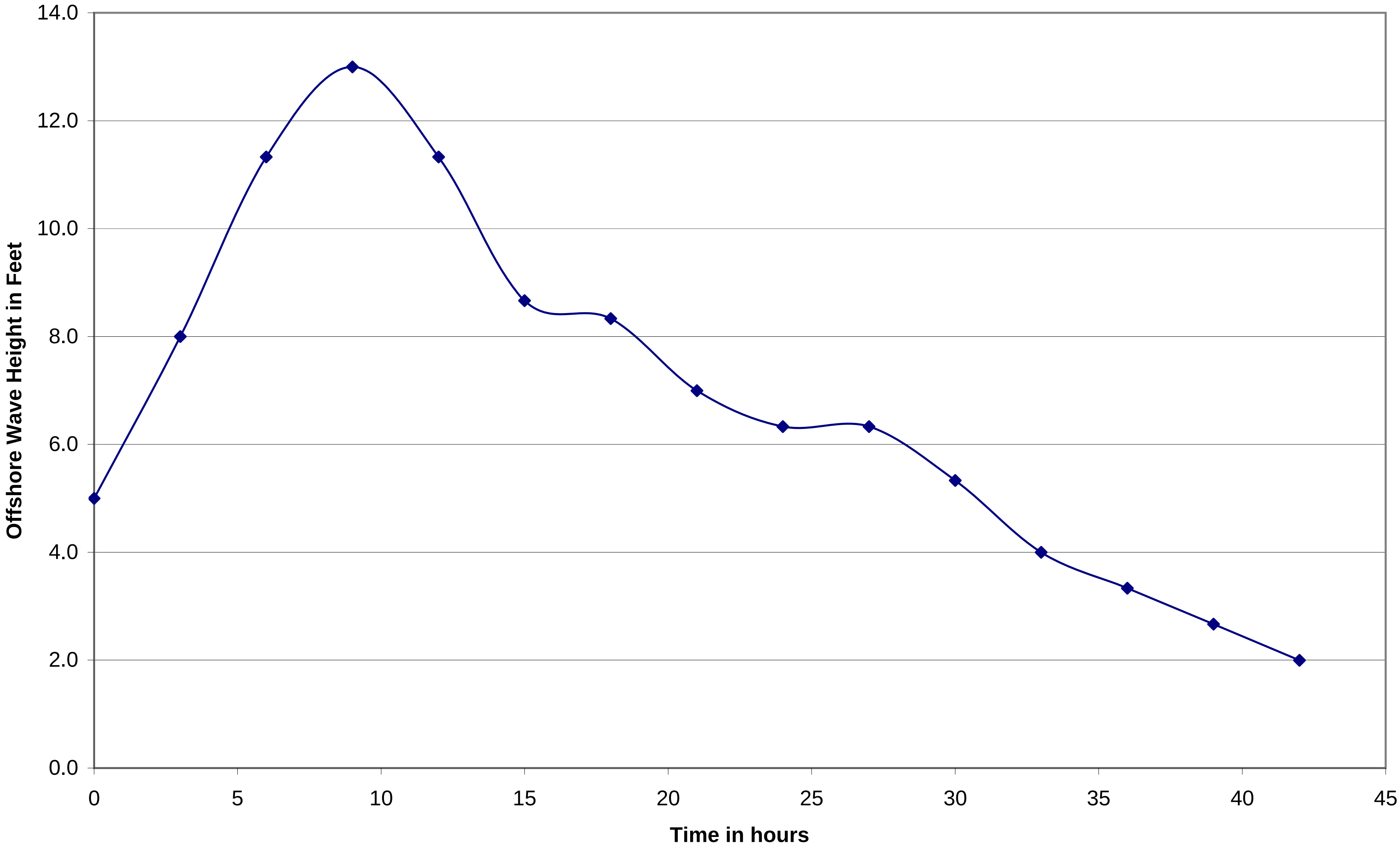
WIS LE10 Wave Direction Distribution, 275 - 44 Degrees

Figure 14



100-Year Storm

Figure 15



10-yr Offshore Waves

Figure 16

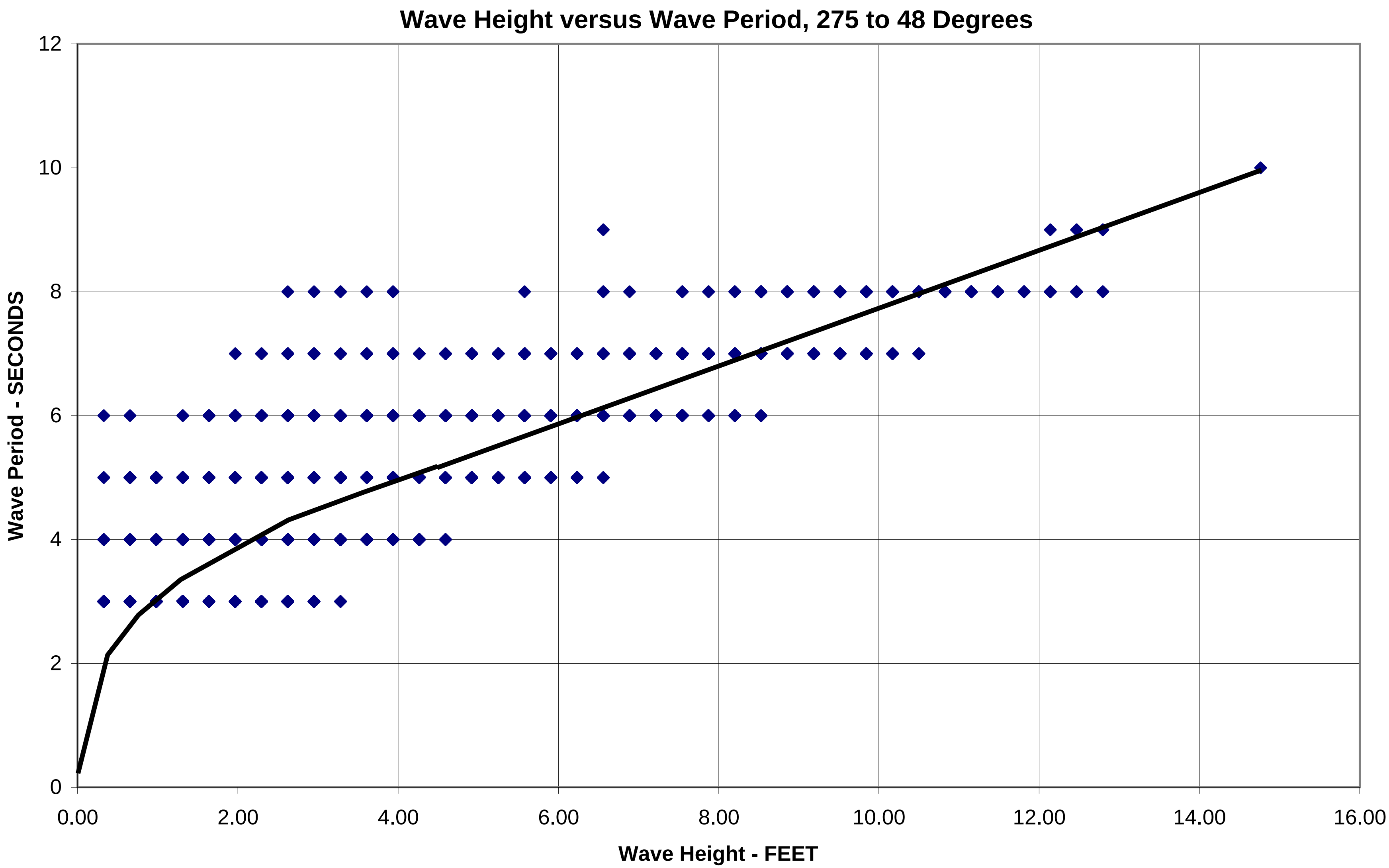
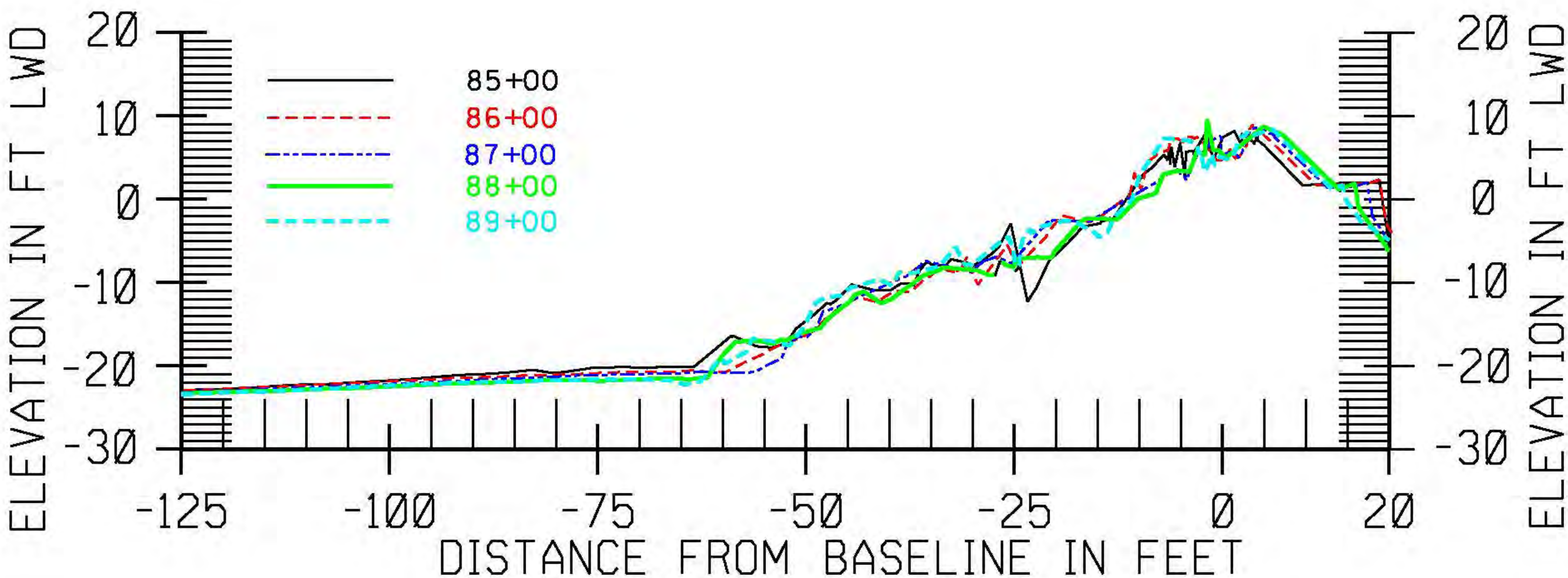

Wave Height versus Wave Period, 275 to 48 Degrees
Wave Period - SECONDS
Wave Height - FEET
0
2
4
6
8
10
12
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00

