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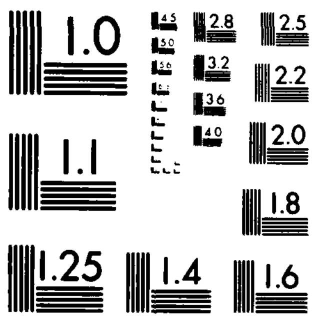
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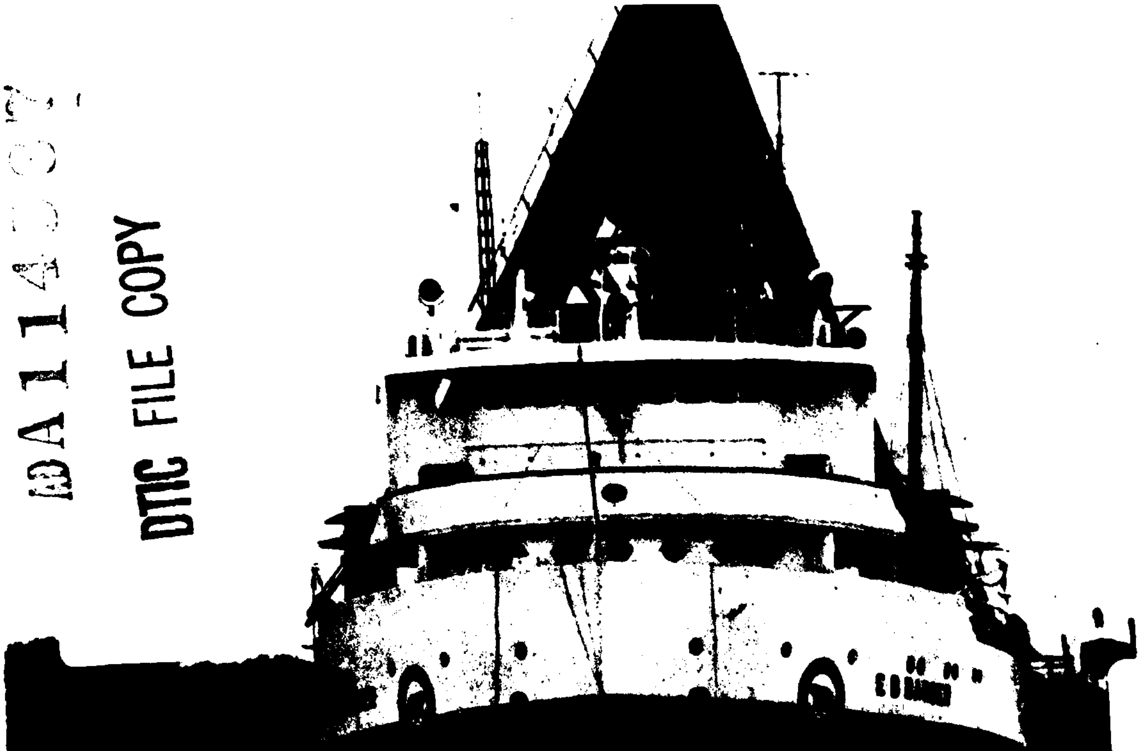

Appendix D
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International Lake Erie Regulation Study Board

International Joint Commission

July 1981

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A114 587
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Lake Erie Water Level Study, Appendix D, Commercial Navigation	5. TYPE OF REPORT & PERIOD COVERED Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS International Lake Erie Regulation Study Board	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Engineer District, Buffalo 1776 Niagara Street Buffalo, N.Y. 14207	12. REPORT DATE July 1981
	13. NUMBER OF PAGES 151
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report)
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Commercial Navigation, Lake Regulation, Water Levels, Great Lakes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Commercial Navigation Appendix describes the effects of limited regulation of Lake Erie on commercial navigation interests within the Great Lakes - St. Lawrence River system.

The effects on navigation were determined by comparing the transportation costs under limited regulation of Lake Erie, with the costs under the present

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20. Lake Erie outlet conditions. Transportation costs were determined for the four bulk commodities of iron ore, coal, limestone, and grain which comprise nearly 85 percent of all Great Lakes traffic. Evaluation of commodities comprising the remaining 15 percent would not affect significantly the results.

The analysis involved forecasting of major operational elements of the navigation system, such as vessel characteristics, vessel operating costs, traffic volumes, trade routes, etc. Transportation costs for 1985, 2000, and 2035 were determined using a computer model which calculated effects on vessel loading and therefore transportation cost using the water level regime determined in the International Lake Erie Regulation Study.

APPENDIX D

COMMERCIAL NAVIGATION

LAKE ERIE REGULATION STUDY

REPORT

TO THE

INTERNATIONAL JOINT COMMISSION

BY THE

INTERNATIONAL LAKE ERIE REGULATION

STUDY BOARD

(UNDER THE REFERENCE OF 21 FEBRUARY 1977)

JULY 1981

SYNOPSIS

The Commercial Navigation Appendix describes the effects of limited regulation of Lake Erie on commercial navigation interests within the Great Lakes - St. Lawrence River system.

The effects on navigation were determined by comparing the transportation costs under limited regulation of Lake Erie, with the costs under the present Lake Erie outlet conditions. Transportation costs were determined for the four bulk commodities of iron ore, coal, limestone, and grain which comprise nearly 85 percent of all Great Lakes traffic. Evaluation of commodities comprising the remaining 15 percent would not affect significantly the results.

The analysis involved forecasting of major operational elements of the navigation system, such as vessel characteristics, vessel operating costs, traffic volumes, trade routes, etc. Transportation costs for 1985, 2000, and 2035 were determined using a computer model which calculated effects on vessel loading and therefore transportation cost using the water level regime determined in the regulation study. All costs and benefits are based on 1979 price levels, using an interest rate of 8-1/2 percent. The benefits or losses are expressed as total present worth values for the period 1985 through 2035, and as equivalent average annual values.

Limited regulation of Lake Erie would have the effect of lowering the water levels of that lake as well as those upstream. As a result, there would be losses to navigation interests. The losses depend on the degree of the lake level lowering and range from about $1,000,000 annually for Plan 6L to about $10,000,000 annually for Plan 25N. As an additional exercise, the cost of dredging all United States harbors and the interconnecting channels of the Great Lakes to offset the lowering effect was also estimated.

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A documentation of the methodology applied in the assessment of the effects of hydro-electric power production at installations on the outlet rivers of the Great Lakes and of the detailed economic evaluation of the effects of plans for limited regulation of Lake Erie on the capacity and energy output of these installations.

APPENDIX F - ENVIRONMENTAL EFFECTS

A documentation of the qualitative assessment of the effects of plans for limited regulation of Lake Erie on fish, wildlife, and water quality within the lower Great Lakes and the St. Lawrence River.

APPENDIX G - RECREATIONAL BEACHES AND BOATING

A documentation of the methodology applied in the assessment of the effects of plans for limited regulation of Lake Erie on beaches and recreational boating activities, along with a detailed economic evaluation, within the lower Great Lakes and the St. Lawrence River.

APPENDIX H - PUBLIC INFORMATION

A documentation of the public information program utilized throughout the study to inform the public of study activities and findings and provide a vehicle for public comment on the study.

Section 1

INTRODUCTION

1.1 Study Purpose

In 1977 the International Joint Commission established a study board to determine the feasibility for limited regulation of the water levels of Lake Erie. The study came about as a result of record high water levels on Lake Erie in the early 1970's. The objective of limited regulation of Lake Erie is to maximize the lowering of the high Lake Erie water levels while maintaining as nearly as possible its long-term average and minimum levels.

1.2 Description of the Study

Limited regulation of Lake Erie would require adjustments to its outflow according to certain prescribed rules through adjustable control works constructed at Lake Erie's outlet (the head of the Niagara River). The study involved several major tasks: 1) developing regulation plans for Lake Erie; 2) identifying the types of control works required in the Niagara River and identifying the types of remedial works required in the St. Lawrence River to accommodate limited regulation of Lake Erie; and 3) evaluating the probable effects of limited regulation of Lake Erie on the water levels and outflows of the Great Lakes and on the major environmental and economic interests. Environmental interests include water quality, wildlife/wetlands and fish, while economic interests include coastal zone, commercial navigation, hydroelectric power, beaches and recreational boating.

The Study Board determined that three types of regulatory works warranted detailed study: 1) a modification to the Black Rock Lock would permit up to a 4,000 cfs increase in Lake Erie outflow; 2) a diversion channel equipped with a control structure on Squaw Island would provide a 10,000 cfs increase; and 3) a control structure on the Niagara River would provide a 25,000 cfs increase. The average Lake Erie outflow is about 200,000 cfs.

This appendix presents the results of the evaluation of the impacts of limited regulation of Lake Erie on the cost of commercial navigation.

The customary (British) units of measurements are used throughout the appendix. A British/metric conversion table is contained in Annex A. Cargo and vessel tonnage are given in terms of short tons.

The most significant previous study was that conducted by the International Great Lakes Levels Board (IGLLB), entitled "Regulation of Great Lakes Water Levels." That study was conducted for the International Joint Commission under the Reference of October 7, 1964. The results were published in December 1973. The methodologies used in the present study are based on those developed by the IGLLB.

1.3 Commercial Navigation Impact Evaluation Study

1.3.1 Subcommittee Organization and Function

This appendix was prepared by a subcommittee composed of United States and Canadian members knowledgeable in the general areas of commercial navigation. United States agencies represented included the Corps of Engineers (Department of the Army) and the St. Lawrence Seaway Development Corporation (Department of Transportation). Canadian agencies represented included Transport Canada and the Department of Public Works. A chairman was selected for each section of the subcommittee (Canadian and United States). Each section was responsible for developing data on its commercial navigation activities (commerce, vessel operations, costs, etc.) for input into a computer model to evaluate the impact of changes in Lake Erie water levels on each nation's commercial navigation. Basic assumptions, data, methodology and results were coordinated by the subcommittee and this report was produced to document the study.

Subcommittee Membership is shown in Annex B.

1.3.2 Objective and Scope of the Study

The objective of the Navigation Subcommittee was to estimate the economic effect of limited regulation of Lake Erie on the transportation cost of commercial goods in the Great Lakes - St. Lawrence River system, by comparing costs at the existing regime of lake levels to those at alternative regimes with Lake Erie regulated.

A secondary objective was to establish a navigation methodology that could be readily applied to any other change in the levels regime in all, or any part, of the Great Lakes system.

The methodology was based on the work of the International Great Lakes Levels Board. Projections were made to the year 2035 for the Great Lakes - St. Lawrence River bulk trades in iron ore, coal, limestone, and grain. This traffic comprises about 85 percent of Great Lakes traffic. Tonnages, trade routes, and trade patterns were forecast as well as the composition, physical characteristics and utilization of the Great Lakes bulk fleets. July 1979 ship operating costs were used, except for fuel costs which were increased an additional 5 percent above inflation until the year 2005. The methodology is based on the concept that ships that can, will take advantage of the full depth of water available. Therefore, when the regime of water levels is changed in a part of the system, the loading of ships wishing to use that part of the system at that time is affected.

Separate analyses were done for the national trades and fleets of the United States and Canada, because of their numerous differences. The results published in this report represent the direct impact on each nation's fleet, whether its vessels are engaged in carrying domestic goods or importing or exporting commodities of the other nation.

It was assumed that the existing navigation system on the lakes, including the physical facilities and methods of operation, would remain essentially the same for the entire period of projection. Some changes were expected to occur, such as the accommodation of larger vessels at the Soo Locks, and the deepening of some shallow-draft harbors by the year 2000, and these were taken into account. The analysis considered only the present navigation season, 9 months on the Welland Canal and above and 8-1/2 months on Lake Ontario and the St. Lawrence River.

To test the sensitivity of the results to uncertainties in forecasts, analyses were conducted for higher and lower traffic projections and vessel operating costs. The sensitivity of the results to a very small change in the levels regime was also tested.

1.4 Great Lakes - St. Lawrence River Navigation System

1.4.1 Major Features

The Great Lakes and their connecting channels, the St. Lawrence River, and the Gulf of St. Lawrence provide a continuous deep draft waterway from the Atlantic Ocean 2,400 miles inland to the heart of the North American continent. The navigational features of this vast inland waterway are presented in Table D-1 and shown in Figures D-1 and D-2.

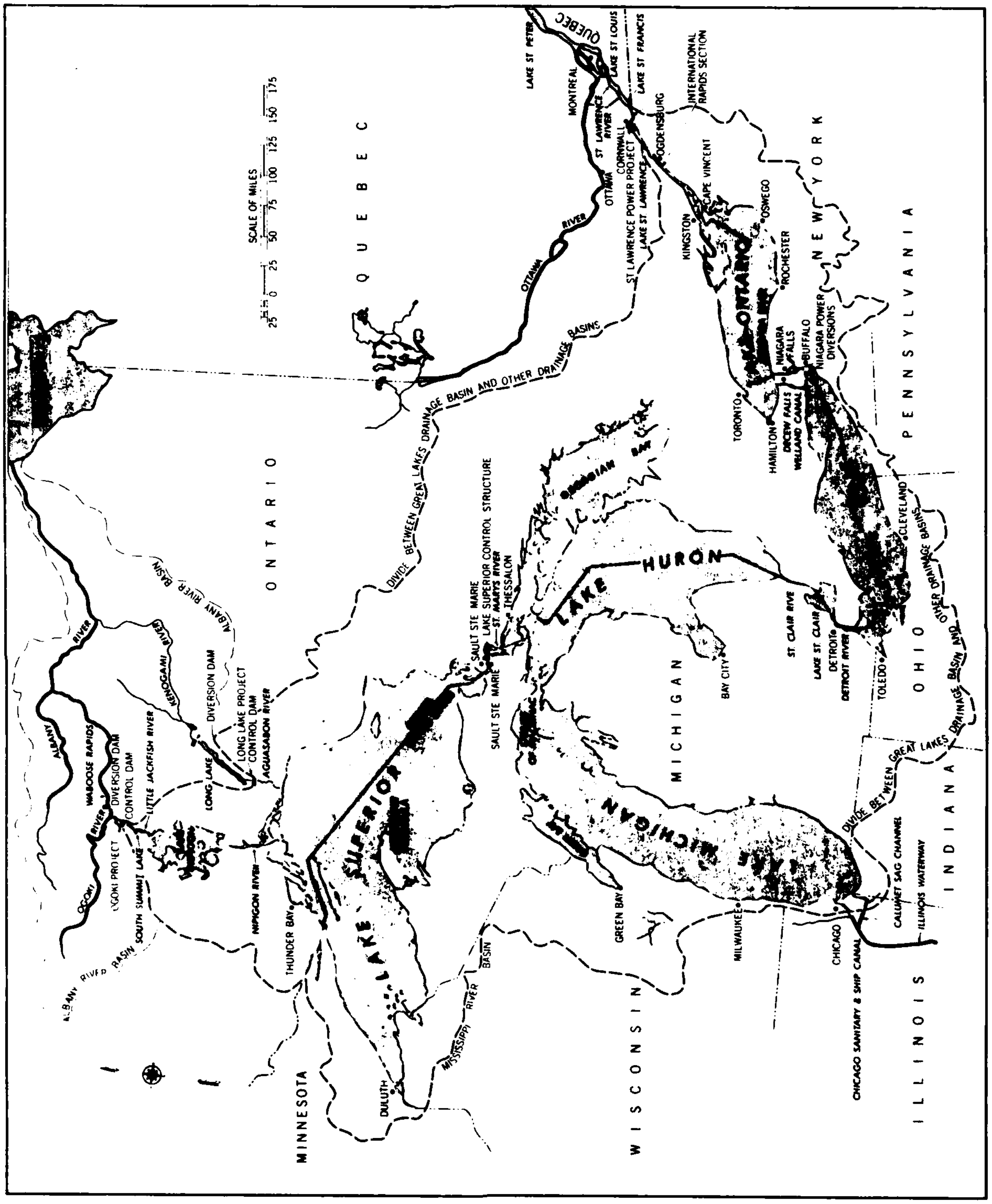
The Great Lakes - St. Lawrence River system connects with several other shallow draft inland navigable waterways to form an important transportation network reaching deep into the continent. At the south end of Lake Michigan, it joins with the Mississippi River Inland Waterways System. The Mississippi River Inland Waterways System consists of 5,000 miles of navigable shallow draft channels and provides barge transportation from the Gulf of Mexico to States in the central part of the United States. The New York State Barge Canal provides a shallow draft link between the Great Lakes and the east coast ports via the Hudson River. The shallow draft Richelieu-Champlain waterways connect the Hudson River to the St. Lawrence River downstream of Montreal. In Canada, the Rideau, Trent-Severn, and Ottawa Canal systems link the hinterland with the Great Lakes and St. Lawrence River.

1.4.2 Economic Development and Area Resources

The Great Lakes - St. Lawrence River navigation system provides the means of transporting over 220,000,000 tons of waterborne freight annually. Part of the area served by the system, commonly referred to as the Midcontinent Region, constitutes the industrial and agricultural heartland of North America. It encompasses 19 States and three Canadian Provinces; Ontario, Manitoba and Saskatchewan. Over 80,000,000 people, some 30 percent of the

Table D-1 - Physical Dimensions of the Great Lakes - St. Lawrence River Navigation System

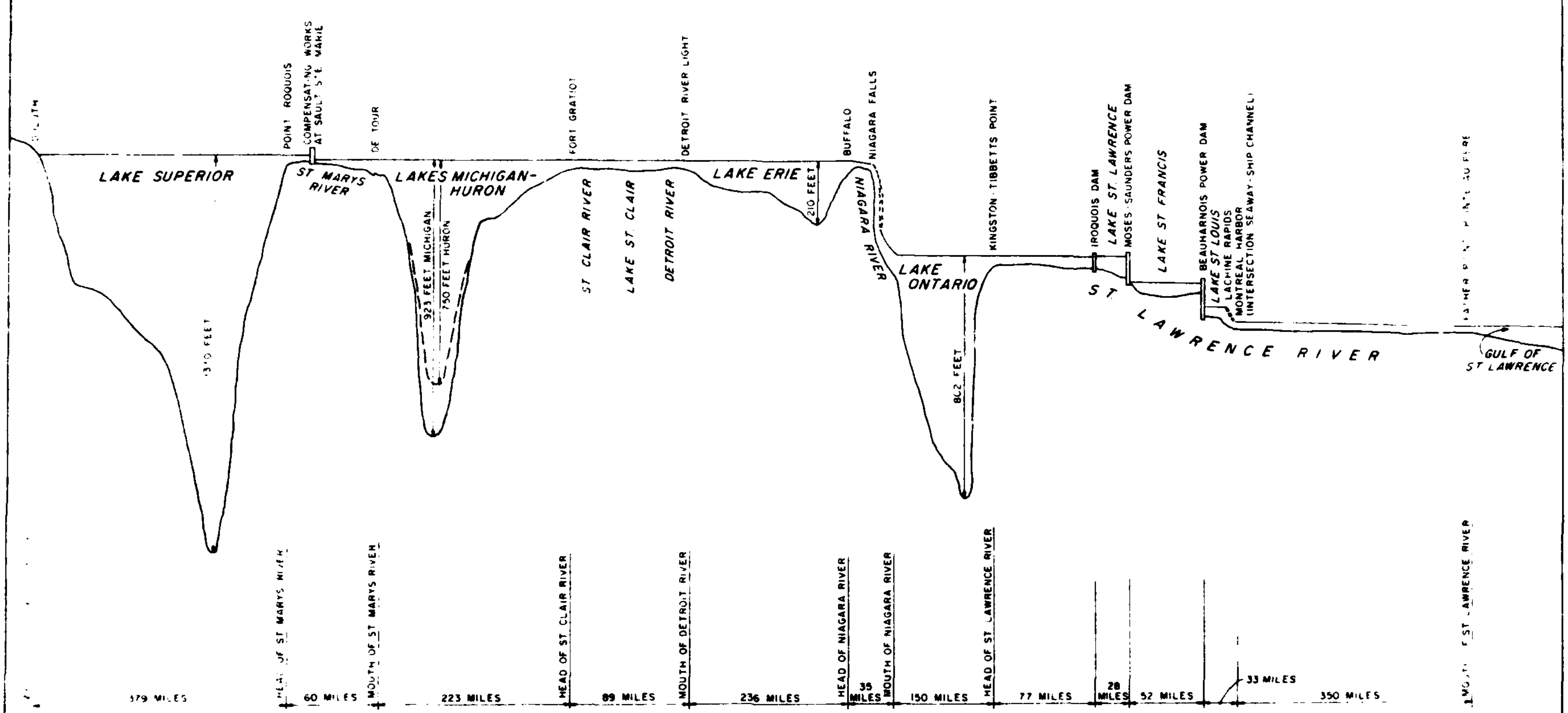
Reach	Lakes and Channels: Open Waters (Miles)	Lakes and Channels: Channels & Canals (Miles)	Lakes and Channels: Minimum Depth (Ft.)	Locks: Number	Locks: Year Completed	Locks: Size Length X Width (Ft.)	Locks: Depth over Sill (Ft.)	Locks: Lift (Ft.)
Atlantic Ocean to Father Point, Que.	700	-		-	-	-	-	-
Father Point to Montreal	300		35	-	-	-	-	-
Montreal to Lake Ontario	189							
Lachine Section		31	27	2 (Can.)	1958	800X80	30	226
Soulanges Section		16	27	2 (Can.)	1958	800X80	30	
International Rapids Sec.		44	27	1 (Can.)	1958	800X80	30	
				2 (U.S.)	1958	800X80	30	
Lake Ontario, Kingston to Welland Canal	160	-	-	-	-	-	-	-
Welland Canal	-	27	27	8	1932	800X80	30	326
Lake Erie, Welland Canal to Detroit River	236	-	27	-	-	-	-	-
Detroit River to Lake St. Clair and St. Clair River	-	77	27	-	-	-	-	-
Lake Huron, St. Clair River to St. Marys River	223	-	-	-	-	-	-	-
Lake Michigan, Chicago to the Straits of Mackinac	345	-	-	-	-	-	-	-
St. Marys River (includes Soo Locks)	70	2	27	2 (U.S.)	1919	1,350X80	23	22
				1 (U.S.)	1943	800X80	31	22
				1 (U.S.)	1968	1,200X110	35	22
				1 (Can.)	1895	900X59	17	22
Lake Superior, St. Marys River to Duluth	383	-	-	-	-	-	-	-



GREAT LAKES-ST. LAWRENCE RIVER DRAINAGE BASIN

FIGURE I

FIGURE I



WATER SURFACE ELEVATIONS (IGLD, 1955)		
	CHART (LOW WATER) DATUM	LONG-TERM AVERAGE (1900 - 1976)
LAKE SUPERIOR	600.0	600.4
LAKES MICHIGAN-HURON	576.8	578.7
LAKE ST. CLAIR	571.7	573.1
LAKE ERIE	568.6	570.4
LAKE ONTARIO	242.8	244.8

GREAT LAKES - ST. LAWRENCE RIVER PROFILE

FIGURE 2

FIGURE 2

combined populations of Canada and the United States, live in this area. This system also serves the large Canadian mining operations in Quebec and Labrador and metropolitan areas on the St. Lawrence River in Quebec.

The Midcontinent of North America is a highly productive area. It produces about 34 percent of the combined gross national products of the United States and Canada, a third of their capital investments and about 30 percent of their combined personal incomes. Its industrial- and agricultural-based economy accounts for 37 percent of values added to manufacture in Canada and the United States, and over 42 percent of the two countries' total agricultural income. Heavy industry is predominant (steel and other metals, transport equipment, and machinery). The agricultural sector is concentrated on grains, livestock, dairy and poultry products, with much of this production being surplus to the area's requirements. At the same time, the region is a net importer of light and diversified industrial products, fiber, fish and forestry products. The Midcontinent region depends heavily upon transportation, initiating 42 percent of the total tonnage of rail freight in the United States, and 45 percent of the rail movement in Canada, and being the destination for over 41 percent of the shipments of the United States, and 38 percent of Canada. Moreover, it is the strategically located centre of both nations through which most of the other east-west interregional traffic and much of the north-south contiguous trades must flow. The United States Midcontinent portion generates over one-third of the nation's exports of manufactured products.

Section 2

EVALUATION METHODOLOGY

2.1 Introduction

A small change in the regime of water levels in any part of the Great Lakes - St. Lawrence River system can have an effect on the cost of shipping certain bulk commodities in the system. This section describes the methodology which was established by the Navigation Subcommittee to assess those impacts quantitatively. Basically, the methodology is a detailed mathematical procedure which calculates the annual cost of transporting bulk waterborne commerce in the system under any given regime of water levels. Benefits or losses to the shipping industry are determined by comparing the transportation cost under an alternative scenario to the cost under the base condition (where Lake Erie is unregulated). The rationale behind the methodology is based on the effect of changes in water depth on the allowable draft and loading of ships. This is discussed in Section 2.2, and the major assumptions used in establishing the assessment model are given in Section 2.3.

Because of the comprehensive level of detail in the assessment model, the model was computerized, using three programs. The component elements of these programs are described briefly in this section, and are described fully in Annex C to this appendix. The complete program listings are also included in Annex C.

2.2 Rationale for Assessing *Economic Impacts*

The relationship between lake levels and the cost of transporting bulk commodities is based on the allowable draft of shipping. Lake vessels tend to take advantage of every inch of available depth because shipper's profits essentially come from the last few inches of loading. In the Great Lakes-St. Lawrence River system, allowable draft is limited by one of two factors, either the depth of water available in the harbors and connecting channels between the lakes, or the legal allowable draft specified under Seasonal Load Line Regulations. Except under very high water conditions, available water depth is generally the governing factor.

When the water depth in a part of the system is altered by a change in lake levels, the allowable draft, and therefore the loading of ships wishing to use that part of the system at that time may be affected. For instance, 230 tons of cargo must be left behind for every inch less in the allowable draft of a Class 10 (1,000-foot) laker. Any change in the loading capacity of ships on a route, results in a change in the number of trips required to move a given volume of goods over that route. A change in the number of trips required, changes the total operating expenses involved, in direct proportion to the time involved. Thus, the total cost for transporting those goods will change inversely with the change in water levels. In this study, a raising of transportation cost is termed a "loss" to navigation, and lowering of costs is termed a "benefit."

Because of the physical maximum draft capability of ships, as set by their Seasonal Load Line Regulations, there will not necessarily always be a benefit or loss associated with a change in levels. For instance, there will be no further benefit realized when water depths are increased beyond the ships' loading capability. Similarly, there is no loss incurred by lowering water depth, if vessel load limit regulations remain the controlling factor.

Draft limitations in the Welland Canal and Montreal-to-Lake Ontario portion of the St. Lawrence Seaway also tend to buffer the effect of small water level changes on shipping which pass through those reaches. In these portions of the Seaway, allowable draft is restricted to 26 feet regardless of small fluctuations in water depth above the minimum profile (controlling depth). Therefore, additional water depth above controlling depth provides no benefit. However, lowering the depth below the controlling depth would result in a decrease in allowable draft and a loss to shipping.

