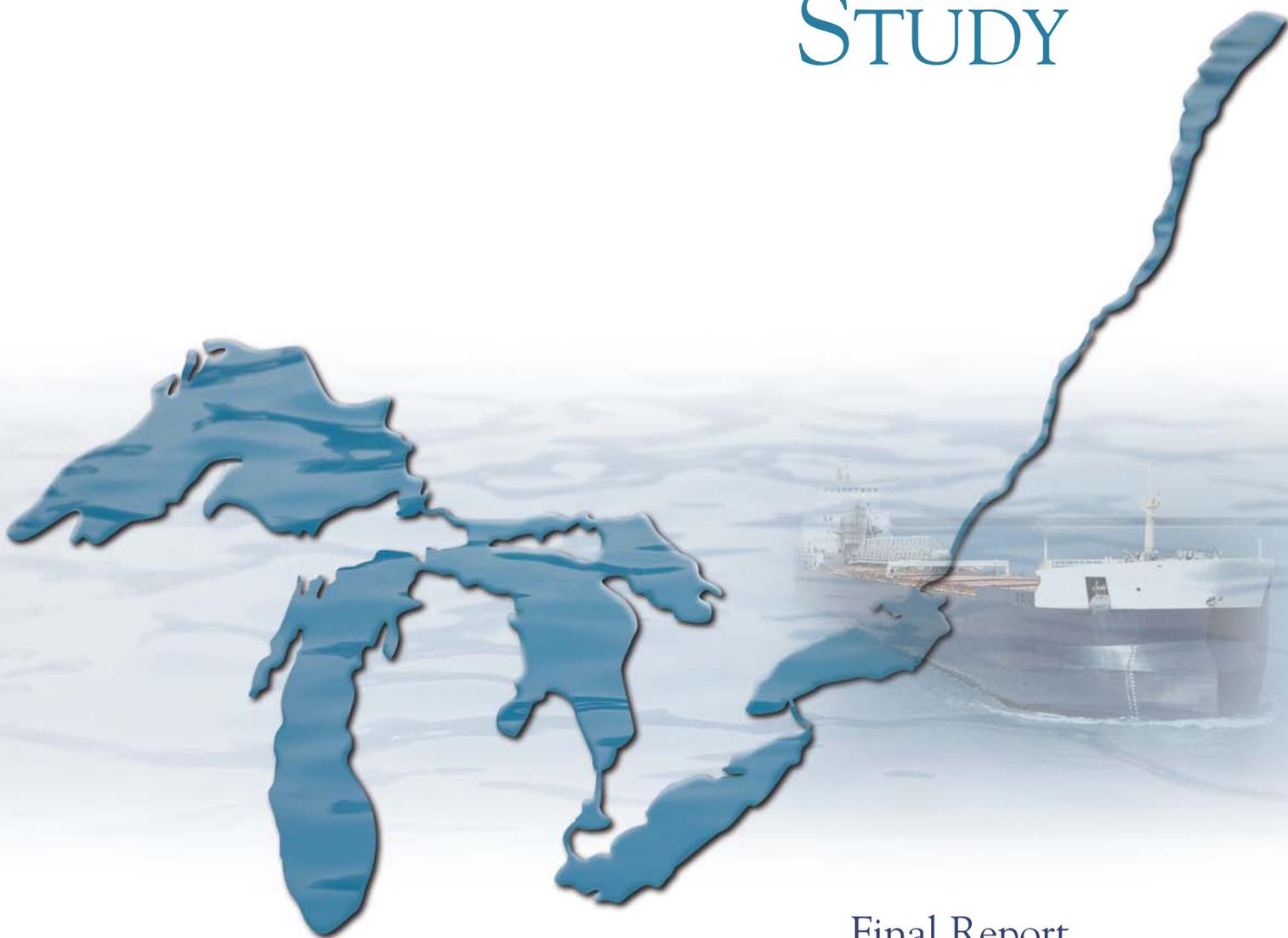


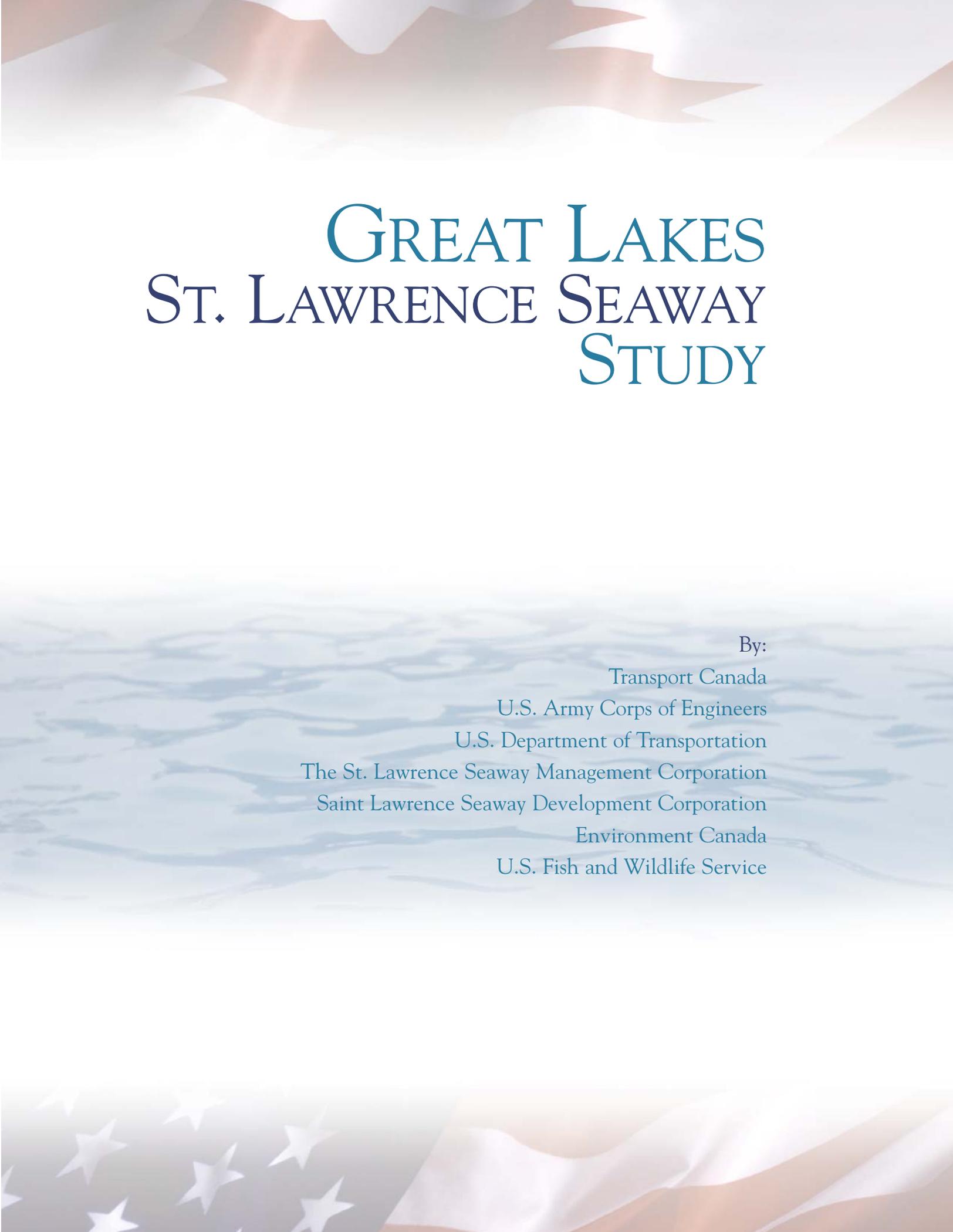


GREAT LAKES ST. LAWRENCE SEAWAY STUDY



Final Report
Fall 2007



The background of the entire page is a stylized, semi-transparent American flag. The top portion shows the red and white stripes, while the bottom portion shows the blue field with white stars. The flag appears to be waving, creating a sense of movement and depth.

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

Publication

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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.

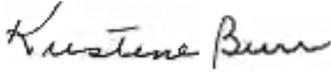
This binational report is a unique document. It expresses not only a common determination, but also a climate of mutual understanding, sharing and confidence among the study partners. This is a testament to the scores of individuals representing the seven participating departments and agencies who devoted 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



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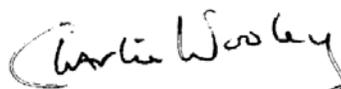
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EXECUTIVE SUMMARY

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?

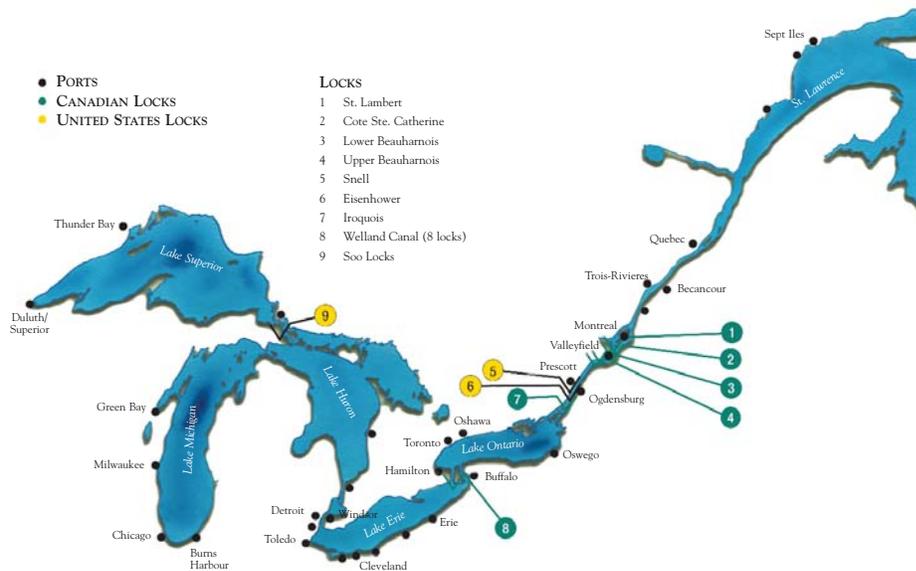
Seven Canadian and U.S. federal departments and agencies were involved in a multi-year study of this issue: Transport Canada, the U.S. Department of Transportation, the U.S. Army Corps of Engineers, the Canadian St. Lawrence Seaway Management Corporation, the U.S. Saint Lawrence Seaway Development Corporation, 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.

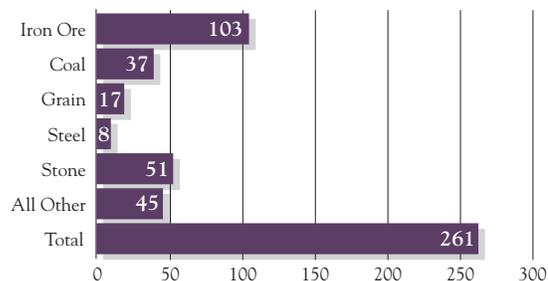
Physically, the GLSLS consists of an interconnected system of locks located at 16 different sites, four major navigational channels, more than 50 ports, several bridges, tunnels and a variety of approach roads. Within this array there are four distinct segments. The Great Lakes waterway links Lakes Superior, 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 includes 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.



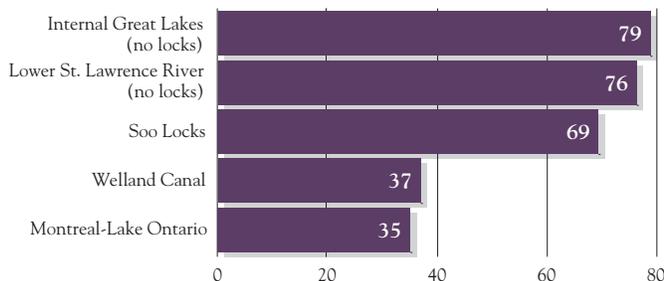
ECONOMIC ROLE

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 Montreal-Lake Ontario locks 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 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
Non-navigational related	Global	Climate change
		Water withdrawal & diversions
	Development and land use	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
	Shoreline alteration/hardening	
	Waste disposal/pollution	
Erosion and sediment re-suspension		
Navigational related	Channel & port maintenance	Wildlife conflicts
		Channel modification
		Dredge material placement
	Water management	Shoreline alteration/hardening
		Maintenance dredging
	Land-based support activities	Water management for all purposes
		Infrastructure development
		Facility maintenance
	Ship operations	Uncontrolled releases
		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

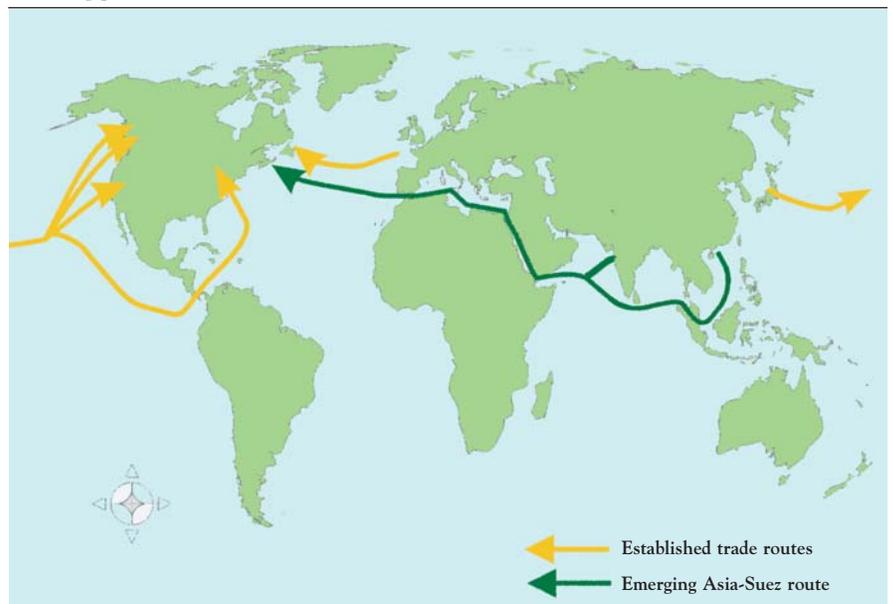
It is clear that the GLSLS offers shippers significant savings: surveys suggest that the system saves them approximately \$2.7 billion a year in transportation costs. Moreover these savings are especially felt in strategic sectors such as steelmaking and energy, the competitiveness of which is vital 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.