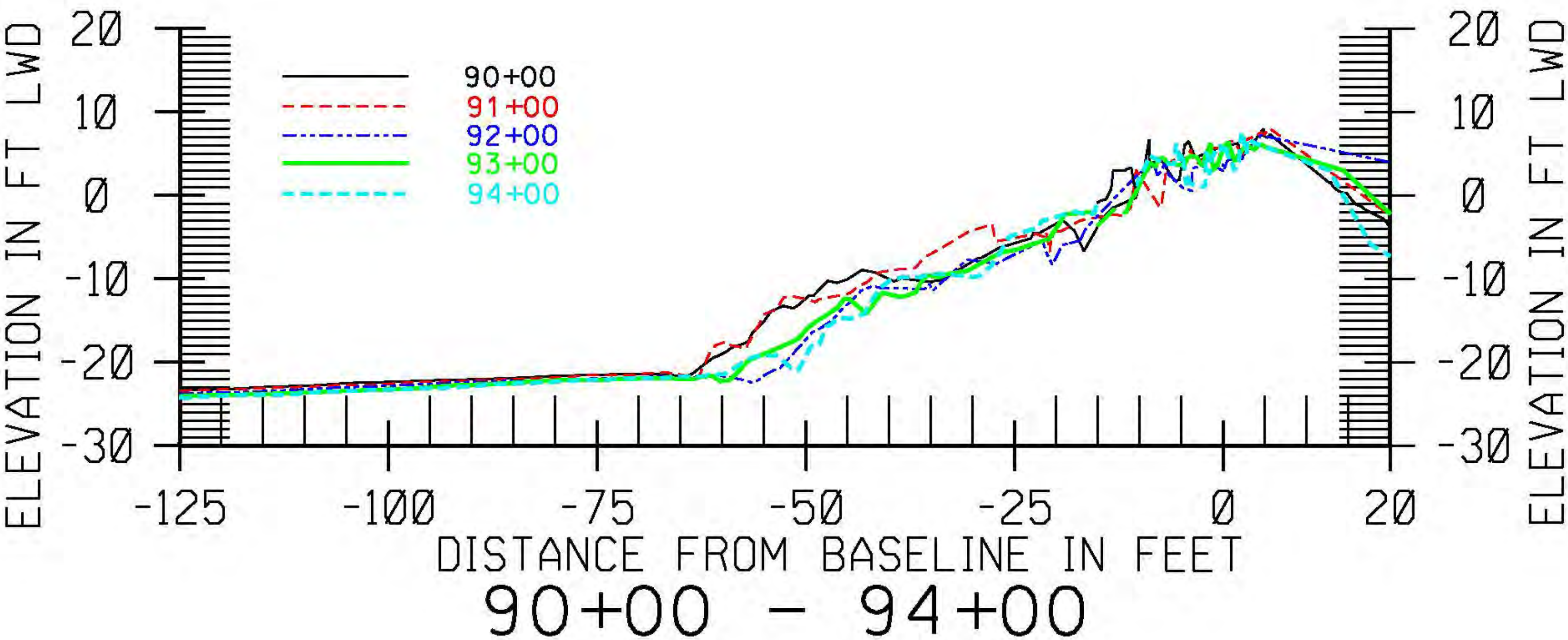
Figure 17

Fig



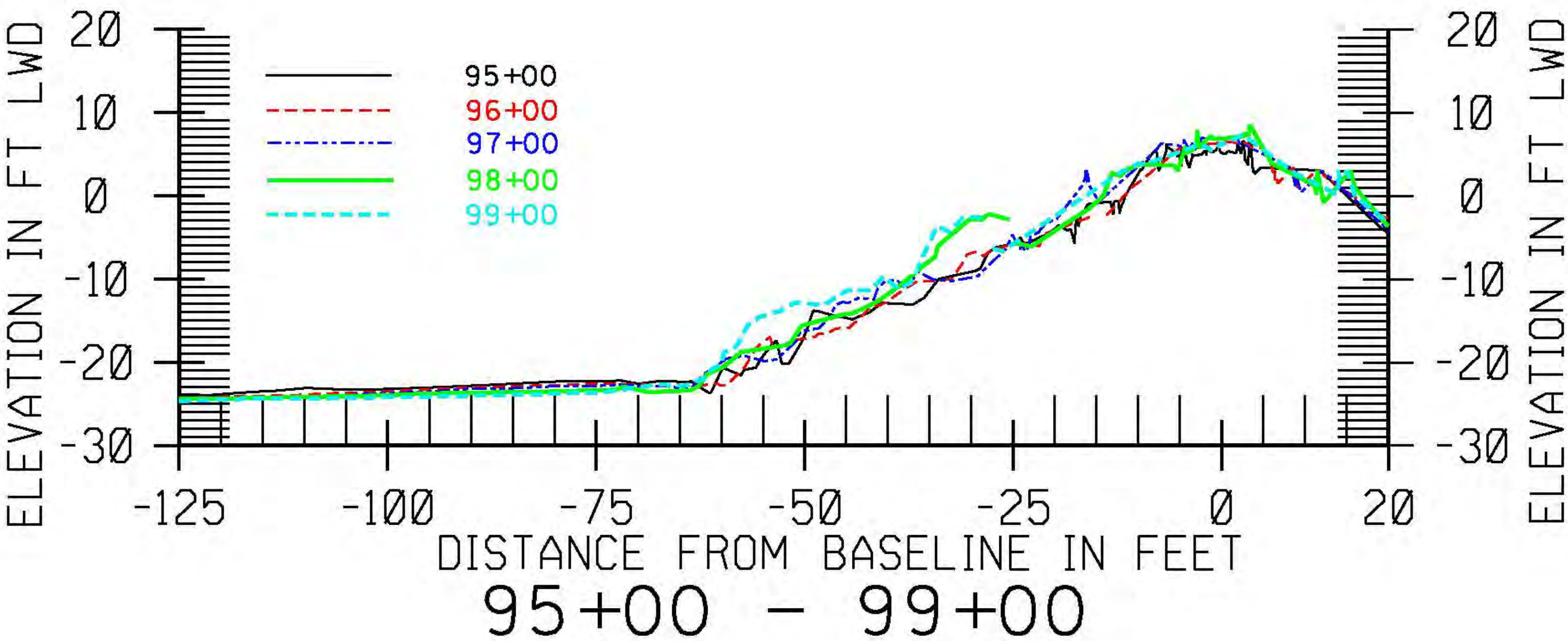
85+00 - 89+00

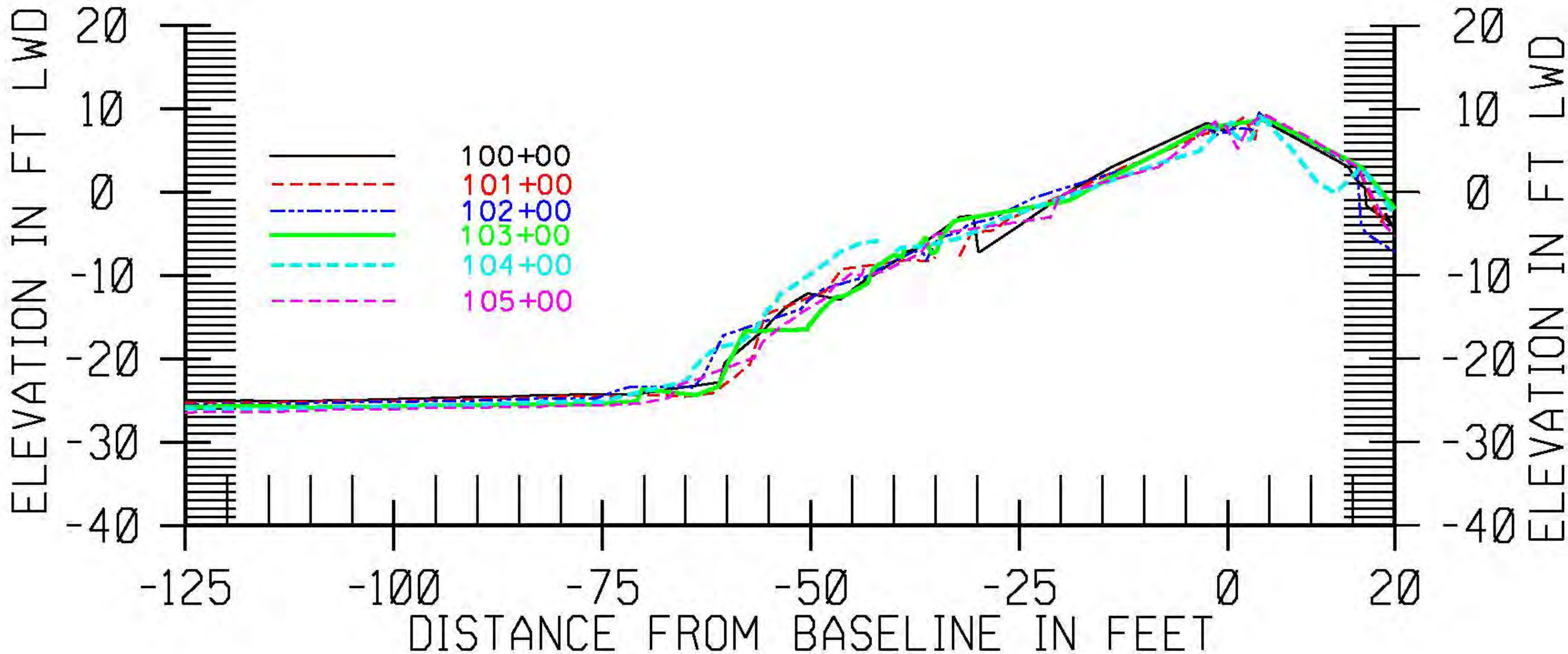
Fi

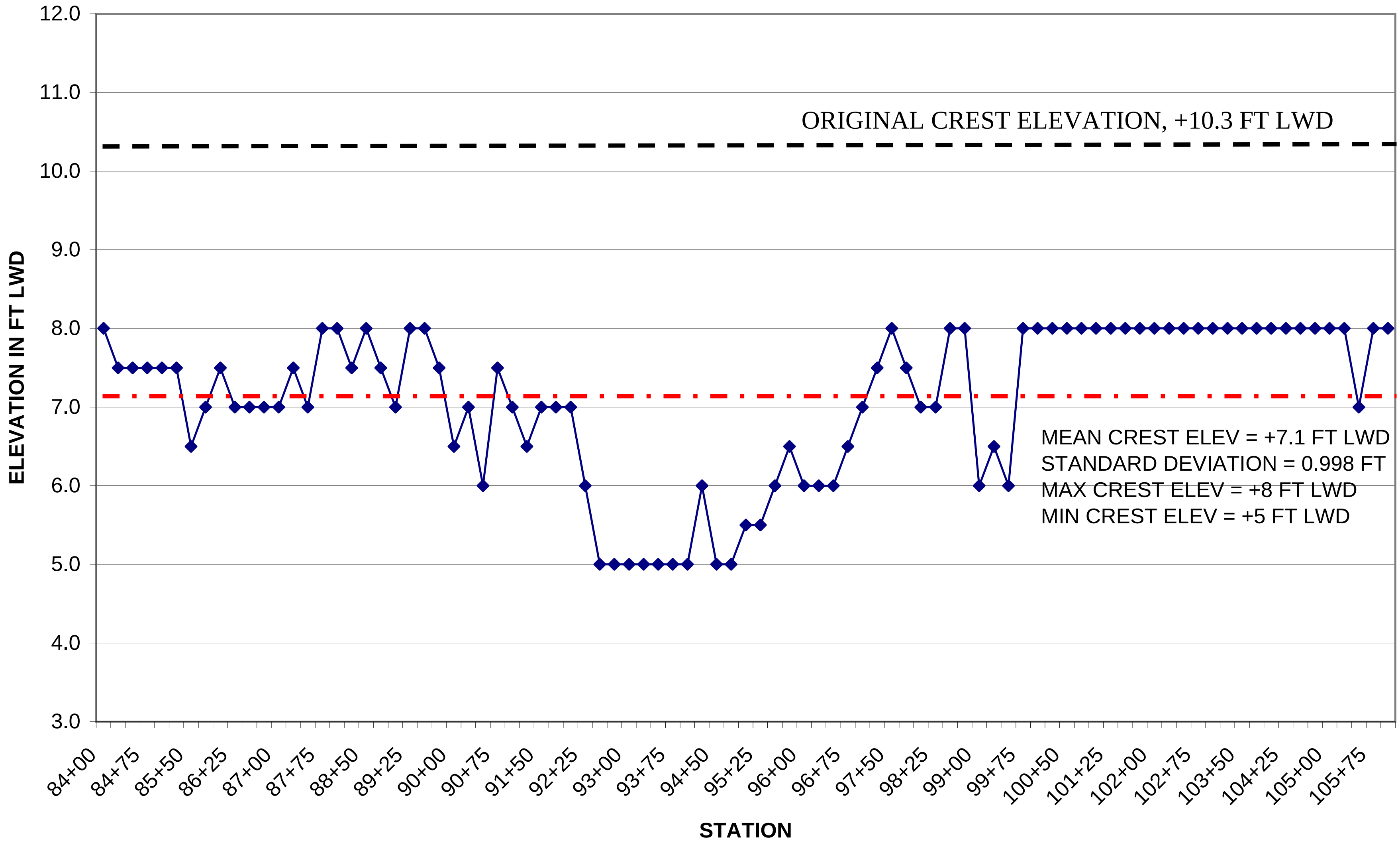


90+00
91+00
92+00
93+00
94+00
ELEVATION IN FT LWD
20
10
0
-10
-20
-30
-125
-100
-75
-50
-25
0
20
DISTANCE FROM BASELINE IN FEET
90+00 - 94+00