This reasoning, in combination with the basic assumptions regarding future operations of the system, which are outlined in the next section, forms the basis of the evaluation methodology.

2.3 Major Assumptions

The assessment methodology is composed primarily of forecasts and projections concerning the operation of the future navigation system. There are many things political that can affect the future operation of the system that cannot be predicted very far in advance. These include wars, major depressions and government transportation policies. To cover the uncertainties in these areas, the following assumptions were made:

1. There will be no wars or national economic depressions during the period of projection.

2. Policies, including those concerning tolls and user charges, will not change to an extent which would seriously unbalance the present relationships between modes of transportation.

Regarding the overall philosophy of the system's operation, it was assumed that existing trade patterns and national fleet utilization on the lakes would continue essentially unaltered. This was mainly because of the absence of any current indication that the future would bring significant change. Specifically, the assumptions in these areas are as follows:

3. Except for some new or changed sources and markets for portions of some bulk trades (e.g. western coal), there will be no other radical changes in the sources and markets of the principal commodities moving on the Great Lakes, and therefore, no other major changes in the present general pattern of traffic.

4. The patterns and proportions of utilization of the two national fleets in the lakes bulk trades will remain unchanged.

Further details regarding trade patterns and fleet utilization are given in Sub-sections 2.5.1 and 2.5.2.

Since major structural changes to the system are uncertain at this time, the following assumption was made:

5. The major physical make-up and operational aspects of the navigation system, as it presently exists, will remain essentially unchanged for the entire period of projection. That is, there will be no major development or modernization, except the Poe Lock which will be permitted to pass vessels of 1,100 feet by 105 feet after 1990.

The major structural features of the system currently are as follows:

a. 35-foot minimum depth in the St. Lawrence Ship Channel up to and including some berths in Montreal Harbor;

b. 27-foot controlling depth in the main canals and channels in the system above Montreal;

c. Maintenance of present controlling depths in all major Canadian harbors handling a significant volume of one or more of the commodities analyzed, for the entire period of projection;

d. The tonnage shipped to United States harbors with less than 27 feet available water depth will decrease in the future as harbors are deepened to allow more efficient operation;

e. 26-foot maximum permissible draft in the St. Lawrence Seaway, including the Welland Canal;

f. 1.5-foot minimum allowable underkeel clearance in all parts of the system except the Seaway and the Welland Canal;

g. 730 feet by 76 feet maximum vessel dimensions for all locks except the Poe Lock; and

h. 1,000 feet by 105 feet maximum vessel dimensions for the Poe Lock until 1990, and 1,100 feet by 105 feet after 1990.

As directed by the Study Board, Assumption 5 included the continuance of the present navigation seasons for the various reaches of the system. The navigation seasons which were used for the entire period of projection were as follows:

a. Montreal Harbor to the Gulf of St. Lawrence - year round;

b. Lake Ontario and the Montreal-to-Lake Ontario portion of the Seaway - 8.5 months, April 1 to December 15; and

c. The Welland Canal, Lake Erie and the Upper Lakes - 9 months, April 1 to January 1.

Further discussion of the physical and operational characteristics of the navigation system used in this study appear in Sub-section 2.5.3.

One final, but important aspect of navigation for which a major assumption was necessary was the capability of the system to accommodate future growth. For the period of projection ending in 2035, it is the capacity of the lock systems in the Welland Canal and at the Soo that are the potential bottlenecks in the system. This is discussed further in Sub-section 2.5.3. Under the assumption of no major reconstructions or modernizations, the assumption regarding these facilities is:

6. The Welland Canal will reach capacity in terms of lockages per day, by the early 1990's and the Soo Locks by about 1995.

Because of the continuous intense study with respect to improving lockage procedures being carried out by the operators of these facilities, this assumption was relaxed in a more optimistic "high growth" scenario in order to test the sensitivity of the study results to alternative future traffic volumes. The results of the sensitivity analysis are discussed in Section 4 of this appendix.

2.4 Base Year and Forecast Years

The economic analyses were based upon July 1979 cost levels, and the United States and Canadian dollars were assumed to be at par. The base year for computing the present worth of benefits or losses was 1985.

Forecasts for the model were produced for the years 1985, 2000, and 2035. Therefore, the model returns economic results for those years. For the purposes of producing total present worth and average annual benefits or losses for each regulation plan for the full 50-year period of projection, interpolation between forecast years was done using a curve of constant rate of change.

The discount rate used to establish present worth and average annual benefit or loss (or average annual annuity) was 8-1/2 percent.

2.5 The Economic Assessment Model

2.5.1 General

The assessment model is contained in three computer programs. The first program computes the difference in monthly mean water levels between the basis-of-comparison regime and any alternative regime, by lake, for each month of each year in a 77-year study period, the length of period used to establish the basis-of-comparison (1900-1976). These changes in water level are then used to compute the new regime of water depths available throughout the system, based on shipping datum.

The second, more complex program determines for each month the allowable draft of shipping along each of the many trade routes in the system, based on the available water depths computed in the first program. Among the factors involved in this computation are underkeel clearance allowances, seasonal load line regulations for the various classes of ships and the type of commodity carried, draft restrictions in canals and channels and the design drafts of the ships. These allowable drafts are, in turn, converted into shiploading capability, from which the number of trips required to move the system's cargoes is calculated. These computations require detailed knowledge of the many aspects of fleet composition, vessel characteristics operating speeds, trade distribution by national fleet and ship size, and several other operational characteristics of the system, all of which are discussed later in this section.

The final steps in the second program compute the ships' operating time required to move the cargoes, and thus, on the basis of vessel operating costs for the various vessel sizes employed, the transportation cost under the given regime of lake levels is computed. This computation is carried out on a monthly basis by country, type of commodity, type of trade (domestic, import or export), trade route, size (class) of vessel and type of harbor (shallow-draft or deep-draft) for the full 77-year period of study. The 77 years of results are averaged for each month in a final table, along with the total annual cost of transportation in the system.

The full sequence described above is repeated for each of the 3 years evaluated (1985, 2000, and 2035); the value for each year is the average of 77 values computed with the given levels scenario in operation for the full 77-year period. For each year (1985, 2000, and 2035) the model contains a complete set of forecasts for commodity tonnages, trade patterns, fleet composition, vessel characteristics, system operational data and so on. The results for the 3 years are compared with the costs under the basis-of-comparison condition, and the differences are termed the "loss" or "benefit" to navigation. A "loss" occurs if an alternative levels scenario causes the transportation cost to rise, and a "benefit" is realized if the new scenario lowers the cost.

The third computer program step simply converts to present worth (in 1985) the annual cost difference between basis-of-comparison and alternative scenario, using an 8-1/2 percent discount rate. This is done by assuming a curve of constant rate of change for intermediate years between the forecasts for 1985, 2000, and 2035. An equivalent constant annual annuity for the full 50-year period of projection is also computed.

The three basic components of the main portion of the evaluation model (second program) are discussed in the following sub-sections entitled "Existing and Prospective Bulk Commerce," "Existing and Prospective Bulk Fleets" and "Physical and Operational Characteristics of the Navigation System." In many areas it was necessary to analyze and report upon United States and Canadian operations separately because of their differences.

2.5.2 Existing and Prospective Bulk Commerce

The methodology is based on the four principal dry bulk commodities in the system, namely iron ore, coal, limestone, and grain. These four commodities comprise about 85 percent of the system's commerce. Currently more than 200 million tons of cargo move in these trades annually, in a complex network of domestic, export, and import trades. In addition to being the major portion of the system's traffic, the bulk trades are the most sensitive to changes in water level because the vessels employed in these trades generally grasp every opportunity to take full advantage of available water depths.

The bulk commodities are shipped in specially developed lakes vessels which are designed to operate efficiently in the Great Lakes system. There are two national fleets of lake vessels, one Canadian and one U.S., which transport all of the trades in these four commodities within and between the two countries.

The remaining 15 percent of Great Lakes traffic is composed of a number of cargoes including petroleum products, newsprint, rock salt, iron and steel products, cement, chemicals, and many other goods which either are carried by smaller, lesser draft vessels which generally do not take full advantage of available water depths, or are shipped in quantities too small to warrant separate analysis in this study. For example, petroleum products move in small tankers to a large number of receiving ports, with a tanker typically making many calls on each trip. The effect of low water levels is to cause the shippers to alter their sailing plans to call at deeper harbors first, then at shallower harbors when their load has been reduced. While this can cause some inconvenience, the effect on costs is not great and would be extremely difficult to calculate. For this reason, no detailed evaluation of this traffic was carried out. Newsprint is carried entirely in small ships which are rarely affected by water levels in the ports to which they trade. Commerce in rock salt on the Great Lakes has increased somewhat in recent years. However, it too is moved mainly in relatively small vessels which are not greatly affected by water level fluctuations, and therefore no detailed evaluation of this traffic has been made.

The 15 percent also includes overseas general cargo trades which employ specialized lake-ocean carries. Although, overseas cargo is of high value, traffic to and from the Great Lakes must transit the 27-foot St. Lawrence Seaway. Since the Seaway restricts draft to 26 feet, this traffic cannot take advantage of water depths greater than about 27.5 feet in the harbors on the lakes (allowing 1.5 feet for underkeel clearance). Since lake levels are such that harbor depths are rarely below this depth, overseas, general cargo traffic would not be affected significantly by a small change in the levels regime. In addition, many of these vessels call at several ports and therefore often do not travel fully loaded. Thus they do not normally take full advantage of water depths available. For these reasons, overseas general cargo traffic was excluded from this analysis.

Detailed analyses were made of present and prospective Canadian trades in the four bulk commodities. The historical data, policy guidance and assistance needed to develop forecasts for the Canadian bulk trades were obtained from a variety of government and other sources, including Transport Canada branches, Statistics Canada, the St. Lawrence Seaway Authority and the National Harbours Board. Base year commerce tonnages were developed from detailed historical shipping records for each port-to-port route in the domestic, export and import trades. The "present" (1976) or base condition on a trade route was taken to be either the average of recent historical trade volumes (for the years 1973 through 1976), or if a trend was known to exist, the latest trade figure on that route.

Forecasting rationale was applied to each trade route to develop a set of future trade patterns covering the 59-year period from 1976 through 2035. The port-to-port forecasts were aggregated into lake-to-lake groupings to coincide with the manner in which the hydrologic data is generated. The lake-to-lake forecasts for the years 1985, 2000, and 2035 were used in the assessment model.

The United States traffic projections were obtained from a transportation planning tool (The Great Lakes Route Split Traffic Model) developed by the Corps of Engineers for use in its navigation studies. The output is in the form of tonnage forecasts. Improvement alternatives change the cost basis to users and therefore tonnage levels. The three principal data inputs to the model are: 1) forecasts of origin/destination cargo flow*; 2) a file of transportation rates, and 3) a service profile from interviews of shippers. The model operates on these data to predict Great Lakes traffic levels. The lock capacity of the Great Lakes system to accommodate the predicted cargo flow is then evaluated.

The traffic forecasts are built into the model and classified into 22 bulk commodity groups such as coal and iron ore and 15 general cargo groups such as prime containers for food and machinery. The bulk cargo forecasts were obtained from expert secondary sources such as the U.S. Bureau of Mines and U.S. Department of Agriculture. The utility needs of western coal were further refined by the 1975 interview program conducted by A.T. Kearney (Great Lakes/St. Lawrence Seaway Traffic Forecast Study...Contract No. DACW-23-75-C-0052).

Recent total bulk commerce tonnages (by commodity) on the Great Lakes are summarized in Table D-2. The 1973-to-1976 average trade volumes and future trade volumes for each of the lake-to-lake routes in United States and Canadian domestic, export, and import trades of iron ore, coal, limestone, and grain are given in Tables D-3 through D-6. These tables include only those portions of the bulk trades which move across, into or out of the Great Lakes-St. Lawrence River System by Canadian and United States registered vessels. Bulk shipping by foreign vessels in the Canadian trades above Montreal is insignificant in any event; the major movement being about 700,000 tons annually of grain shipped directly overseas by ocean vessels from Thunder Bay. Similarly, there is some U.S. grain that is carried in foreign vessels. For the purpose of this analysis it is assumed that all U.S. grain is shipped in either U.S. or Canadian vessels.

* These forecasts of iron ore, coal, limestone and grain were made in 1975-76 by A.T. Kearney Inc., based on expert secondary source predictions of future demand. The base traffic year was 1972. The projection methodologies are described in detail in "Great Lakes/St. Lawrence Seaway Traffic Forecast Study Technical Appendices", August 1976.

Table D-2 - U.S. and Canadian Bu'k Commerce on the Great Lakes 1972-1979

	1972	1973	1974	1975	1976	1977	1978	1979
	(1,000 short tons)							
Total All Commodities	190,832	208,590	195,363	186,395	191,515	170,781	199,602	208,229
Iron Ore Shipments on Lakes								
Total	90,283	105,890	98,088	89,562	97,012	75,096	99,584	103,101
From U.S. Canadian Great Lakes	78,052	90,534	84,473	76,194	77,050	53,686	86,012	88,197
From Eastern Canada	12,231	15,356	13,615	13,368	19,962	21,410	13,572	14,904
Coal Shipments								
Total	43,196	39,586	34,966	39,179	37,487	38,984	37,766	45,833
From Lake Erie Ports	38,001	34,101	29,801	33,175	31,736	32,032	31,628	37,044
From Lake Michigan Ports	5,195	5,354	4,044	3,943	3,199	3,035	2,762	2,392
From Lake Superior Ports	-	131	1,121	2,061	2,552	3,917	3,376	6,397
Grain Shipments								
Total	20,007	20,226	19,213	19,973	18,812	19,481	22,498	22,319
To U.S. Ports	1,879	1,461	1,288	1,567	1,706	1,520	1,595	1,466
To Canadian Ports	18,128	18,765	17,925	18,406	17,106	17,961	20,903	20,853
Limestone Shipments Total	37,346	42,888	43,096	37,681	38,204	37,220	39,754	36,976
	INDEXES 1972 = 100							
TOTAL ALL COMMODITIES	100	109	102	98	100	89	105	109
Iron Ore	100	117	109	99	107	83	110	114
Coal	100	92	81	91	87	90	87	106
Grain	100	101	96	100	94	97	112	112
Limestone	100	115	115	101	102	100	106	99

Source: Lake Carriers Association Annual Reports

Note: Lake Carrier Assoc. iron ore statistics in long tons were converted to short tons. Also, the grain statistics were converted from bushels to short tons. For statistical convenience the weight factors for wheat and soybeans were applied to the total. Slightly lower tonnage figures would have resulted if the lesser weight per bushel of corn and barley were averaged into the total.

Table D-3 - Great Lakes - St. Lawrence River
Iron Ore Traffic Forecasts

Type	Route: From	Route: To	Total Annual Trade (1000's of short tons): Present Average	1985	2000	2035
U.S. Domestic	S	H		7,300	8,400	8,000
		M		20,800	24,100	24,600
		E		39,500	47,300	47,700
	M	H		2,500	3,300	5,800
		M		5,500	7,200	13,600
		E		4,300	6,000	11,200
Total				79,900	96,300	110,900
Canadian Domestic	S	S	1,200	1,500	1,800	3,100
		E	100	1,500	1,500	1,600
		O	1,700	2,000	2,000	2,000
	H	E	-	-	100	100
	EX	O	2,800	3,400	4,900	8,500
Total			5,800	8,400	10,300	15,300
U.S. Export - Canadian Import	S	S	900	1,100	1,300	2,200
		E	100	800	900	500
		O	1,700	2,000	2,100	1,200
	M	O	200	300	300	300
Total			2,900	4,200	4,600	4,200
Canadian Export - U.S. Import	S	M	1,900	2,300	2,900	3,000
		E	200	200	300	500
	H	H	700	1,000	1,000	1,700
		M	300	300	400	800
		E	500	700	800	1,100
	O	E	400	-	-	-
	EX	M	3,200	3,900	4,400	4,400
		E	10,100	12,700	14,500	14,500
Total			17,300	21,100	24,300	26,000

Note: The route designators used in the data tables are the first letter of the lake or waterway name, for example, "S" for Superior, "SLS" for St. Lawrence Seaway and so on. The category "EX" refers to all points below Montreal.

Table D-4 - Great Lakes - St. Lawrence River
Coal Traffic Forecasts

Type	Route: From	Route: To	Total Annual Trade (1000's of short tons): Present Average	1985	2000	2035
U.S. Domestic	S	S		300	400	1,000
		H		7,600	8,100	7,300
		M		1,400	1,700	2,600
		E		-	9,000	8,600
	M	S		500	500	600
		M		4,300	5,300	9,600
	E	S		2,300	2,700	3,600
		H		100	200	500
		M		4,300	5,900	11,200
		E		3 400	5,100	12,000
Total				24,200	38,900	57,000
Canadian Domestic	S	H	-	-	100	100
		E	100	3,500	4,800	4,400
		O	200	300	300	300
	EX	E	200	200	200	200
Total			500	4,000	5,400	5,000
U.S. Export - Canadian Import	E	S	2,500	3,400	4,400	6,500
		H	4 600	5 100	6,300	8,500
		E	3,800	7,000	7,000	9,000
		O	8,000	9 800	8 600	5,400
		SLS	200	300	200	100
Total			19,100	25,600	26,500	29,500
Canadian Export - U.S. Import	Nil					

Note: The route designators used in the data tables are the first letter of the lake or waterway name, for example, "S" for Superior, "SLS" for St. Lawrence Seaway and so on. The category "EX" refers to all points below Montreal.

Table D-5 - Great Lakes - St. Lawrence River
Limestone Traffic Forecasts

Type	Route		Total Annual Trade (1000's of short tons)			
	From	To	Present Average	1985	2000	2035
U.S. Domestic	S	H		700	800	1,100
		M		1,000	1,100	1,400
		E		600	700	800
	H	S		700	700	800
		H		6,600	8,400	13,900
		M		8,400	10,400	16,500
		E		6,900	8,000	11,700
	M	H		800	1,000	1,600
		M		3,400	4,200	6,700
		E		1,000	1,200	1,700
	E	H		700	1,000	1,600
		E		1,600	1,900	2,900
Total				32,400	39,400	60,700
Canadian Domestic	SLS	O	2,400	2,900	3,500	3,500
U.S. Export - Canadian Import	H	S	600	1,100	1,300	1,600
		H	600	1 100	1,400	2,000
		E	400	500	600	800
		SLS	200	300	300	200
	E	H	100	100	200	200
Total			1,900	3,100	3,800	4,800
Canadian Export - U.S. Import	E	E	1,200	1,300	1,700	2,500

Note: The route designators used in the data tables are the first letter of the lake or waterway name, for example, "S" for Superior, "SLS" for St. Lawrence Seaway and so on. The category "EX" refers to all points below Montreal.

Table D-6 - Great Lakes - St. Lawrence River
Grain Traffic Forecasts

Type	Route From	Route To	Total Annual Trade (1000's of short tons) Present Average	1985	2000	2035
U.S. Domestic	S	M		100	100	100
		E		500	600	800
		O		1,100	900	700
		SLS		100	100	100
Total				1,800	1,700	1,700
Canadian Domestic	S	H	1,300	1,600	2,100	3,600
		E	400	400	600	1,000
		O	400	500	500	500
		SLS	3,000	3,700	4,100	4,100
		EX	6,500	8,100	9,000	9,000
	H	H	-	100	100	100
		E	-	-	-	100
		SLS	200	200	200	200
		EX	200	300	300	300
	E	H	-	-	-	100
		SLS	100	100	100	100
		EX	100	100	100	100
	SLS	SLS	-	-	100	100
		EX	100	100	200	300
Total			12,300	15,200	17,400	19,600
U.S. Export - Canadian Import	S	SLS	200	200	300	300
		EX	600	800	900	900
	H	SLS	100	100	100	100
		EX	100	200	200	200
	M	O	200	200	200	400
		SLS	100	100	100	100
		EX	800	1,000	1,200	1,200
	E	O	500	600	600	600
		SLS	200	300	300	300
		EX	1,500	1,800	2,000	2,000
Total			4,300	5,300	5,900	6,100
Canadian Export - U.S. Import	S	M	300	300	300	400
		E	-	-	100	100
Total			300	300	400	500

Note: The route designators used in the data tables are the first letter of the lake or waterway name, for example, "S" for Superior, "SLS" for St. Lawrence Seaway and so on. The category "EX" refers to all points below Montreal.

For the purpose of this study, domestic trade refers to trade between two ports in the same country, at least one of which is in the Great Lakes-St. Lawrence River system. Export trade refers to shipments to any foreign destination which originate at a port in the system, and import trade refers to all shipments which land at a port in the system from any foreign origin. For example, United States grains shipped to Canadian elevators on the St. Lawrence River for transshipment overseas are included as Canadian imports.

Descriptions of the forecasts for each of the four commodities are given in the following paragraphs.

United States Commerce - Iron Ore: Iron ore represents the major commodity moved on the Great Lakes. In the 1970's about 85 million tons of ore moved annually to U.S. steel mills bordering the lakes. Nearly 70 million tons moved in domestic trade from traditional Lake Superior sources to various demand regions on Lakes Michigan, Huron, and Erie. Imports from Canada represent the bulk of the iron ore foreign trade on the Great Lakes, totaling the remaining 15 million tons.

Several major steel companies have developed large fleets of ore carriers on the lakes in order to take advantage of the overwhelming cost savings that exist. As such, over 97 percent of Superior District (i.e., Minnesota, Wisconsin and Michigan) iron ores destined for Great Lakes steel facilities move on the lakes.

Two important trends in the steel industry key to any forecast of iron ore production and movements in the United States are: 1) beneficiation and pelletization, and 2) furnace type.

As the high grade (i.e., high iron content) iron ores of the United States are depleted, lower grade resources (taconite) must be utilized in order to meet demand. However, it is wasteful to transport unneeded materials along with the iron ore. Thus, by various separation processes, U.S. iron ore producers are shipping higher grade ore from the mines than the normal "run-of-mine" grade. This process is called beneficiation. The separated ore is then pelletized for ease of shipment. This process has manifested itself as a gradual shift to movement of higher iron content ores. More than 95 percent of all ores are beneficiated and over 2/3 of all ore produced is pelletized.

It appears that by the late 1980's the open hearth furnaces will be phased out and totally replaced by the more efficient Basic Oxygen Furnace (about 75 percent of production) and the electric furnace (25 percent).

U.S. and world reserves of iron ore are sufficient to maintain present and increased levels of production throughout the forecast period of this study. Economical beneficiation and pelletization has allowed the development of large taconite (lower grade ore) reserves. This will ensure continued lake movements of iron ore, as many steel firms have recently invested in large pelletization facilities, (particularly in northern Minnesota) and in self-unloading vessels to transport pelletized ore. About 85 percent of the total U.S. production is produced in the Lake Superior District (65 percent of the total is produced in the Mesabi Range alone).

Over 98 percent of iron ore used in the United States was used in blast furnaces for the production of iron and steel. The small remaining portion was used in the manufacture of miscellaneous products (primarily cement). Traditionally, growth in the steel industry is not entirely reflected in the growth of iron ore movements. Increased concentrations of iron in the ore shipped due to beneficiation and pelletization, along with growing usage of electric furnaces which require a 100 percent scrap charge, have caused the growth in iron ore shipments to lag behind the growth rate of steel manufacturing. This has been particularly true as higher grade reserves are being depleted and the process of taconite beneficiation has emerged.

Domestic traffic is expected to only increase at a rate of 0.8 percent. Traffic of Lake Superior origin, which uses the locks at Sault St. Marie, will peak about the year 2000. The Lake Michigan traffic from the port of Escanaba is unconstrained by locks and follows the normal growth in economic potential. U.S. imports of iron ore from Canada are expected to only increase at a rate of 0.7 percent. This traffic is restricted from further growth by the capacity conditions at the Welland Canal. Canadian imports of U.S. ore from Lake Superior are expected to increase at the total rate of iron ore growth because of no lock capacity constraints. Almost all of the Canadian domestic iron ore movements do not require passage through a lock system. Therefore, the rate of growth of 1.63 percent parallels the growth in steel production.

United States Commerce - Coal: Coal reserves in the United States are vast. During the forecast period under consideration in this study, there will not be any shortages of coal due to reserve depletion on either a national or regional basis. Spot shortages may occur in the short run due to limited production capacity.

Approximately 25 million tons, or 60 percent of total movements in the 1970's were domestic movements of coal, generally of thermal quality, moving annually to electric utilities in the U.S. The remaining 18 million tons were exported from Lake Erie ports to Canadian users. Approximately half of this exported coal is of thermal quality moving to Ontario Hydro electric generating plants located along the Lake. The other half of this exported coal is of metallurgical grade moving to Canada's "Big Three" steelmakers, for coking purposes.

The traditional pattern of coal movements has been out of Lake Erie ports to Canadian and western U.S. lake destinations. Nearly 85 percent of all Great Lakes movements of coal have traditionally moved out of the Lake Erie ports of Ashtabula, Conneaut, Lorain, Sandusky, Toledo, and others. For movements to Lake Superior ports, a return haul of iron ore makes this route profitable to the ship owner. Movements to Canada (principally Lake Ontario) are relatively short haul and can almost be considered a "shuttle" service. Coal also moves through Chicago to other Lake Michigan and Lake Superior ports to satisfy utility demands.

These patterns of coal movement on the Lakes have developed due to the location of utilities and steel plants on the Lakes. Many of these facilities do not have rail handling terminals capable of the volume that is moved by water, and, therefore are restricted in large part to water receipt of coal unless major rail investments are made.

However, future growth of coal movements on the Great Lakes will come from movements of Western coal to utilities located on Lake Huron and Lake Erie. These coal movements will be in addition to Eastern coal movements.

In 1974, it was estimated that 45 percent of the total power generated by electric utilities was generated by coal. This fact is mirrored by the fact that about two-thirds of all coal production was used by electric utilities. Fifteen percent was used for coking, 8 percent for export and the remainder for other industrial and retail users (primarily cement plants and paper mills).

On the Great Lakes, these markets are represented by the electric generating stations of Detroit Edison, Consumers Power, Wisconsin Electric and the Upper Peninsula Generating Company, by the coking facilities of the Canadian Steelmakers STELCO, DOFASCO, and Algoma Steel, and by the paper mill of Fort Howard Paper near Green Bay, Wisconsin.

The supply of coal traditionally moving on the Great Lakes comes from Kentucky, West Virginia, Southern Ohio, Western Pennsylvania and to some extent from Southern Illinois. These coal sources typically have higher sulfur content, but also have a high BTU content. This BTU/sulfur relationship is the single most important factor that will affect coal movements on the Great Lakes.