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.

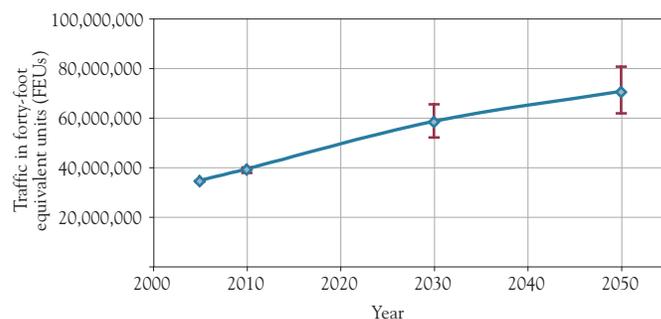
Perhaps the most fundamental competitive consideration, however, is reliability: shippers will not use a system in which there are frequent unplanned closures and traffic interruptions. The GLSLS offers them a high level of dependability. Historically, it has been available to vessels for 98 percent 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.

Forecast of market for container traffic carried by all modes in the GLSLS binational region



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.

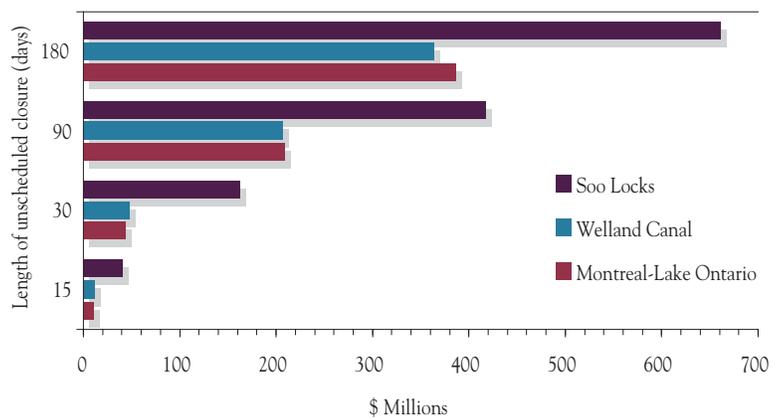
Analysis has also developed models that can be used to predict when components are likely to fail. Criticality assessments coupled with reliability data have identified and prioritized key operating components with an elevated risk of failure and significant consequences. Knowing this allows for the 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.

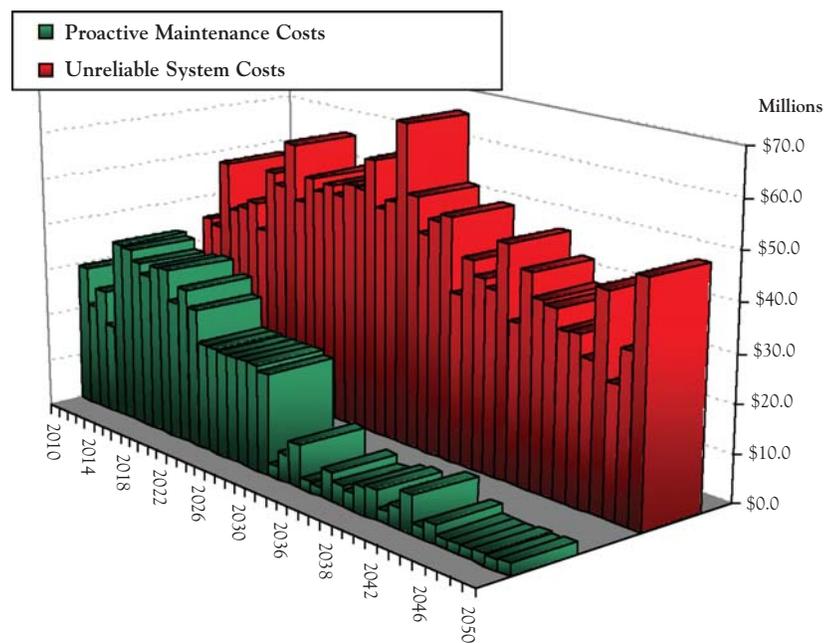
Reliability is critical because the GLSLS is essentially a series of structures that must be transited with no alternatives (except at the Welland Canal flight locks and the dual chambers at Sault Ste. Marie). As a result, closure of one of the structures in the series closes the entire system. Moreover, 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 optimize the many different components 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?

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 needs 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:

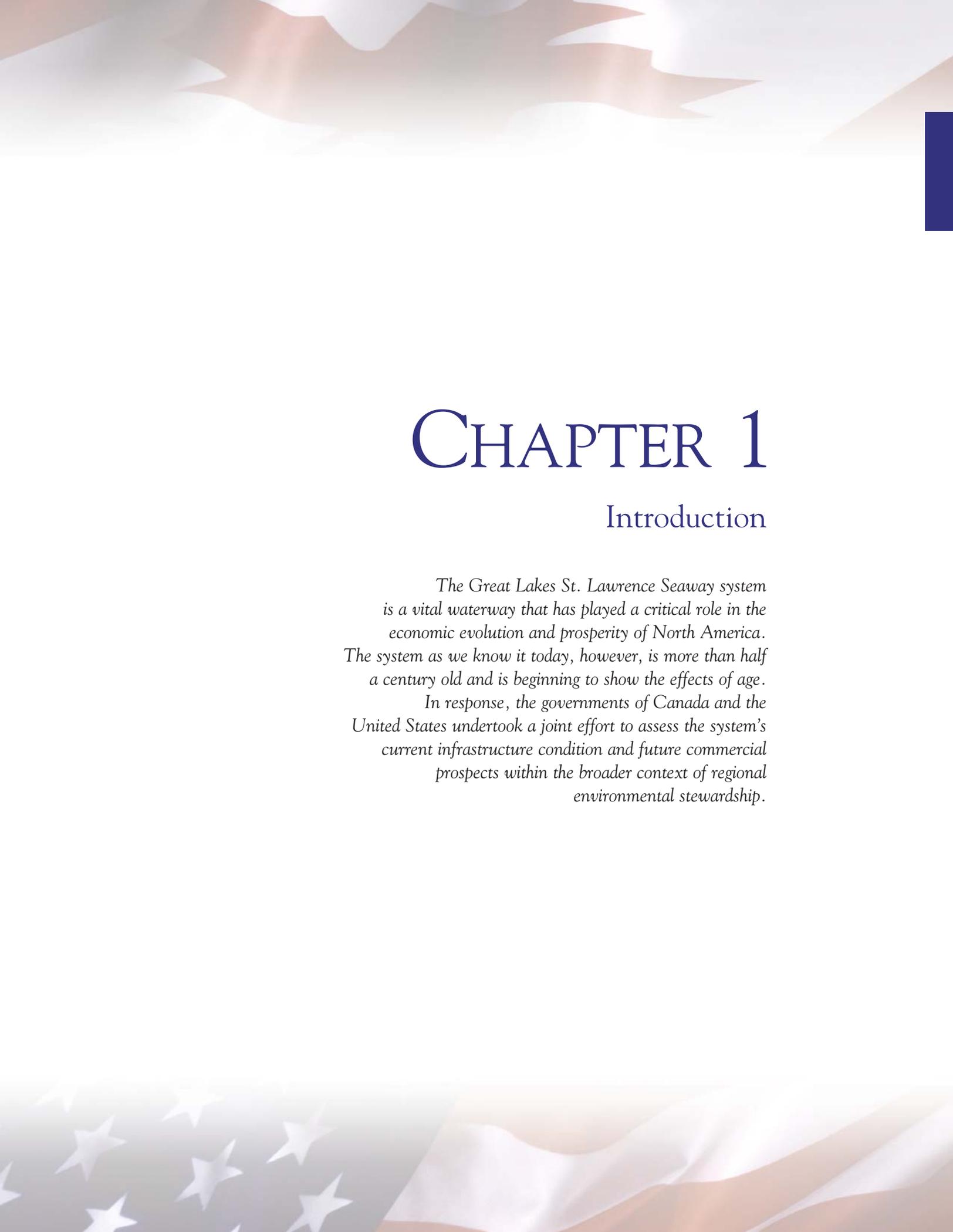
- The GLSLS system should be managed in a way that prevents the inadvertent introduction and transmission of non-indigenous invasive species and supports the objectives of programs designed to minimize or eliminate their impact.
- The existing sustainable navigation strategy for the St. Lawrence River 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.

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.

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?



Satellite view of the Great Lakes
 Source: U.S. Army Corps of Engineers

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.

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 on 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.

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 REGION¹

- 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.

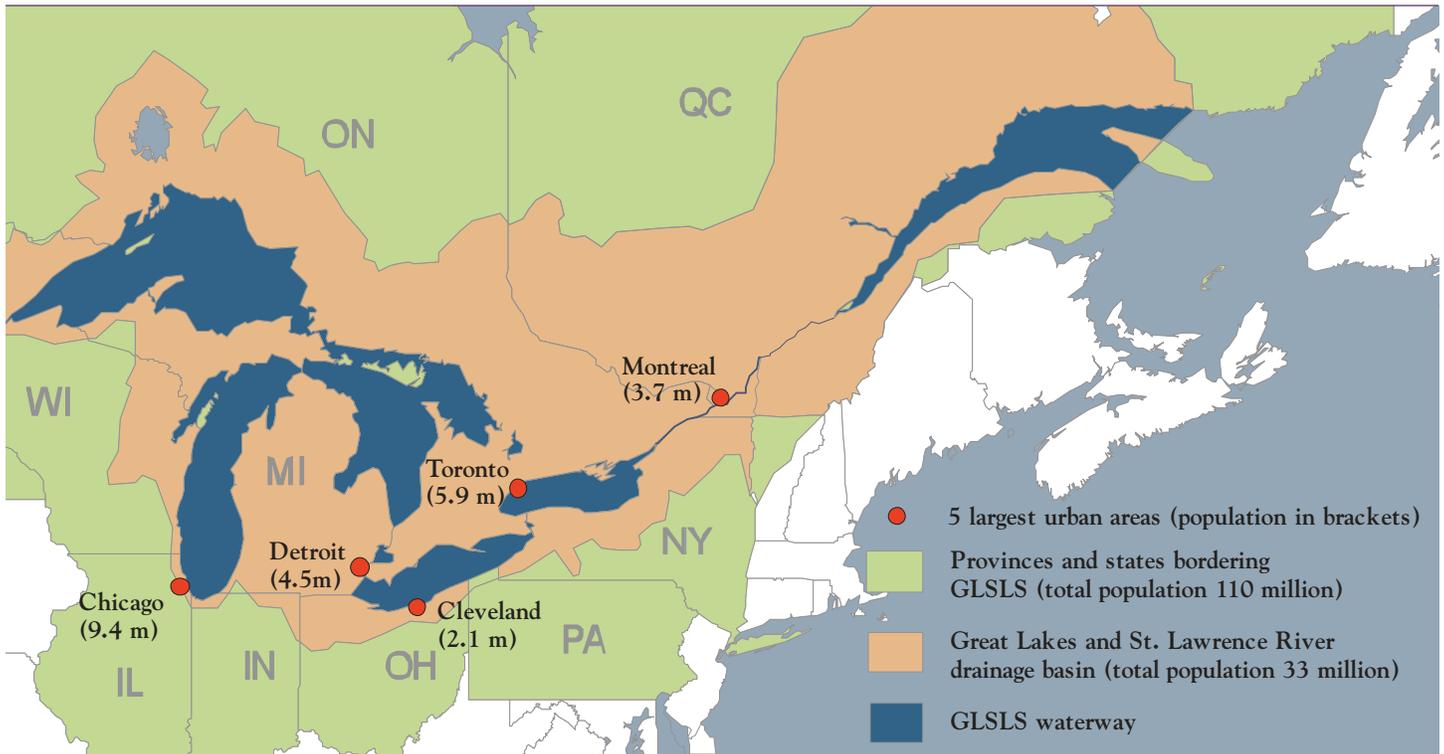
SYSTEM OVERVIEW

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 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.);

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

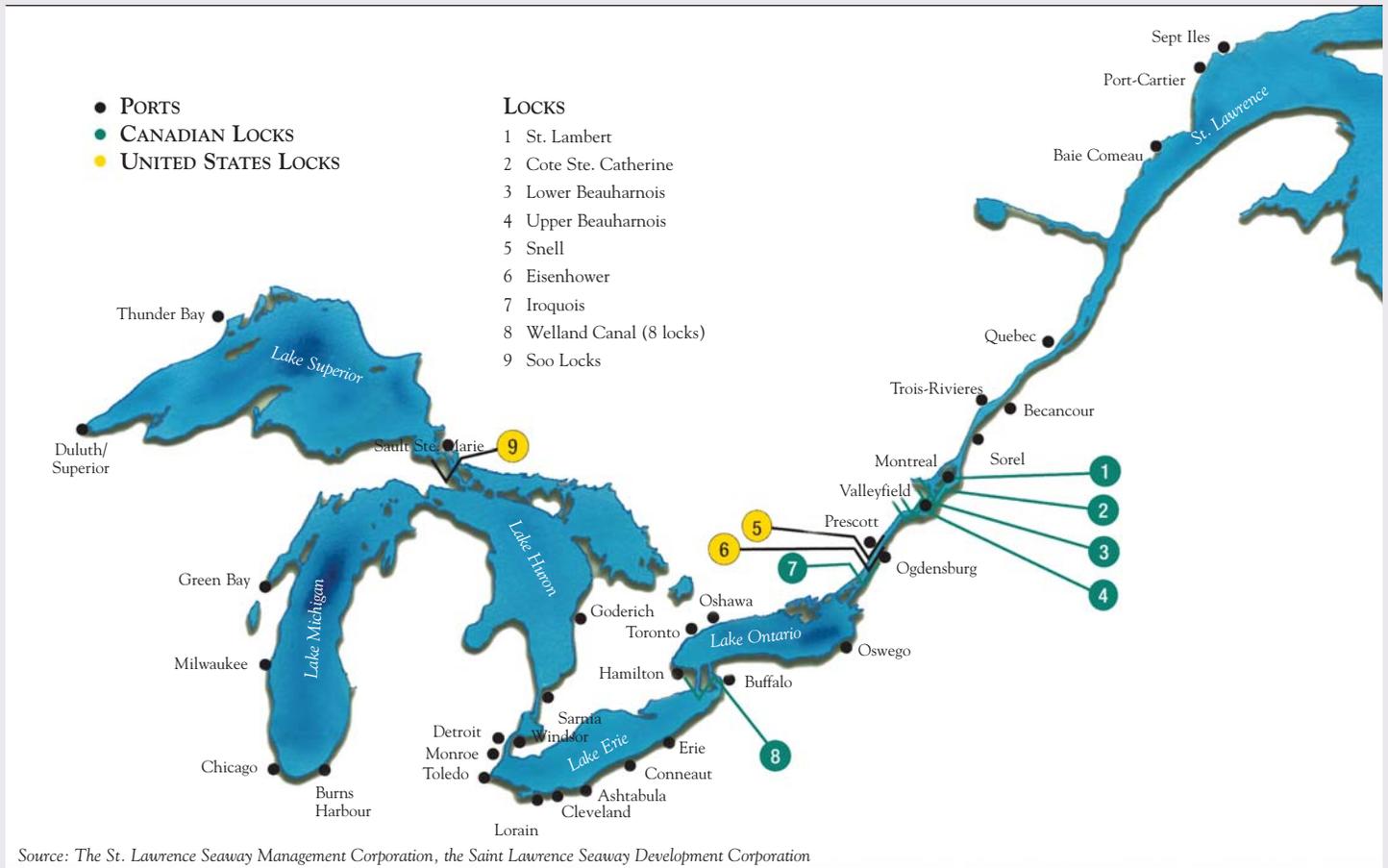
Cargo shipped through the Soo locks since 1959: 4.2 billion tons

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

- 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.