Figur

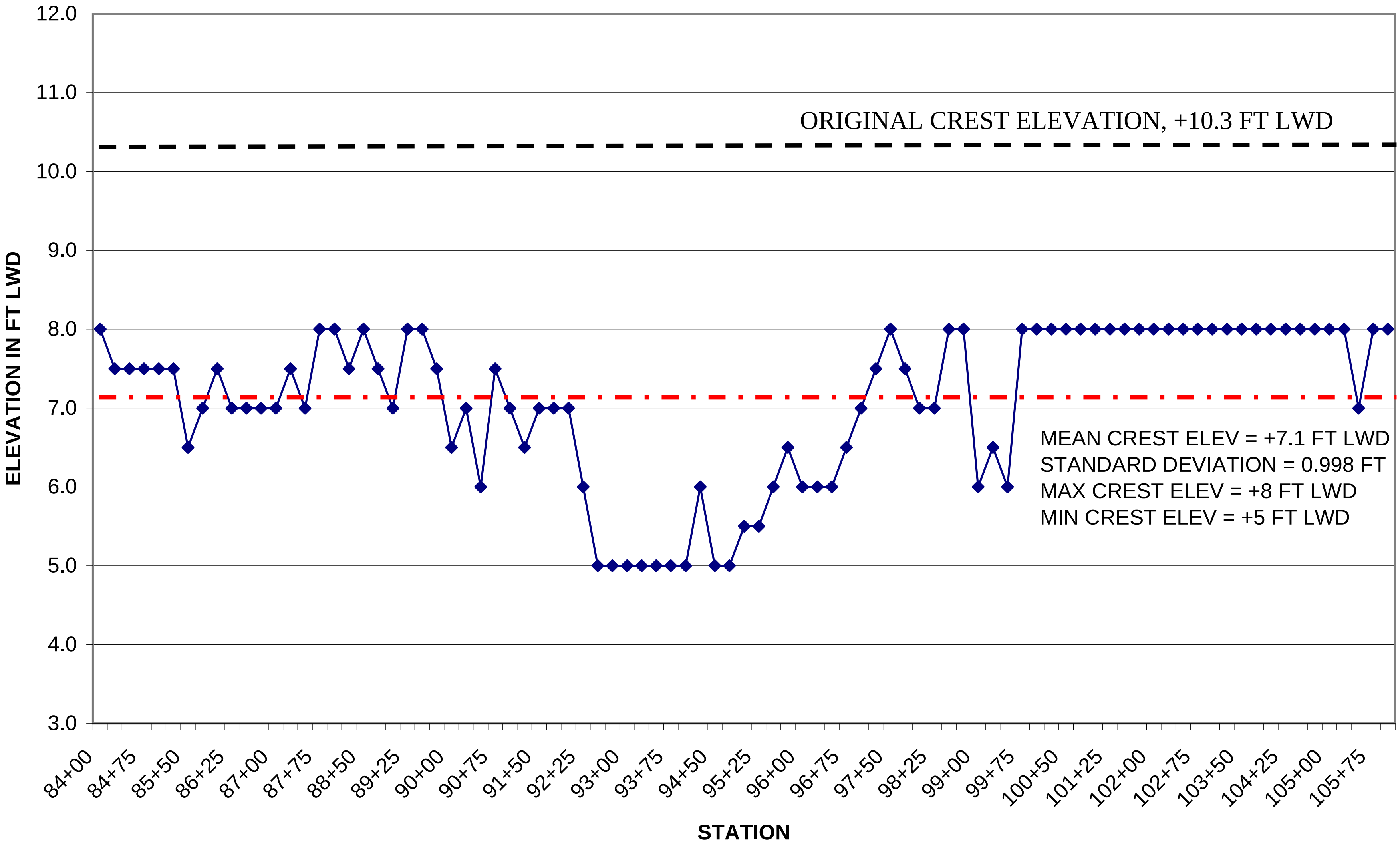

95+00
96+00
97+00
98+00
99+00
ELEVATION IN FT LWD
20
10
0
-10
-20
-30
-125
-100
-75
-50
-25
0
20
DISTANCE FROM BASELINE IN FEET
95+00 - 99+00


ELEVATION IN FT LWD
20
10
0
-10
-20
-30
-40
100+00
101+00
102+00
103+00
104+00
105+00
-125
-100
-75
-50
-25
0
20
DISTANCE FROM BASELINE IN FEET
100+00 - 105+00



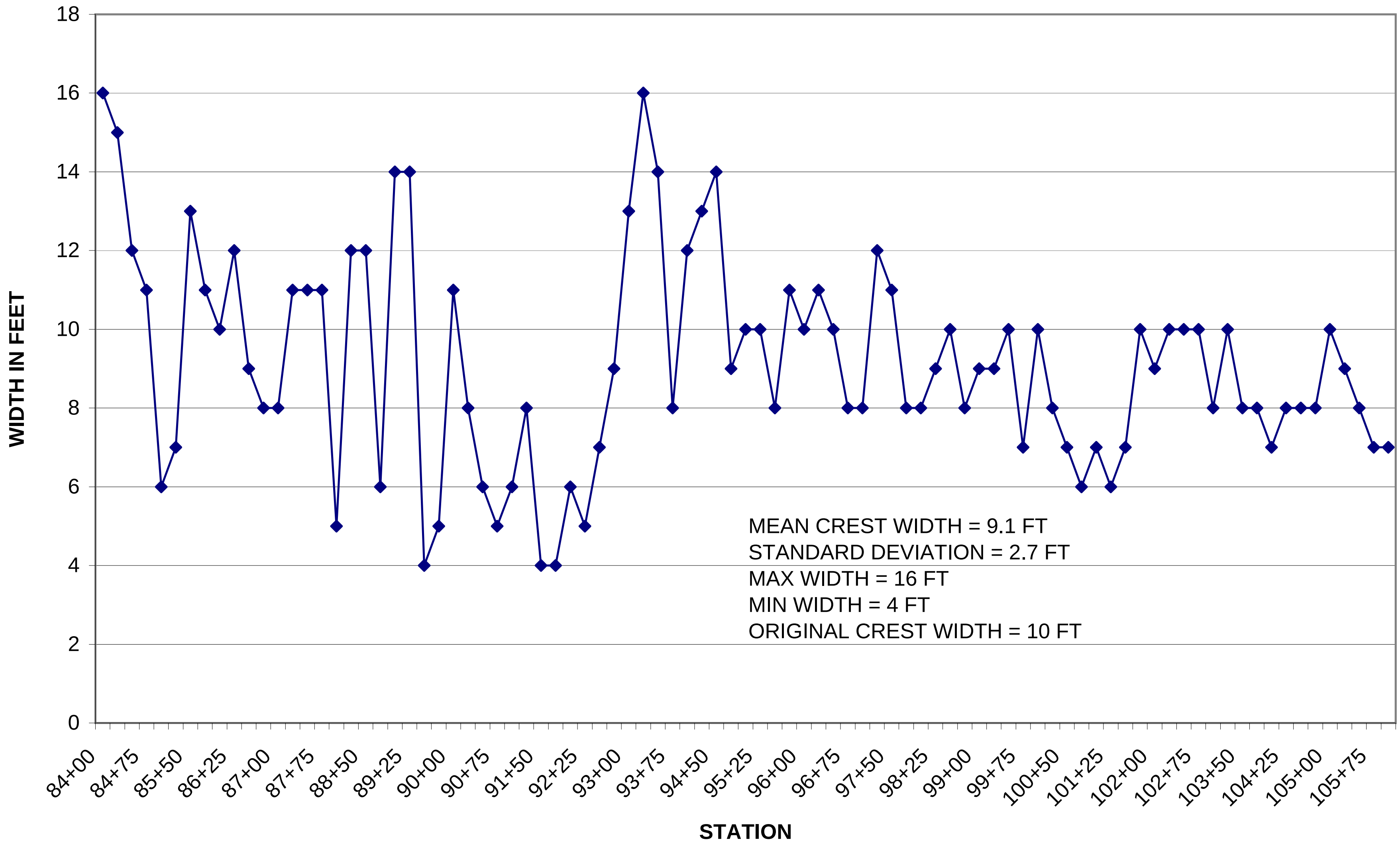
CLEVELAND EAST BREAKWATER EXISTING CREST ELEVATION, 2008

Figure 22



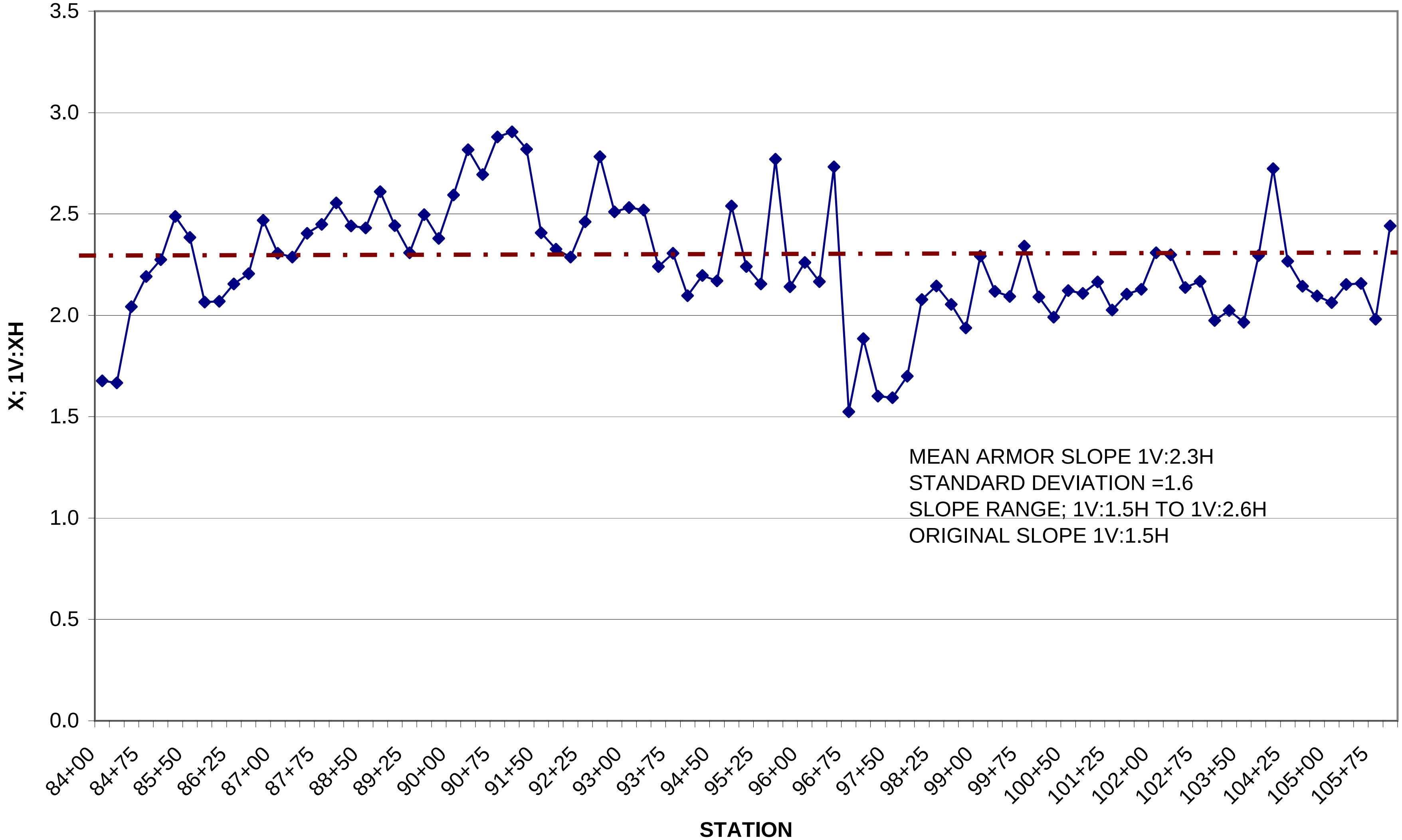
CLEVELAND EAST BREAKWATER EXISTING CREST ELEVATION, 2008

Figure 22



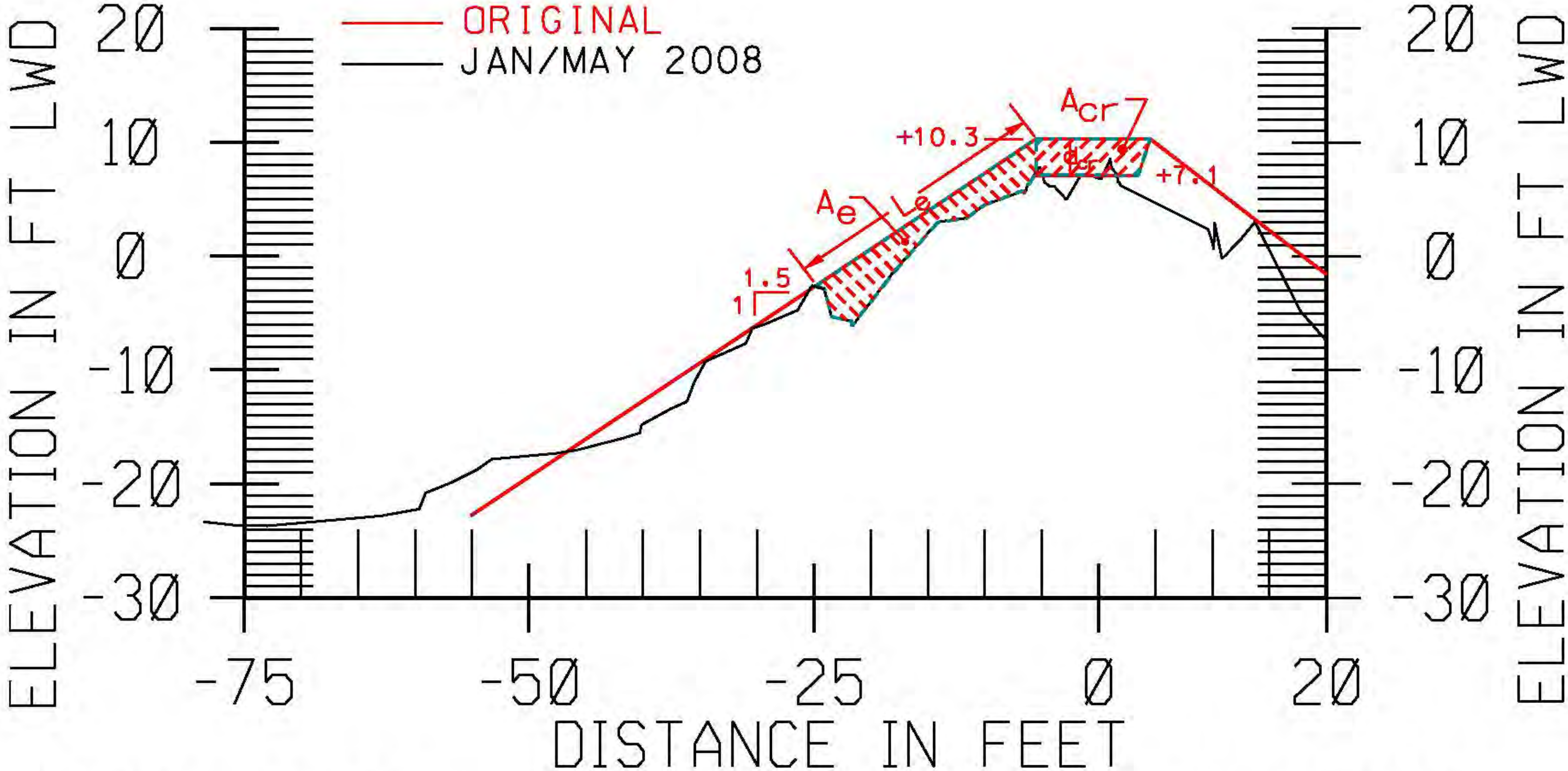
CLEVELAND EAST BREAKWATER EXISTING CREST WIDTH, 2008