In this study, coal projections were based on assumptions which relied upon current conditions and plans. Western coal movements were not included in the forecast base unless some reasonable assurance could be made as to its ultimate usage. Specifically, it was assumed that:

1. Few, if any, existing facilities would be converted to Western coal due to high conversion costs;

2. Only new facilities that have announced plans for use of Western coal would be included in the forecast;

3. Stack gas scrubbers would be economically efficient and available by 1990;

4. Current emission standards will remain unchanged throughout the forecast period;

5. Variances to burn high sulfur coal will be extended until stack gas scrubbing technology becomes available;

6. Canada will adopt emission standards that will not preclude usage of U.S. Eastern coals; and,

7. Continued delays will retard the development of nuclear power generation facilities.

Projections were then made by contacting the individual utilities moving the coal or planning the move. This approach was taken since these movement volumes will show large jumps as new facilities come on stream. Timing, therefore, is of greatest importance in the forecast of Western coal movements. This approach was feasible since relatively few users represent the majority of coal demanded in the Great Lakes.

Traditional movements of Eastern coal to lakeside utilities (particularly on the southern shores of Lake Superior and on Lake Michigan) are projected to continue with moderate growth. Individual growth rates are based on the growth rates of utilities earnings in the destination region developed by the Bureau of Economic Analysis in their OBERS (Office of Business Economics - Economic Research Service) projections.

Projections of coal movements to Canada were taken directly from company contacts with Ontario Hydro, DOFASCO, STELCO, and Algoma Steel.

Where possible, all projections were checked relative to published forecasts and consistency was attained.

Actual coal traffic on the Great Lakes is expected to increase from 25 million tons in 1985 to 81 million tons in 2035 for an average annual rate of change of 1.89 percent. In particular, traffic with a Lake Superior origin is expected to show dramatic growth. Traffic levels do not increase after the year 2000 because of lock capacity constraints at Sault Ste. Marie. Overall, U.S. coal exports to Canada are expected to increase from 19 million tons to 35 million tons for an average annual rate of increase of 1.0 percent. Exports using the Welland Canal to get to Lake Ontario have no increase in traffic levels after the year 1990 because of capacity conditions. The Erie to Superior traffic is unconstrained because of utilization of ships that can fit through the smaller uncongested locks at Sault Ste. Marie.

United States Commerce - Limestone: Limestone is the third largest volume commodity on the Great Lakes. The main use of limestone moving on the Great Lakes is in the steel industry as a flux in blast and open hearth furnaces. Flux helps remove impurities from the molten metal. Since lime is a perishable commodity, limestone is transported to the steelmaking site where it is crushed and processed into lime.

Limestone is also used extensively by the construction industry as an aggregate, land fill, road material or in railroad ballast. Other uses are as an input material for Portland cement manufacture, and in the chemical industry.

Limestone reserves in the Great Lakes area occur near the western end of Lake Erie in Ohio and Michigan, and along the south shore of the upper peninsula of Michigan. The State of Michigan has traditionally been the major source of limestone in the Great Lakes limestone shipments. Virtually all of the GL/SLS limestone traffic is captive traffic to the steel industry. As the steel companies are vertically integrated and largely self-sufficient in iron ore and coal, so are they in limestone.

The major limestone shipping ports are the ports of Stoneport, Rockport, Drummond Island, Calcite Harbor, and Port Dolomite on Lake Huron; Port Inland on Lake Michigan; and Cobourg and Port Colborne on Lake Ontario. The major destinations are the steelmaking facilities on the Lakes in the Chicago-Gary area, Detroit, and Cleveland and other Lake Erie ports.

Since limestone is found at or near the earth's surface in about 10 percent of the continental area and because limestone is such a low-valued commodity, the minimization of transportation cost becomes of utmost importance in determining supply sources. Consequently, virtually all of the limestone that is moved on the Great Lakes is both produced and consumed at lakeside.

U.S. domestic limestone traffic is expected to increase from 29 million tons in the base year to 61 million tons in 2035 for an average annual rate of change of 1.16 percent. Lock capacity constraints are not coming into play because limestone is assumed to be carried on ships small enough to fit through locks other than the Poe Lock at Sault Ste. Marie. The rate of growth to Lake Michigan steel centres is about 1.5 percent while rate of growth to Lake Erie steel centres is less than 1.0 percent. Limestone traffic with Canada as an origin and/or destination is expected to about double in the projected period from 6.6 million tons in the base period to 12 million tons in year 2035.

United States Commerce - Grain : Agricultural products (grain) represent the fourth largest commodity movement on the lakes. Most movements of grain on the Great Lakes are export for either overseas destinations or Canadian destinations as transshipment points for ultimate overseas destinations. As a result, the projections made in this section are highly dependent upon projected levels of U.S. agricultural exports.

The importance of grain movements is unquestioned. The potential geographic market area from Great Lakes transport services includes most of the prime U.S. field crop growing acreage. However, at this time, most exported grain (approximately 65 percent) moves through Gulf ports and not through Great Lakes ports.

The traditional movement of grain on the lakes is out of Western lake ports to overseas destinations, particularly Northern and Mediterranean Europe, and to milling centres in the East located on the lakes, particularly Buffalo, NY (wheat for milling).

The historical performance of the United States in terms of world-wide production and exports of grain is discussed in the following paragraphs.

a. Corn. The United States produces about half of the world's corn and supplies 90 percent of the world's corn exports. Most (approximately 85 percent) of the U.S. corn production is used for livestock feed; consequently, much of it never leaves the farm on which it was grown. The corn not used for domestic feed purposes is used for export, human consumption, industrial uses, and for seed. The principal industrial uses are wet millers producing starches, sugars, syrup, corn oil, and gluten feed. Dry millers make cereals and similar products.

U.S. exports of corn have risen significantly in the past 25 years. In recent years, there has been a sharp increase in the share of production exported, from 4 percent in 1950 to 24 percent in 1974.

The major importers of corn from the United States are Mediterranean Europe, Northern Europe, Communist Europe, Japan, and Canada. Total potential Great Lakes movements of corn are expected to grow at an average annual rate of 3.3 percent throughout the forecast period. This relatively high growth rate reflects continued dependence on the U.S. by overseas nations for food supplies.

b. Wheat. Wheat is a food grain as contrasted to the other grains which are often grouped into the category of feed grains. Because wheat is a food grain, it differs from the grain crops in that very little (usually far less than 10 percent) of the wheat crop is exported. The United States produces about one-eighth of the world's wheat crop.

The United States, Canada, Australia, and Argentina are currently the major wheat exporters. Currently, the major destinations of U.S. wheat exports are East Asia, Communist Europe, Japan, South Asia, eastern America, and Northern Europe. Total potential movements of wheat are only expected to double over the study period.

c. Soybeans. Except for a very small portion of the crop used as seed, practically all U.S. soybeans are exported or processed into oil or meal. Very little is used as feed. Increases in the nutritional value of this crop and advances in soybean oil processing and refining have greatly stimuated both foreign and domestic demand. In 1960, more than one-quarter of the crop (mostly unprocessed) was exported. However, by 1970 over half of the crop was being exported. Soybeans have become the leading U.S. agricultural export in dollar value and are second only to corn in the number of bushels exported.

The major importers of U.S. soybeans are Northern Europe, Japan, and Mediterranean Europe. Potential soybean movements on the Great Lakes are expected to increase more than tenfold by 2040. The average annual percentage increase is 3.5 percent per year.

d. Barley and Rye. The principal use of barley is as animal feed. Over half of the barley crop is typically used for this purpose. About a quarter of the crop is used by the distilling industry. The United States exports barley, however, the export demand for this crop has been declining. As is the case with feed grains, a major portion of the barley crop is typically consumed on the farm on which it is produced. Over the last 5 years, the U.S. has produced an average of slightly over 400 million bushels per year, of which an average 62 million bushels (or 15.3 percent) has been exported.

Rye is used mostly as an animal feed, for hay and pasturage, and as a cover crop. It is also used for bread and as a distillers grain in making whiskey and gin. Rye is a relatively unimportant crop in the United States because it grows well where wheat grows well, and wheat is the preferred crop. However, rye will produce a good crop on soil that is too poor to produce a good crop of wheat. Barley and rye potential movements on the Great Lakes are expected to less than double in the forecast period.

U.S. domestic traffic is basically a slow growth commodity, with lock capacity constraints on the Welland Canal after the year 1990 depressing growth in traffic. Export traffic is also affected by lock capacity constraints.

Canadian Commerce - Iron Ore: Present and projected Canadian Great Lakes iron ore trade volumes are given in Table D-3. Iron ore and iron ore concentrates make up more than 38 percent of Canadian commerce on the Great Lakes. In recent years, more than 26 million tons have been shipped annually. Iron ore is used exclusively in the production or iron and steel.

Canadian Great Lakes iron ore commerce consists principally of the movement of ore from Quebec-Labrador deposits up the St. Lawrence River to Canadian and United States steel mills on Lake Ontario, Lake Erie, the Detroit River and Lake Michigan. Smaller quantities of western Canadian ore move from Thunder Bay on Lake Superior and Georgian Bay to United States mills at Chicago, Detroit, Buffalo, and Cleveland. The planned major expansion of Stelco's mill at Nanticoke on Lake Erie will create a demand for an additional 1.4 million tons annually of western Canadian ore.

St. Lawrence Seaway Authority studies have shown that two factors essentially determine the movement of iron ore through the Seaway: the growth in demand for iron and steel products in the United States and Canada, and the ability of Quebec-Labrador ores to compete in the United States with Lake Superior and other foreign ores. Despite possible declines in demand for steel in certain sectors, for instance, the use of smaller automobiles, demand for steel is expected to remain strong; especially as the new, stronger, lighter steels are finding favour over other costlier metal alloys or petroleum based plastics. The proportion of Canadian iron and steel production in the Great Lakes is not expected to change. In fact, some major Canadian mills are planning to double their capacities by 1990, to keep abreast of the anticipated market.

It has been assumed that plans to construct a major new steel mill in the vicinity of Conneaut, Ohio, on Lake Erie will come about by 1990. This plant, and Stelco's expanded facilities at Nanticoke on Lake Erie, are expected to increase the demand for Seaway shipments of Quebec-Labrador ore.

Although continued expansion in production from the Labrador trough to fulfill United States import and Canadian domestic needs appears likely, at least in the intermediate term, no major expansions are anticipated in the operations of the Iron Ore Company of Canada, the Quebec-Cartier Mining Company and other principal mine operators. Growth will be gradual and proportional to general market growth.

Western Canadian ores are not expected to assume any greater role in supplying the United States growing import needs in the upper lakes. These supplies will continue to come mainly from foreign suppliers (South America) and Quebec-Labrador. Large proven reserves and the recently expanded infrastructure at the Quebec-Labrador mines will strengthen the area's competitiveness with South American sources.

In summary, it is expected that Canadian iron ore westbound through the Seaway will grow at about 2.5 percent per annum in short term, perhaps declining to 2 percent or so by 1990. After 1990, capacity limitations at the Welland will curtail further growth in traffic destined to the upper lakes, as some bulk traffic is displaced by higher valued general cargoes.

Canadian Commerce - Coal: Present and projected Canadian Great Lakes coal trade volumes are given in Table D-4. By far the largest volume of coal shipped in Canadian trades on the Great Lakes is imported from United States Lake Erie ports by steel mills at Sault Ste. Marie, Nanticoke and Hamilton, and Ontario Hydro's generating stations at Lampton on the St. Clair River, Nanticoke and Lakeview near Toronto. Smaller volumes of United States Lake Erie coal move to various Canadian users on the lakes, and a small amount of western Canadian coal moves domestically from Thunder Bay to the steel mills at Nanticoke and Hamilton. In recent years, Canada's total annual coal commerce on the Great Lakes has amounted to about 19.5 million short tons, of which 19 million tons was imported from the U.S.

Growth in the Canadian requirement for coal for steel making is expected to remain proportional to the growth in the requirement for iron ore. This was forecast to be generally about 2.5 percent per annum in the short term, declining to 2 percent or so by about 1990. Like other bulk commodities, coal traffic moving through the Welland Canal and Soo Locks may suffer declines when those facilities reach capacity around 1990 and 2000 respectively. Other Great Lakes coal traffic will continue to increase at about 2 percent per year until the year 2000, and at 1.5 percent thereafter. It is anticipated that Stelco's expanded facilities at Nanticoke will rely on traditional supply sources on Lake Erie for its coal.

Anticipating that the growth in demand for electrical energy will be increasingly met by expansion in nuclear-powered generating facilities, Ontario Hydro expects little growth in their coal requirements at Lakeview and Lampton. Both of these plants are supplied from Lake Erie. Likewise, its new facility at Nanticoke will import most of its coal from across the lake; but plans are being studied to supply about one-third of this plant's needs with western Canadian coal via Thunder Bay. New 1,000-foot Canadian built lakers may be used for this trade. The forecasts have been based on these plans coming to fruition.

Industrial and other miscellaneous uses of coal should continue to grow at about the same rate as population growth in the consuming regions. There will not, however, be much growth in Quebec's metallurgical coal requirements for its iron and steel industry. This coal is presently imported down the Seaway from Lake Erie, in small volume. Similarly, there is not expected to be any growth in the volume of Cape Breton coal entering the lakes, though some will continue to be supplied to the Hamilton steel industry.

Canadian Commerce - Limestone: Present and projected Canadian Great Lakes limestone trade volumes are given in Table D-5. Limestone is used primarily in the steel making and portland cement making processes. Some is used for aggregate for road building and the making of lime, other chemicals and fertilizer. Canadian Great Lakes traffic in this commodity has averaged about 5.5 million short tons annually in recent years. The main requirements for waterborne deliveries have been the Toronto area, Sarnia, Sault Ste. Marie and Michipicoten Harbor on Lake Superior. Toronto has been supplied traditionally with domestic limestone from Colborne on Lake Ontario. Nearly all other Canadian requirements are imported from the State of Michigan through United States ports on Lake Huron.

The future demand for limestone in the Canadian Great Lakes region will depend on the growth in each of the industries that use it. Limestone demands which are tied to the steel industry may be slightly lower in the future due to a change in technology which permits the use of less limestone per ton of iron produced. In the near term, limestone requirements in this sector should increase at about 2.5 percent per year and subsequently decline to 1 percent per year by about 1990.

A modest growth rate, somewhat reflecting general population and industrial growth in the Canadian Great Lakes region in general, has been used for other limestone requirements around the lakes. Two percent per year in 1980, declining to 1 percent per year by 1990, appears to be in line with other forecasts for minor bulk commodity commerce on the lakes. It is expected that future supply sources for Canadian needs will not change significantly; a fair assumption considering the very large known reserves in current supply areas.

Canadian Commerce - Grain: Present and projected Canadian Great Lakes grain trade volumes are given in Table D-6. Annual shipments of Canadian grain in the Great Lakes - St. Lawrence River system are in excess of 12.5 million tons. To this are added another 4.5 million tons of United States grain shipped from the upper lakes to Canadian elevators in the St. Lawrence for transshipment overseas, resulting in a total Canadian lakes grain trade of about 17 million tons annually. This represents about one-quarter of the country's total Great Lakes' commerce.

The main Canadian grain movements are western wheats moving eastward to lake ports and lower St. Lawrence River elevators for domestic use or export overseas. Most of this trade is through Thunder Bay. This traffic increased greatly following the opening of the Seaway in 1959. Today, the Seaway plays an important role in the world distribution of grain. Recent studies carried out by the St. Lawrence Seaway Authority indicate that the Seaway will probably maintain its position for years to come due to its location in the major grain surplus area of the world; the United States, and Canada. Grain moving eastward on the Seaway consists primarily of exports destined for Western Europe and the U.S.S.R. The Seaway Authority's studies have examined a large number of factors which will affect the future of these export trades, including the agricultural policy in Western Europe, world grain market conditions, as well as conditions at home such as prairie production, foreign aid policies, transportation system capacity in western Canada, modernization of Seaway grain handling facilities and transportation.

There has been nearly a 50 percent increase in prairie grain production over the past 20 years. It is expected that grain production will continue to increase throughout the forecast period due to improvements in agricultural management and increased usage of fertilizers. But the future rate of increase will be lower than in the past because Canada, like most other countries, is running out of land on which to grow food crops.

Canada's domestic demand for grain is for milling flour, livestock feeds and brewing purposes. Domestic demand is expected to increase at about the same rate as population growth, about 12 percent every 10-year period.

Canadian grain exports are expected to grow at a rate more or less proportional to world population growth (about 2.6 percent per annum) for the next 10 years or so. However, opinion varies on whether Canada will be able to maintain its present share of the world's wheat market (20 percent to 25 percent) and coarse grain market (10 percent), in view of the anticipated declining rate of increase in production in the western provinces. In line with the declining rate of increase in production, a declining rate of increase in exports was adopted after about 1990.

The proportion of the country's total grain exports, which will move eastward through Thunder Bay, will decline as markets in Japan and other Asian and Pacific Rim countries open up (these markets will be served by west coast terminals) and as the European Economic Community continues its protectionist purchasing policy. Additionally, anticipated markets in the Middle-East and North Africa which would be served through the Seaway, are not expected to become significant due to the unsuitability of Canadian wheats for the diets of those populations.

The net effect of developments in the export trades and the growth in the domestic market is an expected decline in the annual rate of growth for eastbound grain traffic from about 2.5 percent in 1976 to less than 2 percent by 1990. After 1990 eastbound grain traffic will continue to grow at a slow rate, but capacity problems at the Welland Canal are expected to dampen further growth in bulk traffic destined to Lake Ontario and the St. Lawrence

River. In addition, by about the year 2000 the United States Soo Locks are expected to begin experiencing capacity problems, causing the displacement of bulk commodities from the system in favour of higher valued general cargoes.

Seasonality: Recent historical data were analyzed to establish a seasonal distribution pattern for each of the four bulk commodity trades. It was assumed that the present shipping seasons on the Great Lakes, i.e., 9 months on the Welland Canal and the upper lakes and 8.5 months on Lake Ontario and the rest of the system downstream to Montreal, would not change significantly during the forecast period. Furthermore, there was no reason to believe that the pattern of shipping during the season would change significantly. Typical seasonal distribution curves for the bulk commodities are shown on Figure D-3. As the figure shows, during a typical season, traffic in each of the commodities builds up gradually during the first few weeks of April, peaks in May and again in October and declines rapidly in December. The specific projected seasonal distribution patterns for the United States and Canadian trades in iron ore, coal, limestone and grains are given in Tables D-7 and D-8 respectively.

2.5.3 Existing and Prospective Bulk Fleets

The world fleet has seen remarkable changes in the 1960's and 1970's. World ports deal with new, special purpose ships carrying such commodities as chemicals, molten sulphur, liquified natural gas, wine, and orange juice. Dry bulk carriers of 150,000 tons and tankers up to 400,000 and 500,000 tons have appeared. The years since World War II have marked the collapse of the historic Great Lakes package fleet trade, the demise of Great Lakes passenger ships, and the retirement through bloc obsolescence of several hundred small "canallers," uneconomical and incapable of survival in an era of mass production and mass movement. The Great Lakes fleet is now characterized by fewer but larger vessels, deeper draft requirements in harbors and channels, and emphasis on automated handling. The lakes region pioneered in vessel automation with the first self-unloading ships and the first giant dockside equipment for continuous automated handling of grain, coal, cement, and iron ore.

As of 1980, this fleet (comprising both United States and Canadian vessels) consisted of five vessel types totalling some 331 vessels. There were 163 dry bulk carriers, 93 self-unloaders, 46 tankers, 3 crane vessels, and 26 package freight vessels. The four bulk commodities analyzed in this study are carried by the dry bulk carriers, including regular bulk carriers and self-unloaders, and this group is the most significant in terms of both tonnage and number. These vessels are primarily involved in the bulk trades of iron ore, coal, limestone, and grain.

Of the 256 regular and self-unloading bulk vessels actively engaged in domestic dry bulk transportation in 1980, 87 percent were 600 or more feet in length. Ten ships are 1,000 feet long and 14 ships are between 767 feet and 858 feet in length. All of the ships greater than 730 feet long are United States ships. In terms of cargo capacity, 90 percent of the dry bulk fleet carries 10,000 long tons or better. The United States dry bulk fleet presently contains 136 vessels, and the Canadian fleet presently contains 120 vessels.

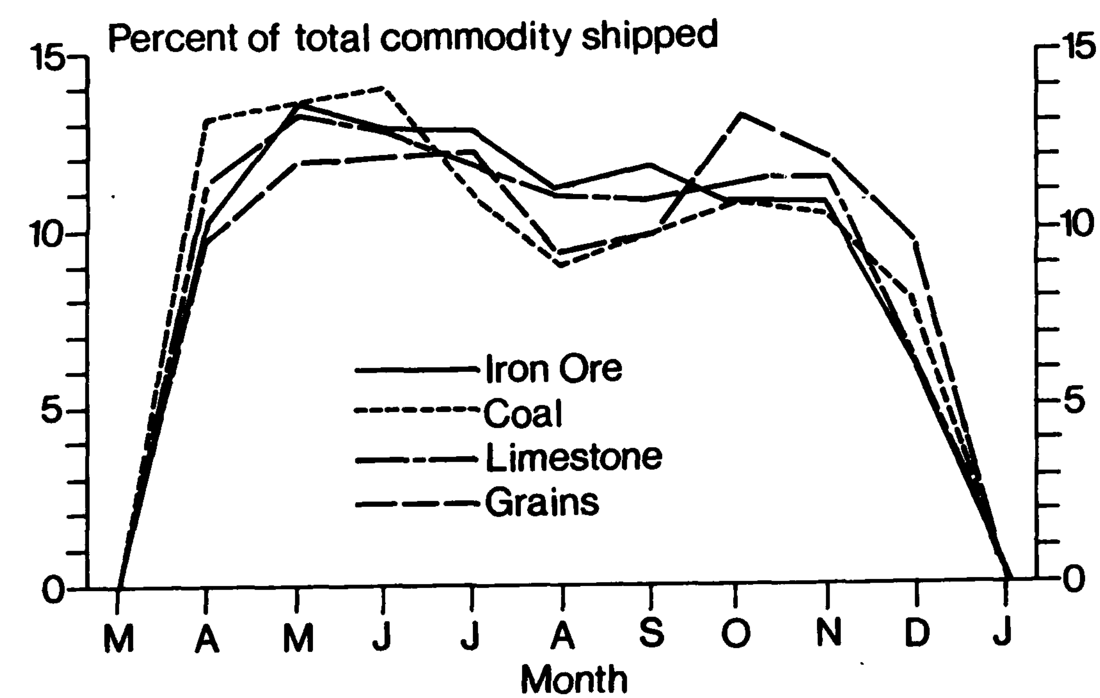


Figure D-3 Distribution of Canadian Great Lakes - St. Lawrence River dry bulk cargo traffic during the navigation season

Table D-7 - Distribution of U. S. Great Lakes Dry Bulk Cargo Traffic During Navigation Season

Commodity	Percent of Total Commodity Shipped								
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Iron Ore									
Routes on S, M, H, E	06.20	12.40	13.40	13.40	13.40	12.40	11.30	10.30	07.20
Routes on Ontario	08.00	13.00	13.00	13.00	13.00	12.00	11.00	12.00	05.00
Coal									
Routes on S, M, H, E	09.40	13.50	13.50	11.50	12.50	12.50	12.50	10.40	04.20
Routes on Ontario	10.00	13.00	13.00	13.00	11.00	09.00	11.00	10.00	10.00
Limestone									
Routes on S, M, H, E	08.00	13.00	12.00	13.00	12.00	12.00	12.00	12.00	06.00
Routes on Ontario	08.00	13.00	12.00	13.00	12.00	12.00	12.00	12.00	06.00
Grain									
Routes on S, M, H, E	08.00	11.00	10.00	11.00	12.00	12.00	13.00	14.00	09.00
Routes on Ontario	08.00	13.00	12.00	10.00	09.00	11.00	15.00	14.00	08.00

Note: Projection for the years 1976 through 2035.

Table D-8 - Distribution of Canadian Great Lakes Dry Bulk Cargo Traffic During Navigation Season

Commodity	Percent of Total Commodity Shipped								
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Iron Ore	10.17	13.61	12.79	12.79	11.23	11.84	10.84	10.75	6.07
Grains	9.75	11.88	12.14	12.16	9.42	9.86	13.17	12.04	9.59
Coal	13.21	13.65	13.99	10.97	9.07	9.77	10.99	10.49	7.91
Limestone	11.26	13.29	12.71	11.74	10.85	10.85	11.44	11.49	6.36

Note: Projection for the years 1976 through 2035.

Forty-five ships in use were built between 1898 and 1920, 34 ships in use were built between 1921 and 1940, 72 ships in use were built between 1941 and 1960, 105 ships in use were built between 1960 and 1980. Canada accounts for only 19 of the 79 ships currently in use that were built before 1940.

Self-unloaders are essentially adaptations of the dry bulk vessel. The basic difference is that the self-unloader is fitted with its own unloading system. This self-unloading capability results in a vessel that is efficient and flexible in its use. It is attractive to the ship operator because it requires a minimum of dock equipment. All that is needed is an adequately sized stockpile area within reach of the vessel's unloading boom.

The increased pelletization of iron ore opened a new segment of commerce to self-unloaders. Many natural iron ores have physcial characteristics that prevent them from being handled readily by belt conveyor systems. Since most self-unloaders use belt conveyor systems, they were excluded from the ore movement. Pellets, however, can be handled by belt conveyors.

Although both U. S. and Canadian fleets are composed of a mix of regular bulkers and self-unloaders, there are many important differences in fleet composition, fleet utilization, vessel characteristics and vessel employment between the two fleets. For this reason the two fleets are discussed separately in this report.

This section describes in detail the present compositions and operational characteristics of each national fleet. It also describes the forecasts of fleet composition and vessel characteristics which have been made to the year 2035, and the basis on which they were developed.

For the purpose of this study the fleets have been subdivided into 11 categories, or classes, according to overall length of the hull. These classes are defined in Table D-9. It is to these classes that reference is made throughout this report.

United States Fleet - Vessel Characteristics: Future additions to the United States fleet are expected to exhibit similar dimensions and operating characteristics to those now in service. The one exception being the possibility of ships up to 1,100 feet in length transiting the Poe Lock at Sault Ste. Marie after the year 1990. The characteristics of the existing and future United States fleet are shown in Tables D-10 and D-11.

United States Fleet - Distribution of Commerce by Fleet Nationality and Vessel Class: All United States domestic shipments are carried in United States vessels. However, as shown in Table D-12, very little export traffic is carried in United States vessels. It was assumed that the percentages of cargo carried by the United States and Canadian fleets would not change during the 50-year project evaluation period (1985-2035).