FIGURE 2.2

Key features of the GLSLS system



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

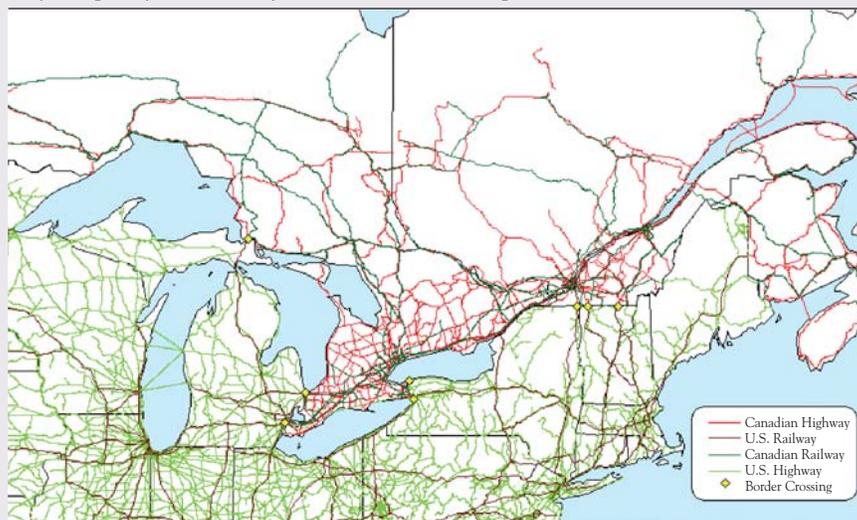
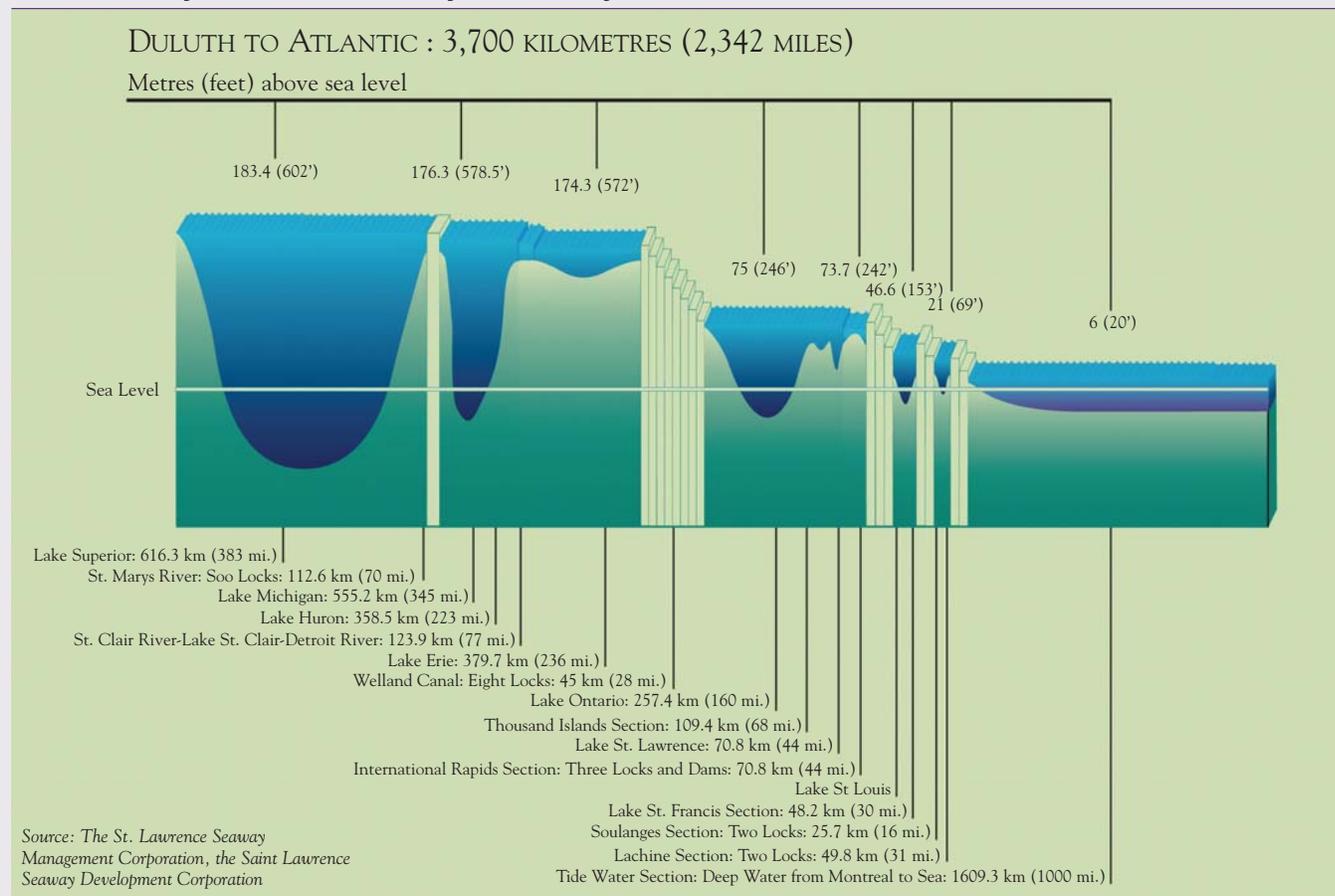


FIGURE 2.4

Schematic of the profile of the GLSLS in steps from Lake Superior to the Atlantic Ocean



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

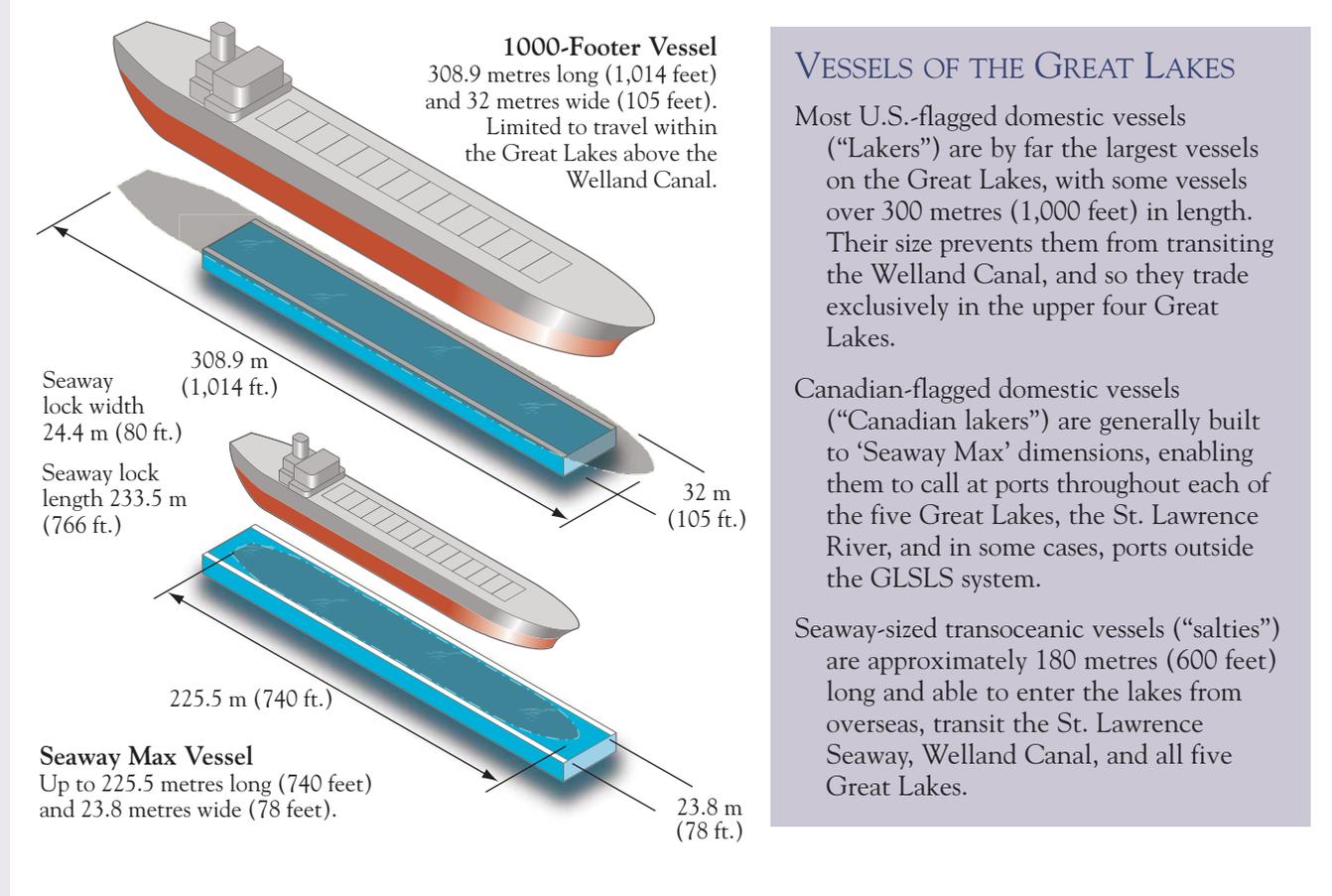
	<i>Superior</i>	<i>Michigan</i>	<i>Huron</i>	<i>Erie</i>	<i>Ontario</i>
Elevation in metres (ft)	182 (598)	176 (577)	176 (577)	173 (569)	74 (243)
Average depth in metres (ft)	147 (483)	85 (279)	59 (195)	19 (62)	86 (283)
Maximum depth in metres (ft)	406 (1,332)	282 (925)	229 (750)	64 (210)	244 (802)
Water 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



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.

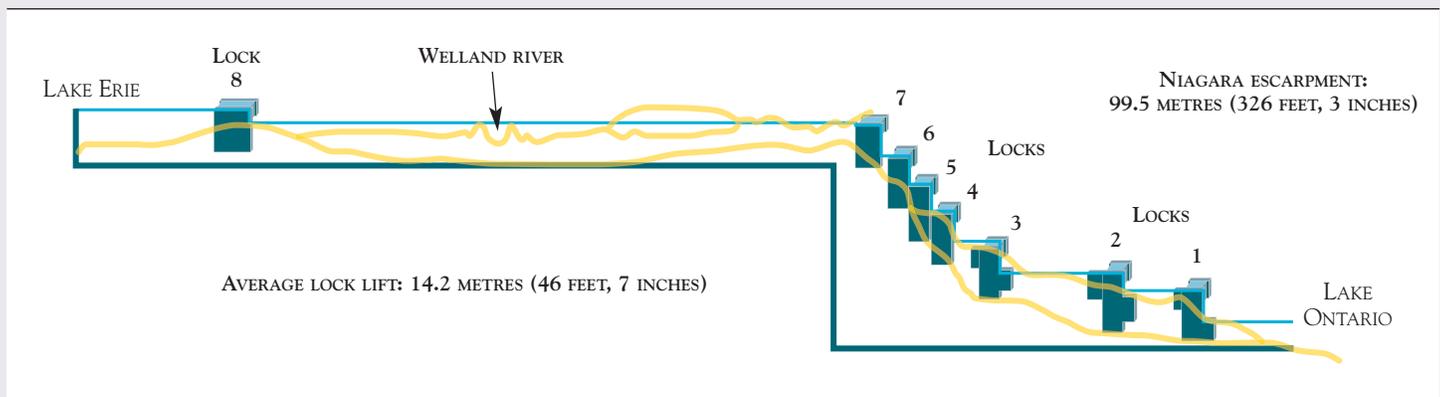


A siphon allows the Welland River to cross perpendicular to the canal by flowing underneath the canal in a large concrete culvert.

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 St. Lawrence Seaway Management 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 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.