Figure 23

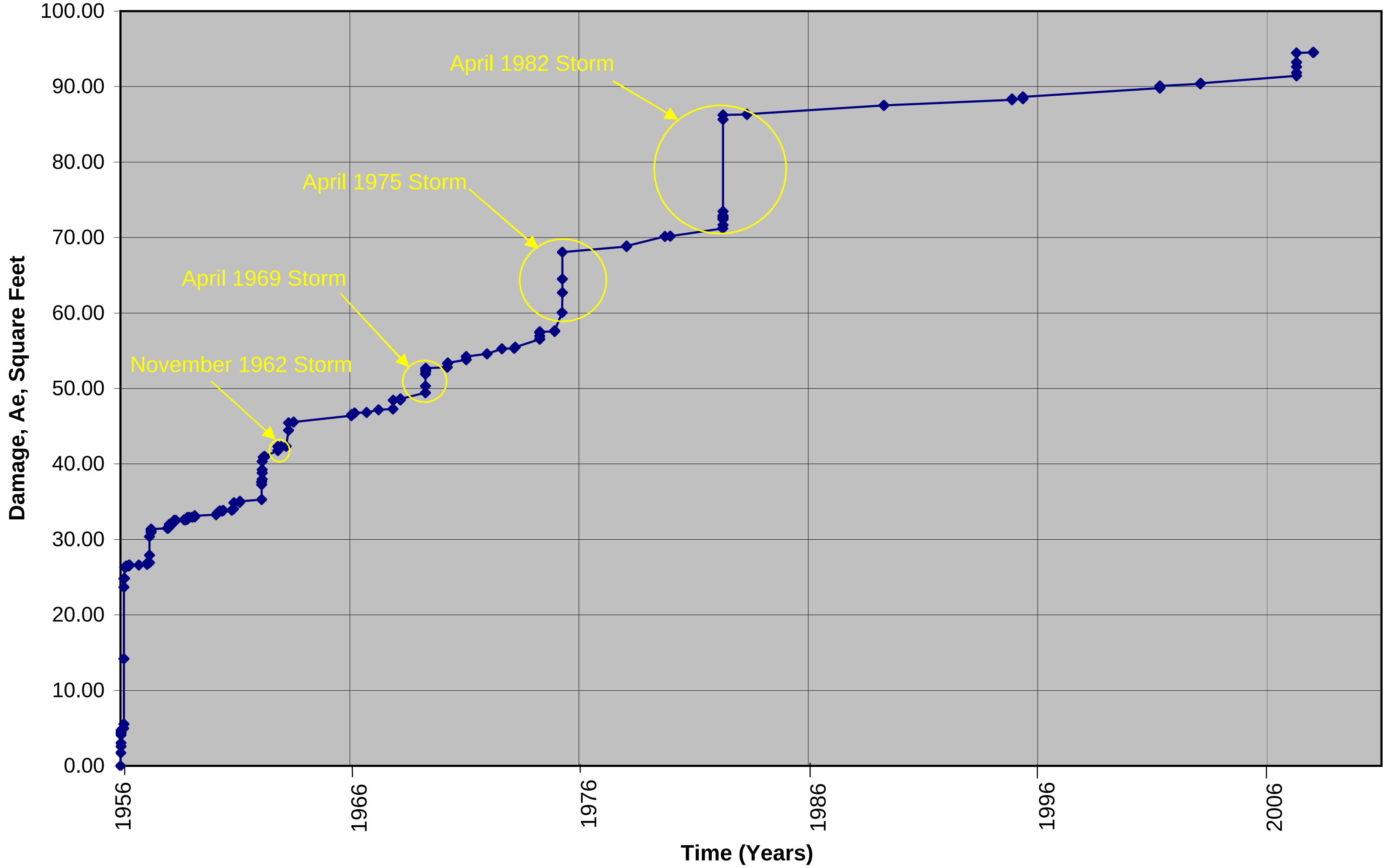


CLEVELAND EAST BREAKWATER EXISTING ARMOR SLOPE, 2008

Figure 24

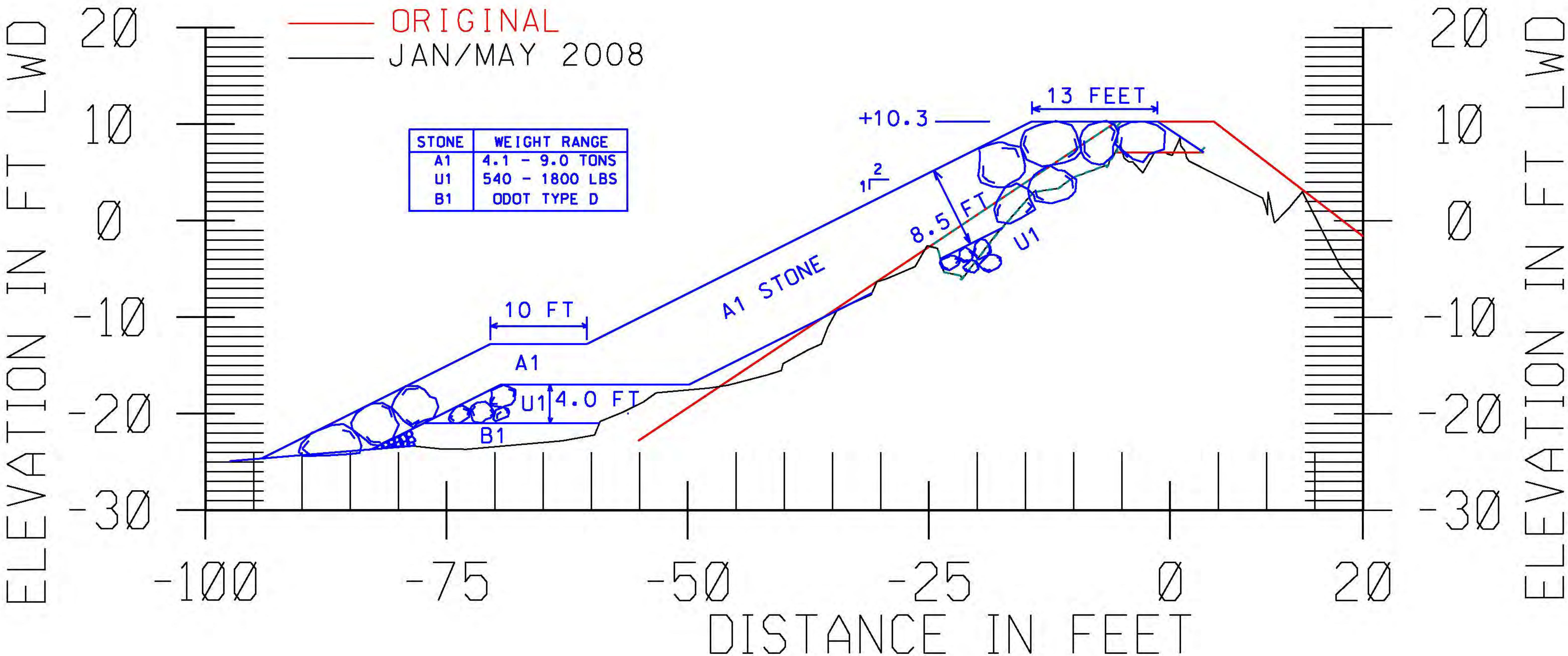


TYPICAL DAMAGED SECTION

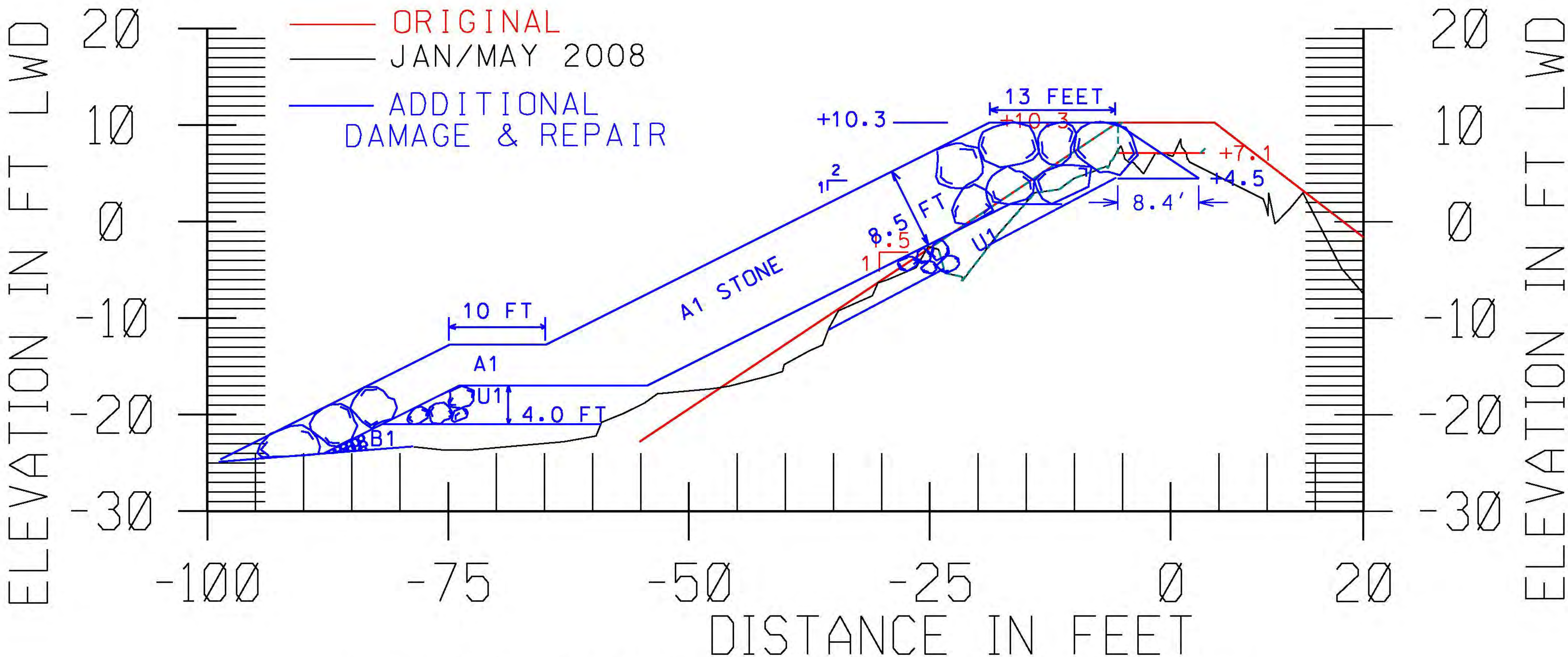


Accumulated Damage to Breakwater

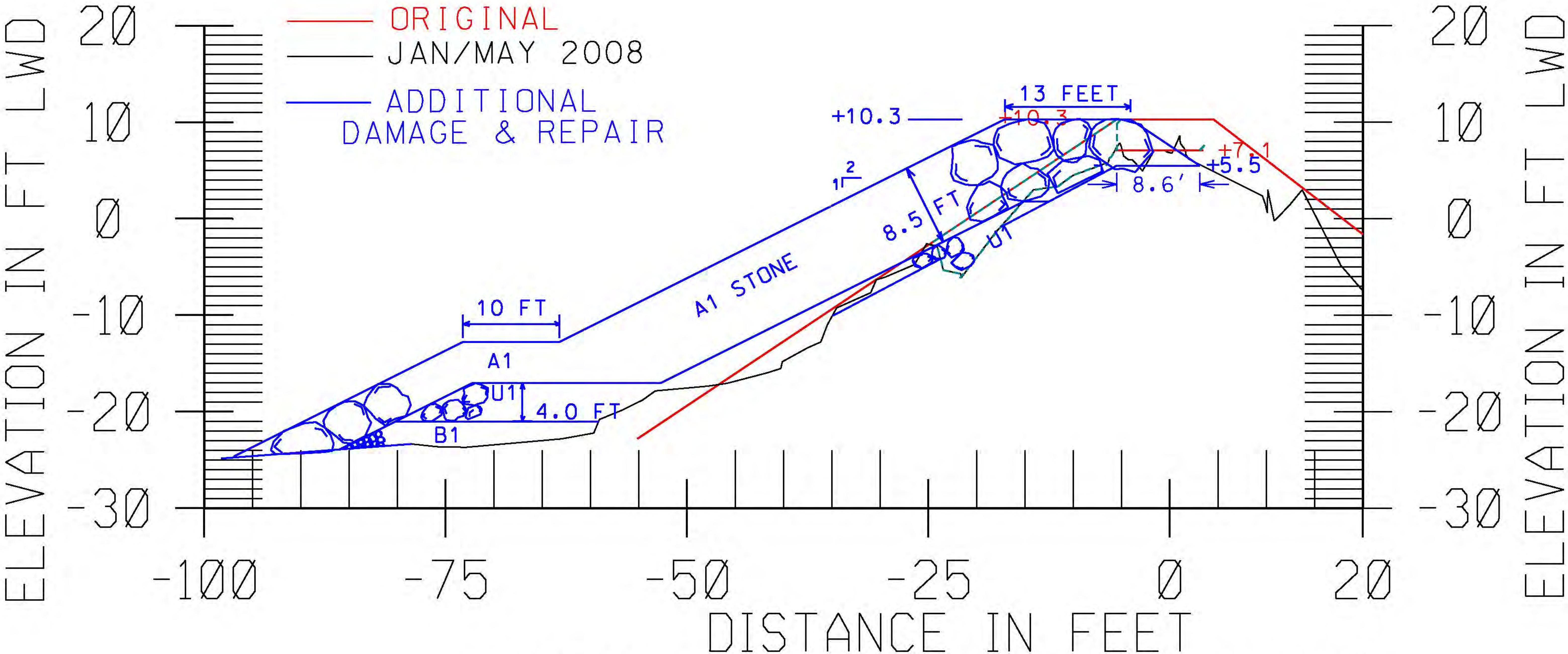
Figure 26



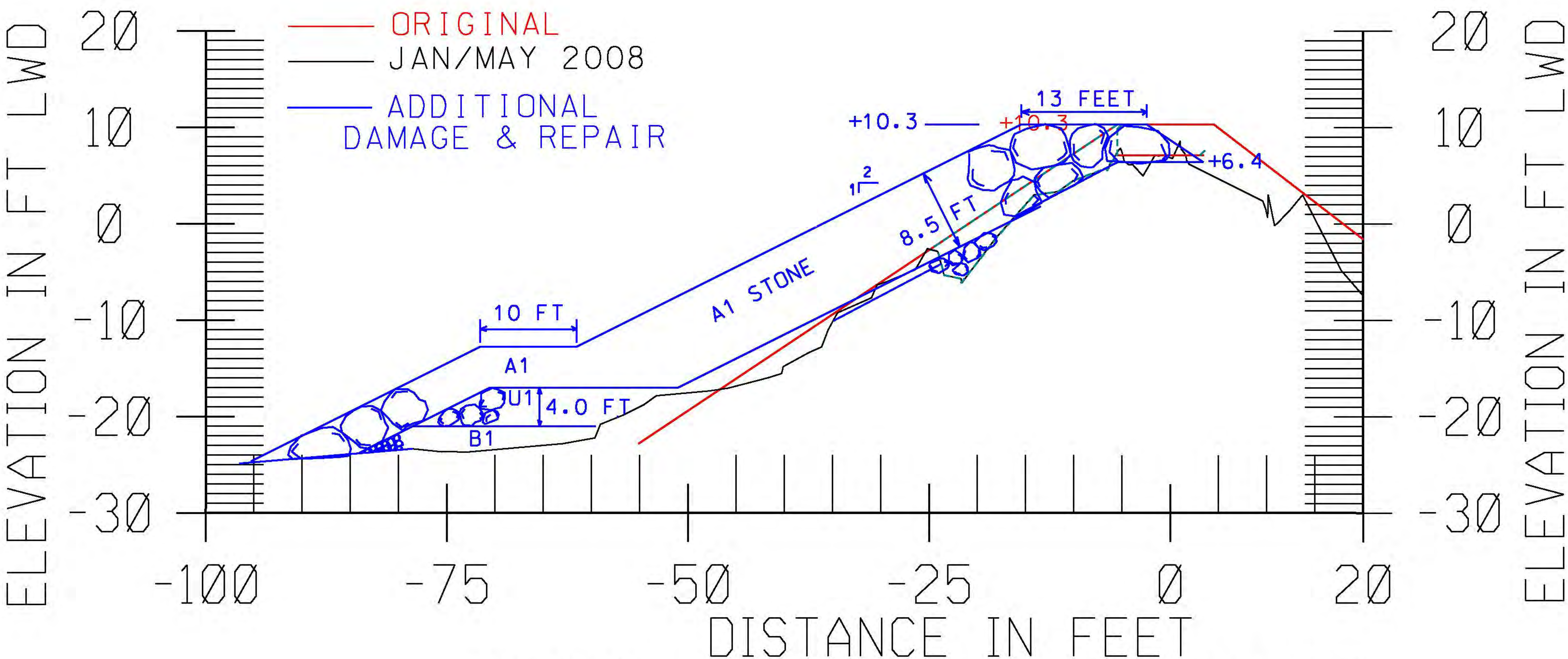
EXISTING CONDITION REPAIR



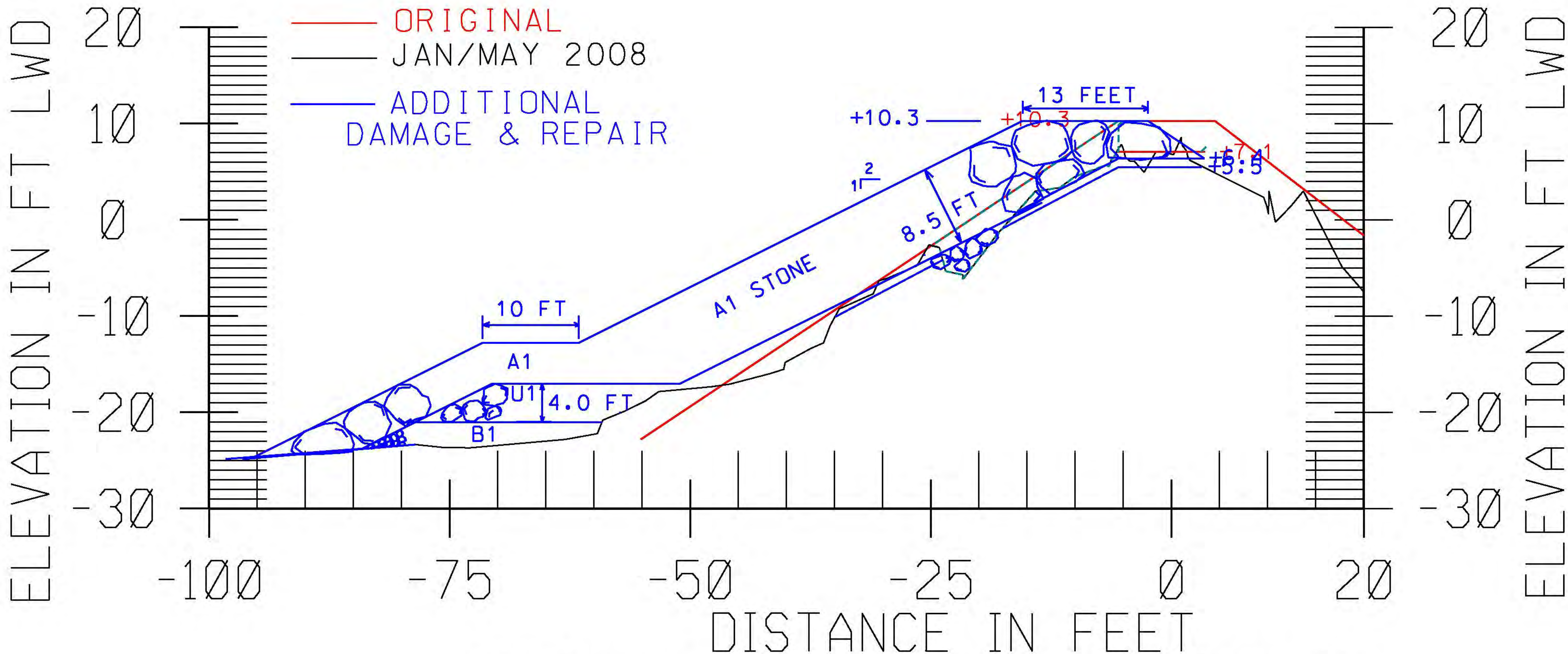
TYPICAL REPAIR TO DAMAGED SECTION:
100-YR WAVE & 100-YR WATER LEVEL