Table D-9 - Vessel Classification in the Great Lakes Dry Bulk Fleet

Class	Overall Length of Hull in Feet
1	under 400
2	400-499
3	500-549
4	550-599
5	600-649
6	650-699
7	700-730
8	731-849
9	850-949
10	950-1000
11	greater than 1000

Table D-10 - Vessel Data - U. S. Fleet (Iron Ore and Limestone)

Commodity Trade	Vessel 1/ Class	Vessel Capacity (Net tons)	Vessel Maximum Capacity (Feet)	Net Tons Per Foot of Immersion (For Drafts in Excess of 18 Feet)	Average Speed M.P.H. (Statute)	Seasonal Load Line Limits - (by months) (1) 6/1 to 8/31	(2) 5/1 to 5/30, 9/1 to 9/30	(3) 4/1 to 4/30, 10/1 to 10/31	(4) 11/1 to 3/31
Iron Ore & Limestone	5	22,000	26.0	1,270	13.9	26.0	25.4	25.2	24.9
	6	26,000	26.9	1,480	14.7	26.9	26.2	26.2	26.0
	6w	37,900	30.6	2,030	14.7	30.6	29.8	28.7	28.6
	7	30,400	29.1	1,620	14.7	29.1	28.4	28.1	27.8
	7w	39,400	30.6	2,050	14.7	30.6	29.9	28.8	28.6
	8	29,700	27.0	1,610	14.9	27.0	26.3	26.0	25.8
	8a	36,400	28.5	1,940	14.9	28.5	27.8	27.5	27.2
	8w	49,300	30.0	2,380	14.9	30.0	30.0	30.0	30.0
	9	49,800	27.9	2,420	14.9	27.9	27.9	27.9	27.9
	10	69,000	28.7	2,930	14.9	28.7	28.0	28.0	28.0
	11	81,000	30.0	3,460	14.9	30.0	30.0	30.0	30.0

1/ Designations such as 6w, 7w, 8a, and 8w indicate vessels in the same length class but significantly different widths and design capacities.

Table D-11 - Vessel Data - U. S. Fleet (Coal and Grain)

Commodity Trade	Vessel Class	Vessel Capacity (Net tons)	Vessel Maximum Capacity (Feet)	Net Tons Per Foot of Immersion (For Drafts in Excess of 18 Feet)	Average Speed M.P.H. (Statute)	Seasonal Load Line Limits - (by months) (1) 6/1 to 8/31	(2) 5/1 to 5/30; 9/1 to 9/30	(3) 4/1 to 4/30; 10/1 to 10/31	(4) 11/1 to 3/31
Coal & Grain	5	14,700	20.3	1,270	13.9	20.8	20.8	20.0	20.8
	6	15,000	19.5	1,480	14.7	21.5	21.5	21.5	21.5
	6w	25,600	24.5	2,030	14.7	24.5	24.5	24.5	24.5
	7	21,500	23.7	1,620	14.7	23.7	23.7	23.7	23.7
	7w	26,700	24.4	2,050	14.7	24.4	24.4	24.4	24.4
	8	24,100	23.5	1,610	14.9	23.5	23.5	23.5	23.5
	8a	24,500	22.4	1,940	14.9	22.4	22.4	22.4	22.4
	8w	49,300	30.0	2,380	14.9	30.0	30.0	30.0	30.0
	9	50,000	28.0	2,420	14.9	28.0	28.0	28.0	28.0
	10	68,000	28.0	2,930	14.9	28.0	28.0	28.0	28.0
	11	80,000	28.0	3,460	14.9	28.0	28.0	28.0	28.0

Table D-12 - Percent Traffic Carried by the U. S. Fleet

Commodity	Percent Annual Traffic Carried: U. S. Domestic	U. S. Export	U. S. Import
Iron Ore	100	2	13
Coal	100	2	2
Limestone	100	3	0
Grain	100	7	2

United States Fleet - Average Operating Speeds: The average operating speeds for the United States fleet were derived in a manner similar to that described for the Canadian Fleet, which is presented in a subsequent section *(Canadian Fleet - Average Operating Speeds)*.

United States Fleet - Vessel Operating Costs: Hourly operating costs for U.S. vessels are based upon data furnished by the Maritime Administration, United States Department of Commerce, and are representative of costs in July 1979, the base economic period selected for this study. Operating costs were developed on the basis of a 270-day operating year and a 15 percent profit (on the capital investment) to the ship operator. Construction costs were amortized over a 50-year period at 8-1/2 percent interest.

In view of the recent rapid rise in the price of fuel, the fuel portion of daily operating costs has been estimated to rise 5 percent faster than inflation for the first 20 years of the project evaluation period (1985-2005). This results in increases in the fuel portion of 34, 179, and 256 percent by 1985, 2000, and 2005 respectively. The computation of hourly vessel operating costs is shown in Tables D-13, D-14, and D-15.

Table D-13 - Vessel Hourly Operating Costs (VHOC) For the U.S. Fleet

	Vessel Class										
	5	6	6w	7	7w	8	8a	8w	9	10	11
	$	$	$	$	$	$	$	$	$	$	$
Budget Cost*	30,000,000	33,000,000	47,000,000	37,000,000	49,000,000	41,000,000	45,000,000	58,000,000	53,000,000	64,000,000	74,000,000
Interest & Amortization @ 8-1/2% (50 yrs.) (.08646)	2,594,000	2,853,000	4,064,000	3,199,000	4,237,000	3,545,000	3,891,000	5,015,000	4,582,000	5,533,000	6,398,000
Cost per day (270 days)	9,607	10,567	15,050	11,848	15,691	13,129	14,410	18,573	16,972	20,494	23,696
Daily Operating Expense (DOE)	14,029	15,127	18,500	15,657	19,240	16,521	18,173	22,527	20,479	21,269	23,029
Overhead (12% of DOE)	1,683	1,815	2,220	1,879	2,309	1,983	2,181	2,703	2,457	2,552	2,763
Profit 15% (.15 X cost per day)	1,441	1,585	2,258	1,777	2,354	1,969	2,162	2,786	2,546	3,074	3,554
Total Daily Expense	26,760	29,094	38,028	31,161	39,594	33,602	36,926	46,589	42,454	47,389	53,042
Hourly Operating Cost	1,115	1,212	1,585	1,298	1,650	1,400	1,539	1,941	1,769	1,975	2,210

*Contract in 1979, delivery in June 1981.

Table D-14 - Vessel Hourly Operating Costs (VHOC) for the U.S. Fleet including Fuel Factor

Vessel Class	Jul 1979 VHOC	Fuel Portion	Increase in Fuel Cost (34%)	1985 VHOC	Increase in Fuel Cost (179%)	2000 VHOC	Increase in Fuel Cost (256%)	2035 VHOC
	$	$	$	$	$	$	$	$
2	639	79	27	666	141	780	202	841
3	767	125	42	809	224	991	320	1,087
4	982	263	89	1,071	471	1,453	673	1,655
5	1,115	287	98	1,213	514	1,629	735	1,850
6	1,212	323	110	1,322	578	1,790	827	2,039
6w	1,585	424	144	1,729	759	2,344	1,085	2,670
7	1,298	339	115	1,413	607	1,905	868	2,166
7w	1,650	441	150	1,800	788	2,438	1,126	2,776
8	1,400	360	122	1,522	644	2,044	922	2,322
8a	1,539	396	135	1,674	709	2,248	1,014	2,553
8w	1,941	489	166	2,107	875	2,816	1,252	3,193
9	1,769	489	166	1,935	875	2,644	1,252	3,021
10	1,975	489	166	2,141	875	2,850	1,252	3,227
11	2,210	537	183	2,393	961	3,171	1,375	3,585

Table D-15 - Summary of U. S. Vessel Hourly Operating Costs (Dollars)

Class	1985	2000	2035
3	810	990	1,090
4	1,070	1,450	1,660
5	1,210	1,630	1,850
6	1,320	1,790	2,040
6w	1,730	2,340	2,670
7	1,410	1,900	2,170
7w	1,800	2,440	2,780
8	1,520	2,040	2,320
8a	1,670	2,250	2,550
8w	2,110	2,820	3,190
9	1,940	2,640	3,020
10	2,140	2,850	3,230
11	2,390	3,170	3,580

Canadian Fleet - Fleet Composition: Trends in the makeup of the Canadian fleet have been governed by the opening of the St. Lawrence Seaway. Prior to 1959, much traffic to and from the lower St. Lawrence River had to be transshipped in small canallers of about 250 feet in length, and these dominated the fleet in numbers. Upper lakes traffic was handled mainly by medium-sized lakers, mostly in the 400 to 600-foot length categories, although a few over 600 feet in length were built in the 1950's while the Seaway was under construction.

Following the opening of the Seaway, most of the canallers were quickly phased out of operation, with the exception of those in specialized trades or using shallow harbors, such as tankers. At the same time, a very heavy new-building program was undertaken, almost entirely of maximum Seaway-size lakers (730-foot length), to take full advantage of the dimensions of the new Seaway locks. Today, plans are being considered for the construction of Canada's first 1,000-foot, 65,000-ton superlaker to carry western Canadian coal from Thunder Bay to Ontario Hydro's generating plant at Nanticoke on Lake Erie.

There are presently 120 Canadian dry bulk carriers engaged in grain, iron ore, coal and limestone trades on the Great Lakes. They range in size from the 259-foot, 4,100-ton Troisdoc to the new 730-foot, 35,100-ton Canadian Olympic. There are about 45 vessels still in active service in the fleet which were built prior to the opening of the St. Lawrence Seaway in 1959.

The fleet consists of 87 bulkers and 33 self-unloaders. The bulkers must be unloaded by dockside equipment, while the self-unloaders carry their own unloading system on board. Both types of ships have basically the same characteristics regarding size, speed, capacity, draft and so on. However, they differ considerably in the rapid turnaround time in port for self-unloaders, and the flexibility in the type of port which the self-unloader can serve. At this time, self-unloaders are used mainly in the coal and limestone trades. Because their belt conveyor unloading system cannot handle many natural iron ores, self-unloaders have not been used as extensively in the iron ore trades. The iron ore trades, as well as the grain trades employ mostly regular bulkers.

Throughout this section, the term "fleet" refers to the total combined fleet consisting of bulkers and self-unloaders. Additionally, all fleet and vessel characteristics which are presented represent averages for the total combined fleet. For the purpose of forecasting, it has been assumed that the present proportions of employment of bulkers and self-unloaders in the various trades will be maintained throughout the period of projection.

The compositions of present and projected Canadian dry bulk fleets and designated commodity service capability (by vessel class) are given in Table D-16. The overall hull lengths corresponding to these vessel classes are as presented in Table D-9. Class 7, or maximum Seaway-size vessels presently dominate the fleet in numbers. All indications are that they will continue to do so, as smaller vessels retire and new Class 7's take their place.

Table D-16 - Present and Future Compositions of the Canadian Dry Bulk Fleet (Including Designated Commodity Service Capability)

Class	No. Ships in Class	Number of Ships in Designated Service			
		Iron Ore	Coal	Limestone	Grains
1977 Fleet					
1	14	0	10	0	14
2	2	1	1	1	1
3	5	2	5	4	2
4	13	10	12	7	9
5	18	18	15	10	15
6	15	15	14	6	10
7	53	53	41	16	40
Total	120	99	98	44	91
1985 Fleet					
1	14	0	10	0	14
2	1	1	1	1	1
3	5	2	5	4	2
4	10	8	10	7	7
5	17	17	14	10	14
6	16	16	15	6	11
7	80	61	49	18	42
Total	143	105	104	46	91
2000 Fleet					
1	13	0	10	0	13
2	1	0	1	1	1
3	0	0	0	0	0
4	2	2	2	1	0
5	14	14	13	10	10
6	16	16	14	6	11
7	101	80	72	36	98
10	2	0	2	0	0
Total	149	112	114	54	133
2035 Fleet					
1	10	0	10	0	10
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	5	5	3	2	0
6	10	5	2	6	5
7	136	115	88	64	135
10	2	0	2	0	0
Total	163	125	105	72	150

Furthermore, nearly all expansion of tonnage in the Canadian fleet is expected to occur in the maximum Seaway-size class, because of the limiting size of the locks in the Welland Canal and the St. Lawrence River.

It is probable that a few 1,000-foot (Class 10) self-unloaders will be added to the fleet within the next 10 or 15 years to supply Ontario Hydro's generating station at Nanticoke on Lake Erie with western Canadian coal transshipped from Lake Superior. These vessels will be too long and too wide to enter the locks on the Welland Canal.

A fleet of some 14 Class 1 vessels will continue to operate out of Thunder Bay in upper lakes shipping of grain and coal. New vessels have been added to this fleet as late as 1976, and no vessel in the fleet is more than 26 years old. It has been assumed that this fleet of Class 1's will continue to operate at its present size for most of the period of forecast, perhaps declining in number after the year 1990 when retirements are replaced by larger vessels.

Judging by the present age of the vessels in the fleet and recent reports on retirements due to age, most vessels seem to serve a useful life of 65 years or so. On this basis, and in view of the latest listings of new ships on order, re-builds, conversions and projections of retirements from shipbuilders and shipowners, it is estimated that the intermediate-sized lakers, Classes 3 and 4, will all but disappear from the Canadian fleet before 1990, and Classes 5 and 6 will steadily dwindle to few in number by 2035. All of these will be replaced by Class 7's and Class 10's as discussed above.

Canadian Fleet - Vessel Characteristics: Future additions to the Canadian fleet are not expected to differ significantly from ships in existence now, in either physical dimensions or operational characteristics. Average maximum load carrying capacities and operating drafts for vessels involved currently in each of the four commodity trades are given in Tables D-17 through D-20. The allowable operating draft of a ship varies with the time of year according to the vessel's design. A ship is required by law to operate within its designated safe seasonal load line limits. Average seasonal load line limits for vessels in each class of the Canadian fleet are given in Table D-21. Depending on the density of the cargo being carried, the maximum operating draft of a ship will be the lesser of the seasonal load line limit or the maximum draft attainable when the holds are full. For instance, a vessel may be loaded to capacity with grain before the allowable load line limit is reached, but the load line limit would be reached before the holds were completely filled with iron ore. Therefore, in Table D-17 through D-20 the "maximum draft" shown is the lesser of the average seasonal load line limit or the maximum physically attainable draft at full load.

Table D-17 - Maximum Capacities and Drafts by Cargo Type for Projected Vessels in the Canadian Great Lakes Dry Bulk Cargo Fleet (Iron Ore)

Vessel Class	Winter Max. Draft[1] (ft.)	Winter Capacity[2] (s. tons)	Intermediate Max. Draft (ft.)	Intermediate Capacity (s. tons)	Summer Max. Draft (ft.)	Summer Capacity (s. tons)	Midsummer Max. Draft (ft.)	Midsummer Capacity (s. tons)
1	18.82	5,643	19.13	5,773	19.52	5,937	19.82	6,063
2	22.54	9,912	22.88	10,124	23.56	10,549	24.11	10,892
3	18.98	9,722	19.79	10,228	20.44	10,633	20.63	10,752
4	20.09	11,993	20.91	12,583	21.68	13,138	22.12	13,455
5	23.23	17,555	23.78	18,136	24.57	18,970	25.17	19,604
6	25.12	22,018	25.89	23,025	26.14	23,352	26.71	24,098
7	26.45	28,574	26.65	28,910	27.53	30,389	28.22	31,548

[1] "Maximum Drafts" shown are the lesser of the seasonal load line limit or the maximum draft attainable at net capacity (see note 2).

[2] "Capacities" shown are the lesser of the net load on board at the seasonal load line limit or the net load on board when the holds are full.

Table D-18 - Maximum Capacities and Drafts by Cargo Type for Projected Vessels in the Canadian Great Lakes Dry Bulk Cargo Fleet (Coal)

Vessel Class	Winter: Max. Draft [1] (ft.)	Winter: Capacity [2] (s. tons)	Intermediate: Max. Draft (ft.)	Intermediate: Capacity (s. tons)	Summer: Max. Draft (ft.)	Summer: Capacity (s. tons)	Midsummer: Max. Draft (ft.)	Midsummer: Capacity (s. tons)
1	18.83	5,647	18.83	5,647	18.83	5,647	18.83	5,647
2	22.16	9,675	22.16	9,675	22.16	9,675	22.16	9,675
3	18.77	9,590	18.77	9,590	18.77	9,590	18.77	9,590
4	20.09	11,986	20.84	12,526	20.84	12,526	20.84	12,526
5	23.23	17,554	23.23	17,554	23.23	17,554	23.23	17,554
6	24.26	20,897	24.26	20,897	24.26	20,897	24.26	20,897
7	26.45	28,582	26.65	28,918	26.67	28,952	26.67	28,952

1 "Maximum Drafts" shown are the lesser of the seasonal load line limit or the maximum draft attainable at net capacity (see note 2).

2 "Capacities" shown are the lesser of the net load on board at the seasonal load line limit or the net load on board when the holds are full.

Table D-19 - Maximum Capacities and Drafts by Cargo Type for Projected Vessels in the Canadian Great Lakes Dry Bulk Cargo Fleet (Limestone)

Vessel Class	Winter: Max. Draft [1] (ft.)	Winter: Capacity [2] (s. tons)	Intermediate: Max. Draft (ft.)	Intermediate: Capacity (s. tons)	Summer: Max. Draft (ft.)	Summer: Capacity (s. tons)	Midsummer: Max. Draft (ft.)	Midsummer: Capacity (s. tons)
1	16.98	5,912	16.98	5,912	17.34	6,063	17.34	6,063
2	21.08	11,371	21.58	11,706	22.00	11,987	22.58	12,376
3	18.98	9,274	19.79	9,780	20.44	10,185	20.63	10,304
4	19.52	12,570	20.45	13,240	21.19	13,773	21.65	14,104
5	21.67	23,044	22.26	23,667	22.99	24,438	23.54	25,019
6	23.28	23,742	23.36	23,847	24.28	25,050	24.88	25,835
7	26.56	31,091	26.73	31,377	27.53	32,721	28.23	33,897

1 "Maximum Drafts" shown are the lesser of the seasonal load line limit or the maximum draft attainable at net capacity (see note 2).

2 "Capacities" shown are the lesser of the net load on board at the seasonal load line limit or the net load on board when the holds are full.

Table D-20 - Maximum Capacities and Drafts by Cargo Type for Projected Vessels in the Canadian Great Lakes Dry Bulk Cargo Fleet (Grain)

Vessel Class	Winter: Max. Draft[1] (ft.)	Winter: Capacity[2] (s. tons)	Intermediate: Max. Draft (ft.)	Intermediate: Capacity (s. tons)	Summer: Max. Draft (ft.)	Summer: Capacity (s. tons)	Midsummer: Max. Draft (ft.)	Midsummer: Capacity (s. tons)
1	17.28	4,995	17.28	4,995	17.28	4,995	17.28	4,995
2	20.57	8,680	20.57	8,680	20.57	8,680	20.57	8,680
3	18.50	11,441	19.25	11,936	19.62	12,180	19.62	12,180
4	20.09	11,993	20.75	12,468	20.75	12,468	20.75	12,468
5	22.86	17,164	22.86	17,164	22.86	17,164	22.86	17,164
6	24.71	21,478	24.71	21,478	24.71	21,478	24.71	21,478
7	26.45	28,577	26.70	28,997	26.70	28,997	26.70	28,997

[1] "Maximum Drafts" shown are the lesser of the seasonal load line limit or the maximum draft attainable at net capacity (see note 2).

[2] "Capacities" shown are the lesser of the net load on board at the seasonal load line limit or the net load on board when the holds are full.

Table D-21 - Seasonal Load Line Limits for Vessels of Projected Canadian Great Lakes Dry Bulk Cargo Fleet 1/

Vessel Class	Draft in Feet: Winter (November through March)	Intermediate (April and October)	Summer (May and September)	Midsummer (June through August)
1	18.82	19.13	19.52	19.82
2	22.54	22.88	23.56	24.11
3	18.98	19.79	20.44	20.63
4	20.09	20.91	21.68	22.12
5	23.23	23.78	24.57	25.17
6	25.12	25.89	26.14	26.71
7	26.45	26.65	27.53	28.22

1/ Combined fleet; i.e., bulk freighters and self-unloaders.

Consequently, the "capacity" shown is the lesser of the net load on board at the seasonal load line limit or the net load on board when the holds are full.

The most important effect of variation in water depth on shipping, is on the operating draft of the ship. For example, an inch less draft for a Class 7 ship means 130 tons less cargo can be carried. This translates into a requirement for more trips to move a given volume of cargo. More trips involves more time, which in turn raises the unit transportation cost. Values of the net capacity per inch of draft, or "immersion factors" for the seven classes in the existing Canadian fleet are given in Table D-22. These are average values for vessels of the approximate average carrying capacity shown and apply when the vessel is near its maximum loaded condition. An immersion value for the possible new 1,000-foot lakers to be used in the coal trades has been approximated at 230 short tons per inch.

Table D-22 - Immersion Factors for Canadian Great Lakes Dry Bulk Fleet

Class	Approximate Average Maximum Carrying Capacity (short tons)	Net Capacity Per Inch of Immersion (short tons)
1	6,063	42
2	10,892	67
3	10,752	67
4	13,455	79
5	19,604	100
6	24,098	112
7	31,548	129
10	65,000	230

Canadian Fleet - Distribution of Commerce by Fleet Nationality and Vessel Class: Present and future utilization of the total Canadian fleet in the four bulk commodity trades are given in Table D-23. These forecasts were prepared by comparing the total annual ton-mile capacity of all vessels in each class engaged in the given trade, with the total forecast ton-miles for that trade for the year. Ton-mile capacity for each class involved in a given trade was determined from historical data or by multiplying the total number of round trips possible on each lake-to-lake route involved in that trade by the round-trip distance, summing, and multiplying the result by the average load capacity for that vessel class.

Canadian Fleet - Average Operating Speeds: The round-trip time involved on a given trade route is largely a function of the speed of the vessel in open water and of the time required to transit canals, channels and locks on the route. The average operating speeds for vessel classes in the Canadian fleet are given in Table D-24. These represent the average speed of all vessels in the size range specified, and take into account typical delays encountered in transiting the locks at Sault Ste. Marie, the Welland Canal, and the St. Lawrence River, as well as speed restrictions in the St. Marys River, St. Clair and Detroit Rivers, Welland Canal and reaches of the St. Lawrence Seaway below Lake Ontario. Intralake traffic, even though not restricted by speed limits and waiting time at locks, is generally of the smaller class of vessel, so it has been assumed that its average speed would be about the same as that of traffic in larger vessel sizes after delay time has been accounted for.

Table D-23 - Distribution of Canadian Great Lakes Dry Bulk Cargo Traffic By Vessel Class

Class	1973-76 Average	Percent Carried by Canadian Fleet 1980	1985	1990	2000	2035
A. Iron Ore - Domestic						
1	0.4	0	0	0	0	0
2	0.4	0.3	0.3	0	0	0
3	0	0.6	0.6	0	0	0
4	1.3	3.1	2.5	0.6	0.5	0
5	13.7	13.6	11.6	9.7	8.1	2.3
6	13.3	10.6	10.2	8.5	8.7	2.2
7	70.9	71.8	74.8	81.2	82.7	95.5
B. Iron Ore - Export						
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	1.9	1.5	0.5	0	0	0
4	5.0	4.6	4.1	0.5	0.1	0
5	16.4	15.0	13.5	10.0	8.0	2.5
6	9.6	10.0	10.0	9.0	8.0	2.5
7	54.1	55.9	58.6	67.5	70.9	82.0
C. Iron Ore - Import						
1	0.4	0	0	0	0	0
2	0.4	0.3	0.3	0	0	0
3	0	0.6	0.6	0	0	0
4	1.3	3.1	2.5	0.6	0.5	0
5	12.2	13.6	11.6	9.7	8.1	2.3
6	13.2	10.6	10.2	8.5	8.7	2.2
7	70.4	69.8	72.8	79.2	80.7	93.5
D. Coal - All						
1	0.9	3.5	3.3	3.1	3.0	2.5
2	0.5	0	0	0	0	0
3	1.0	0	0	0	0	0
4	2.2	0.9	0.8	0.2	0.1	0
5	7.7	3.7	3.4	3.2	3.0	0.5
6	1.6	1.0	1.0	0.8	0.8	0.1
7	84.1	88.9	89.5	90.7	82.2	83.7
10	0	0	0	0	8.9	11.2

Table D-23 - Distribution of Canadian Great Lakes Dry Bulk Cargo Traffic By Vessel Class (Cont'd)

Class	1973-76 Average	Percent Carried by Canadian Fleet				
		1980	1985	1990	2000	2035
E. Limestone - Domestic and Export						
1	1.4	0	0	0	0	0
2	2.6	0	0	0	0	0
3	13.9	15.9	14.0	0	0	0
4	39.1	38.9	27.8	10.6	3.2	0
5	28.1	28.1	19.2	17.8	16.1	2.2
6	5.6	8.0	5.5	5.1	4.6	3.3
7	9.3	9.1	33.5	66.5	76.1	94.5
F. Limestone - Import						
1	1.4	0	0	0	0	0
2	2.6	0	0	0	0	0
3	13.4	15.4	13.5	0	0	0
4	37.6	37.4	26.8	10.1	3.2	0
5	21.7	27.1	18.7	17.3	15.1	2.2
6	5.6	8.0	5.5	5.1	4.6	3.3
7	9.3	9.1	32.5	64.5	74.1	91.5
G. Grain - Domestic						
1	5.3	3.8	3.3	2.8	2.5	1.5
2	0.4	0.1	0.1	0.1	0.1	0
3	3.7	0.3	0.2	0	0	0
4	6.4	5.6	4.3	0	0	0
5	16.3	14.0	12.3	9.3	7.4	0
6	10.9	9.9	9.7	8.8	8.3	3.3
7	57.0	66.3	70.1	78.8	81.5	95.0
H. Grain - Export						
1	20.0	19.0	17.6	16.2	14.4	9.3
2	0	0	0	0	0	0
3	35.9	33.0	32.6	0	0	0
4	33.3	27.4	24.4	0	0	0
5	7.8	12.6	12.4	10.3	8.3	0
6	0	0	0	0	0	0
7	0	0	11.0	71.5	75.3	88.7

Table D-23 - Distribution of Canadian Great Lakes Dry Bulk Cargo Traffic By Vessel Class (Cont'd)

Class	1973-76 Average	Percent Carried by Canadian Fleet				
		1980	1985	1990	2000	2035
I. Grain - Import						
1	5.0	3.6	3.1	2.8	2.5	1.5
2	0.4	0.1	0.1	0.1	0.1	0
3	3.5	0.3	0.2	0	0	0
4	6.1	5.2	3.9	0	0	0
5	15.2	12.9	11.2	8.2	6.3	0
6	10.2	9.2	9.0	8.1	7.6	2.6
7	52.6	61.7	65.5	73.8	76.5	88.9

Table D-24 - Operating Speeds for Canadian Great Lakes Dry Bulk Vessels

Class	Speed in Statute Miles Per Hour
1	14
2	14
3	14
4	14
5	14
6	14
7	14
10	17

Canadian Fleet - Vessel Operating Costs: Operating costs for Canadian lakers are given in Table D-25. These costs represent the approximate average operating costs for all dry bulk vessels in each class in mid-July 1979. They were developed from information on vessel running costs obtained by the St. Lawrence Seaway Authority from vessel operators, and vessel capital costs obtained from the Department of Industry, Trade, and Commerce. Operating costs were computed on the basis of a 250-day operating year and a 15 percent profit margin to the ship operator. Construction costs, after subsidy, were amortized over a 10-year period at 8.5 percent. The subsidy level was 20 percent. The operating cost of the proposed Class 10 coal vessels has been estimated to be $2,237 per hour.