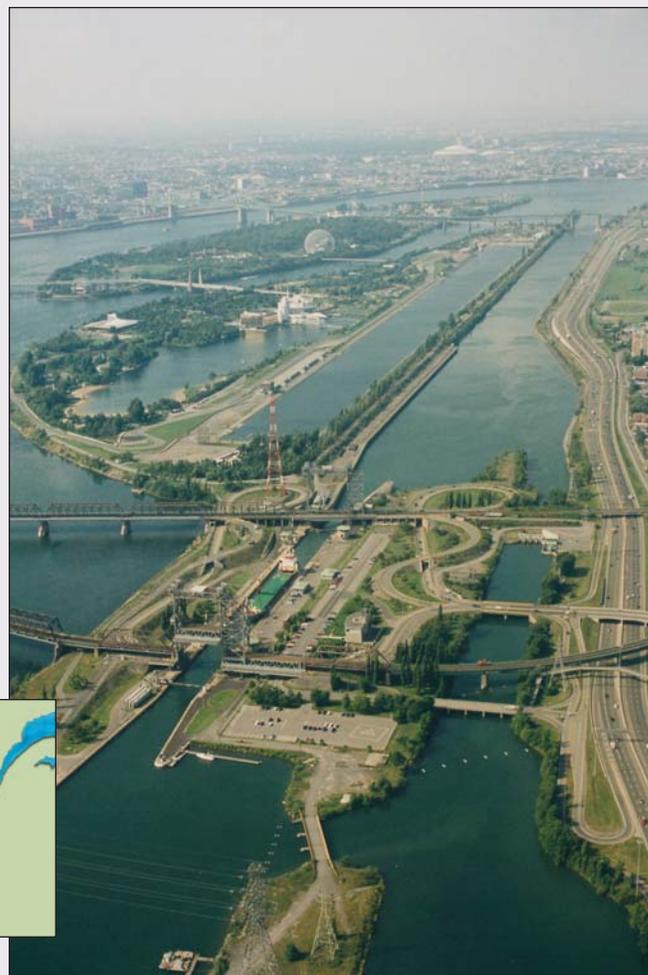
At the Eisenhower Lock, access to the Moses-Saunders generating station is obtained via a tunnel passing through the lock sill.



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.

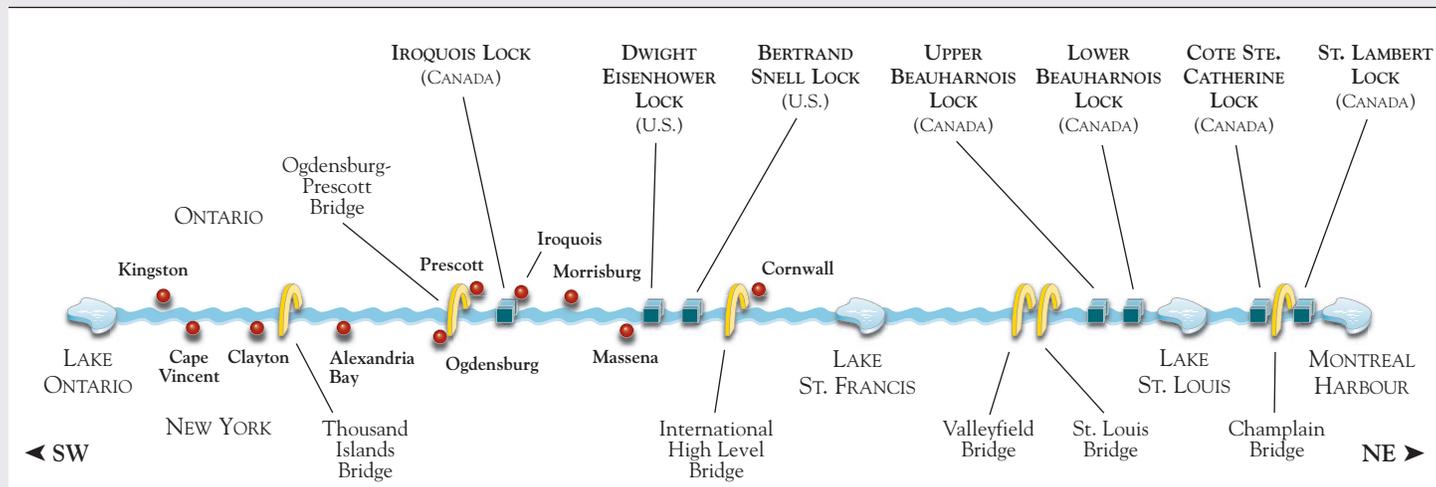
The navigation season on the waterway extends generally from late March to late December. Since the Seaway opened in 1959, new technologies against ice formation in locks and canals have been implemented and more than 25 days have been added to the shipping season. Between the opening of the Seaway in 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 transhipped 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

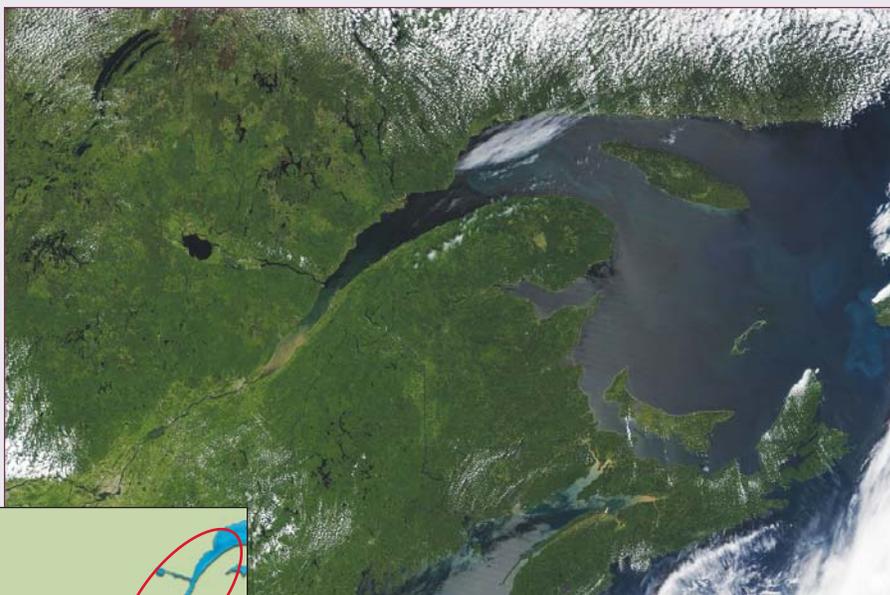


Vessel arriving at the Port of Montreal, Quebec
Source: Environment Canada

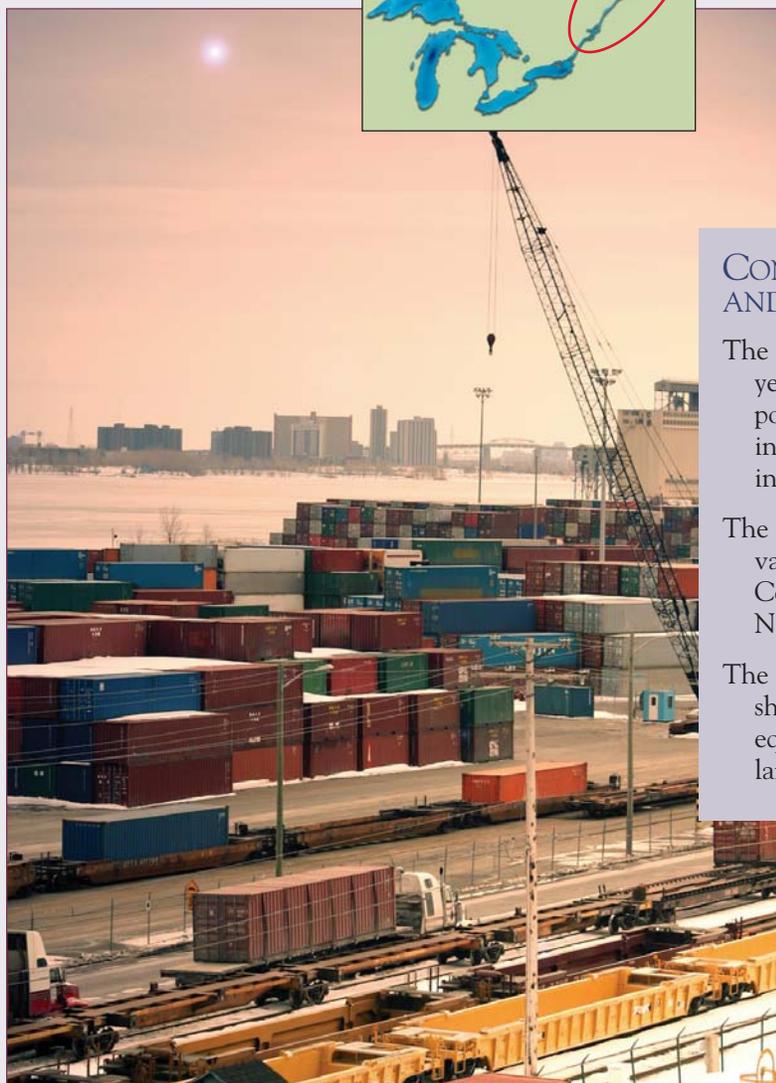


Ship in ice
Source: Port of Montreal

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



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.

Containerized cargo at the Port of Montreal, Quebec
Source: Transport Canada

SYSTEM OPERATION AND MANAGEMENT

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.



Aerial view of the Beauharnois dam and power station, next to the Lower Beauharnois Lock.
Source: The St. Lawrence Seaway Management Corporation

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



Two lakers passing in the St. Clair River, Michigan
 Source: U.S. Army Corps of Engineers

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?

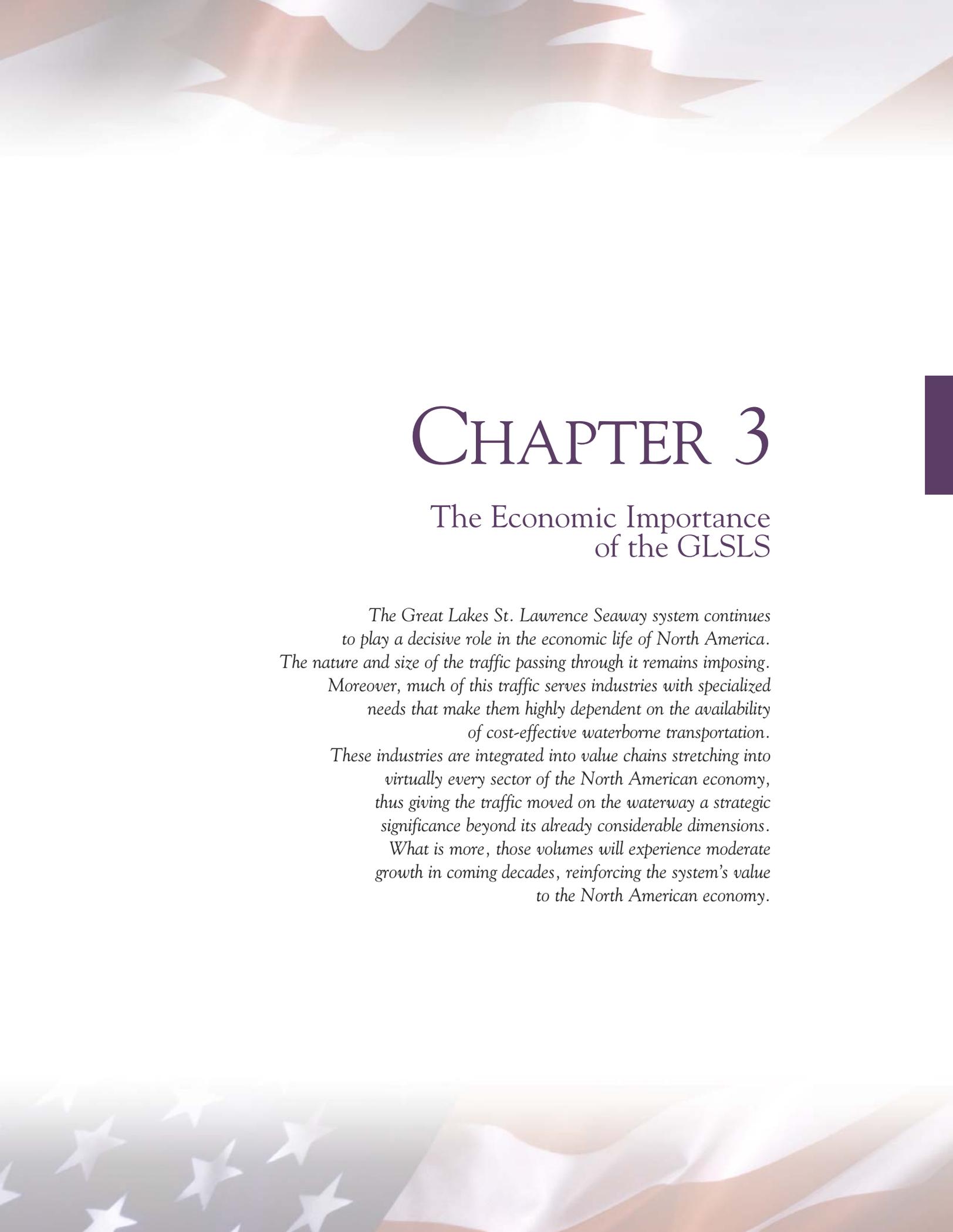
Over the past few decades, the railways have introduced significant improvements, especially to their container services. For example, significant enhancements have been made to “through services” from Montreal and Halifax, and new container lines are now serving ports on the U.S. East Coast, including 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 transshipment, 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.



Grain 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

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.

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 lakemen 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.

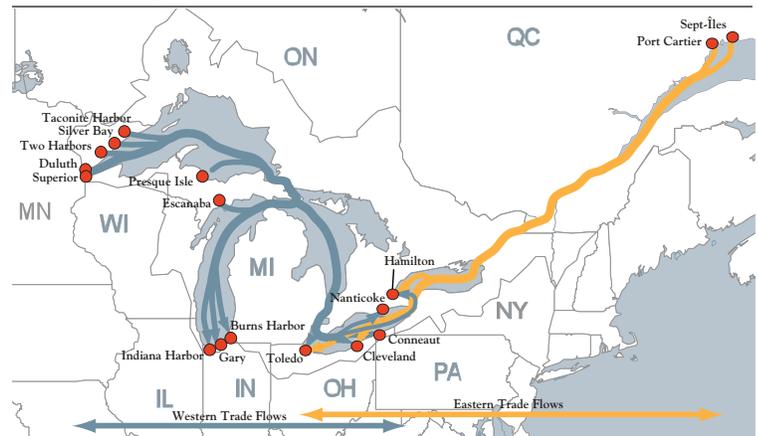
Rail transportation from the Prairies directly to Quebec City is a cost competitive alternative to the GLSLS, especially in the winter months when the latter is closed. However, given the large volumes of grain that move through the eastern transfer elevators, marine transportation should continue to 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, metallurgical 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 transshipment 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.

for steel: North American steel usage has increased by almost four 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.