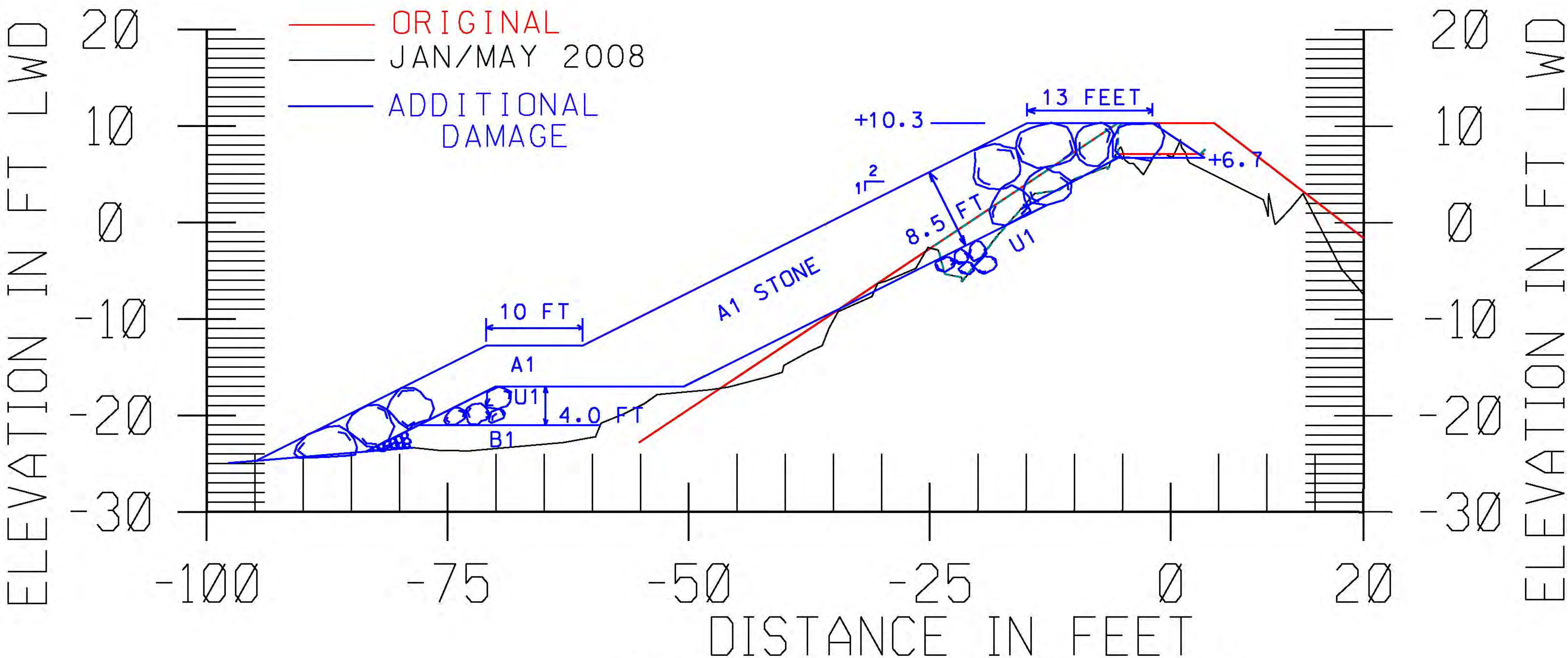
TYPICAL REPAIR TO DAMAGED SECTION:
100-YR WAVE & 2-YR WATER LEVEL



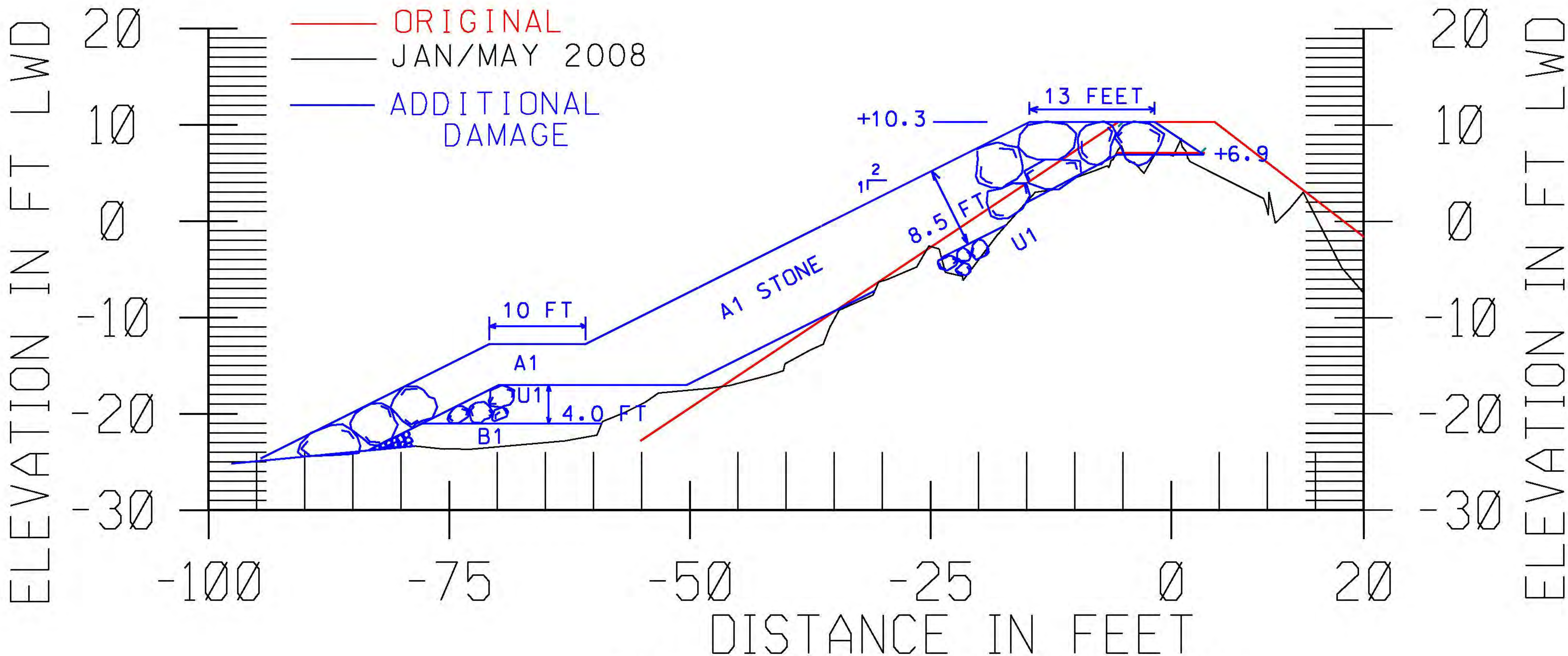
TYPICAL REPAIR TO DAMAGED SECTION:
100-YR WAVE & 1.001-YR WATER LEVEL



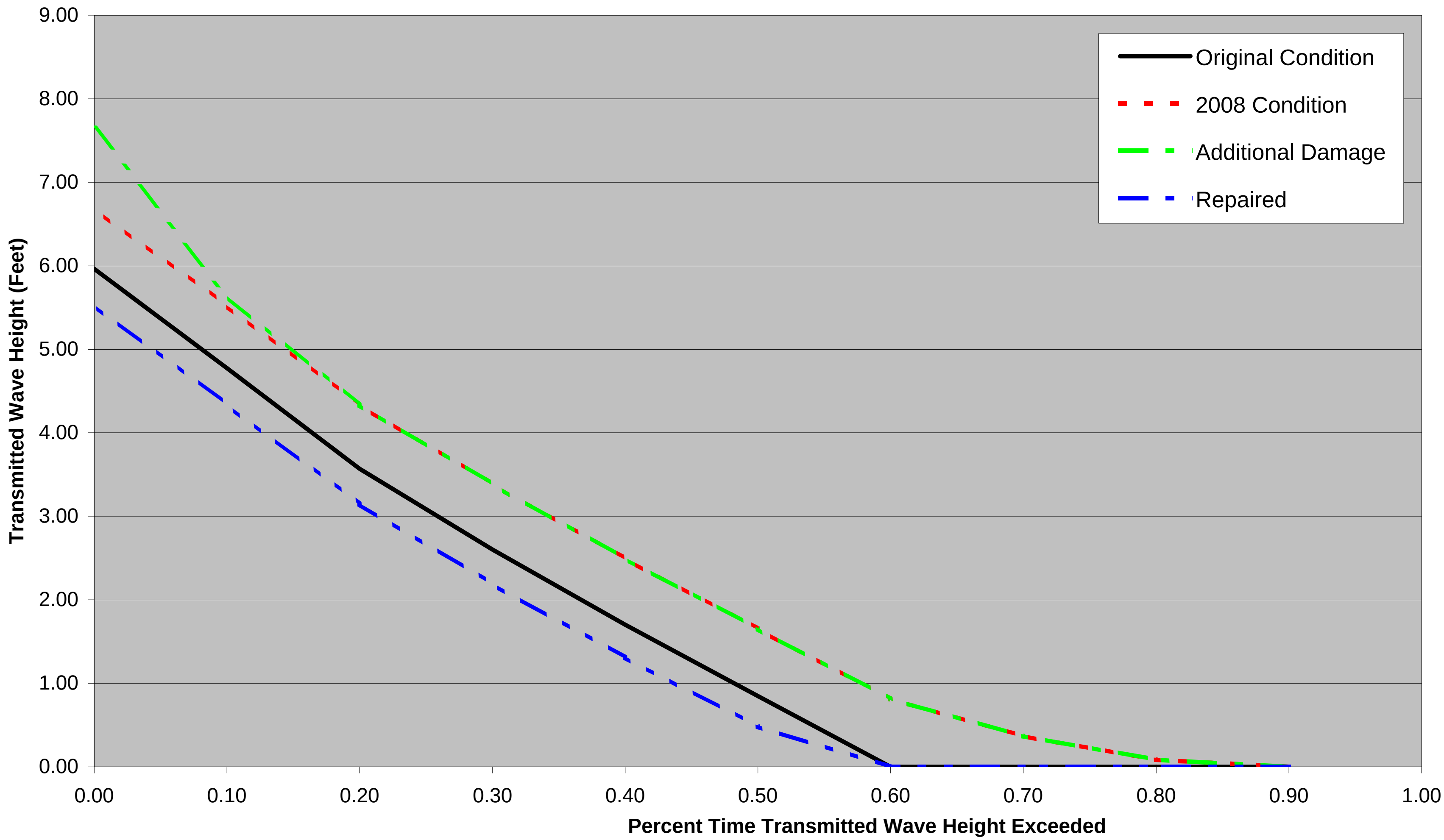
TYPICAL REPAIR TO DAMAGED SECTION:
10-YR WAVE & 100-YR WATER LEVEL



TYPICAL DAMAGED SECTION:
10-YR WAVE & 2-YR WATER LEVEL

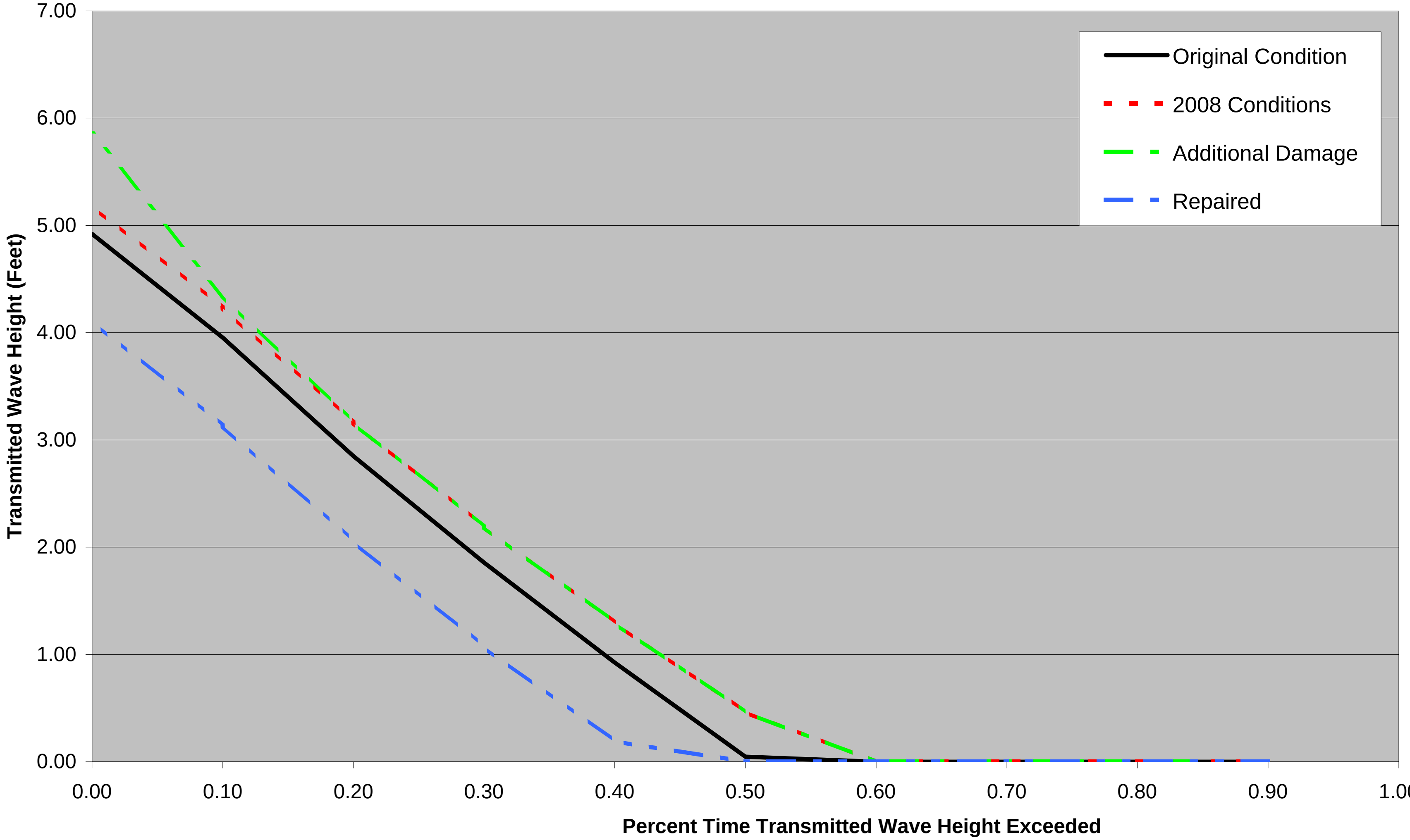


TYPICAL DAMAGED SECTION:
10-YR WAVE & 1.001-YR WATER LEVEL



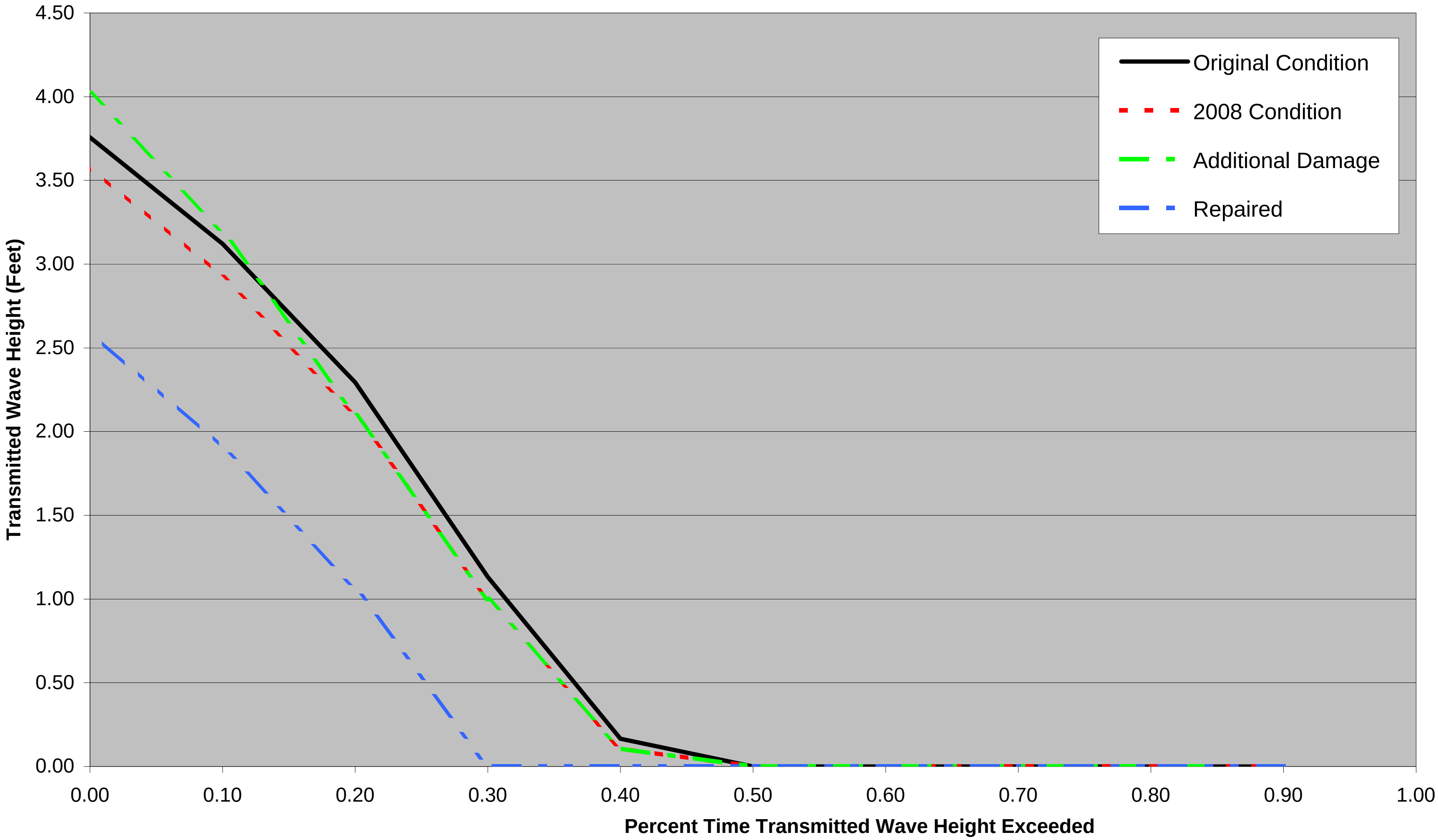
Cleveland East Breakwater Transmitted Wave Height Duration Diagram
100-Year Water Level

Figure 34



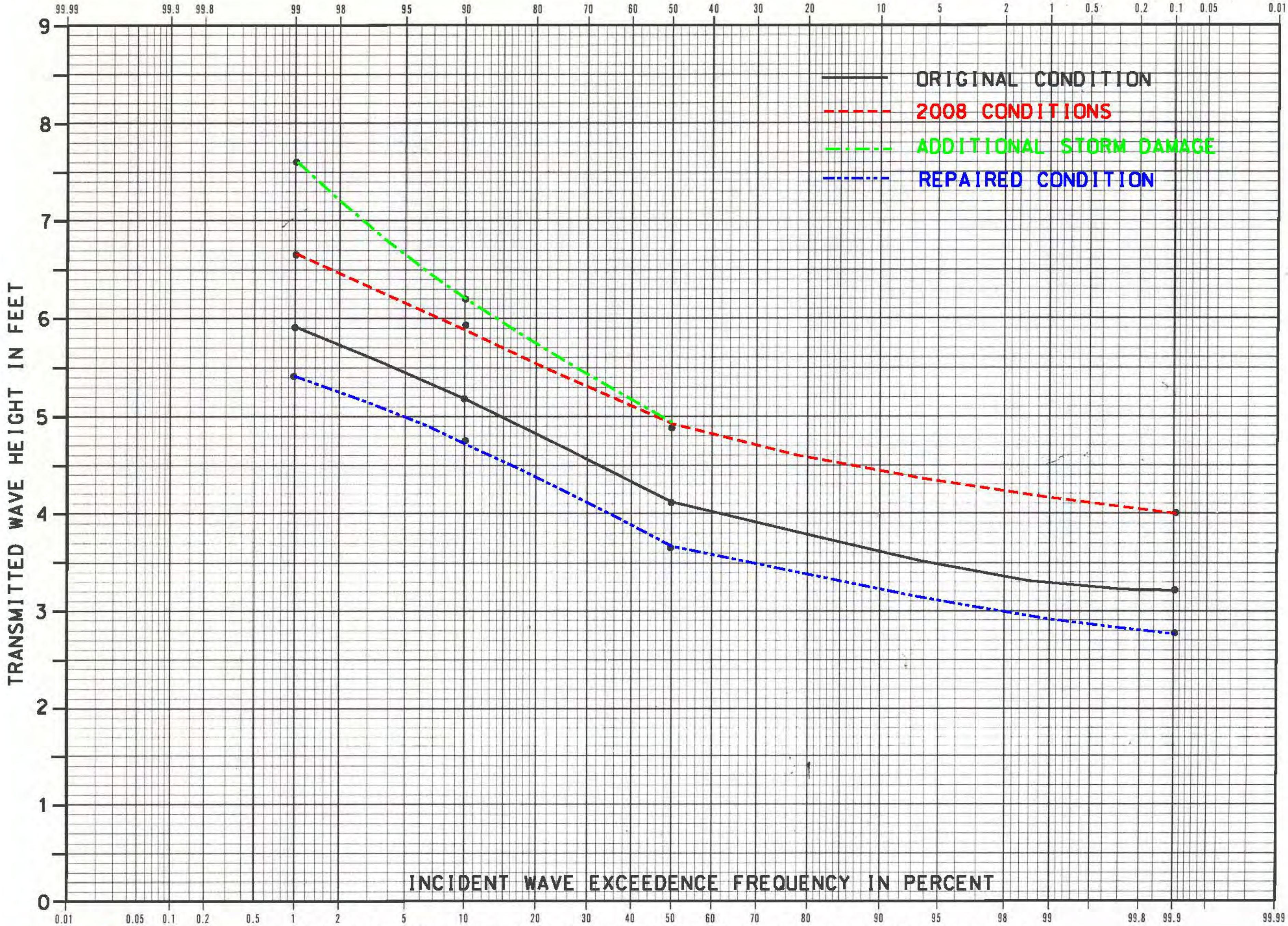
Cleveland East Breakwater Transmitted Wave Height Duration Diagram
2.00-Year Water Level

Figure 35

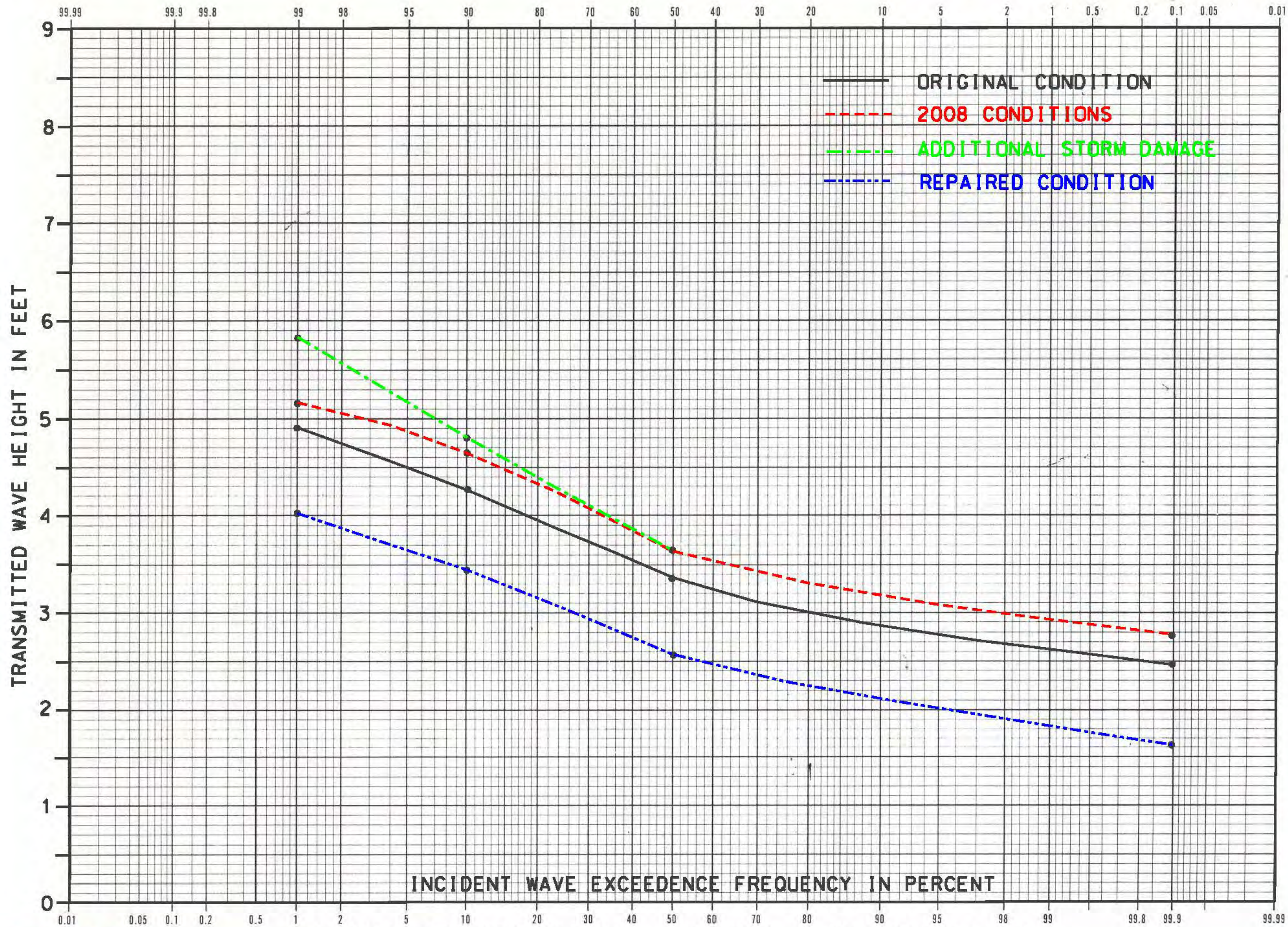


Cleveland East Breakwater Transmitted Wave Height Duration Diagram
1.001-Year Water Level

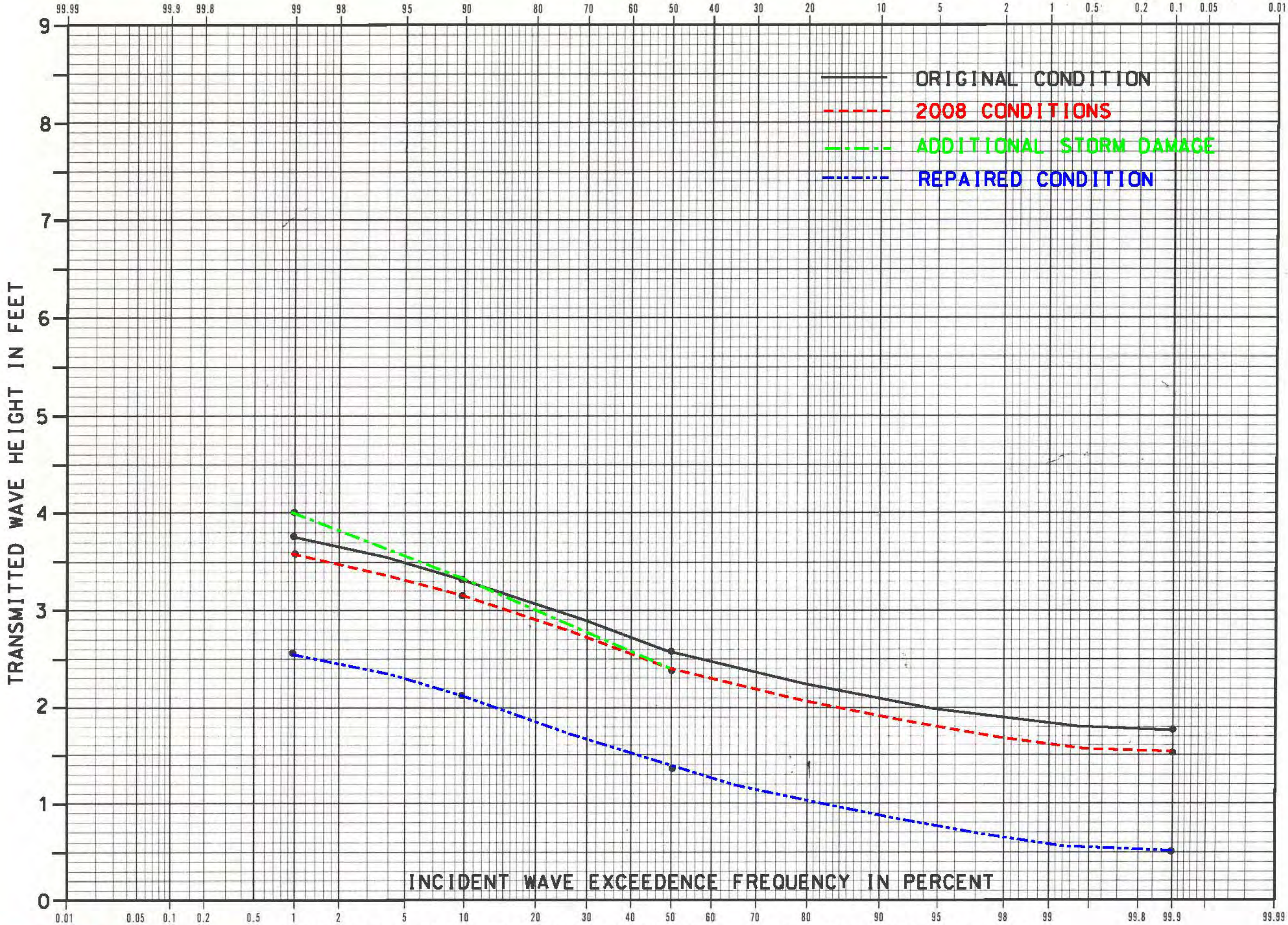
Figure 36



TRANSMITTED WAVE HEIGHT - FREQUENCY, 100-YEAR WATER LEVEL



TRANSMITTED WAVE HEIGHT - FREQUENCY, 2-YEAR WATER LEVEL



TRANSMITTED WAVE HEIGHT - FREQUENCY, 1.001-YEAR WATER LEVEL

CERTIFICATION OF LEGAL REVIEW

Supplemental Reconnaissance
Great Lakes Navigation System Review

The Supplemental Reconnaissance report for the Great Lakes Navigation System Review has been reviewed by Detroit District, Office of Counsel, and is approved as legally sufficient.