2.5.4 Physical and Operational Characteristics of the Navigation System

Water Depths: The water levels of the Great Lakes vary from year to year, and from month to month during each year. The higher levels for the year occur during the summer months. The lower levels occur during the winter months. The seasonal variation between the summer high and the winter low averages about 1 foot on the upper lakes, 1-1/2-feet on Lake Erie, and nearly 2 feet on Lake Ontario.

Navigable channel depths (project depths) and charted depths in the Great Lakes are recorded in feet below low water datum, which is a plane on each lake and a sloping surface on each outflow river. Low water datum elevations (Chart Datum) are given in feet above the mean water level in the Gulf of St. Lawrence at Father Point, Quebec, International Great Lakes Datum (1955). Low water datum elevations represent what might be termed the average low water levels rather than the extreme low water levels.

The sloping surfaces representing low water datum in the St. Clair, Detroit, and Niagara Rivers are the surfaces of the rivers which would exist under conditions of stable flow with the water surfaces of the influencing lakes at their low water datum elevations. For the St. Marys River and the Montreal to Lake Ontario reach of the St. Lawrence River, low water datums are the sloping surfaces of the rivers when the water surfaces of the influencing lakes are at their low water datum elevations and/or specified water surface elevations exist at designated points on the rivers.

With the low water datums as planes of references, depths in navigation channels are generally equal to or greater than project depths except during extreme low water years, such as those which occurred during the mid-1920's, mid-1930's and the early 1960's.

One inch of vessel draft on a freighter of 25,000 tons carrying capacity represents 125 short tons of cargo. On a 1,000-foot, 68,000-ton capacity bulk carrier, 1 inch means a loss or gain of 230 tons or about 0.3 percent of carrying capacity. It is evident that raising or lowering of water levels will affect both the volume and the unit cost of cargo movements. It is therefore desirable that a relatively stable water level, uniformly balanced relative to low water datum throughout the system, be maintained on the Great Lakes and that occurrences of extreme low lake levels be reduced.

Table D-25 - Operating Costs for Canadian Great Lakes Dry Bulk Vessels (July 1979)

Class	Operating Cost ($ Per Hour)
1	555
2	667
3	792
4	997
5	1,095
6	1,200
7	1,509
10	2,237

Major channels and harbors on the Great Lakes are authorized and dredged to a 27-foot system depth. The ship channel in the St. Lawrence River up to and including some berths in Montreal Harbor are maintained at a 35-foot depth.

Allowable Drafts: The legal draft to which a vessel may load, known as the load line limit, is assigned by the U.S. Coast Guard and the Canada Shipping Act. The load line is not the same throughout the navigation season, but varies according to the time of year. The year is divided into four navigation "seasons" and a specific load line is assigned to each vessel for each season. Tables D-10, D-11, and D-21 give the average seasonal load line limits for United States and Canadian Great Lakes fleets, respectively.

For the purpose of this study, it is assumed that ships would operate with a minimum net underkeel clearance of 1-1/2 feet. That is, if the water level is at low water datum (LWD) a ship would not load to a draft greater than 25.5 feet (27.0 feet minus 1.5 feet underkeel clearance for squat, maneuverability, etc.). If the water level were 1 foot above LWD, a ship could load to 26.5 feet.

Shipping Season: The shipping season is assumed to be 9 months on the upper four lakes and the Welland Canal and 8-1/2 months on Lake Ontario and the St. Lawrence River down to Montreal. These are considered to be the current normal operating seasons without consideration of any season extension. The effect of season extension on the impact of lake regulation on navigation is discussed in Section 4, Sensitivity Analyses.

Route Mileages: The average route mileages from lake of origin to lake of destination were determined by weighting the trip distance between shipping and receiving harbors by the tonnage involved, summing the totals for each lake and dividing by the total tons for all routes. The average one way route mileages are shown in Table D-26 for United States trades and in Table D-27 for Canadian trades.

Backhauling: The percent of time ships return empty to the shipping harbor is used to determine the portion of the total round trip that should be charged to the commodity carried. For example, the class 10, 1,000-foot long ships are committed to carry a single commodity such as iron ore and return empty for another load of ore after each trip. Thus, 100 percent of the loaded trip plus 100 percent of the return trip, plus loading and unloading time, is charged to the commodity carried. The round trip factor is then 200 percent plus loading and unloading time. If a ship carries some other commodity for part or all of the backhaul, then the portion of the round trip charged to each commodity is prorated according to the length of the loaded trip for each commodity. Round trip time factors are shown in Tables D-28 and D-29 for United States and Canadian trades, respectively. These factors were determined by examining the detailed records of each ship's trips during the entire 1976 shipping season. The 1976 records were the latest available at the time of the analysis.

Turnaround Time in Port: The port turnaround time for United States vessels, consisting of loading and unloading times, docking, taking on stores, supplies and equipment, and minor maintenance and repair, were determined as follows:

a. Bulk Carriers. Information in Greenwoods Guide shows loading and unloading rates at docks in the Great Lakes. Loading rates for iron ore vary from 3,000 to 6,000 tons per hour (TPH) and average 4,000 TPH. Unloading rates vary from 200 TPH to 3,500 TPH and average 2,300 TPH weighted by storage capacity at dock. It is assumed that the trend toward more efficient use of equipment will result in a shift to the more rapid unloading equipment and the average of the unloading rates of 2,000 or higher is more representative of the 50-year period. Therefore, 2,500 was used, resulting in an average of loading and unloading rates of 3,300 TPH.

Average loading and unloading times are calculated by dividing the ship capacity by the 3,300 TPH, assuming .8 efficiency and adding 2 hours for maneuvering and docking times (one hour at each end of trip). The loading and unloading times for bulk carriers are shown in Tables D-30, 31, and 32.

b. Self-Unloaders. Loading rates at docks are given in Greenwoods Guide and average 4,000 tons per hour. Unloading rates are claimed to be as high as 10,000 TPH for class 10 vessels. Such rates have not been achieved under actual operating conditions. It is considered that a rate of 5,000 or 6,000 TPH is the maximum for class 10 vessels. The rate for smaller vessels (class 5 or 6) is considerably less, say 3,000 to 4,000 TPH. Average unloading times are calculated by dividing the ship capacity by the unloading rate as shown in Table D-33. A lower range of rates was used for the smaller and older ships and a higher range for the bigger and newer ships.

Table D-26 - U. S. Fleet Shipment Distances by Origin and Destination, Traffic Type and Commodity Trade (Statute Miles)

Route		Domestic Traffic				Import Traffic				Export Traffic			
Origin	Destination	Iron Ore	Coal	Limestone	Grain	Iron Ore	Coal	Limestone	Grain	Iron Ore	Coal	Limestone	Grain
S	S	-	200	-	-	-	-	-	-	180	-	-	-
S	M	780	820	300	810	700	-	-	690	-	-	-	-
S	H	690	730	170	-	-	-	-	-	-	-	-	-
S	E	800	900	530	980	700	-	-	860	840	-	-	-
S	O	-	-	-	1,020	-	-	-	-	930	-	-	-
S	SLS	-	-	-	1,700	-	-	-	-	-	-	-	1,710
M	S	-	500	-	-	-	-	-	-	-	-	-	-
M	M	290	130	280	-	-	-	-	-	-	-	-	-
M	H	440	-	360	-	-	-	-	-	-	-	440	-
M	E	560	-	520	-	-	-	-	-	-	-	-	-
M	O	-	-	-	-	-	-	-	-	725	-	-	1,000
M	SLS	-	-	-	-	-	-	-	-	-	-	-	1,700
H	S	-	-	510	-	-	-	-	-	-	-	100	-
H	M	-	-	360	-	470	-	-	-	-	-	-	-
H	H	-	-	240	-	300	-	-	-	-	-	100	-
H	E	-	-	410	-	300	-	-	-	-	-	330	-
H	SLS	-	-	-	-	-	-	-	-	-	-	870	1,170
E	S	-	710	-	-	-	-	-	-	-	400	-	-
E	M	-	720	-	-	-	-	-	-	-	-	-	-
E	H	-	330	110	-	-	-	-	-	-	240	-	-
E	E	-	60	50	-	-	-	-	-	-	90	-	-
E	O	-	-	-	-	-	-	-	-	-	350	-	560
E	SLS	-	-	-	-	-	-	-	-	-	800	-	1,030
O & SLS	M	-	-	-	-	1,680	-	-	-	-	-	-	-
O & SLS	E	-	-	-	-	960	-	-	-	-	-	-	-
O & SLS	O	-	-	-	-	-	-	-	-	-	-	-	-

Table D-27 - Canadian Fleet Shipment Distances by Origin and Destination, Traffic Type and Commodity Trade (Statute Miles)

Route		Domestic Traffic				Import Traffic				Export Traffic			
Origin	Destination	Iron Ore	Coal	Limestone	Grain	Iron Ore	Coal	Limestone	Grain	Iron Ore	Coal	Limestone	Grain
S	S	266	-	-	-	180	-	-	-	-	-	-	-
S	M	-	-	-	-	-	-	-	-	695	-	-	632
S	H	-	542	-	532	-	-	-	693	-	-	-	-
S	E	750	807	-	844	836	-	-	-	690	-	-	862
S	O	913	913	-	904	952	-	-	-	-	-	-	-
S	SLS	-	-	-	1,200	-	-	-	1,320	-	-	-	-
S	EX	-	-	-	1,602	-	-	-	1,835	-	-	-	-
M	S	-	-	-	-	-	634	-	-	-	-	-	-
M	H	-	-	-	-	-	-	-	550	-	-	-	-
M	E	-	-	-	-	-	-	585	-	-	-	-	-
M	O	-	-	-	-	725	-	-	932	-	-	-	-
M	SLS	-	-	-	-	-	-	-	1,219	-	-	-	-
M	EX	-	-	-	-	-	-	-	1,740	-	-	-	-
H	S	-	-	-	-	-	-	113	-	-	-	-	-
H	M	-	-	-	-	-	-	-	-	469	-	-	-
H	H	-	-	-	250	-	-	179	-	305	280	-	-
H	E	536	-	-	-	-	-	258	-	430	-	-	-
H	O	-	-	-	-	-	-	-	-	-	-	-	-
H	SLS	-	-	-	650	-	-	870	797	-	-	-	-
H	EX	-	-	-	1,278	-	-	-	1,363	-	-	-	-
E	S	-	-	-	-	-	400	-	-	-	-	-	-
E	H	-	-	-	-	-	230	135	-	-	-	-	-
E	E	-	-	-	-	-	84	60	-	-	-	145	-
E	O	-	-	-	-	-	218	-	288	-	-	-	-
E	SLS	-	-	-	421	-	568	-	540	-	-	-	-
E	EX	-	-	-	800	-	-	-	1,097	-	-	-	-
EX	M	-	-	-	-	-	-	-	-	1,777	-	-	-
EX	E	-	1,167	-	-	-	-	-	-	1,008	-	-	-
EX	O	867	-	-	-	-	-	-	-	-	-	-	-
SLS	O	-	-	367	-	-	-	-	-	-	-	-	-
SLS	SLS	-	-	-	139	-	-	-	-	-	-	-	-
SLS	EX	-	-	-	525	-	-	-	-	-	-	-	-

Table D-28 - Round Trip Distance Factors for the U.S. Fleet by Vessel Class and Commodity Trade (Percent of Loaded Trip Time plus Loading and Unloading Hours)1/

Vessel Class	Commodity Trade			
	Iron Ore	Coal	Limestone	Grain
5	170% + 20 hrs.	150% + 20 hrs.	160% + 20 hrs.	150% + 20 hrs.
6	170% + 22 hrs.	150% + 22 hrs.	160% + 22 hrs.	160% + 22 hrs.
6w	180% + 24 hrs.	150% + 24 hrs.	-	-
7	180% + 22 hrs.	180% + 22 hrs.	180% + 22 hrs.	180% + 22 hrs.
7w	180% + 22 hrs.	-	200% + 22 hrs.	-
8	200% + 22 hrs.	200% + 22 hrs.	-	-
8a	200% + 26 hrs.	-	200% + 26 hrs.	200% + 26 hrs.
8w	-	200% + 26 hrs.	-	-
9	200% + 26 hrs.	-	-	-
10	200% + 28 hrs.	200% + 28 hrs.	-	-
11	200% + 30 hrs.	200% + 30 hrs.	200% + 30 hrs.	200% + 30 hrs.

1/ A factor of 200 percent means vessel carries only one commodity and entire trip is chargeable to that commodity. A factor of 100 percent means vessel carries one cargo in one direction and another cargo on return trip. A factor of 125 percent means that loaded trip plus 25 percent of return trip is chargeable to cargo shown and 75 percent is chargeable to some other cargo carried on some return trips.

Table D-29 - Round Trip Distance Factors for the Canadian Fleet by Vessel Class and Commodity Trade (Percent of Loaded Trip Time)

Vessel Class	U W 1/	Commodity Trade			
		Grain	Iron Ore	Coal	Limestone
1	U	200 2/	200	200	200
	W	200	200	200	200
2	U	200	200	200	200
	W	200	200	200	200
3	U	200	200	200	200
	W	160	160	200	200
4	U	180	180	200	200
	W	137	135	200	200
5	U	180	180	200	200
	W	130	138	200	200
6	U	200	200	200	200
	W	132	134	200	200
7	U	200	200	200	200
	W	137	143	200	200

1/ U - For inter- and intralake trades on the Upper Lakes, i.e., S, M, H, and E, which do not pass through the Welland Canal.
W - For all interlake trades which pass through the Welland Canal.

2/ Factor of 200 percent represents "dedicated" routing, i.e., no, or insignificant, backhaul.

Table D-30 - Loading Rates at U.S. Harbors

Harbor	Loading Rate, tons per hour: Iron Ore	Loading Rate, tons per hour: Coal
Duluth	3,500	8,500
Superior	3,200	-
Silver Bay	5,000	-
Taconite	6,000	-
Two Harbors	3,800	-
Marquette	3,100	-
Escanaba	2,500	-
Chicago	-	2,500
Toledo	-	3,000
Ashtabula	-	7,000
Conneaut	-	7,700
Sandusky	-	3,500
	27,100	32,200
Average Rate	4,000 TPH	5,400 TPH

Table D-31 - Iron Ore Unloading Rate at U.S. Harbors - Bulk Carriers

Harbor	Tons of Traffic (Millions)	Unloading Rate (Tons per Hour)
Ashtabula	1.0	2,500
	1.2	1,500
Buffalo	3.8	2,600
	.7	500
	.6	200
		200
Burns Waterway		2,200
Cleveland	1.0	3,300
	.5	650
	.8	1,000
	.8	900
		2,300
Conneaut	3.2	3,500
Detroit		1,000
	1.0	800
		500
		450
	.9	350
		200
		1,400
	2.0	500
Gary	3.9	2,500
Huron	.6	1,700
Indian Harbor	1.0	1,450
	1.0	2,000
	.9	1,000
	2.1	1,000
Lorain	1.0	1,200
	2.5	1,900
South Chicago	.2	630
	.9	200
		900
	2.0	2,000
	.4	1,000
	.9	1,400
	2.1	600
Toledo		1,450
		1,050
		1,700
		600
Trenton	1.8	700

Average unloading rate 2,300 TPH (weighted by tons of traffic). The highest unloading rates are considered more representative of conditions over the 50-year project life. The average of these rates is 2,500 TPH.

Table D-32 - Loading and Unloading Time
U. S. Bulk Carriers

Class 5: $2 \times \frac{22{,}000 \text{ (capacity class 5)}}{3{,}100} \times \frac{1}{.80 \text{ (eff.)}}$ + 2 hrs. = 18 + 2 = 20

Class 6: $\frac{26{,}000 \text{ (capacity class 6)}}{22{,}000 \text{ (capacity class 5)}} \times$ 20 hrs. + 2 hrs. = 24 + 2 = 26

Class 6w: $2 \times \frac{37{,}900 \text{ (capacity class 6w)}}{3{,}300} \times \frac{1}{.80}$ + 2 hrs. = 29 + 2 = 31

Class 7: $2 \times \frac{30{,}400 \text{ (capacity class 7)}}{3{,}300} \times \frac{1}{.80}$ + 2 = 23 + 2 = 25

Class 7w: $\frac{39{,}400 \text{ (capacity class 7w)}}{30{,}400 \text{ (capacity class 7)}} \times$ 23 hrs. + 2 = 30 + 2 = 32

Class 8: $2 \times \frac{29{,}700 \text{ (capacity class 8)}}{3{,}500} \times \frac{1}{.8}$ + 2 = 21 + 2 = 23

Class 8a: $2 \times \frac{36{,}400 \text{ (capacity class 8a)}}{3{,}500} \times \frac{1}{.8}$ + 2 = 26 + 2 = 28

Class 8w: $\frac{49{,}300 \text{ (capacity class 8w)}}{36{,}400 \text{ (capacity class 8a)}} \times$ 26 hrs. + 2 = 35 + 2 = 37

Class 9: $\frac{49{,}800 \text{ (capacity class 9)}}{36{,}400 \text{ (capacity class 8a)}} \times$ 26 hrs. + 2 = 36 + 2 = 38

Class 10: No bulk carriers in this class.

Table D-33 - Vessel Loading and Unloading Time; U. S. Fleet

Vessel Class	Time, hours		
	Bulk Carriers	Self-Unloaders	Weighted Average Time
5	20	20	20
6	26	21	22
6w	31	24	24
7	25	21	22
7w	32	22	22
8	23	21	22
8a	28	25	26
8w	37	24	26
9	38	26	26
10		28	28
11		30	30

Vessel Class	Unloading Times for Self-Unloaders, hours Average Unloading Rate, tons/hour				
	3,000	4,000	5,000	6,000	7,000
5	20 1/				
6	21	23			
6w		24	21		
7		21			
7w			22		
8		21			
8a		25			
8w			26	24	
9			26	24	
10			36	31	28
11					30

1/ Times are determined by:

$$\frac{(2)\ (\text{Maximum Ship Capacity})\ (\text{Efficiency} = .8)}{\text{Average Rate}} + (\text{maneuvering time} = 2\ \text{hrs.})$$

Personnel employed in lake fleet operations have indicated that average unloading time to stockpile is 8 to 12 hours for self unloaders and longer for bulk carriers. Loading rates can be as short as 5 to 8 hours, but normally require 10 to 20 hours. The normal combined rates would then be 18 to 32 hours which encompass the range used in this study of 20 to 30 hours. Selections of time were weighted slightly toward the self-unloader fleet as this represents the most recent and fastest growing portion of the fleet.

The average turnaround time in port for the Canadian trades are given in Table D-34. These are average times for the combined fleet of bulkers and self-unloaders. They were determined in a manner similar to that used for United States ships. The total time spent in port consists of time to berth and de-berth, load and unload, take on supplies, have minor maintenance performed, make measurements and documentation, and average waiting time. The mean loading and unloading rates for the major Canadian and United States terminal facilities used in the Canadian trades, which were used to develop average loading and unloading times, are given in Tables D-35 through D-38.

Shallow Draft United States Harbors : A shallow draft harbor is defined as "any harbor or dock area with less than 27 feet of water depth available." Traffic tapes were analyzed for 1976, the most recent year that tapes were available, to determine the traffic at 27-foot and less than 27-foot deep harbors. Results are shown on Tables D-39 through D-42. Nearly all of the iron ore shipped on the Great Lakes is shipped and received at harbors having system depth of 27 feet. Nearly all of the grain travels at 27 feet with the exception of U.S. grain shipped to Buffalo, NY (about 1.5 million tons annually), which is received at less than 27-foot docks.

However, limestone and coal are shipped to many of the smaller harbors for use in the construction industry and as fuel. Some of the shipping and receiving harbors have not been dredged to 27 feet, but offer only 20 to 25-foot water depths. There are many reasons for this, such as, lack of sufficient commerce, long and/or restrictive channels to negotiate, difficult and/or expensive dredging required for deepening.

The percent of traffic at harbor locations with depths less than 27 feet is determined as described in the following paragraphs and shown in Tables D-43, 44, and 45 for projection years 1985, 2000, and 2035, respectively.

a. Iron Ores. Harbors shipping or receiving iron ore on Lakes Superior and Michigan are all at 27 feet. However, about 10 to 11 million tons of iron ore received on Lake Erie is restricted in draft. At Cleveland Harbor, about 1 to 2 million tons is received on the Cuyahoga River at 23-foot draft. In addition, Canadian shipping harbors on Lake Huron are at 25-foot draft and the Rouge River (Ford Plant) dock is at 25 feet and receives about 1-1/2 million tons of ore annually. Therefore, about 12 million tons or 17 percent of the 70 million tons shipped in U.S. ships must be shipped at less than 27 feet. The weighted average depth for these harbors is 23.4 feet.

Table D-34 - Average Turnaround Time in Port for Canadian Combined Fleet

Vessel Class	Turnaround Time, Hours
1	20
2	20
3	20
4	20
5	22
6	22
7	22
10	26

Table D-35 - Average Loading and Unloading Rates at Major Terminals used in the Canadian Dry Bulk Trades (Iron Ore)

Harbor	Loading Terminals		Unloading Terminals	
	Number	Average Rate, Tons/Hour	Number	Average Rate, Tons/Hour
Canadian Ports				
Lake Superior:				
Michipicoten	1	1,700		
Thunder Bay	2	6,000		
Sault Ste. Marie			1	S.U.'s only 1/
Lake Huron:				
Depot Harbor	1	1,500		
Little Current	1	2,700		
Lake Erie:				
Port Colborne			1	S.U.'s only
Nanticoke			1	S.U.'s only
Lake Ontario:				
Picton	1	2,200		
Hamilton			3	1,270
St. Lawrence River:				
Sept Iles	2			
Port Cartier	1			
Contrecoeur	2	1,925		
United States Ports				
Lake Superior:				
Duluth	1	3,500		
Marquette	1	3,100		
Silver Bay	1	5,000		
Superior	1	3,200		
Taconite	1	6,000		
Two Harbors	1	3,800		
Lake Michigan:				
Burns Waterway			1	2,200
Portage			1	2,500
Gary			1	1,450
Indiana Harbor			3	1,340
Chicago			4	1,630
Escanaba	1	2,500		
Lake Erie:				
Ashtabula			2	2,000
Buffalo			1	2,600
Cleveland			4	1,880
Conneaut			1	3,500
Detroit			5	840
Lorain			2	1,550
Toledo			3	1,400
Huron			1	1,770

1/ S.U. = Self-Unloader

Table D-36 - Average Loading and Unloading Rates at Major Terminals used in the Canadian Dry Bulk Trades (Coal)

Harbor	Loading Terminals Number	Loading Terminals Average Rate, Tons/Hour	Unloading Terminals Number	Unloading Terminals Average Rate, Tons/Hour
Canadian Ports				
Lake Superior:				
Marathon			1	S.U.'s only 1/
Thunder Bay			1	S.U.'s only
			1	600
Sault Ste. Marie			1	S.U.'s only
Lake Huron:				
Little Current			1	S.U.'s only
Courtwright			1	S.U.'s only
Lake Erie:				
Windsor			1	S.U.'s only
Nanticoke			1	S.U.'s only
Kingsville			1	S.U.'s only
Port Stanley			1	S.U.'s only
Lake Ontario:				
Oshawa			1	S.U.'s only
Toronto			1	S.U.'s only
Lakeview			1	S.U.'s only
St. Lawrence River:				
Montreal			1	600
United States Ports				
Lake Michigan:				
Chicago	1	2,500		
Lake Erie:				
Ashtabula	1	8,000		
Conneaut	1	10,000		
Toledo	6	2,650		

1/ S.U. = Self-Unloader

Table D-37 - Average Loading and Unloading Rates at Major Terminals used in the Canadian Dry Bulk Trades (Limestone)

Harbor	Loading Terminals Number	Loading Terminals Average Rate, Tons/Hour	Unloading Terminals Number	Unloading Terminals Average Rate, Tons/Hour
<u>Canadian Ports</u>				
Lake Superior:				
Thunder Bay			1	S.U.'s only 1/
			1	65
Michipicoten			1	S.U.'s only
Sault Ste. Marie			2	S.U.'s only
Lake Huron:				
Killarney	1	2,000		
Whitefish			1	1,000
Courtwright			1	S.U.'s only
Sarnia			5	S.U.'s only
Parry Sound			1	S.U.'s only
Sombra			2	S.U.'s only
Serpent River			1	S.U.'s only
Lake Erie:				
Port Colbourne	2	1,400		
Windsor	1	400	4	S.U.'s only
Amherstburg				
Kingsville			1	S.U.'s only
Killarney	1	2,000		
Lake Ontario:				
Bathe	1	900		
Hamilton	2	400	3	S.U.'s only
Picton	2	1,000	1	S.U.'s only
Clarkson	1	2,000		
Colborne	1	1,000		
Toronto	1	400	3	S.U.'s only
St. Lawrence River:				
Montreal	4	500	3	S.U.'s only
Sept. Iles			2	700
			1	S.U.'s only
Baie Comeau	3	140	1	200
Quebec	1	500		
<u>United States Ports</u>				
Lake Superior:				
Superior	2	400	2	350
Duluth	1	1,500	1	700
Lake Huron:				
Calcite	2	3,900	2	S.U.'s only
Drummond Is.	1	2,000		
Stoneport	1	2,500	1	S.U.'s only
Lake Erie:				
Conneaut	1	S.L.'s Only 2/	1	S.U.'s only
Marblehead	1	1,500		
Cleveland	1	1,200		

1/ S.U. = Self-Unloader

2/ S.L. = Self-Loader

Table D-38 - Average Loading and Unloading Rates at Major Terminals used in the Canadian Dry Bulk Trades (Grain)

Harbor	Loading Terminals: Number	Loading Terminals: Average Rate, Bushels/Hour	Unloading Terminals: Number	Unloading Terminals: Average Rate, Bushels/Hour
Canadian Harbors				
Lake Superior:				
Thunder Bay	25	48,840	4	10,300
Lake Huron:				
Collingwood	1	16,000	1	16,000
Goderich	1	12,000	2	18,500
Midland	3	15,700	3	31,700
Owen Sound	1	15,000	1	22,000
Port McNicholl	1	12,000	1	49,000
Sarnia	1	22,000	1	30,000
Wallaceburg	1	15,000	1	
Lake Erie:				
Port Colborne	2	58,000	2	28,000
Windsor				
Port Stanley	1	22,000	1	15,000
Lake Ontario:				
Toronto	3	18,400	3	10,000
Kingston	2	44,000	1	35,000
Hamilton			1	5,000
St. Lawrence River:				
Montreal	5	99,200	4	41,250
Baie Comeau	1	47,000	1	85,000
Port Cartier	1	70,000	1	100,000
Quebec	1	45,000	2	80,000
Sorel	2	65,000	1	32,000
Trois Rivieres	1	55,000	1	45,000
Cardinal			1	15,000
Prescott	1	80,000	1	96,000
United States Harbors				
Lake Superior:				
Duluth	13	26,900	3	10,000
Superior	15	23,700	3	15,300
Lake Michigan				
Chicago	8	34,400	7	11,000
Milwaukee	2	26,000	2	10,000
Lake Huron:				
Saginaw	2	30,000		
Lake Erie:				
Toledo	3	40,700		
Detroit				
Huron	1	15,000	1	20,000
Buffalo	4	14,500	5	22,600

Table D-39 - Iron Ore Traffic at U.S. Harbors for 1976

Harbor	Depth	Millions of Tons Receipts	Shipments
L. Superior			
Two Harbors	27'		8.3
Duluth - Superior	27'		0.3 Can.
			22.3 U.S.
Presque Isle	27'		1.2 Can.
			5.0 U.S.
Silver Bay	27'		10.8
Taconite	27'		11.5
Total			59.4
At less than	27'		0
L. Michigan			
Escanaba	27'	0	11.5
Calumet Har. & River	27'	2.4 Can.	
		6.0 U.S.	
Indiana Harbor	27'	2.6 Can.	
		8.4 U.S.	
Burns Waterway	27'	0.04 Can.	
		4.1 U.S.	
Gary Harbor	27'	8.0 U.S.	
Total		31.5	11.5
At less than	27'	0	0
L. Huron			
St. Clair River	27'	Up 0.1 Can.	0
			Up 1/ 4.8 Can.
			0.0 U.S.
			Down 1/ 3.1 Can.
			42.8 U.S.
Detroit River	27'	Up 1.2 Can.	0
		0 U.S.	
		Down 0.6 Can.	
		7.9 U.S.	
			Up 1/ 4.8 Can.
			0 U.S.
			Down 1/ 2.5 Can.
			34.9 U.S.
Detroit Harbor	27'	1.8 Can.	0
		2.5 U.S.	0
Rouge River	27'	3.0 U.S. 2/	0
Trenton	27'	2.4 U.S.	0
Total		19.5	0
At less than	27'	0 2/	0

1/ Thru Traffic
2/ Some ore (perhaps 1 to 1-1/2 million tons) is received at Ford plant at 25' project depth.