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

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.



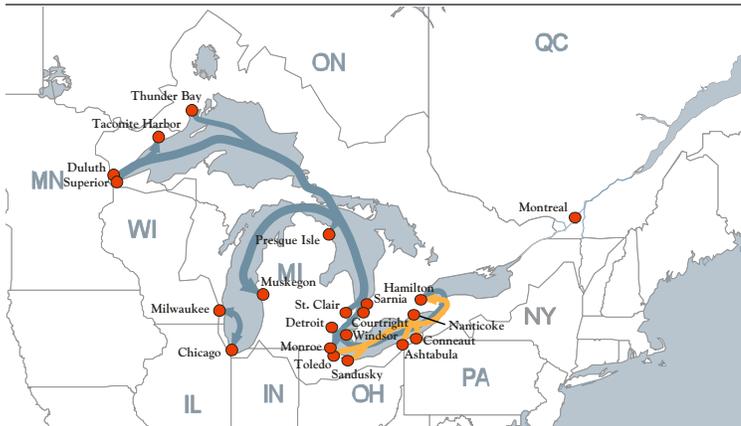
Midwest Energy terminal in Superior, Wisconsin
Photo: <http://www.midwestenergy.com>

The Midwest Energy Resources Company coal transshipment 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 transships 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

FIGURE 3.7
Average annual tonnage shipped 1995-2003
(millions of metric tons)

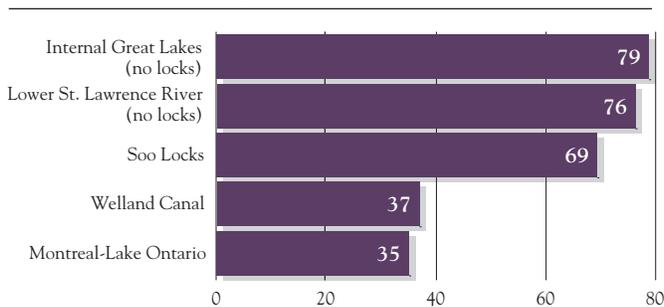
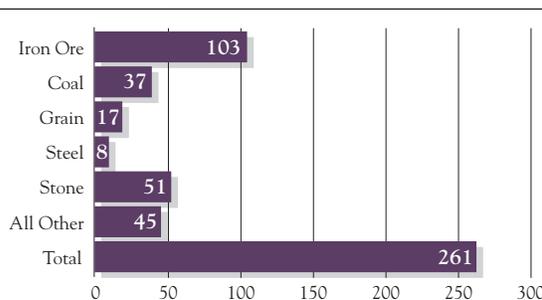


FIGURE 3.8
Average annual tonnage shipped 1995-2003
(millions of metric tons)



about 20 percent. Coal accounted for 15 percent of the total, grain – 7 percent, steel – 3 percent and all other cargo for 17 percent. 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.

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 9 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 cargoes 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

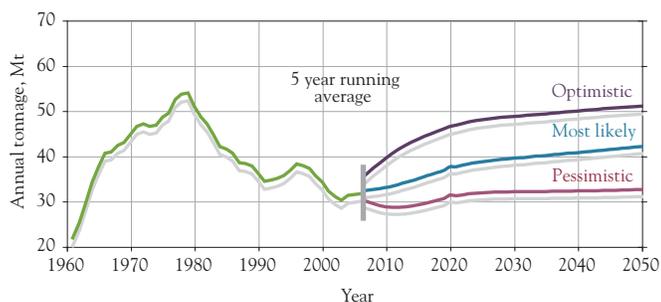
As shown in the Figures 3.9, 3.10 and 3.11, traffic in bulk commodities through the GLSLS system is expected to increase gradually through to the year 2030 and to grow steadily for the 20 years thereafter.

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.

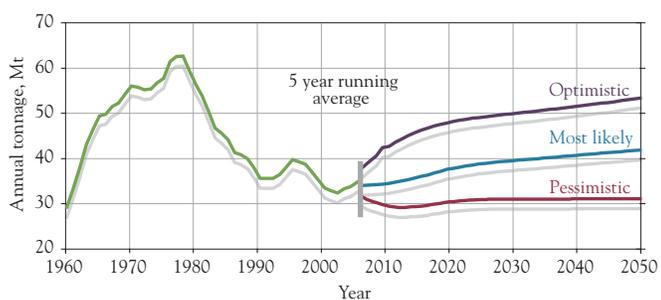
² At the time of printing of this report, the value of the U.S. dollar has declined relative to the Canadian dollar and many other currencies. Hence, U.S. exports to Canada (and other countries through the Seaway) will rise so long as they stay competitively lower in price, while Canadian exports to 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



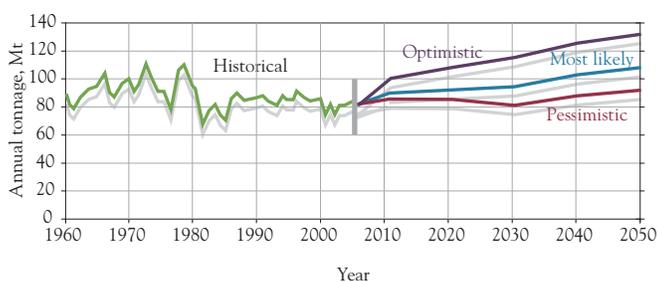
Cargo traffic through the MLO section is expected to grow at average annual rates of 0.1 percent, 0.7 percent and 1.1 percent under the pessimistic, most likely and optimistic scenarios, respectively, reaching 33 Mt, 42 Mt, or 51 Mt by 2050.

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 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 Great Lakes and Seaway 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

FIGURE 3.12

Forecast by commodity for Montreal – Lake Ontario section to 2050 (most likely scenario)

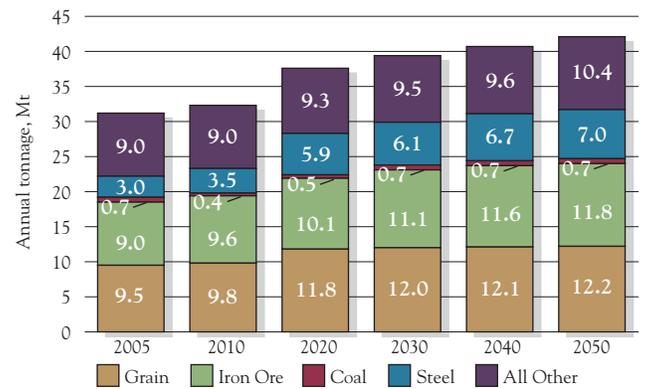


FIGURE 3.13

Forecast by commodity for Welland Canal to 2050 (most likely scenario)

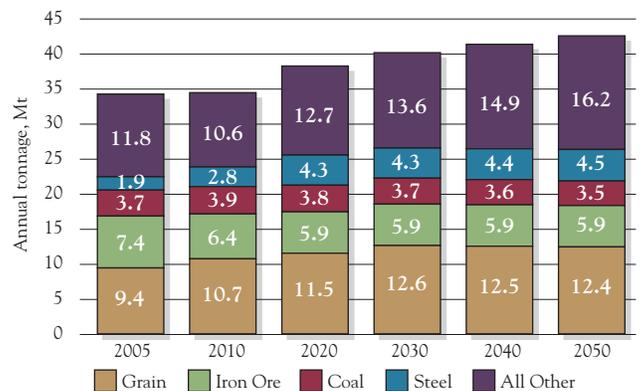
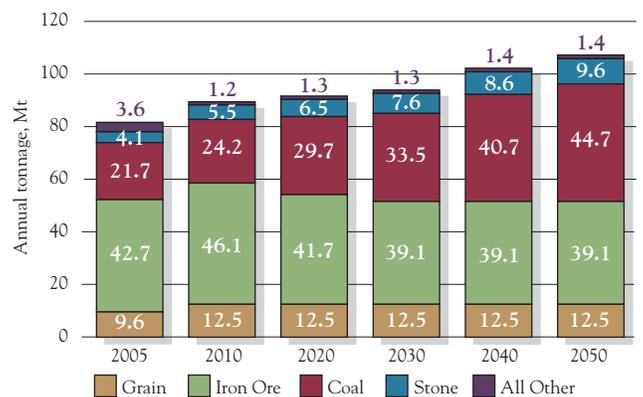


FIGURE 3.14

Forecast by commodity for Soo Locks to 2050 (most likely scenario)



and unloading charges, 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 commodity³

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.

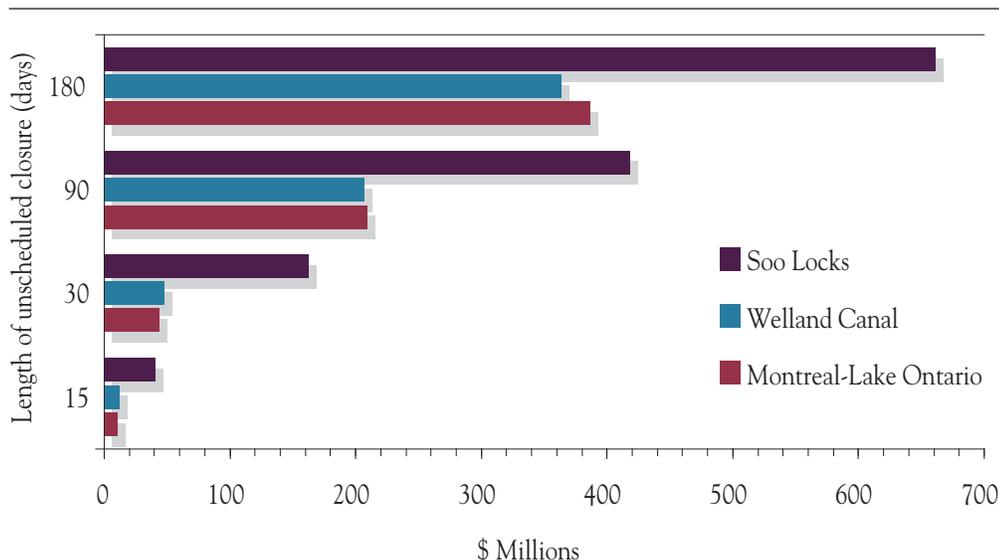
For closure lasting up to 30 days, the primary impact would likely be delays in the movement of cargoes since shippers would be more likely at this level to wait out the closure. Closures in excess of 90 days, however, resulted in a modal shift to rail or truck, or both and they could also involve shifting 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

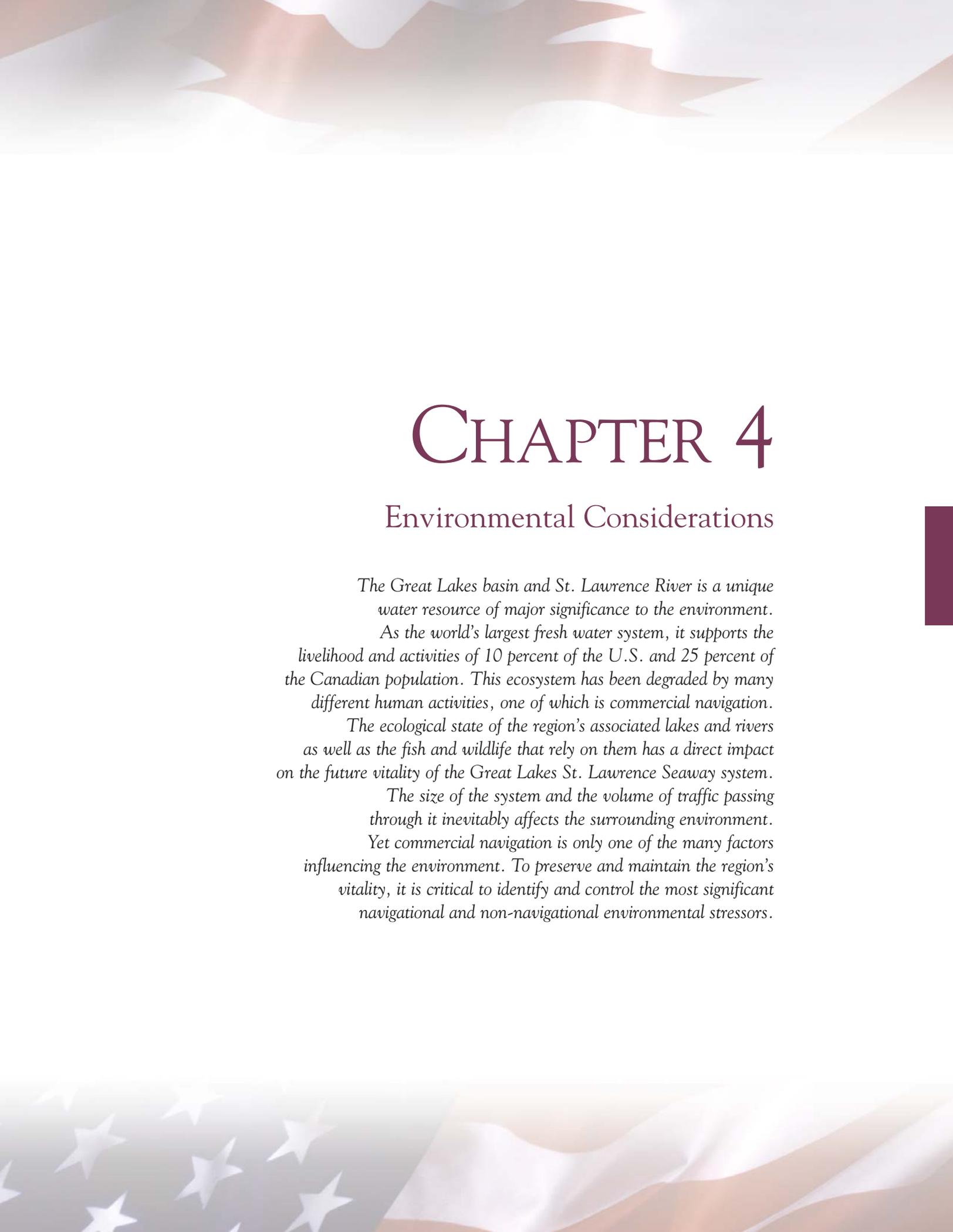


CONCLUSIONS

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.