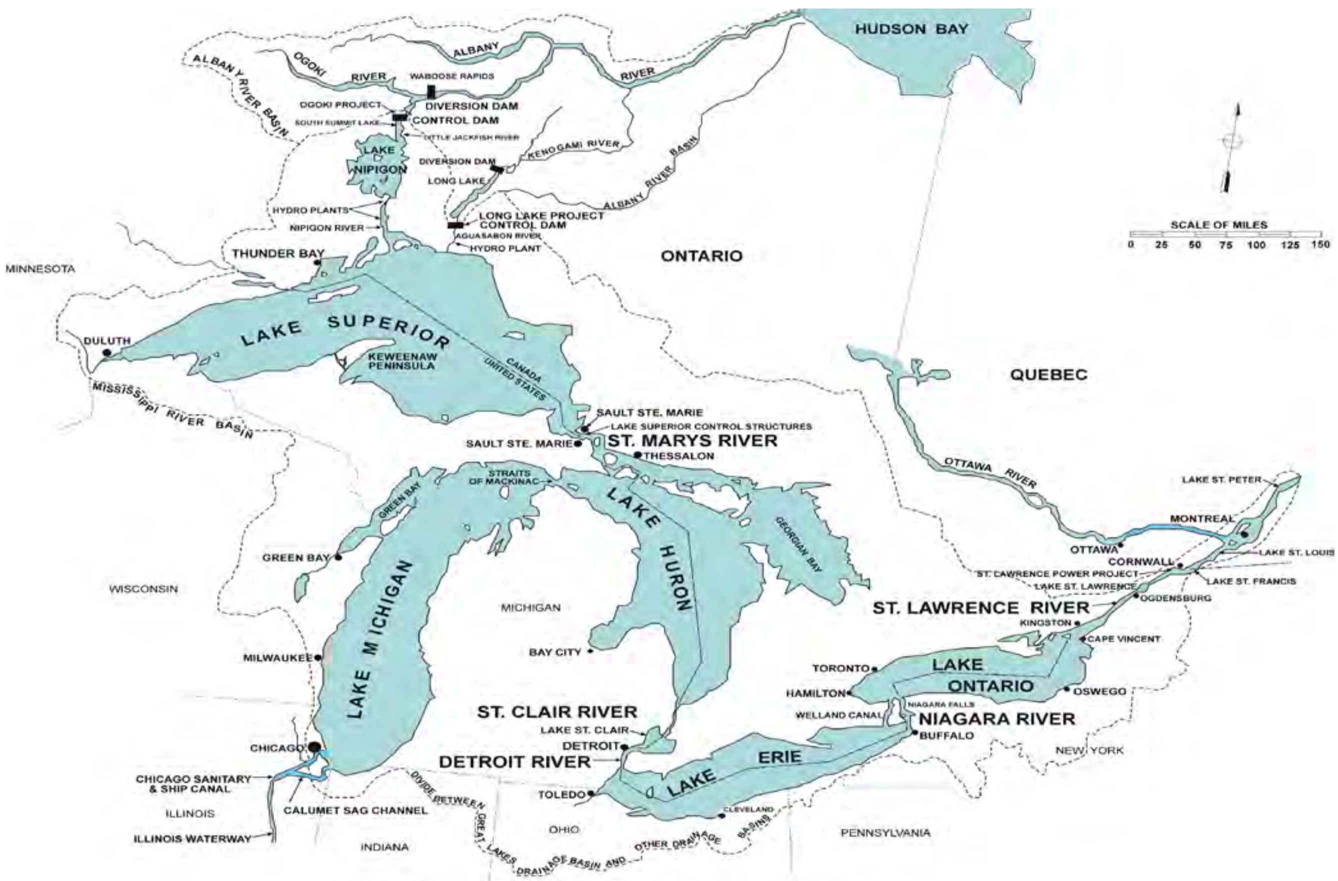
Christine Nowka-Bailey 6/12/09

District Counsel Date

SUPPLEMENTAL RECONNAISSANCE REPORT

February 2010

GREAT LAKES NAVIGATION SYSTEM REVIEW



Great Lakes - St. Lawrence River System

US Army Corps of Engineers®

Great Lakes &
Ohio River Division

Supplemental Reconnaissance Report
Great Lakes Navigation System Review

Executive Summary

For more than half a century, the Great Lakes Navigation System (GLNS) has served as a vital transportation corridor for the single largest concentration of industry in the world. Straddling the Great Lakes Basin, North America's industrial heartland depends on this system of locks, channels, ports and open water. Yet the waterway is facing new challenges that could not have been anticipated when it came into full operation in 1959. Changes in the economy and in the transportation industry have altered product demand, traffic patterns and shipping volumes. Although these developments have transformed the economic drivers underlying the system, it continues to fulfill a vital transport function not only for the Great Lakes region, but also for the entire industrial core of the North American economy. Given its ongoing importance, it is essential that the system be maintained as a safe, reliable, efficient and sustainable component of the continent's overall transportation network.

A system as large and complex as the GLNS inevitably affects the environment around it. Generally, society has become far more aware of such environmental impacts, exacerbated as they are by the parallel pressures of population growth, urbanization and lifestyle changes. Recent scientific research has yielded a better understanding of the cumulative effect of human action on the environment. It has also led to a deeper appreciation of unique environments such as those existing in the Great Lakes Basin, and has transformed the way in which such ecosystems are studied and evaluated.

The infrastructure of the GLNS is starting to show its age. After 50 to 70 years of service, the system of locks and approach channels shows wear and tear from the passage of tens of thousands of ships. Other parts of the system are over a century old. As the system ages, the demands for maintenance grow, as do the costs. Recognizing this, Congress authorized the U.S. Army Corps of Engineers (Corps) to conduct an analysis of the Great Lakes Navigation System (excluding the mostly-Canadian St. Lawrence Seaway) in Section 456 of the Water Resources Development Act (WRDA) of 1999. The initial reconnaissance report was completed by the Corps Detroit District in 2002 and submitted to the Corps' Great Lakes and Ohio River Division (CELRD) regional Headquarters on February 3, 2003 for review and comment. The study also was forwarded to the Corps' Washington DC headquarters (USACE-HQ) for review and comment.

After the review, CELRD informed the Detroit District that the initial Reconnaissance Report was tentatively approved to support a recommendation to proceed to the feasibility phase. However prior to initiation of a more detailed feasibility study, further information was required by USACE-HQ. It was mandated that a Supplement to the Reconnaissance Report must be prepared in order to clarify the "Without Project Condition" (to establish a baseline) and to develop a more definitive determination of the Federal interest in the navigation system. The "Without Project Condition" scenario would assume that nothing would be done to expand the GLNS beyond routine maintenance and replacements over the coming 50 years.

Separately, but on a similar schedule to the Supplemental Reconnaissance report, a joint Canadian/United States study (the bi-national *Great Lakes St. Lawrence Seaway Study)* was begun in May 2003, following the signing of a Memorandum of Cooperation (MOC) between Transport Canada and the U.S. Department of Transportation. The MOC facilitated a binational study partnership that included Canadian and United States departments and agencies with expertise in transportation policy and economics, navigation-related infrastructure engineering and environmental science. These experts acted as the members of the Project Delivery Teams for the study.

The bi-national study (which is discussed in greater detail in Section 4.5) facilitated an international, collaborative effort to produce a wide-ranging investigation that addresses the fundamental question: *What is the current condition of the GLNS, and how best should we use and maintain the system, in its current physical configuration, in order to remain competitive in the world market while facing the challenges that will present themselves in coming years?*

Furthermore, there are two common findings in reports written recently by the Brookings Institute, the RAND Corporation, the National Academy of Science, and various U.S. and Canadian departments; the first being that the GLNS is at a tipping point that will see the commercial navigation industry either flounder or flourish in the next several decades; the second, that success of the navigation system hinges on coordinated planning and action among stakeholders. The reports also indicate that the future viability of the GLNS will come directly from maintaining the value and function of the existing infrastructure, while bringing more containerized cargo into the Great Lakes, and through providing options to alleviate congested overland transportation.

The point of view for managing the system in a way that focuses on economic growth is compelling. Trends indicate that the population and wealth of North America will be greater in the future and more raw materials and goods will be moved. These materials and goods can be transported on railroads, trucks or ships. Highways are heavily congested now and will be more congested in the future. Some rail systems are underutilized while others are congested. Expanding rail or roadways almost always requires widening existing routes, which is extraordinarily costly because it requires rebuilding bridges across the wider routes. It is estimated that the Great Lakes Navigation System is at about half capacity and could accept more traffic without expansion. Also, Ships use less fuel per ton to carry the same cargo and produce less atmospheric carbon; the European Union touts inland shipping as the green alternative.

There are clear disadvantages to shipping as well. Ships are slower than terrestrial or airborne transportation, and delivery speed is an important financial factor for finished, perishable and high value goods. Further, water-borne shipping, especially ocean-lake transit, is considered the leading cause for the introduction of invasive species that have caused enormous financial and environmental disruption. This risk can be reduced but not eliminated.

The GLNS infrastructure (locks, dams, breakwaters) is old, risking serious and costly delays, which makes shipping even less attractive for moving high value cargo. Winter ice impedes or stops navigation each year, meaning that shippers have to employ a winter alternative to waterborne transit. Shorelines are impacted by the wakes of these big vessels; more ship traffic means more impacts. Climate change poses additional uncertainties. Navigation requires dredging of shoaled sediments, much of which has to be stored in confined disposal areas because it is contaminated from past industrial discharges.

More effective and coordinated management of the GLNS will improve the chances of economic viability into the future. As such, the binational and Supplemental Reconnaissance reports both conclude that the GLNS remains an important element in the North American economy, with a transportation rate savings of approximately $3.6 billion per year (U.S. only, and not including St. Lawrence Seaway shipping). Its upheld value and future prospects justify the costs of maintaining its infrastructure. Moreover, future operation and maintenance of the system can likely be performed in a manner that minimizes environmental impacts.

This report, intended to supplement a June 2002 (Revised February 2003) Corps of Engineers *Reconnaissance Report - Great Lakes Navigation System Review*, concludes that the Great Lakes and Ohio River Division should, subject to the Federal budget process, further investigate or implement

- improved Water Level Data Access, subject to interest by NOAA and the Canadian Marine Environmental Data Service (MEDS);
- review of GLNS Activities to Reduce Environmental Impacts;
- maintenance of the Great Lakes Connecting Channels and Harbors using a system approach that recognizes the interdependency of Great Lakes harbors and the need for a Long Term Dredged Material Management Strategy;
- maintenance of the GLNS Infrastructure, using an Asset Management approach and investigation of harbor impacts associated with structure degradation;
- investigation of the navigational restrictions within the Chicago Sanitary and Ship Canal[*] and the practicality of a St. Clair River Ice Boom;
- deepening individual ports, (and possibly key connecting channel pinch-points) subject to interest by a viable cost-sharing sponsor,

Because of the economic benefit that has been recognized that the GLNS provides the nation, there is Federal interest in Corps of Engineers implementation of the above actions.

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[*] This particular inclusion may need to be carefully analyzed in light of the Asian Carp issue. When this alternative was included in the 2002 Reconnaissance report, Asian Carp were not a serious threat for entry into the Great Lakes. Now, with the Carp suspected to be close to entering Lake Michigan, most of the Great Lakes States and the Province of Ontario have made demands to permanently close the Canal. This contentious issue may defer public or private interest in navigational improvements to the Sanitary and Ship Canal.