Table D-39 - Iron Ore Traffic at U.S. Harbors for 1976 (Cont'd)

Harbor	Depth	Millions of Tons Receipts	Millions of Tons Shipments
L. Erie			
Toledo	27'	0.6 Can.	
		4.2 U.S.	
Sandusky	27'	.02 Can.	
Huron	25'	.2 Can.	
		1.7 U.S.	
Lorain	27'	0.4 Can.	
		4.1 U.S.	
Cleveland	27' & 23'	3.0 Can.	
		10.4 U.S.	
	23'	9.0 1/	
Fairport		0	
Ashtabula	27'	1.3 Can.	
		4.7 U.S.	
Conneaut	27'	2.3 Can.	
		6.1 U.S.	
Erie		0	
Buffalo	27' (1.9) & 22' (1.5)	3.4 Can.	
Total		42.4	
At less than	27'	12.4 1/ (29% of Total)	
Lake Ontario - None at U. S. Harbors			

1/ Up to 9.0 offloaded at 27' by 1985.

Table D-40 - Coal Traffic at U.S. Harbors for 1976

Harbor	Depth	Millions of Tons: Receipts	Millions of Tons: Shipments
L. Superior			
Duluth-Sup	27'	.9	2.2
Presque Isle	27'	0.6	0
Marquette	27'	0.5	
Ashland	24'	.1	
Keweenaw	25'	.1	
Silver Bay	27'	.2	
Taconite	27'	.6	
Total		3.0	2.2
At less than	27'	0.2 (7% of Total)	
Sault Ste. Marie	27'	2.8 Can. 3.0 U.S.	
Total		5.8	
L. Michigan			
Traverse City	21'	.06	
Ludington	20'	.04	
Muskegon	27'	1.7	
Grand Haven	23'	.1	
Holland	21'	.1	
Burns	27'	.1	
Indiana	22'	.2	
Cal. Har & River	27'	0	3.5
Milwaukee	21'	.9	
Sheboygan	21'	.03	
Menominee	24'	.05	
Port Washington	21'	.9	
Manitowoe	21'	.15	
Green Bay	24'	1.4	
Escanaba	27'	.2	
Total		5.9	3.5
At less than	27'	3.9 (66% of Total)	0
L. Huron			
Alpena	24'	0.6	
Saginaw River	21'	1.7	
Harbor Beach	21'	0.3	
St. Clair River	27'	Up 1.5 Down 0 (Note thru traffic Up 4.8 Can, 6.7 U.S.; Down 0.1)	
Detroit River	27'	Up 6.2 (Note thru traffic Up 4.8 Can, 8.3 U.S.; Down 0.1)	
Detroit Harbor		1.4	0
Rouge River		4.0 (2@27' 2@25')	0 0
Wyandotte	27'	0.5	0
Trenton	21'	0.4	0
Calcite		0.04	
Total		16.6	0
At less than	27'	5.0 (30% of Total)	0

Table D-40 - Coal Traffic at U.S. Harbors for 1976 (Cont'd)

Harbor	Depth	Millions of Tons		
		Receipts	Shipments	
<u>L. Erie</u>				
Monroe	27'	1.0	TO Can.	TO U.S.
Toledo	27'	0	3.9	10.7
Sandusky	24'	0	2.9	2.1
Huron		0	0	0
Lorain		0	0	0
Cleveland		0	0	0
Fairport		0	0	0
Ashtabula	27'		4.1	0.9
Conneaut	27'	0	5.6	1.1
Erie		0	0	0
Buffalo		0	0	0
Niagara River	21'	0.3	0	0
Total		1.3	16.5	14.8
At less than	27'	0.3 (25% of Total)	2.9 (18% of Total)	2.1 (14% of Total)
			Avg.	16%
<u>L. Ontario</u>				
None at U.S. Harbors				

Table D-41 - Limestone Traffic at U.S. Harbors for 1976

Harbor	Depth	Millions of Tons: Receipts	Millions of Tons: Shipments
L. Superior			
Duluth - Sup.	27'	0.7 U.S.	0
Ashland		0.05 U.S.	
		0.7	
L. Michigan			
Green Bay	24'	0.2	
Manitowoc	21'	0.01	
Milwaukee	21'	0.01	
Cal. Har & River	27'	1.6	
Indiana Har	27'	1.8	
Burns (Part of Indiana)	27'	0.5	
Buffington	26'	2.0	
Gary Harbor	27'	1.6	
St. Joseph	21'	0.1	
Holland Harbor	21'	0.1	
Grand Haven	23'	0.5	
Ludington	20'	1.0	
Port Inland	25'	0	3.3
Total		9.4	3.3
At less than	27'	3.9 (42% of Total)	3.3 (100%)
L. Huron			
Drummond Island	27'		2.1
Port Dolomite (U.S. Steel)	27'		3.5
Calcite (U.S. Steel)	25' (27' by 2000)		11.3
Stoneport	25' (27' by 2000)		9.7
Alpena	24'		.07 Can.
Saginaw River	21'	1.7	
St. Clair River	27' Up	0.1	0
	0 Down		0
Thru Traffic Up			0.1 Can.
Down			1.5 Can.
			13.4 U.S.
Detroit River	27' Up	0.2	0
	Down	4.7	0
Thru Traffic Up			0.2 Can.
			0.1 U.S.
Down			0.3 Can.
			8.7 U.S.
Detroit Harbor	27'	1.6	0
Rouge River	27' & 25'	2.2	
Wyandotte	27'	1.0	
Trenton	27'	0.1	
Total		11.6	26.7
At less than	27'	2.7 (25% of total)	21.1 (79% of Total, 0% by 2000)

Table D-41 - Limestone Traffic at U.S. Harbors for 1976 (Cont'd)

Harbor	Depth	Millions of Tons: Receipts	Millions of Tons: Shipments
L. Erie			
Toledo	27'	0.1	
Marblehead	24'	0	1.3
Sandusky	25'	0.2	
Huron	25'	0.7	
Lorain	27'	1.3	
Cleveland	27' & 23'	1.9	
Fairport	27'	1.9	
Ashtabula	27'	0.5	
Conneaut	27'	1.3	
Erie	27'	0.3	
Buffalo	25'	1.7	
Total		9.9	1.3
At less than	27'	4.0 (40% of Total)	1.3 (100%)
L. Ontario		by 2000 0.9 (10%)	
None at U.S. Harbors			

Table D-42 - Grain Traffic at U.S. Harbors for 1976

Harbor	Depth	Millions of Tons		
		Receipts		Shipments
Lake Superior				
Duluth-Superior	27'	Overseas		2.2
		Canadian		0.7
		U.S.		1.6
Total				4.5
		At less than 27'		0
Lake Michigan				
Milwaukee	27'	Overseas		0.2
		Canadian	0.1	0.1
		U.S.		0.02
Chicago Harbor	27'		0	0
Lake Calumet	27'	Overseas		0.2
		Canadian		0.06
		U.S. (internal)		0.05
Calumet	27'	Overseas		0.8
		Canadian		0.8
		U.S. (internal)	0.1	0.1
Total			0.2	2.3
At less than	27'		0	0
Lake Huron				
Saginaw River	25'	Canadian		0.2
Lake Erie				
Toledo	27'	Overseas		1.5
		Canadian		2.0
Huron	25'	Canadian		0.2
Cleveland	23'	Canadian		.01
		U.S.	0.1	
Buffalo 1/	24'	Canadian	0.04	
		U.S.	1.5	
Total			1.6	3.7
At less than	27'		1.6 1/ (100% of Total)	0.2 (5% of total)
Lake Ontario				
None at U. S. Harbors				

1/ Received at 27' by 2000.

Table D-43 - Percent of Year 1985 U.S. Traffic at Harbors with Depths 1/, 2/ Less than 27' by Commodity, Origin and Destination

Route		Commodity			
Origin	Destination	Iron Ore	Coal	Limestone	Grain
		%	%	%	%
S	S	-	0	-	0
S	M	0	0	-	-
S	H	0	0	-	-
S	E	5.0	0	-	90.0
S	O	0	-	-	0
M	S	-	0	-	-
M	M	0	70.0	100.0	-
M	H	0	0	100.0	-
M	E	5.0	-	100.0	-
M	O	-	-	-	0
H	S	-	-	10.0	-
H	M	100.0	-	80.0	-
H	H	-	-	80.0	-
H	E	100.0	-	80.0	-
E	S	-	15.0	100.0	-
E	M	-	70.0	-	-
E	H	-	30.0	100.0	-
E	E	-	25.0	100.0	-
E	O	-	20.0	100.0	0
E	SLS	-	15.0	-	-
O & SLS	M	0	0	-	-
O & SLS	E	30.0	-	-	-
O & SLS	O	-	0	-	-

1/ Average Federal channel depth at these locations in feet below LWD is: iron ore, 23.4 feet, coal, 23.0 feet, limestone, 24.1 feet, grain, 23.8 feet.

2/ The first letter of each lake name is used to denote lake of origin or destination.

Table D-44 - Percent of Year 2000 U.S. Traffic at Harbors with Depths 1/, 2/ Less than 27' by Commodity, Origin and Destination

Route		Commodity			
Origin	Destination	Iron Ore	Coal	Limestone	Grain
		%	%	%	%
S	S	-	-	-	0
S	M	0	-	-	-
S	H	0	0	-	-
S	E	0	-	-	0
S	O	0	-	-	0
M	M	0	50.0	100.0	-
M	H	0	-	100.0	-
M	E	0	-	100.0	-
M	O	-	-	-	0
H	S	-	-	5.0	-
H	M	100.0	-	40.0	-
H	H	-	-	25.0	-
H	E	100.0	-	20.0	-
E	S	-	10.0	-	-
E	M	-	50.0	-	-
E	H	-	20.0	100.0	-
E	E	-	15.0	100.0	-
E	O	-	15.0	-	0
O & SLS	M	0	0	-	
O & SLS	E	15.0	-	-	-
O & SLS	O	-	-	-	-

1/ Average Federal channel depth at these locations in feet below LWD is: iron ore, 23.4 feet; coal, 23.0 feet; limestone, 24.1 feet; grain, 23.8 feet.

2/ The first letter of each lake name is used to denote lake of origin or destination.

Table D-45 - Percent of Year 2035 U.S. Traffic at Harbors with Depths 1/, 2/ Less than 27' by Commodity, Origin and Destination

Route		Commodity			
Origin	Destination	Iron Ore	Coal	Limestone	Grain
		%	%	%	%
S	S	-	-	-	0
S	M	0	-	-	-
S	H	0	0	-	-
S	E	0	-	-	0
S	O	0	-	-	0
M	M	0	15.0	50.0	-
M	H	0	-	25.0	-
M	E	0	-	25.0	0
M	O	-	-	-	0
H	S	-	-	5.0	-
H	M	100.0	-	20.0	-
H	H	-	-	15.0	-
H	E	100.0	-	10.0	-
E	S	-	5.0	-	-
E	M	-	15.0	-	-
E	H	-	5.0	50.0	-
E	E	-	5.0	50.0	0
E	O	-	5.0	-	0
O & SLS	M	0	0	-	-
O & SLS	E	0	-	-	-
O & SLS	O	-	-	-	-

1/ Average Federal channel depth at these locations in feet below LWD is: iron ore, 23.4 feet; coal, 23.0 feet; limestone, 24.1 feet; grain, 23.8 feet.

2/ The first letter of each lake name is used to denote lake of origin or destination.

The Corps of Engineers has studies underway to determine the need for improvements at Buffalo and at Cleveland Harbors. There are plans to ship ore to the Cleveland outer harbor in 1,000-foot ships, offload and ship ore upriver in smaller ships. In addition, Republic Steel opened a new transshipment facility in Lorain outer harbor in 1980. This facility receives ore in 1,000-foot vessels for transshipment. As much as 6-7 million tons of the ore shipped to Cleveland could eventually be handled at Lorain. In view of this, it is expected that by year 1985, no more than 5 percent of iron ore received at U.S. Great Lakes ports will be restricted to less than 27-foot draft and by year 2000, all ore harbors will be at 27-foot draft.

b. Coal. Coal is shipped in large quantities to power plants and steel mills at 27-foot draft with few exceptions. Coal is also shipped in smaller quantities to harbors and docks that do not have 27-foot draft available. Discussions with industry have indicated that the present pattern of coal traffic will not change significantly in the near future. Therefore, the percent of coal moving at depths less than 27 feet will decrease slowly through the early years of project life. By 2035, however, it is estimated that nearly all coal (85-95 percent) will move at 27 feet and only 5 to 15 percent will be restricted to drafts less than 27 feet.

c. Limestone. Limestone is shipped in large quantities for use by the steel and cement industries. It is also shipped in much smaller quantities to many ports for use in the construction industry. Many ports receive as little as 100,000 tons per year. Many of these ports do not have 27-foot draft available. In addition, many of the shipping ports have only 25-foot draft available. Discussions with industry have indicated that this situation will not change much in the near future and the distribution of traffic in 1976 is representative of current and 1985 conditions. However, by year 2000, it is expected that the two major shipping ports (Calcite and Stoneport) will be deepened to 27 feet and the restriction will no longer be the shipping harbor, but will then be the receiving harbor. By year 2035, it is estimated that between 10 and 50 percent of the limestone, depending on the route involved, will be restricted to less than 27-foot draft.

d. Grain. Grain is currently shipped at 27-foot draft except for grain shipped to Buffalo, NY, which has only about 23.8-foot draft (weighted draft at several docks). By the year 2000, it is expected that all grain will travel at unrestricted 27-foot draft.

Canadian Harbors: Many harbor facilities used in the Canadian bulk trades also have depths less than 27 feet. The proportion of traffic in each bulk trade, which is loaded or unloaded at shallow draft harbors is given in Table D-46. These proportions were determined by analyzing 1976 port-to-port traffic in each of the bulk trades, aggregating the shallow draft and deep draft tonnages into lake-to-lake totals, and comparing the total shallow draft component in each lake-to-lake route to the total tonnage of that commodity shipped over that route. For example, from Table D-46, 50 percent of Canadian coal moving from Lake Superior to Lake Ontario either originates or destinates at a shallow draft facility. Table D-47 gives the average depth at the shallow draft facilities encountered in each of the lake-to-lake routes. These were compiled from data on the individual facilities involved in each port-to-port route. The lesser or "controlling" depth was determined for each port-to-port route, and the mean controlling depth for each lake-to-lake grouping, or route, was calculated for each commodity trade by weighting the port-to-port routes according to tonnage shipped.

Table D-46 - Percent of Canadian Great Lakes Dry Bulk Traffic at Shallow Draft Harbors

Route		Commodity			
Origin	Destination	Iron Ore	Coal	Limestone	Grain
S	S	100.0	-	-	100.0
	M	0	-	-	100.0
	H	-	100.0	-	100.0
	E	8.0	50.0	0	100.0
	O	0	50.0	-	100.0
	SLS	-	-	-	0.9
	EX	-	-	-	0
M	S	-	100.0	-	-
	M	-	-	-	-
	H	-	-	-	-
	E	-	-	0	100.0
	O	-	-	-	100.0
	SLS	-	-	-	0
	EX	-	-	-	11.2
H	S	-	-	100.0	-
	M	100.0	100.0	-	-
	H	-	-	84.0	100.0
	E	100.0	-	90.0	100.0
	O	-	-	-	100.0
	SLS	-	-	-	100.0
	EX	-	-	-	100.0
E	S	-	99.0	100.0	-
	M	-	-	-	-
	H	100.0	25.0	100.0	100.0
	E	-	0	90.0	100.0
	O	-	3.5	-	100.0
	SLS	-	-	-	53.0
	EX	-	-	-	5.7
O	S	-	-	-	-
	M	0	-	-	-
	H	-	-	-	-
	E	100.0	-	-	100.0
	O	-	-	0	-
	SLS	-	-	-	-
	EX	-	-	-	-
SLS	S	-	-	-	-
	M	-	-	-	-
	H	-	-	-	-
	E	-	-	-	-
	O	-	0	-	-
	SLS	-	-	-	-
	EX	-	-	-	-
EX	S	-	-	-	-
	M	0	-	-	-
	H	-	-	-	-
	E	30.8	-	-	-
	O	0	0	-	-
	SLS	-	-	-	-

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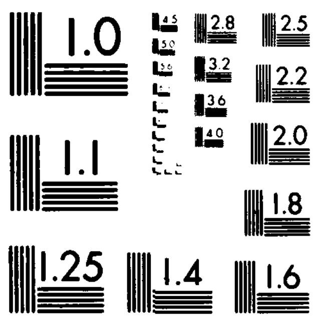

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Table D-47 - Weighted Average Minimum Depths at Shallow Harbors Used in the Canadian Great Lakes Dry Bulk Trades

Route		Depth in Feet			
Origin	Destination	Iron Ore	Coal	Limestone	Grain
S	S	24.0			24.8
	M				23.6
	H		23.7		23.2
	E	23.0	23.7		21.5
	O		23.7		24.8
	SLS				22.3
	EX				
M	S		20.0		
	M				
	H				
	E				21.0
	O				25.0
	SLS				
	EX				23.0
H	S			22.4	
	M	20.5	20.5		
	H			22.0	22.0
	E	22.4		23.3	22.3
	O				23.0
	SLS				22.9
	EX				23.0
E	S		21.0	24.4	
	M				
	H	24.0	25.0	22.1	22.8
	E			22.6	21.0
	O		22.1		22.4
	SLS				23.0
	EX				21.4
O	S				
	M				
	H				
	E	23.3			23.8
	O				
	SLS				
	EX				
EX	S				
	M				
	H				
	E	23.5			
	O				
	SLS				

SECTION 3
EVALUATION OF REGULATION PLANS

3.1 Lake Erie Regulation Plan Objective

Limited regulation of Lake Erie would require increasing the Lake's outflow whenever high water supply conditions exist on the upper Great Lakes (about 80 percent of Lake Erie water comes from the upper Great Lakes). This can be achieved by a control structure near the head of the Niagara River (the outlet of Lake Erie). When the supply condition on the upper Great Lakes is at or below average, the control structure at Niagara would be adjusted to provide the outflow which would have occurred under natural conditions. The objective, therefore, is to maximize the lowering of the high Lake Erie water levels while maintaining as nearly as possible its long-term average and low levels. Several alternative control structures have been examined and regulation plans developed around them. These structures have net capacities on an annual basis, ranging from 3,700 cfs to 25,000 cfs.

3.2 Basis-of-Comparison

3.2.1 Basis-of-Comparison Using Plan 1977 and Plan 1958-D (Categories 1 and 2)

All Lake Erie regulation plans developed by the Board were compared to the basis-of-comparison which is a set of water levels and outflows that the Great Lakes would have experienced for the historical period 1900-1976 if certain assumed physical conditions had been in effect throughout this period. In computing the basis-of-comparison, the Study Board adopted the following conditions: Lake Superior regulated in accordance with Plan 1977; Lake Ontario regulated in accordance with Plan 1958-D (with discretion); average diversions of 5,000 cubic feet per second (cfs) at Long Lake and Ogoki, 3,200 cfs at Chicago, and 7,000 cfs at Welland Canal; 27-foot navigation channel outlet (present) conditions in the St. Clair and Detroit Rivers and 1953 (present) outlet conditions for Lake Erie.

3.2.2 Adjusted Basis-of-Comparison Using Plan 1977 and Plan 1958-D Modified (Category 3)

To take into account the high water supplies of the 1970's, a second basis-of-comparison was developed by modifying Plan 1958-D and considering channel enlargements in the St. Lawrence River. Only Category 3 plans were compared to the adjusted basis-of-comparison.

The main report and Appendix A "Lake Regulation" provide detailed descriptions of the regulation plans, the basis-of-comparison, and the adjusted basis-of-comparison.

3.3 Regulation Plan Development

Limited regulation of Lake Erie requires adjustments to its outflows according to certain prescribed rules through control works constructed at its outlet near the head of the Niagara River. The regulation studies were conducted under three separate categories. Category 1 develops the necessary plans to regulate Lake Erie levels without making any changes to Lake Ontario Regulation Plan 1958-D. Categories 2 and 3 deal with the modifications to Plan 1958-D. Category 3 also deals with channel modifications in the St. Lawrence River to handle the increased outflow from Lake Erie. Plans for Lake Erie regulation under each category were further subdivided into three groups: those which require a regulatory structure in the Niagara River, those which utilize a regulatory structure in a diversion channel cut across Squaw Island, and lastly, plans which use the Black Rock Lock to discharge the additional water from Lake Erie. All of these plans are considered limited regulation schemes since they would only lower the high levels of Lake Erie, but could not raise its levels.

The resulting outflows from Lake Erie, under Category 1, were routed through Lake Ontario in accordance with Regulation Plan 1958-D. Under Category 1 there was no attempt to modify Plan 1958-D to accommodate this increased inflow nor to satisfy the IJC Lake Ontario criteria. Plans under Category 2 included modifications to the operational rules of Lake Ontario Plan 1958-D to accommodate regulation of Lake Erie and to satisfy the IJC criteria for the regulation of Lake Ontario to the same degree as occurred under the development of that plan and under actual operation since 1960.

Regulation of Lake Ontario under Plan 1958-D consists of the selection of an outflow from a basic rule curve and a comparison of that outflow with a series of outflow limitations. If the selected outflow is greater than the minimum limitations or less than the maximum limitations, it is adopted as the outflow to be released from the lake. If, however, it falls outside the limitation, the limitation will govern the flow to be released. Category 2 modification consisted of making changes to these limitations (referred to as the "I", "P", "M", "J", and "L" limitations). This is explained fully in Appendix A.

Category 3 differs from Category 2 in that the resulting Lake Ontario levels and outflows are to satisfy the criteria as written in the Orders and Supplementary Orders of Approval over the entire 1900-1976 test period. This involves channel modifications in the St. Lawrence River as well as modifications to Plan 1958-D.

Three plans were tested under each category; [illegible]nated as 25N (which would increase the outflow from Lake Erie by 25,00[illegible] 15S (which would increase the outflow by 9,600 cfs), and 6L (which wo[illegible] increase the outflow by 3,700 cfs).

3.4 Economic Impact on Commercial Navigation

The Navigation Subcommittee evaluated the effects of each regulation plan on commercial navigation by comparing the cost of transportation under the basis-of-comparison regime of lake levels to the cost of transportation under the three plans for each category (1, 2, and 3).

For example, if the cost of shipping iron ore on the Lake Superior to Lake Erie route is higher under regulation plan conditions, the additional cost is considered to be a loss to navigation.

The depth of navigation channels is measured from low water datum (LWD) on each lake. Since the level of Lake Superior is usually closer to LWD than the other lakes, it usually limits the cargo loading capacity of vessels. Thus, Lake Erie levels must be reduced to a comparable level before they can cause any loss to navigation. When Lake Erie is the controlling lake under basis-of-comparison conditions, then all of the reduction in Lake Erie levels affects navigation. However, when other lakes control, only a portion of the lowering of Lake Erie levels affects navigation. Limited regulation of Lake Erie would increase the number of occasions when Lake Erie controls, as shown in Table D-48.

Table D-48 - Percent of Time that Each Lake Controls the Depth Available to Commercial Navigation (April - December)

	Route				
	S-MH-E			MH-E	
	S	MH	E	MH	E
Basis of Comparison	89.7	9.7	0.6	91.2	8.8
Plan 6L	89.5	9.9	0.6	89.3	10.7
Plan 15S	88.1	11.1	0.8	84.7	15.3
Plan 25N	82.2	13.3	4.5	67.9	32.1

The regime of lake levels under basis-of-comparison and regulation plan conditions is compared using monthly mean lake levels over the period of record.

The losses to navigation due to lowering the level of Lake Erie under different categories of regulation plans result from decreased cargo carrying ability and the consequent need for additional vessel trips. Over the 50-year economic evaluation period, the average annual cost of Great Lakes bulk commodity transportation is about $1.8 billion under all basis-of-comparison conditions (including the adjusted basis-of-comparison). The regulation plan with the greatest impact (25N) would increase that cost by about 10 million dollars. Detailed breakdowns of the economic impacts on commercial navigation are shown in Tables D-49 through D-51.