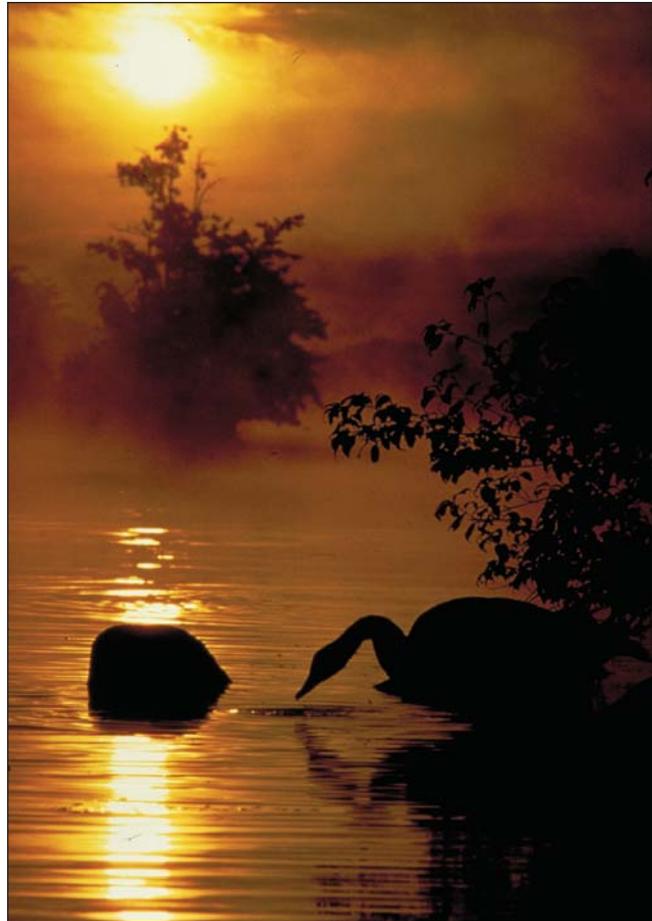
Within this context, the Environmental Working Group considered the environmental implications of potential changes to the volume or type of traffic passing through the system as well as any effects associated with operating or maintaining the infrastructure of the GLSLS.

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



Canada Goose, Kent Lake Kensington Metro Park, Michigan
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office, www.epa.gov

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 (NO _x), sulphur oxides (SO _x), carbon dioxide (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 SO_x, NO_x, 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 in) per century while the southern reaches of the basin are rebounding at only 10 cm (4 in) 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 ft), 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 metres 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



Little Canal, Lake Superior, Wisconsin
Source: U.S. Environmental Protection Agency, Great Lakes National Program Office, www.epa.gov

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.

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	
Non-navigational related	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	
	Navigational related	Water management	Maintenance dredging
	Navigational related	Land-based support activities	Water management for all purposes
			Infrastructure development
			Facility maintenance
	Navigational related	Ship operations	Uncontrolled releases
			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			
Navigational related	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 transshipments.

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 inadvertent 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

Valued ecosystem component

TABLE 4.3
Stressor analysis

Class of stressor	Stressor	Terrestrial systems			Aquatic systems			Sensitivity ranking												
		Air quality ¹	Soil and ground water	Vegetation ²	Fauna ³	Special features ⁴	Water and substrate ⁵	Flora/wetlands ⁶	Aquatic fauna ⁷	Areal extent	Temporal extent	Reversibility	Low	Medium	High					
												3	4	5	6	7	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	
Navigational related	Channel & port maintenance	Wildlife conflicts				✓		✓	1	1	1							3		
		Channel modification					✓	✓	✓	1	3	3							7	
		Dredge material placement		✓	✓	✓	✓	✓	✓	1	3	2							6	
		Shoreline alteration/hardening		✓	✓	✓		✓	✓	1	3	2							6	
	Water management	Maintenance dredging						✓	✓	1	2	2							5	
		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		
Ice breaking	Wildlife encounters						✓	✓	1	1	1							3		
				✓	✓		✓	✓	2	2	2							6		

- 1 Nox, SOx, CO₂, 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 invertebrates, 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 SO_x 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 SO_x emissions: the vast majority of SO_x 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

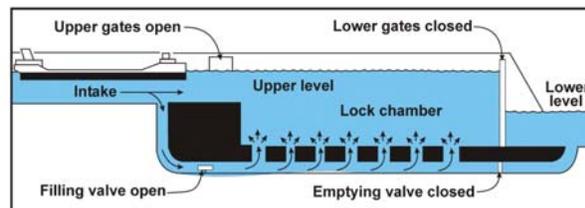
As was highlighted in the system overview included in Chapter 2 of this report, the GLSLS system includes navigation locks located at 16 different sites throughout the St. Lawrence River, Welland Canal and St. Marys River. These locks allow vessels to bypass the rapids and falls throughout these rivers, 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.

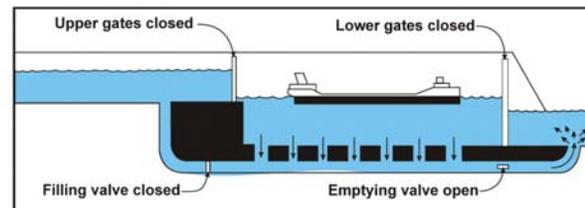
FIGURE 5.1

How navigation locks operate

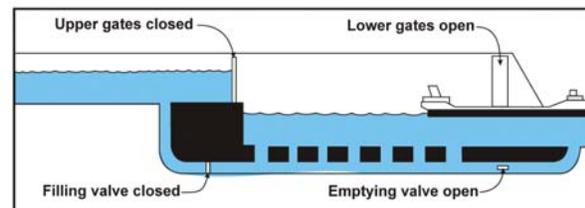
These diagrams show how a ship is lowered in a lock. A ship is raised by reversing the operation. No pumps are required; the water is merely allowed to seek its own level.



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 metre (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 m (21 ft) at the Soo Locks to 15 m (49.2 ft) 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 m (32.8 to 36 ft), 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 a routine 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 m (26.6 ft) depending on available water levels for the St. Lawrence Seaway, and 7.77 m (25.5 ft) 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

The U.S. Army Corps of Engineers (USACE), and the Saint Lawrence Seaway Development Corporation (SLSDC) to a much lesser extent, undertakes some two to four million cubic metres (three to five 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 kilometres (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 metres 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 metres per year (850,000 cubic yards per year) of dredging. An additional 230,000 cubic metres 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.

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).

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.

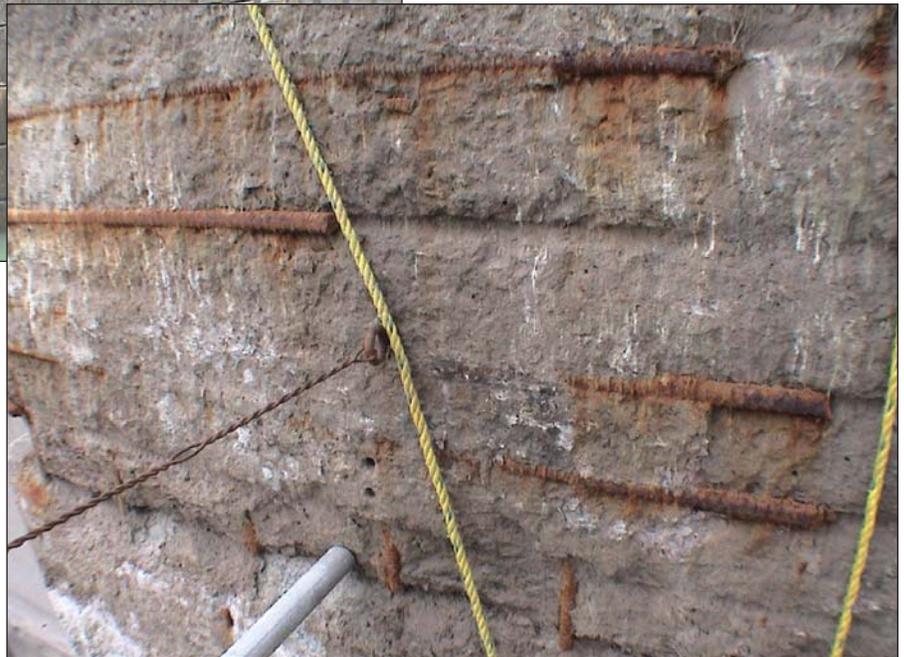
Cyclical operation impacts: Each time a vessel transits a lock, the lock operating machinery is subject to a cycle of operation (gate movement, ship arrestor raising, culvert valve movements, etc.). This continual cycling of these lock components results in long term wear and tear and the ultimate degradation 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

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.



Concrete lock wall surface deterioration at Welland Canal Lock #7 (note exposed rebar at damaged area)
Source: The St. Lawrence Seaway Management Corporation

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 centimetres (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 Working Group 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)

<p>Impact on navigation</p>	<p>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.:</p> <ol style="list-style-type: none"> 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. 																
<p>Other impacts</p>	<p>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.</p> <ol style="list-style-type: none"> 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. 																
<p>Overall ranking</p>	<p>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:</p> <table border="1" data-bbox="500 1465 1507 1900"> <thead> <tr> <th>Rating Category</th> <th>Weighting factor</th> </tr> </thead> <tbody> <tr> <td>Redundancy</td> <td>10%</td> </tr> <tr> <td>Current condition</td> <td>10%</td> </tr> <tr> <td>Likelihood of future problems</td> <td>30%</td> </tr> <tr> <td>Relative cost to replace/upgrade</td> <td>15%</td> </tr> <tr> <td>Impact on navigation</td> <td>25%</td> </tr> <tr> <td>Other impacts</td> <td>10%</td> </tr> <tr> <td>Sum</td> <td>100%</td> </tr> </tbody> </table>	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%
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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.

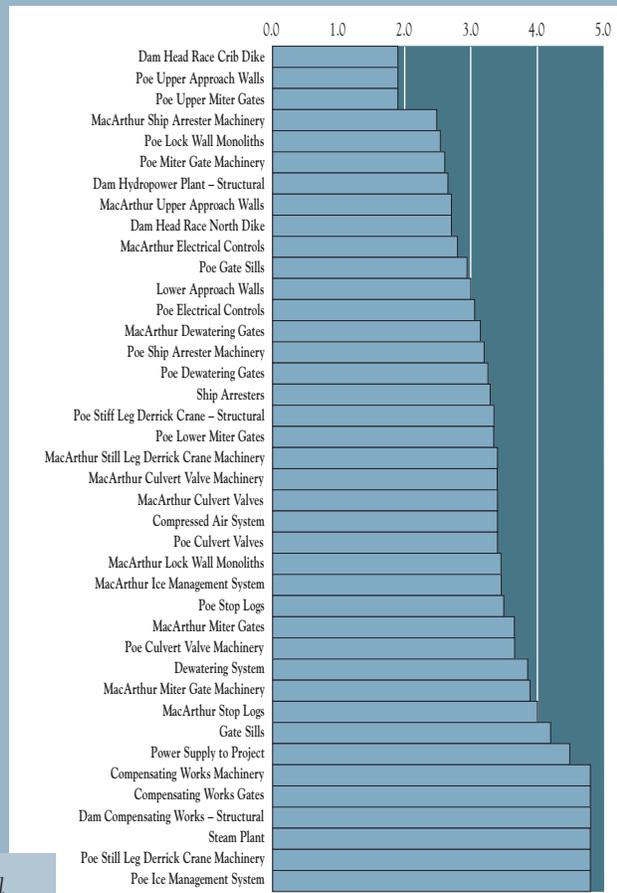
Mass concrete	The lock walls are formed by 76 independent mass concrete gravity monoliths. The miter gate sills are also mass concrete sitting on bedrock. There are no major issues for a structure of this age. Surface deterioration around the seal area of the miter gate sills is addressed by routine 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.

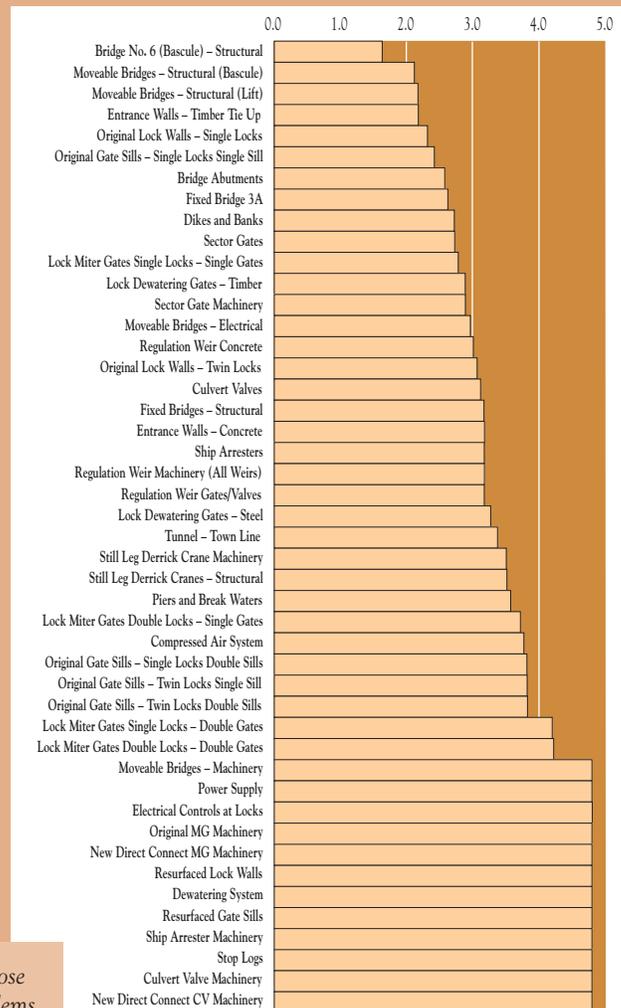
Secondary gates Redundant intermediate gates at some of the Welland Locks and three sets of spare miter gates stored underwater near Lock 1. A set of sector gates near the upstream end at Lock 7 can be used in an emergency but would have to be placed under flowing conditions. There are also dewatering 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.