3.4.1 Impact by Category

There is very little difference between Categories 1, 2, and 3 in the economic impact on the United States fleet. The reason for this is that the only difference between Categories 1, 2, and 3 is a change in Lake Ontario levels (see Table D-52), and only a small percentage of the traffic on Lake

Table D-49 - Economic Impact on Commercial Navigation under Category 1
(Compared to Basis-of-Comparison)

Plan	Annual Transportation Cost 1985	Annual Transportation Cost 2000	Annual Transportation Cost 2035	Present Worth	Average Annual Amount
	$	$	$	$	$
Basis-of-Comparison					
United States	794,596,000	1,258,525,000	1,610,034,000	12,568,500,000	1,086,700,000
Canada	553,061,000	794,912,000	954,839,000	8,134,600,000	703,300,000
Total Costs	1,347,657,000	2,053,437,000	2,564,873,000	20,703,100,000	1,790,000,000
6L					
United States	-494,000	-802,000	-1,252,000	-8,172,000	-707,000
Canada	-226,000	-392,000	-536,000	-3,840,000	-332,000
Total Benefits	-720,000	-1,194,000	-1,788,000	-12,012,000	-1,039,000
15S					
United States	-1,468,000	-2,416,000	-3,660,000	-24,403,000	-2,110,000
Canada	-759,000	-1,313,000	-1,780,000	-12,862,000	-1,112,000
Total Benefits	-2,227,000	-3,729,000	-5,440,000	-37,265,000	-3,222,000
25N					
United States	-4,338,000	-7,195,000	-10,949,000	-72,552,000	-6,273,000
Canada	-2,680,000	-4,558,000	-6,056,000	-44,745,000	-3,869,000
Total Benefits	-7,018,000	-11,753,000	-17,005,000	-117,297,000	-10,142,000

Table D-50 - Economic Impact on Commercial Navigation under Category 2
(Compared to Basis-of-Comparison)

Plan	Annual Transportation Cost			Present Worth	Average Annual Amount
	1985	2000	2035		
	$	$	$	$	$
Basis-of-Comparison					
United States	794,596,000	1,258,525,000	1,610,034,000	12,568,500,000	1,086,700,000
Canada	553,061,000	794,912,000	954,839,000	8,134,600,000	703,300,000
Total Costs	1,347,657,000	2,053,437,000	2,564,873,000	20,703,100,000	1,790,000,000
6L					
United States	-492,000	-800,000	-1,249,000	-8,146,000	-704,000
Canada	-152,000	-259,000	-329,000	-2,526,000	-218,000
Total Benefits	-644,000	-1,059,000	-1,578,000	-10,672,000	-922,000
15S					
United States	-1,466,000	-2,412,000	-3,656,000	-24,366,000	-2,106,000
Canada	-672,000	-1,152,000	-1,525,000	-11,280,000	-975,000
Total Benefits	-2,138,000	-3,564,000	-5,181,000	-35,646,000	-3,081,000
25N					
United States	-4,333,000	-7,190,000	-10,949,000	-72,498,000	-6,268,000
Canada	-2,522,000	-4,272,000	-5,616,000	-41,930,000	-3,625,000
Total Benefits	-6,854,000	-11,462,000	-16,565,000	-114,428,000	-9,893,000

Table D-51 - Economic Impact on Commercial Navigation under Category 3
(Compared to Basis-of-Comparison)

Plan	Annual Transportation Cost			Present Worth	Average Annual Amount
	1985	2000	2035		
	$	$	$	$	$
Basis-of-Comparison					
United States	794,596,000	1,258,525,000	1,610,034,000	12,568,500,000	1,086,700,000
Canada	553,061,000	794,912,000	954,839,000	8,134,600,000	703,300,000
Total Costs	1,347,657,000	2,053,437,000	2,564,873,000	20,703,100,000	1,790,000,000
6L					
United States	-496,000	-803,000	-1,249,000	-8,184,000	-708,000
Canada	-189,000	-322,000	-416,000	-3,148,000	-272,000
Total Benefits	-685,000	-1,125,000	-1,665,000	-11,332,000	-980,000
15S					
United States	-1,472,000	-2,417,000	-3,657,000	-24,424,000	-2,112,000
Canada	-736,000	-1,266,000	-1,691,000	-12,395,000	-1,072,000
Total Benefits	-2,208,000	-3,683,000	-5,348,000	-36,819,000	-3,184,000
25N					
United States	-4,334,000	-7,189,000	-10,944,000	-72,493,000	-6,268,000
Canada	-2,537,000	-4,291,000	-5,629,000	-42,124,000	-3,642,000
Total Benefits	-6,871,000	-11,480,000	-16,573,000	-114,617,000	-9,910,000

Table D-51 - Economic Impact on Commercial Navigation under Category 3 (Cont'd)
(Compared to the Adjusted Basis-of-Comparison)

Plan	Annual Transportation Cost 1985	2000	2035	Present Worth	Average Annual Amount
	$	$	$	$	$
Adjusted Basis-of-Comparison					
United States	794,606,000	1,258,532,000	1,610,032,000	12,568,585,000	1,086,722,000
Canada	553,097,300	794,954,000	954,838,000	8,135,060,000	703,384,000
Total Costs	1,347,703,300	2,053,486,000	2,564,870,000	20,703,645,000	1,790,106,000
6L					
United States	-496,000	-802,960	-1,251,500	-8,178,000	-707,000
Canada	-233,500	-405,600	-553,000	-3,970,700	-343,000
Total Benefits	-729,500	-1,208,560	-1,804,500	-12,148,700	-1,050,000
15S					
United States	-1,470,000	-2,416,000	-3,659,000	-24,412,000	-2,111,000
Canada	-776,100	-1,337,300	-1,802,800	-13,103,000	-1,133,000
Total Benefits	-2,246,100	-3,753,300	-5,461,800	-37,515,000	-3,244,000
25N					
United States	-4,330,000	-7,189,700	-10,951,000	-72,484,000	-6,267,000
Canada	-2,571,000	-4,370,500	-5,795,100	-42,900,000	-3,709,000
Total Benefits	-6,901,000	-11,560,200	-16,746,100	-115,384,000	-9,976,000

Table D-52 - Summary of Hydrologic Evaluation of Lake Erie Regulation Plans

	Basis-of-Comparison	Plan 6L	Plan 15S	Plan 25N
LAKE SUPERIOR				
Mean	600.44	600.43	600.41	600.37
Maximum	601.93	601.93	601.93	601.93
Minimum	598.69	598.68	598.65	598.62
Range	3.24	3.25	3.28	3.31
LAKES MICHIGAN-HURON				
Mean	578.27	578.24	578.18	578.05
Maximum	581.15	581.09	580.99	580.75
Minimum	575.47	575.45	575.42	575.36
Range	5.68	5.64	5.57	5.39
LAKE ERIE				
Mean	570.76	570.67	570.53	570.17
Maximum	573.60	573.45	573.18	572.53
Minimum	568.09	568.07	568.02	567.84
Range	5.51	5.38	5.16	4.69
LAKE ONTARIO - Cat. 1 (with deviation)				
Mean	244.61	244.64	244.65	244.63
Maximum	247.37	247.39	247.56	247.50
Minimum	241.81	241.74	241.59	241.38
Range	5.56	5.65	5.97	6.12
LAKE ONTARIO - Cat. 2				
Mean	244.61	244.66	244.69	244.71
Maximum	247.37	247.34	247.42	247.45
Minimum	241.81	242.04	242.12	242.21
Range	5.56	5.30	5.30	5.24
	Adj. B.O.C.	Plan 6L	Plan 15S	Plan 25N
LAKE ONTARIO - Cat. 3				
Mean	244.63	244.64	244.65	244.67
Maximum	246.77	246.79	246.84	246.83
Minimum	242.38	242.32	242.34	242.47
Range	4.39	4.47	4.50	4.36

Ontario is carried in United States vessels. In addition, Lake Ontario levels are seldom the controlling levels for routes involving other lakes in the system. Therefore, the impacts on the Canadian fleet are also small, but are still much larger than for the U.S. fleet since most of the traffic on Lake Ontario is carried in Canadian vessels.

3.4.2 Impact by Plan

As shown in Tables D-49, D-50, and D-51, the total net loss to navigation increases from Plan 6L to Plan 25N as the Lake Erie levels, and consequently, Lake Michigan-Huron levels are decreased. As stated above, Lake Erie levels directly affect mainly Canadian traffic, while Lake Michigan-Huron levels affect mainly U.S. traffic.

3.4.3 Effect of Adjusting Basis-of-Comparison

The adjustments to the basis-of-comparison only affect the levels on Lake Ontario. Therefore, there are only small impacts on the United States fleet since little traffic on Lake Ontario is carried in U.S. vessels. Most traffic on Lake Ontario is carried in Canadian vessels and, therefore, the impacts are greater on the Canadian fleet. Table D-53 shows a comparison of the effects of Category 3 plans on the U.S. and Canadian fleets under basis-of-comparison and adjusted basis-of-comparison conditions.

Table D-53 - Comparison of Impacts on Transportation Cost Under Basis-of-Comparison and Adjusted Basis-of-Comparison Conditions (Category 3)

Condition	Impact in Dollars (Present Worth)		
	Plan 6L	Plan 15S	Plan 25N
United States Fleet			
Basis-of-Comparison	- 8,184,000	- 24,424,000	- 72,493,000
Adjusted Basis-of-Comparison	- 8,178,000	- 24,412,000	- 72,484,000
Difference	- 6,000	- 12,000	- 9,000
Canadian Fleet			
Basis-of-Comparison	- 3,148,000	- 12,395,000	- 42,124,000
Adjusted Basis-of-Comparison	- 3,970,700	- 13,103,000	- 42,900,000
Difference	822,700	708,000	776,000

Section 4

SENSITIVITY ANALYSES

4.1 Introduction

The purpose of each sensitivity test undertaken was to determine the effect of changes in basic data or assumptions on the losses to navigation caused by limited regulation of Lake Erie. The following assumptions and data were tested:

1. Projections of bulk traffic,

2. extension of the navigation season, and

3. capital cost of ship construction.

In addition, the computer program used in this study was tested by running data from the International Great Lakes Levels Board (IGLLB) Study (7 December 1973) to determine if the IGLLB results could be duplicated.

The differences between data used in this study and data used in the IGLLB study were also examined to identify the reasons for the marked increase in impact on commercial navigation from changes in lake level.

4.2 Projections of Bulk Traffic

The losses to commercial navigation are sensitive to the accuracy of projections of future commerce (commodity and volume), composition of the vessel fleet (number and characteristics of vessels), and traffic patterns (e.g., Mesabi ore and pellets vs. foreign ore and pellets via the Seaway). These factors are all interdependent (if one changes, the others will change), and all are dependent upon the laws of supply and demand, which include new technologies which may develop. Other factors, such as political decisions affecting imports and exports, intermodal competition, and availability of funds for research, planning, or construction for the various transportation modes will also affect future commerce. Because of the complexity of factors involved it is difficult to place a numerical value on the accuracy of projections or on the accuracy of benefits resulting from regulation.

The annual cost of transportation will rise or fall nearly proportionally to the total volume carried. Therefore, a range of high and low estimates of traffic volume was considered to represent the broadest possible range in transportation costs and benefits/losses, and as such, a detailed evaluation of all factors, vessel fleet, technology, etc., was not considered necessary. The evaluation of these variables would require new data, new assumptions, and new evaluations. Such a monumental effort was considered an unnecessary refinement.

The projections of future commerce were modified to include a low projection assuming no growth at all between years 1985 and 2035 and a high projection assuming 2-1/2 percent annual growth between 1985 and 2035. The projections used in this study represent growth of about 1 percent annually. Table D-54 shows the traffic in millions of tons under each assumption and the capitalized value of each.

Table D-54 - Sensitivity Analysis of Traffic Projections

Traffic Projection	Year 1985 (Millions of Tons)	Year 2000 (Millions of Tons)	Year 2035 (Millions of Tons)	Capitalized Value at 8-1/2% (Millions of Dollars)	Effect on Navigation Losses
Low (no growth)	244	244	244	3,072	- 15% 1/
Used in this study: (1% annual)	244	299	378	3,596	-
High (2-1/2% annual)	244	353	839	4,520	+ 26% 2/

1/ $\frac{3072 - 3596}{3596} \times 100 = -15\%$

2/ $\frac{4520 - 3596}{3596} \times 100 = +26\%$

As shown, the no growth assumption would reduce the losses to navigation by 15 percent because less traffic would be in the system to be affected by changes in levels. The high projection, on the other hand, would increase the losses to navigation by about 26 percent.

4.3 Extension of the Navigation Season

The impact of season extension on the losses to navigation due to limited regulation of Lake Erie would be directly proportional to the change in total transportation cost reduction. For example, extension of the season by one month would reduce the required freight rate by about 2-1/2 percent for iron ore, 3 percent for coal, and about 1 percent for grain.3/ The effect on limestone was not evaluated. A one month season extension would reduce total transportation cost for bulk commodities by about 2 percent. As a result, any benefits or losses accruing to commercial navigation due to limited regulation of Lake Erie would also be reduced by about 2 percent.

3/ Data on freight rates taken from 16 December 1975 Winter Rate Study by ARCTEC, Inc.

4.4 Capital Cost of Ship Construction

The vessel operating cost used in this study includes the capital cost of ship construction based on the premise that all costs should be shared equally by the users of the system. Lower water levels result in lower carrying capacities for the vessels in the bulk fleet. More trips are required each year to transport the same tonnage. Shipping authorities have indicated that additional vessels must be added to the fleet to provide the additional trip capacity. Therefore, the capital costs of these additional vessels must be included in the total transportation cost. Capital costs for ships are expected to account for about 30 percent of total trip costs over the 1985-2035 period.

4.5 Changes in Data: International Great Lakes Levels Board (IGLLB) Study vs. International Lake Erie Regulation (ILER) Study

The effect of changes in lake levels on commercial navigation is much greater now than during the IGLLB Study (1973). The evaluation in the IGLLB Study was based on 1971 price levels. The evaluation in this report is based on 1979 price levels. The major changes in data are discussed in the following paragraphs.

4.5.1 Projections of Future Commerce

The projections of commerce for any future calendar year are less under the ILER Study than the IGLLB Study. However, the 50-year evaluation periods are different for each study 1985-2035 for ILER Study and 1970-2020 for IGLLB Study. The resulting growth trends used in the ILER are somewhat higher in the first 25 years and lower in the last 25 years than those assumed for the IGLLB 50-year economic evaluation period.

The impact of the different assumption in tonnage growth can be shown by comparing the present worth of the tonnage used in each study (Figure D-4). As shown, the tonnage used in the ILER Study produces an increase of about 10 percent in results.

4.5.2 Shallow Draft Traffic

A shallow draft harbor is a harbor with channel depth less than 27 feet. The IGLLB assumed that all traffic to shallow draft harbors would be eliminated by 1995. Either the shallow draft harbor would be deepened to 27 feet or the traffic would be transferred to 27-foot deep harbors.

A thorough evaluation of traffic patterns revealed that nearly all iron ore and grain currently is shipped to and from 27-foot harbors. Coal and limestone, on the other hand, are often shipped to harbors where channel depths are less than 27 feet and total receipts at a port are generally 100,000 tons annually or less. Because of the relatively small volume of traffic, some of these harbors will not be deepened. Therefore, a new scenario for the "shallow draft" harbors was developed for this study.

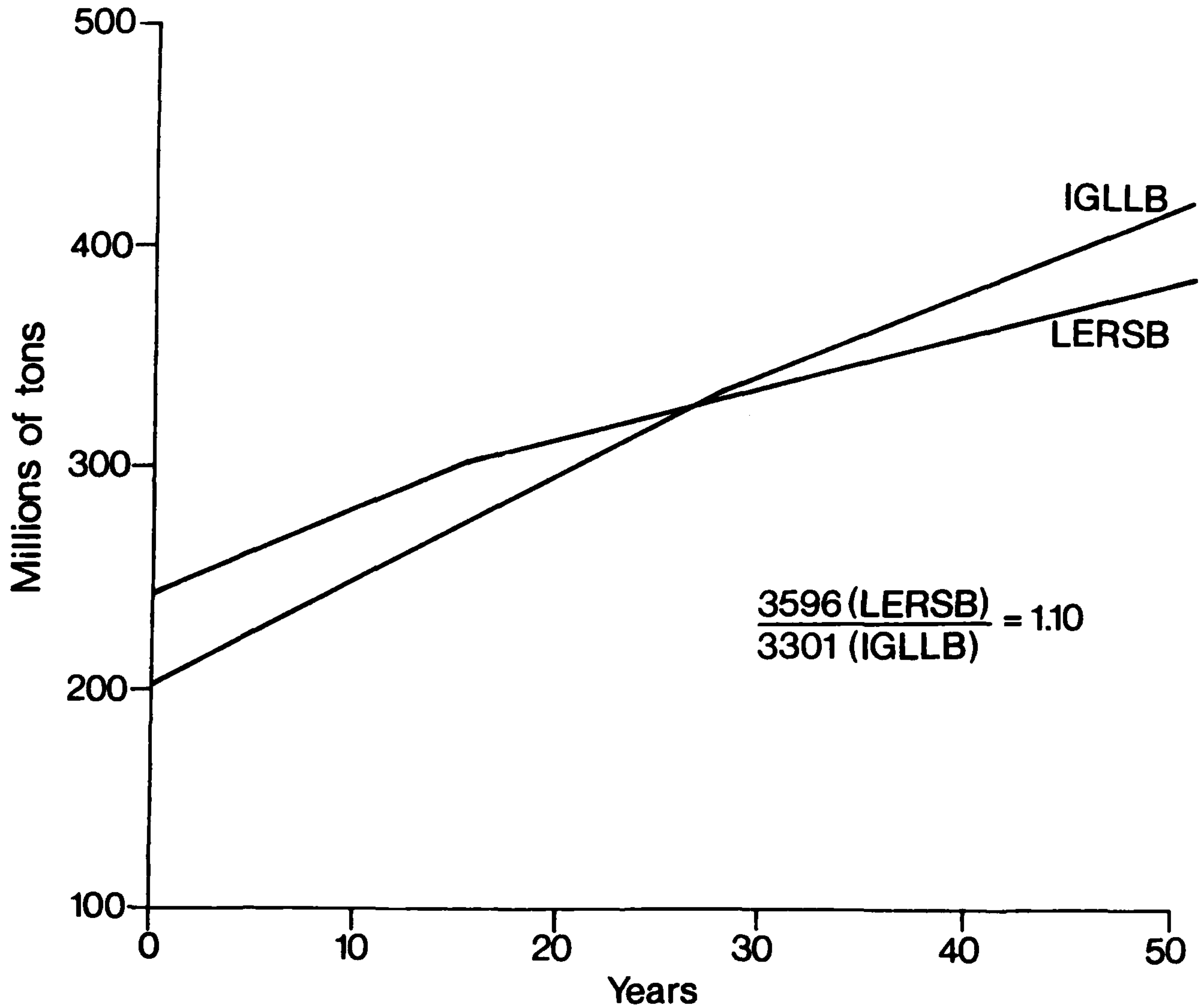

Figure D-4 Present value of tonnage International Great Lakes Levels Board (IGLLB) versus Lake Erie Regulation Study Board (LERSB)

A test run of Plan 25N using the IGLLB assumption of no shallow draft traffic by 1995 indicated losses to navigation of about 58 million dollars (present worth). The losses under the current revised shallow draft analysis are about two times greater ($117 million). Therefore, the revised shallow draft analysis approximately doubles the losses to commercial navigation.

4.5.3 Vessel Operating Costs

Vessel operating costs were obtained from the United States Maritime Administration and in Canada, from the St. Lawrence Seaway Authority and the Department of Industry, Trade, and Commerce. Vessel operating costs for a class 10 vessel are compared in Figure D-5. As shown, the operating costs for the combined U.S. and Canadian fleet are about four times higher in 1979 compared to 1971 (IGLLB Study).

A comparison of ILER and IGLLB hourly vessel operating costs for vessel classes in the United States and Canadian fleets is shown below in Table D-55.

Table D-55 - Comparison of ILER and IGLLB Study Hourly Vessel Operating Costs

	Vessel Class							
	5	6	7	8	9	10	11	Total 1/
U.S. Fleet								
ILER Costs	1115	1212	1298	1400	1769	1905	2210	8699
IGLLB Costs	305	324	345	453	484	563	0	2474
Ratio	3.6	3.7	3.8	3.1	3.6	3.4	N/A	3.5
	1	2	3	4	5	6	7	
Canadian Fleet								
ILER Costs	555	667	792	997	1095	1200	1509	6815
IGLLB Costs	149	179	208	228	228	251	252	1495
Ratio	3.7	3.7	3.8	4.4	4.8	4.8	6.0	4.6

1/ Class 11 costs excluded since these were not considered in the IGLLB Study.

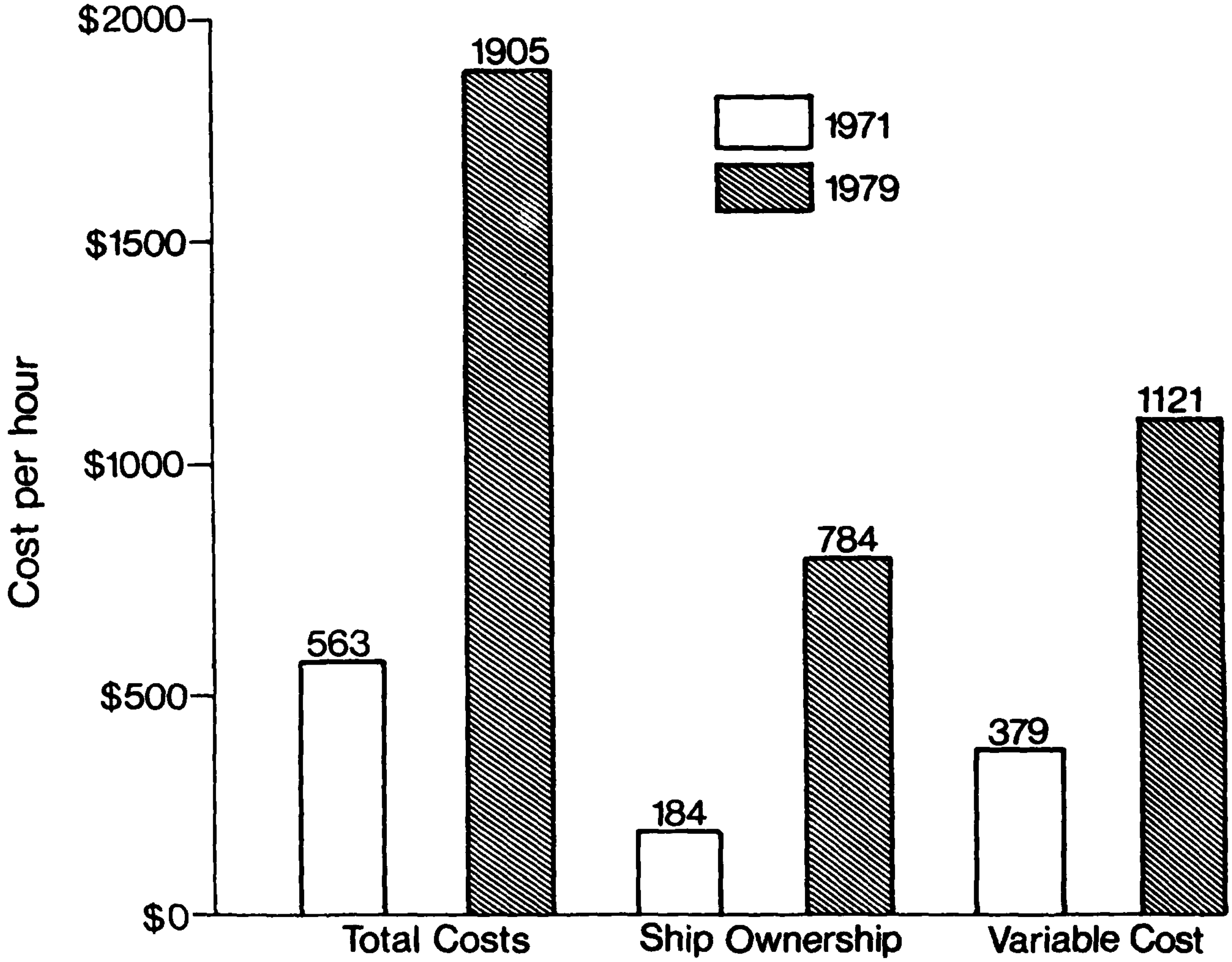

Figure D-5 Vessel cost per hour class 10, 1971 vs. 1979

NOTE: Ship ownership equals interest plus amortization. Ship costs were $22.5 million in 1971 and $64 million in 1979. Variable cost equals overhead, labor, fuel, etc.

Source: MARAD

4.5.4 Fuel Costs

The costs of marine diesel and bunker C #6 fuels have risen dramatically from 1971 to 1979 as shown in Figure D-6. Based on this increase, and the recent rapid increase in prices, it was assumed that fuel costs would increase at a rate of 5 percent greater than the rate of inflation over the first 20 years of the project economic analysis period (from 1985 to 2005). The effect of this is to increase transportation costs and consequently the losses to navigation by about 30 percent as shown in the following analysis for Class 5 and Class 10 vessels.

	Vessel Hourly Operating Cost	
Item	Base Year Costs 1979	Average Annual Costs over the Project Life 1985-2035
Vessel Class 5		
Fuel Cost	\$ 287	\$ 574
Non-Fuel Cost	799	799
Total Cost	\$1,086	\$1,373
Vessel Class 10		
Fuel Cost	\$ 489	\$ 978
Non-Fuel Cost	1,417	1,417
Total Cost	\$1,906	\$2,395

Ratio of Cost Change

Class 5: $\frac{1373}{1086} = 1.26$

Class 10: $\frac{2395}{1906} = 1.26$ Say 1.3 or 30%

4.5.5 Summary of Impact of Data Changes

The total effect of the four data changes described is to increase the impact of lake level changes on commercial navigation by a factor of about 11. That is, the benefit or loss to navigation is now 11 times greater than it was when the IGLLB Study was performed.