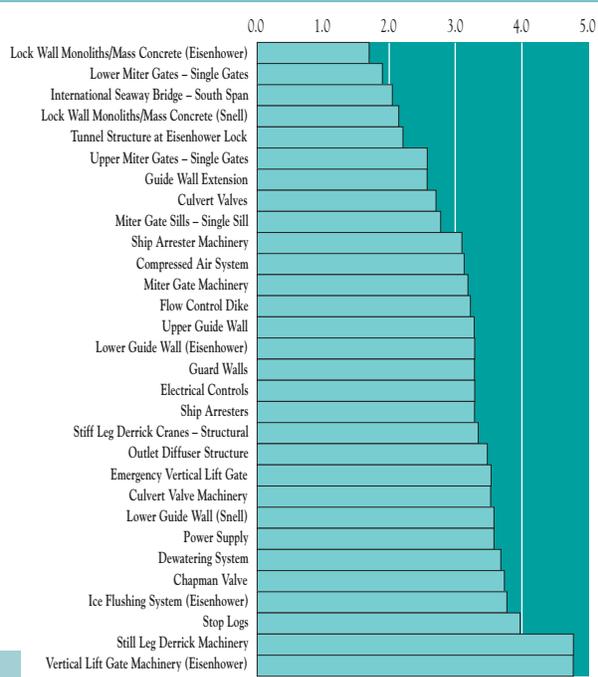


MLO SECTION – U.S. COMPONENTS

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.



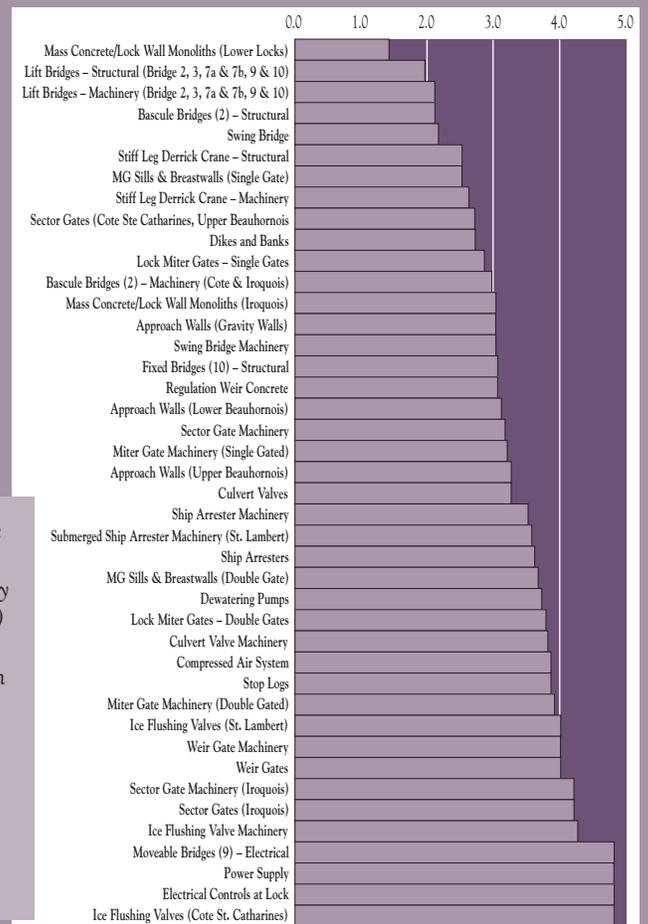
At the SLSDC facilities on the St. Lawrence River, the most critical areas are associated with concrete quality at the Eisenhower Lock, the condition of the lower miter gates at both locks, the south span of the Seaway International Bridge, and the Eisenhower Lock highway tunnel.

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 \$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 centimetres (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.

TABLE 5.1

Summary of criticality assessments

<i>Summary of criticality indices</i>	<i>Overall</i>	<i>Soo-USACE</i>	<i>Welland-SLSMC</i>	<i>MLO-SLSDC</i>	<i>MLO-SLSMC</i>
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

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.

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

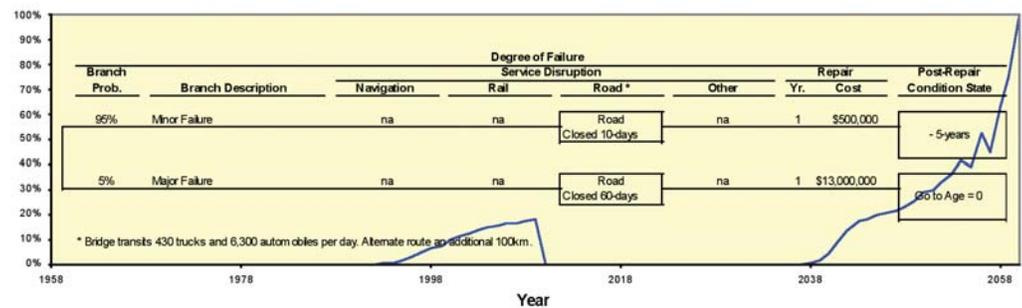
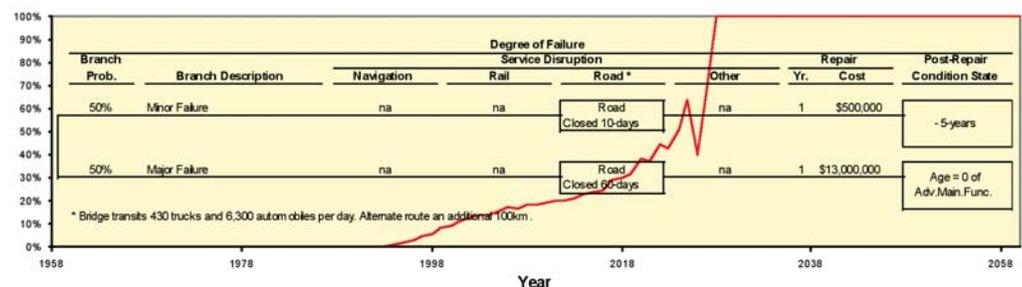


FIGURE 5.3
Likelihood of failure if no investment is made in maintenance



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 tons annually is shipped through the GLSLS upstream of Montreal. Dredging three million cubic metres per year represents roughly one ton of dredged material for every 40 tons of goods passing through the system.

Of the two to four cubic metres 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

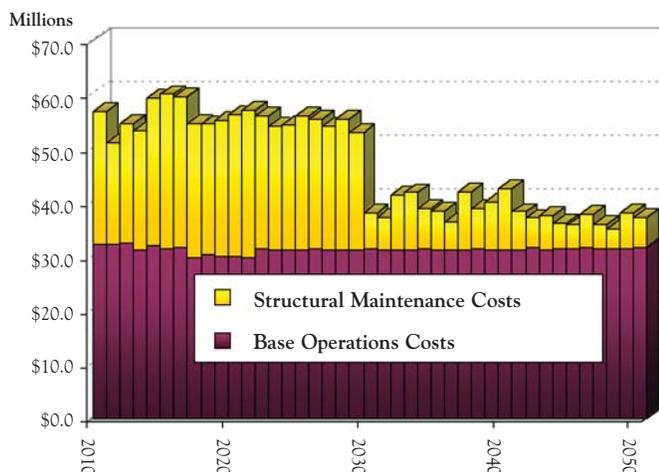
operation and maintenance requirements for each corridor that reflects the fact that past funding limitations have resulted in the delay in various operation and maintenance activities. These delayed activities need to be addressed on a priority basis in order to ensure continued system reliability, and as such are typically timed to occur early in the period of analysis.

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 Beauharnois 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.

FIGURE 5.4
SLSMC – Montreal-Lake Ontario (MLO)



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

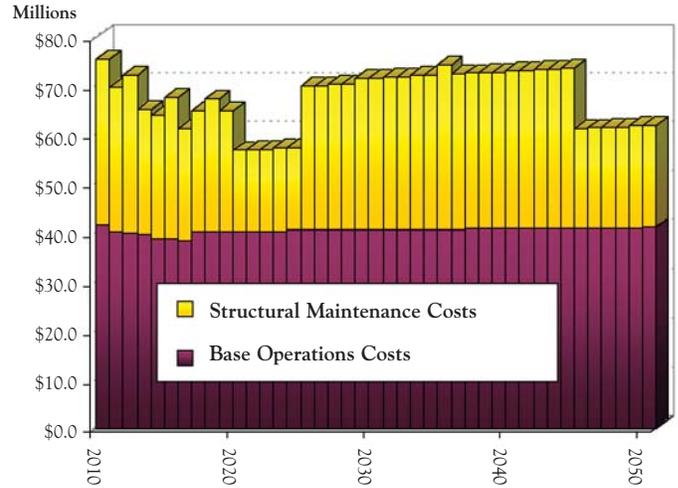


FIGURE 5.6
SLSDC – Montreal-Lake Ontario (MLO)

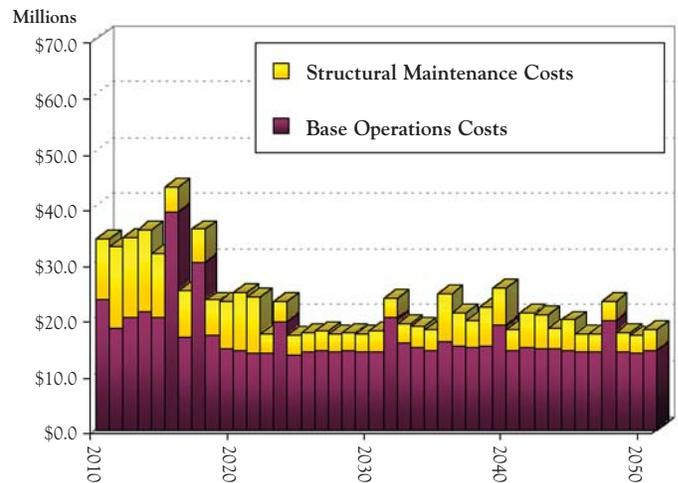


FIGURE 5.7
Soo Locks

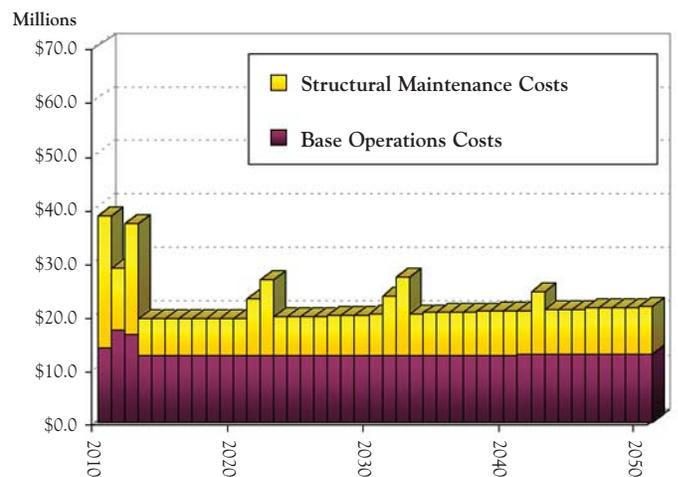


Figure 5.7 presents the Soo Locks, which consists of two operating lock chambers and a hydropower plant which supplies power for lock operations. Base operation costs average around \$12.6 million annually.

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 expen-

ditures 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

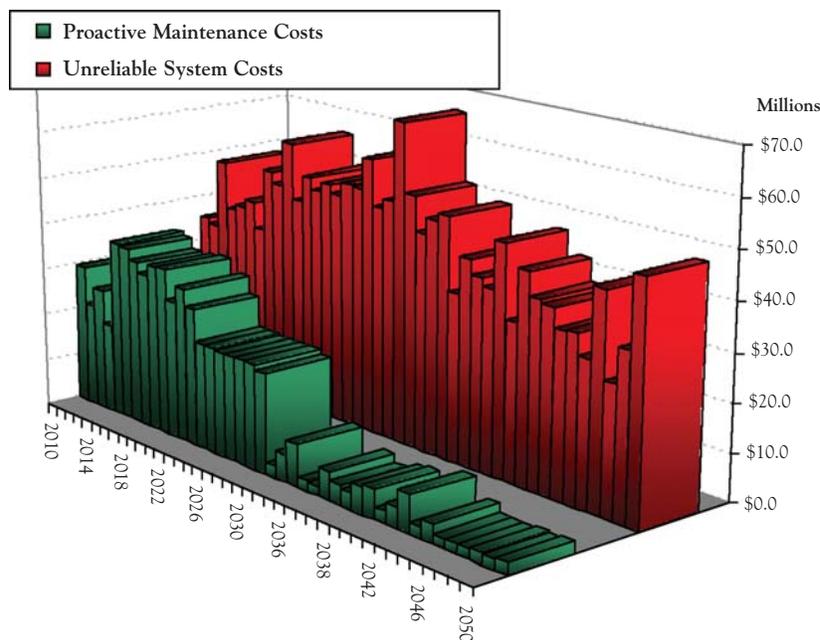


Figure 5.8 includes the projected maintenance costs required to proactively address those infrastructure components for which detailed engineering reliability analyses were undertaken. These costs are then compared to the projected impacts of system disruptions if these high priority components are not addressed in a proactive manner. This includes a total of approximately 35 relatively 'high priority' 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:

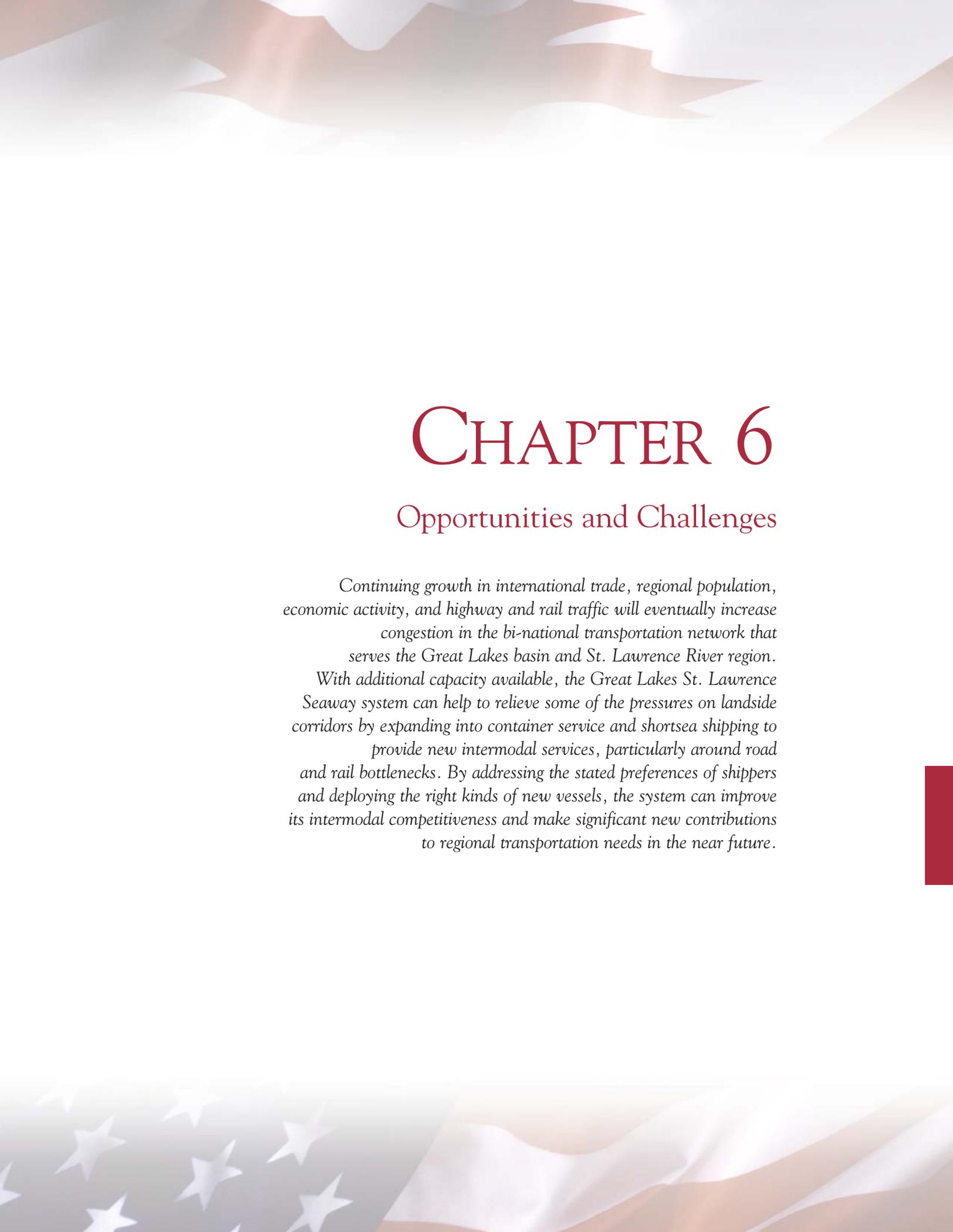
- The current state or condition of all components of the lock infrastructure;
- How likely is it that a particular component will fail given its condition and level of use at a particular point in time, and if a failure occurs what is the impact – a lock closure (15, 30, 90, 180 days?), a shutdown?, 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.

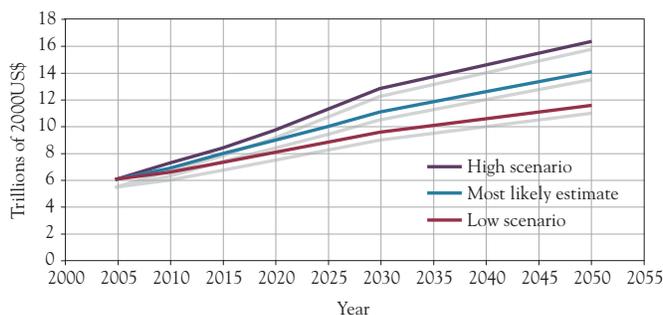
The economies of the Great Lakes and St. Lawrence River are already strongly integrated into the global economy, in part because of the waterway linking it to world markets. As a result, the binational region has already experienced remarkable growth in its trade: adjusted for inflation, it grew twenty-fold 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.

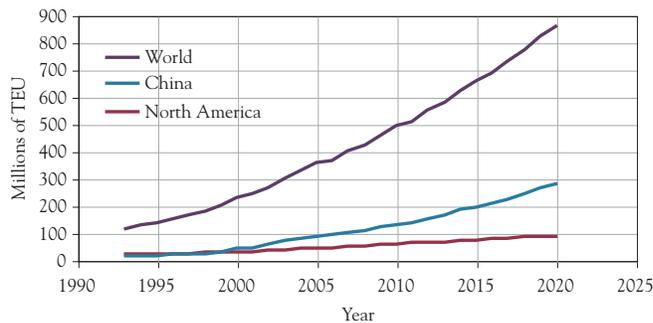
China's share of that traffic should reach approximately 33 percent, while North America's share will grow at a slower rate and account for 10.4 percent by 2020.

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.

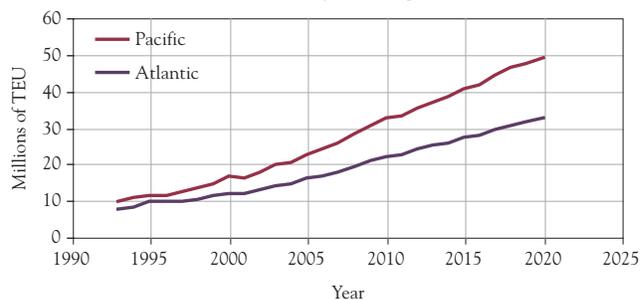
FIGURE 6.2

Projections of world container traffic compared to that of North America

World, North America and China containerized TEU traffic forecast



North America containerized TEU traffic by coastal region forecast



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.

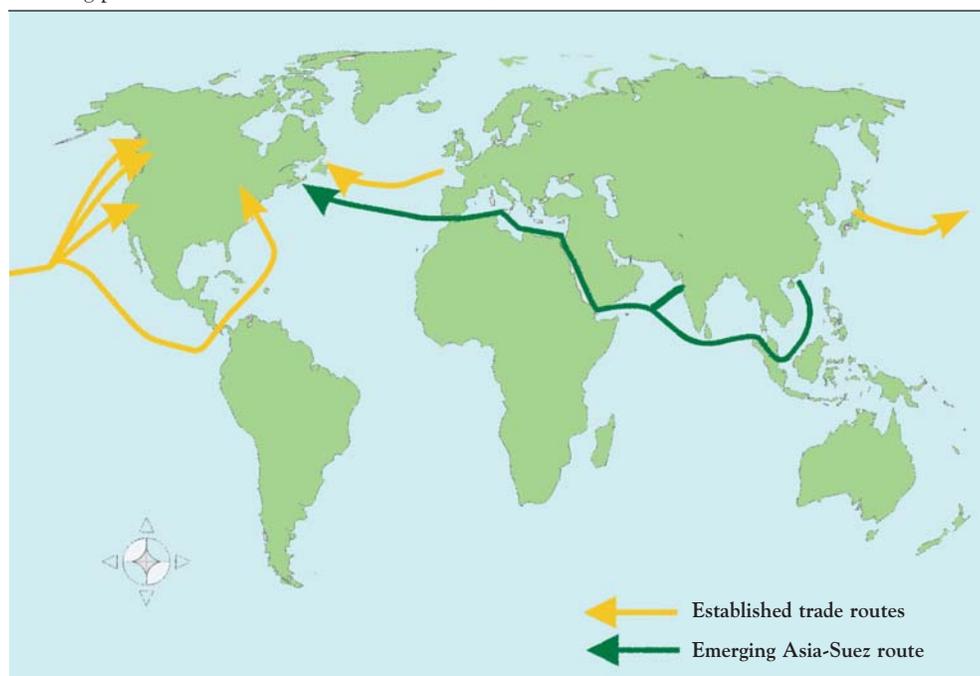
One alternative is to re-direct traffic to less travelled routes. Carriers sailing from Asia-Pacific ports have resumed all-water shipping via the Panama Canal. As a result, that waterway is now operating near capacity and will not be able to absorb more traffic until its current expansion is completed 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 (FEU¹) 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.

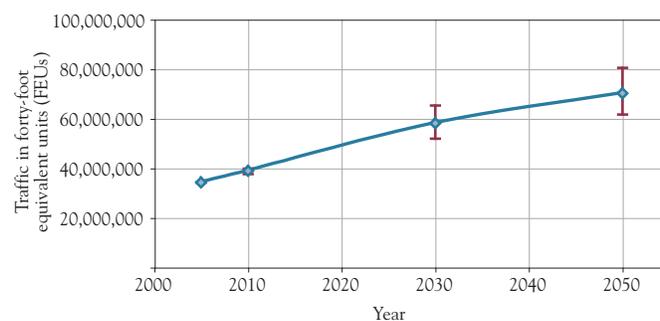
The study's Economic Working Group conducted a modal diversion analysis which showed that with a maximum open-water speed of 20 knots, container ships on the GLSLS could have gained a market share of 2 percent of total cargo traffic in 2005, a level comparable to that of intermodal rail. Much of this 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 by all modes 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 kilometre; 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

<i>Performance parameter</i>	<i>Container on barge</i>	<i>GLSLS container ships</i>	<i>Fast freighter</i>	<i>PASCAT (open water)</i>
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 accommodate four percent of containerized traffic by 2050, if it is competitive with rail and highway.

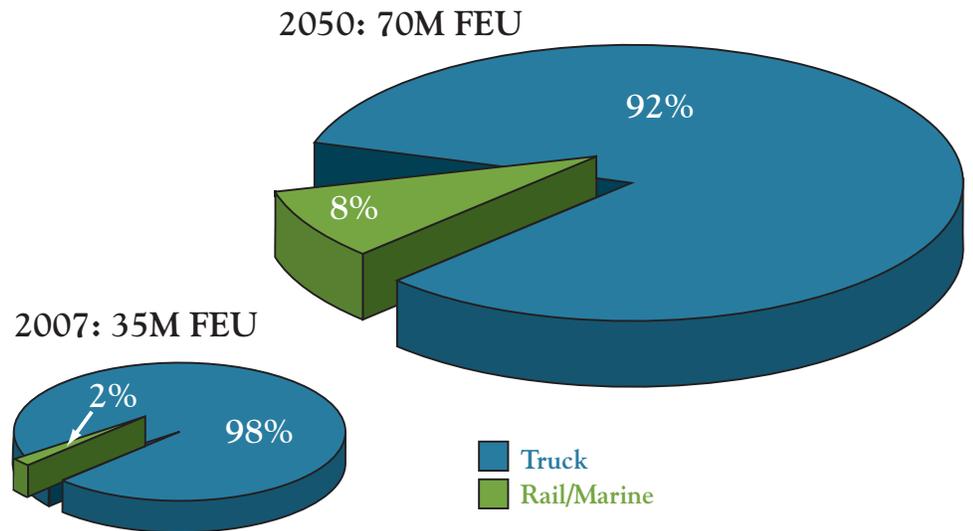
All of this suggests that there are opportunities for the waterway to accommodate part of the container traffic growth to the waterway in selected transportation corridors.

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.



Container being handled at the Port of Montreal
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 optimize the many different components 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 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.



Shortsea shipping
Source: Transport Canada

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 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

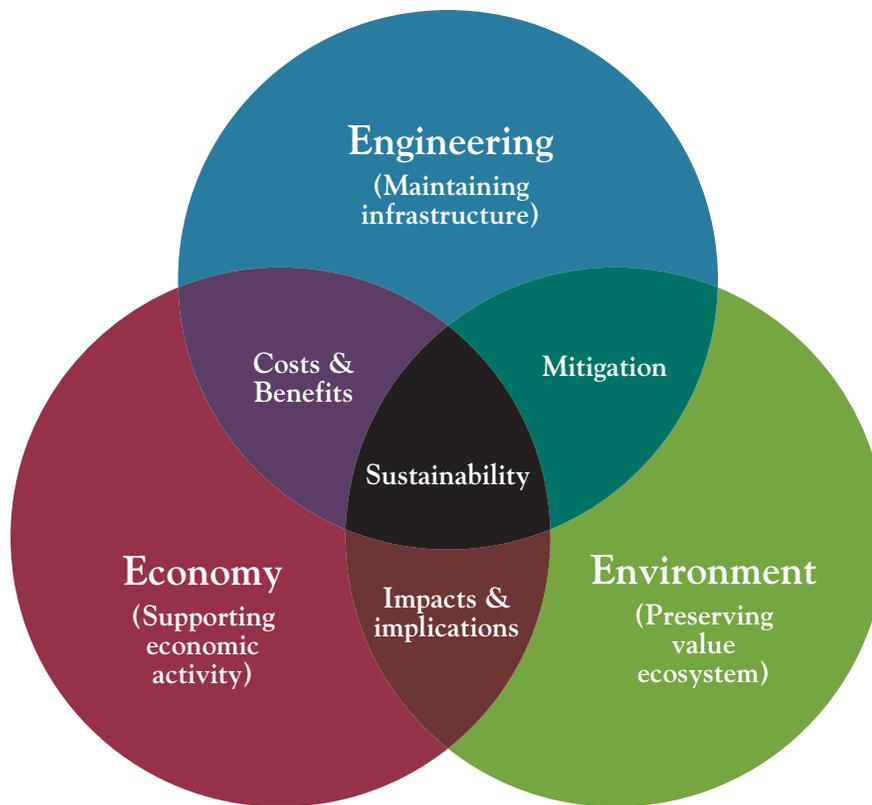
The success of any initiative to build the future of the GLSLS system depends on a commitment by government and industry in both Canada and the U.S. to clear objectives and to the continuous monitoring of progress and success.

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.



*The Great Lakes St. Lawrence Seaway Study
is a joint Canada/United States study
to evaluate the infrastructure needs of the
Great Lakes St. Lawrence Seaway system,
specifically the engineering, economic and
environmental implications of those needs
as they pertain to commercial navigation.*



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