Variable in Sensitivity Analysis	Factor
Commerce Projections	1.1
Shallow Draft Traffic	2.0
Vessel Operating Costs	4.0
Increasing Fuel Costs	1.3

Total Effect (1.1 x 2.0 x 4.0 x 1.3) = 11

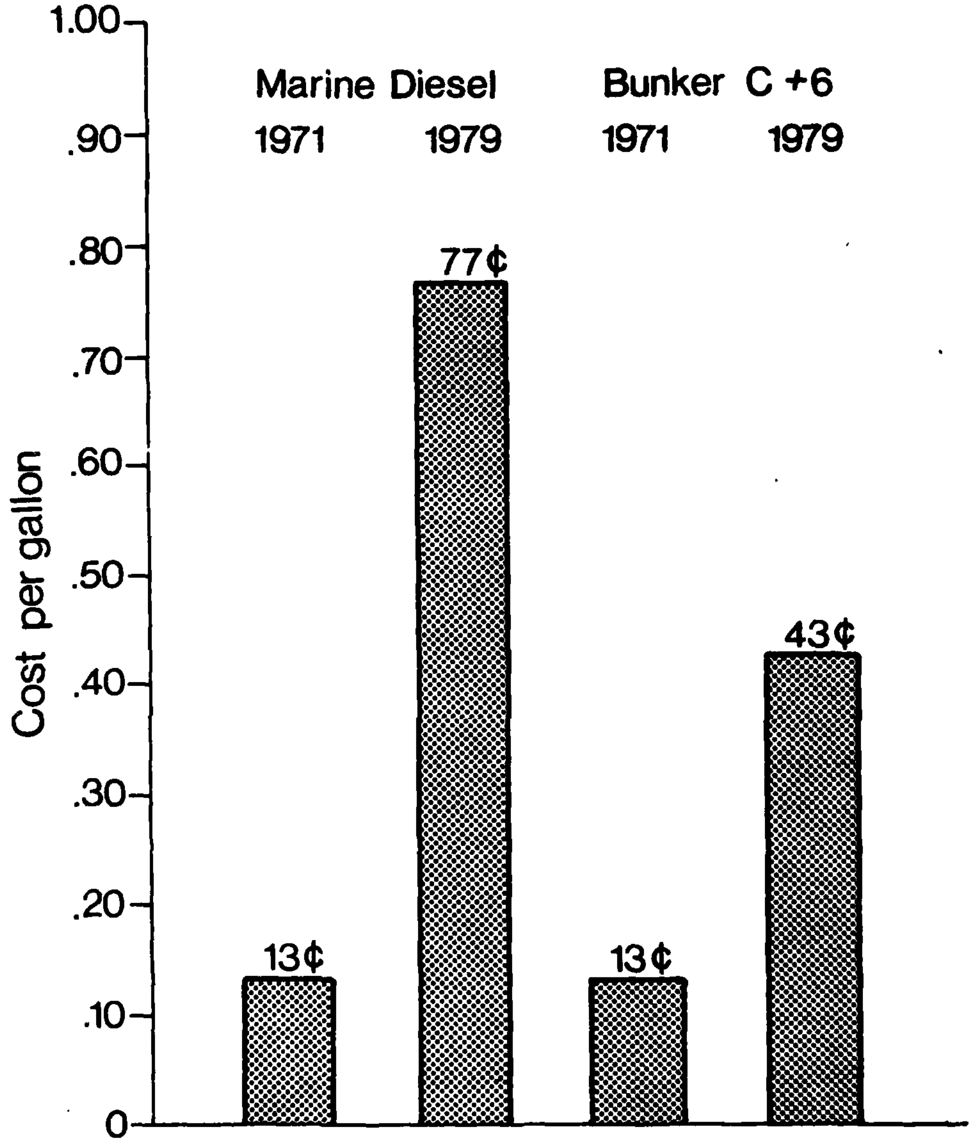

Figure D-6 Fuel costs 1971 to 1979

Source: MARAD

4.6 Verification of 1980 Computer Program

The 1980 computer program used in this study (ILER Study) is a modified version of the program used in the International Great Lakes Levels Board (IGLLB) Study (7 December 1973).

The 1970 data used in the IGLLB Study was run through the modified ILER Study program to test agreement with the earlier (IGLLB) program. The results (see Table D-56 below) showed that the modified program yields results about 2 percent lower than the IGLLB computer program when the same input data are used.

Table D-56 - Comparison of ILER and IGLLB Study Transportation Cost Savings For Regulation Plan SEO-901

Commodity	Computer Program Used: IGLLB Study	Computer Program Used: ILER Study
	$	$
Iron Ore	291,300	284,400
Coal	12,200	12,900
Grain	40,700	40,100
Limestone	9,000	9,200
Total IGLLB Study	353,200	346,600
Total ILER Study	346,600	
Difference	6,600	

Section 5

DREDGING AS AN ALTERNATIVE TO COMPENSATE FOR LOWER LAKE LEVELS

5.1 Introduction

The navigation losses could be eliminated if harbors and connecting channels were dredged deeper to offset the decrease in mean lake level. That is, if mean lake levels were decreased by 0.3 feet and the harbors and channels were dredged 0.3 feet deeper, then there would be no loss in vessel loading. The quantities of material and cost involved in dredging United States Federal harbors and channels to depths of 1/4, 1/2, and 1 foot, have been determined and curves of depth versus cost plotted for each lake and connecting channel. A similar analysis for Canadian harbors was not undertaken due to a lack of sufficient readily available data.

It is recognized that it is not possible to dredge to tolerances of 1/4 foot. However, it is considered likely that such dredging would be accomplished during normal maintenance dredging by modifying the contract to pay for the additional depth desired, for instance, 0.3-foot as in the example above.

5.2 Dredging Costs

Dredging costs were estimated for U. S. harbors on Lakes Michigan, Huron, and Erie (Table D-57). The regulation plans do not affect the high or mean levels on Lake Superior and only lower the minimum level by 0.1 foot. Therefore, dredging costs were not estimated for Lake Superior. Likewise, the mean level on Lake Ontario is essentially unchanged. In view of this, dredging costs were not estimated for Lake Ontario.

Harbor areas, the nature of existing bottom materials, and unit prices for dredging were determined from information available at Corps of Engineer District Offices at Chicago, Illinois; Detroit, Michigan; and Buffalo, New York. If, in the past, dredged material was considered polluted, then the cost of confined disposal was included. All estimates were based on December 1977 price levels.

It should be noted that the decrease in mean water level on Lake Erie for Plan 6L is about 0.1 foot; for Plan 15S, 0.2 foot; and for Plan 25N, 0.6 foot. Practically speaking, dredging is accomplished in terms of 1/2 feet or whole feet of depth. If it were determined to dredge 1/2 foot deeper to offset the decrease in mean lake level caused by Plans 6L or 15S, the initial cost would be much greater than simply paying a contractor for 0.1 or 0.2 foot additional dredging. Nevertheless, the portion of that cost chargeable to a regulation plan is only the amount for the decrease in mean level caused by a regulation plan. Any additional amount would be charged to overdepth maintenance dredging for the existing harbor or channel project.

5.3 Losses to Navigation While Dredging is Being Accomplished

If a regulation plan were implemented, losses would occur to navigation while dredging to offset those losses was being accomplished. If dredging was completed in 5 years, navigation losses will decrease to zero over the 5-year period. Losses were computed using the 1985 loss for the first year and decreasing that loss to zero in equal increments over the 5 or 10-year period. The dredging costs and the navigation losses while dredging is being accomplished are summarized in Table D-57.

5.4 Summary

As shown in Table D-57, the dredging costs plus navigation losses while dredging is being accomplished are greater than the losses to the United States vessel fleet from regulation. It is concluded that dredging is not a viable alternative for the United States, especially for Plans 6L and 15S where dredging costs alone would be greater than the losses caused by regulation.

Table D-57 - Comparison Between Dredging Costs Plus Navigation Losses While Dredging is Being Accomplished and Navigation Losses With No Dredging (Millions of Dollars, Present Worth)

Plan	Dredging Cost		Navigation Loss		Total		U. S. Navigation Loss with no Dredging (Category 3 Plans vs. Basis-of-Comparison)
	5-yr.	10-yr.	5 yr.	10-yr.	5-yr.	10-yr.	
6L	14	11	2	3	16	14	8.2
15S	27	23	6	9	33	32	24.4
25N	63	53	19	29	82	82	72.5

ANNEX A

CONVERSION FACTORS

(BRITISH TO METRIC UNITS)

1 cubic foot per second (cfs) = 0.028317 cubic metres per second (cms)

1 cfs-month = 0.028317 cms-month

1 foot = 0.30480 metres

1 inch = 2.54 centimetres

1 mile (statute) = 1.6093 kilometres

1 ton (short) = 907.18 kilograms

1 square mile = 2.5900 square kilometres

1 cubic mile = 4.1682 cubic kilometres

Temperature in Celsius: $°C = (°F - 32)/1.8$

1 acre-feet = 1,233.5 cubic metres

1 gallon (U.S.) = 3.7853 litres

1 gallon (British) = 4.5459 litres

1 ton (long) = 1016.0 kilograms

ANNEX B

Commercial Navigation Subcommittee Membership

Canadian Section

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Transport Canada

G. Reginald Golding, Member
Transport Canada

Nick Mangione, Member
Department of Public Works

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St. Lawrence Seaway Development Corporation

Donald J. Ward, Member
Corps of Engineers

Sharon Heckman, Member
Corps of Engineers

Fred Kwan, Member
Corps of Engineers

ANNEX C
Computer Programs

"LEVELS" and "GLCOST"

for

NCD Planning Division, Chuck Larsen
to be used by the
International Great Lakes Levels Board
for a report to the
International Joint Commission
on the
Regulation of Great Lakes Water Levels

Source Language: Fortran | System: BCS EKS1

Author(s)

1. Bureau of Mines

2. U. S. Army Corps of Engineers, Detroit District

3. U. S. Army Corps of Engineers, North Central Division
   Sharon Heckman (NCDDO)

Commercial navigation cost comparison figures have been calculated with the help of computer algorithms for various lake level regulation plans. With the assistance of data processing, it was possible to study numerous regulation plans and arrive at transportation costs for both U. S. and Canadian fleets by commodity, month, traffic route, and vessel class.

Two separate computer programs were needed in this study. These programs will be referenced as "LEVELS" and "GLCOST." The first program, "LEVELS," is only used to preprocess the actual lake water level readings and produce the route variation readings needed to execute the second program, "GLCOST." Once all the various plans under consideration have been run and converted by "LEVELS," the output can be saved and input to "GLCOST" as often as necessary or desired.

Input to "LEVELS" consists of files of data that contain monthly mean lake level readings. The first record in each file is a title card. The second and remaining data records consist of 12 lake level readings (January-December), a lake number, and a year. The format for this data is (9A8,2X,I1,1X,I4). The third record contains the monthly values for the same lake and the next year. All data for one lake is grouped together and followed by data for another lake. The program is currently set to extract data for 1900-1976, the years used in the study. The lake numbers to be used are 1, 2, 3, and 4. If any other lake numbers or years exist on the input file, they will be ignored. Input levels for 1 represent Lake Ontario, 2 is Lake Erie, 3 is Lakes Michigan and Huron, and 4 is Lake Superior. Since Lake Michigan and Lake Huron hydraulically react as one lake, only one set of water level readings is available for them.

A maximum of 30 different files may be input for one run. The output will consist of an equal number of files. These output files will also start with a title card. The remaining data records contain the month, year, and 10 numerical values. These numbers represent the variation (plus or minus) that exist relative to the minimum water depth to be used in "GLCOST." The 10 values correspond to 10 different routes that will be evaluated in "GLCOST" and listed later within this documentation. The output format is (12F6.0,2X,I1,1X,I4). Data for each year is grouped together. These files will subsequently be used as water level input to "GLCOST."

"GLCOST" was prepared to utilize all of the data on vessel characteristics, prospective commerce, operating costs, trip times, and water level data in order to calculate the cost of commercial shipping on the Great Lakes. A comparison of these costs will show the monetary effect (cost benefits or losses) of the regulation plans being considered.

One execution of "GLCOST" will produce cost figures for a single year for either U. S. or Canadian data. Within this run, a maximum of 30 different lake level plans may be considered. Each run will evaluate data for four different commodities and produce results for deep draft and shallow draft harbors. The program will handle 77 years of water level data (1900-1976), 11 different vesssel classes, and 10 different trade routes for domestic, export, and import cargo.

Numerical input values may be coded using a free format (separate each number by at least one space) unless otherwise indicated. Titles (words listed in capital letters such as items 5, 7, 9, 11, etc., listed below) are input simply to label data for easier identification. The first three letters are required and any additional letters or comments may be input simply to help the user. Data should be input as follows:

1. Number of files of water level data to be run. (Total number equals base case plus number of alternate plans up to a maximum of 30 files).

2. Short title (maximum of 10 characters in columns 1-10) for each file of water level data.

3. Title (maximum of 80 characters).

This line will be printed as part of each page heading on the output.
This title might contain the country (United States or Canada), commodity (iron ore, coal, limestone, or grain), year, date of run, etc.

4. a. Year

b. Minimum water depth for deep draft harbors (ex. =27 ft.)

c. Minimum water depth for shallow draft harbors (ex. iron = 23.4 feet, coal = 23 feet, limestone = 24.1 feet, grain = 23.8 feet).

d. Percentage of U. S. Exports carried in U. S. ships for U. S. runs or percentage of Canadian imports carried in Canadian ships for Canadian runs (ex. 80 percent = 80).

e. Percentage of U. S. imports carried in U. S. ships for U. S. runs or the percentage of Canadian exports carried in Canadian ships for Canadian runs.

f. Country code:

0 = U. S. Data
1 = Canadian Data

5. CAPACITY - This word represents a title for the following line of data. Input either the entire word or abbreviate by inputting the first three letters (see sample input).

6. Maximum designed cargo capacity (in tons) for each of the 11 vessel classes. Separate numbers by at least one space.

7. DRAFT - Next title line, input entire word or minimum of three letters as underlined.

8. Draft at maximum cargo capacity (feet) for each of the 11 classes.

9. IMMERSION - Another title line.

10. Net capacity (tons)/feet of immersion in excess of 18 feet for each of the 11 vessel classes.

11. SPEED - Next title line.

12. Vessel speed in miles/hour for each vessel class (11 values).

13. COST

14. Vessel operating cost (dollars) per hour for each vessel class (11).

15. CLASS DISTRIBUTION - Title, minimum of first three letters must be input.

16. Percentage of annual shipment by class.

For U. S. runs, input two lines of 11 values each (22 total). The first 11 values are used for deep draft figures unless the route includes Lake Ontario or the St. Lawrence Seaway. The second 11 values are used for shallow draft harbors and for the routes excluded above.

For Canadian runs input three lines of 11 values each (33 total). The first 11 values are used for domestic tonnage. The second 11 values are applied to Canadian import tonnages. The third set of 11 values are used for Canadian export tonnages.

Example: For 15 percent, input 15. Each set of 11 values must total 100 percent.

17. MONTHLY DISTRIBUTION

18. Percentage distribution of traffic by month.

For U. S. data, input two lines of 12 values each (24 numbers). The first 12 values are used for deep draft analyses and the second set of 12 values are used for shallow draft calculations.

Canadian data needs only one set of percentages (12 values). Each set of 12 numbers must add up to 100 percent.

19. ROUND TRIP FACTOR

20. Round trip time factor by class (11 values).

21. UNLOADING TIME

22. Unloading time in hours by class (11 values).

23. LOAD LINE LIMITS

24. Next four lines consist of four sets of seasonal load line limits (11 numbers/line). Limits should be input in seasonal order of winter, intermediate, summer, and midsummer.

Winter limits will be used for January, February, March, November, and December.
Intermediate for April and October.
Summer data will be applied to May and September.
Midsummer for June, July, and August.

25. TONNAGE, MILEAGE, AND SHALLOW DRAFT PERCENTAGE

26. DOMESTIC - If no domestic cargo is shipped, this category may be omitted.

27. Shipping data for domestic cargo. This data must be input in specific columns instead of simply separated by spaces as in the previous data. Use as many lines as is necessary to describe domestic cargo.

Column 1 - Lake Origin

Vessel loads cargo at a port on one of five lakes. Input S for Superior, M for Michigan, H for Huron, E for Erie, and O for Ontario.

Column 3 - Lake Destination

Vessel unloads cargo at a port on one of five lakes. Input S, M, H, E, or O.

Column 4-13 (F10.0) - Tonnage (in thousands of tons)

Column 14-23 (F10.0) - Mileage (distance from origin to destination)

Column 24-33 (F10.0) - Percentage of tonnage that travels to shallow draft harbors.

28. EXPORTS - U. S. Exports

For Canadian runs, data for Canadian imports should follow this heading. Omit this title if data is not available.

29. Code exported cargo as described for domestic cargo in 27.

30. IMPORTS - U. S. Imports

For Canadian runs, data for Canadian exports should follow this heading. Omit this title if data does not exist for this category.

31. Code imported cargo as described in 27.

32. END - Indicates the end of all data for commodity specified in 3.

33. Repeat items 3-32 for coal.

34. Repeat items 3-32 for limestone.

35. Repeat items 3-32 for grain.

The commodity input order of iron, coal, limestone, and grain only relates to the titles and headings printed in the summary report; therefore, the order may be changed or substitutions may be made provided the user realizes that the first group will be printed under the heading iron, the second group under coal, the third under limestone, and the fourth under grain. Total cost figures are printed in millions of dollars. The actual total cost will be printed for the first water level plan. All subsequent costs will be printed as differences between the base case (Plan 1) and the following alternative plans. If the differences are negative, the plan being considered costs more than the base case; and if the differences are positive, the base case costs more than the alternate plan. Execution of "GLCOST" automatically outputs a listing of all input data and the summary cost report as mentioned previously. A lengthly detailed cost report is also generated and stored as a file which may be printed as desired by the user. This report consists of five pages for each plan input. These reports print cost breakdowns by route and month or by vessel class and month or as input by route. It also prints the number of vessels required by class and month or by route and month.

```
      PROGRAM LEVELS    ( INPUT, OUTPUT ,TAPE2,
     1    TAPE5=INPUT,TAPE6=OUTPUT,TAPE11,TAPE12,TAPE13,TAPE14,TAPE15,
     2  TAPE16,TAPE17,TAPE18,TAPE19,TAPE20,TAPE21,TAPE22,TAPE23,
     3  TAPE24,TAPE25,TAPE26,TAPE27,TAPE28,TAPE29,TAPE30,TAPE31,
     4  TAPE32,TAPE33,TAPE34,TAPE35,TAPE36,TAPE37,TAPE38,TAPE39,TAPE40)
C
C      CRITICAL DEPTHS - 4812 - 724F3023
C      UP JUL 1975
C      THIS PROGRAM WAS ACQUIRED FROM G.D. LARSEN, DETROIT DISTRICT
C      MODIFIED AND RUN IN 1980 BY S. HECKMAN, NCO ADP CENTER
C
C      NOTE - WITHIN THIS PROGRAM THE ORDER OF THE LAKES IS CHANGED TO
C             SUPERIOR = 1
C             MICHIGAN-HURON = 2
C             ERIE = 3
C             ONTARIO = 4
C      THE NUMERICAL ORDER OF THE LAKES INPUT IS
C                         ONTARIO = 1
C                         ERIE = 2
C                         MICHIGAN-HURON = 3
C                         SUPERIOR = 4
C
      DIMENSION  ITITLE(26), SS(12),HS(12),ES(12),OS(12),ISS(12),IMS(12)
      DIMENSION IES(12),IOS(12),DATA(9)
C
C      START OF PROGRAM
C      THIS SECTION CONVERTS LAKE NUMBERS AS DESCRIBED ABOVE AND
C        EXTRACTS ONLY THE INPUT RECORDS FOR LAKES 1-4 AND YEARS 1900-1976
C
      WRITE (6,2010)
C       READ TOTAL NUMBER OF FILES TO BE PROCESSED IN THIS RUN
      READ (5,*) ITAPE
      NTAPE=10
      MAX=10+ITAPE
C       MAXIMUM OF 30 FILES CAN BE CHANGED IN ONE RUN OF THIS PROGRAM
    1 IF (NTAPE .GE. MAX) GO TO 231
      NTAPE=NTAPE+1
      REWIND NTAPE
      REWIND 2
      MYR=1977
      MM=77
C       READ TITLE CARD
      READ (NTAPE,10) ITITLE
      WRITE (2,10) ITITLE
C       READ DATA
    5 READ (NTAPE,8   ) DATA,NUM,NYR
    8 FORMAT (9A8,2X,I1,1X,I4)
      IF(EOF(NTAPE)) 18,  9
    9 IF (NUM .GT. 4) GO TO 5
      IF (NYR .GE. MYR) GO TO 5
      IF (NYR .LT. 1900) GO TO 5
      IF (NUM .LT. 1) NUM=1
      GO TO (11,12,13,14),NUM
   11 NUM=4
      GO TO 15
   12 NUM=3
      GO TO 15
   13 NUM=2
      GO TO 15
```

```
   14 NUM=1
   15 WRITE (2,8) DATA,NUM,NYR
      GO TO 5
   18 ENDFILE 2
      REWIND 2
      REWIND NTAPE
C
C     FILES ARE SORTED BY YEAR AND THEN BY LAKE, THUS THE DATA FOR ALL
C       FOUR LAKES IS TOGETHER FOR EACH YEAR
C         (I.E. 1,1900 THEN 2,1900 THEN 3,1900 THEN 4,1900 THEN 1 1901   ETC
      CALL SMSORT(80)
      CALL SMFILE("SORT","CODED",2,"REWIND")
      CALL SMFILE("OUTPUT","CODED", 2 ,"REWIND")
      CALL SMKEY (77,1,4,0,"DISPLAY")
      CALL SMKEY(75,1,1,0,"DISPLAY")
      CALL SMEND
      REWIND  2
      READ ( 2 ,10) ITITLE
      WRITE (NTAPE,10) ITITLE
C
C     REREAD ALL LAKE VALUES FOR ONE YEAR AT A TIME
      IYR=1900
      IERR=0
      WRITE (6,2011) ITITLE
   21 FORMAT (//" DATA ERRORS - VALUES MAY BE MISSING OR OUT",
     1  " OF ORDER OR LABELLED INCORRECTLY"/)
      DO 230     MN=1,MM
      READ ( 2 ,510) SS,NUM,JYR
      IF (NUM .EQ. 1 .AND. JYR .EQ. IYR) GO TO 31
      WRITE (6,51) SS,NUM,JYR
   51 FORMAT (2X,12F6.2,2X,I1,1X,I4)
      IERR=1
   31 READ ( 2 ,510) HS,NUM,JYR
      IF (NUM .EQ. 2 .AND. JYR .EQ. IYR) GO TO 32
      WRITE (6,51) HS,NUM,JYR
      IERR=1
   32 READ ( 2 ,510) ES,NUM,JYR
      IF (NUM .EQ. 3 .AND. JYR .EQ. IYR) GO TO 33
      WRITE (6,51) ES,NUM,JYR
      IERR=1
   33 READ ( 2 ,510) OS,NUM,JYR
      IF (NUM .EQ. 4 .AND. JYR .EQ. IYR) GO TO 34
      WRITE (6,51) OS,NUM,JYR
      IERR=1
   34 IF (IERR .EQ. 1) GO TO 230
C
      DO   180  J=1,12
      CALL ROUND (SS(J)*100.,ISS(J))
      CALL ROUND (HS(J)*100.,IMS(J))
      CALL ROUND (ES(J)*100.,IES(J))
      CALL ROUND (OS(J)*100.,IOS(J))
  180 CONTINUE
C
C     CALCULATE THE ADJUSTMENT TO THE LOW WATER DATUM FOR EACH OF
C           THE 10 ROUTES.
C     THESE 10 ROUTES CONSIST OF  S, MH, E, O, S-MH, S-MH-E, S-MH-E-O,
C                MH-E, MH-E-O,E-O.
      CALL CRTDEP (NTAPE,   ISS, IMS, IES, IOS, IYR )
      IYR=IYR+1
  230 CONTINUE
```

```
      ENDFILE NTAPE
      REWIND NTAPE
      GO TO 1
C
C
  231 WRITE (6,2000)
      STOP
C
C     FORMAT STATEMENTS
C
   10 FORMAT (26A3)
  510 FORMAT (12F6.0,2X,I1,1X,I4)
 2000 FORMAT ( 1H1 )
 2010 FORMAT ( 1H1,10X,"CRITICAL DEPTHS - 4812 - 724F3023")
 2011  FORMAT (11X,26A3/)
      END
      SUBROUTINE CRTDEP (NTAPE,  ISS, IMS, IES, IOS, IYR )
C     08 JUL 1975
C
C     PURPOSE -
C        COMPUTE CRITICAL DEPTH
C
C     DESCRIPTION OF PARAMETERS -
C        ISS      - SUPERIOR ELEVATIONS
C        IMS      - MICHIGAN-HURON ELEVATIONS
C        IES      - ERIE ELEVATIONS
C        IOS      - ONTARIO ELEVATIONS
C        IYR      - BEGINING YEAR FOR PERIOD
C
C     REMARKS -
C        ISS IMS IES IOS MUST BE DIMENSIONED 12 IN CALLING PROGRAM
C
      DIMENSION ISS(1), IMS(1), IES(1), IOS(1), LWD(4), ID(4), IB(6)
C
C     LOW WATER DATUM FOR SUP M-H ERE ONT
C
      LWD(1) = 60000
      LWD(2) = 57680
      LWD(3) = 56660
      LWD(4) = 24280
C
C      VARIATION FROM LOW WATER DATUM
      DO 20 J=1,12
      ID(1) = ISS(J) - LWD(1)
      ID(2) = IMS(J) - LWD(2)
      ID(3) = IES(J) - LWD(3)
      ID(4) = IOS(J) - LWD(4)
C
      DO 18  N=1,6
      GO  TO  (21,22,23,24,25,26),N
   21 L=1
      M=2
      GO TO 30
   22 L=1
      M=3
      GO TO 30
   23 L=1
      M=4
      GO TO 30
   24 L=2
```

```
      M=3
      GO TO 30
   25 L=2
      M=4
      GO TO 30
   26 L=3
      M=4
   30 ISUM=ID(L)+2000
C
      DO 40 KK=L,M
      IF  ( ISUM-(ID(KK)+2000))  50,51,51
   50 CONTINUE
      GO TO 40
   51 ISUM=ID(KK)+2000
   40 CONTINUE
C
      IB(N)=ISUM-2000
   18 CONTINUE
C
      JJ=J
      WRITE (NTAPE,910) JJ,IYR,ID,IB
   20 CONTINUE
C
      RETURN
C
C     FORMAT STATEMENTS
C
  910 FORMAT (7XI2,I4,17X,10I5)
      END
      SUBROUTINE ROUND ( A, IA )
C     01 FEB 1974
C
C     PURPOSE -
C        ROUND FLOATING POINT NUMBERS
C
C     USAGE -
C        CALL ROUND ( A, IA )
C
C     DESCRIPTION OF PARAMETERS -
C        A        -  INPUT FLOATING POINT NUMBER
C        IA       - OUTPUT FIXED    POINT NUMBER
C
C     REMARKS -
C        FUNCTION WRITTEN BY G O LARSEN, DETROIT DISTRICT
C        FORTRAN 4
C        PRECISION OF A1 A2 A3 IS NUMBER OF COMPUTER WORD FLOATING POINT
C        SIGNIFICANT DECIMAL DIGITS
C
C     SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED -
C        SIGN IABS INT
C
C     METHOD -
C        US LAKE SURVEY METHOD
C
C
      DATA A1/0.4999999999991/, A2/0.0000000000018/, A3/0.5000000000009/
C
      XROUND (A)=A+SIGN (A1+IABS ( INT (A)-2*( INT (A)/2))*A2,A+A3)
C
      IA = XROUND ( A )
```

```
RETURN
END
```

```
      PROGRAM GLCOST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7,
     1 TAPE11,TAPE12,TAPE13,TAPE14,TAPE15,TAPE16,TAPE17,TAPE18,
     2 TAPE19,TAPE20,TAPE21,TAPE22,TAPE23,TAPE24,TAPE25,TAPE26,
     3 TAPE27,TAPE28,TAPE29,TAPE30,TAPE31,TAPE32,TAPE33,TAPE34,
     4 TAPE35,TAPE36,TAPE37,TAPE38,TAPE39,TAPE40,TAPE3)
C
C     *******   REGULATION OF GREAT LAKES WATER LEVELS   *******
C
C     USED BY THE INTERNATIONAL GREAT LAKES LEVELS BOARD FOR REPORT TO
C     THE INTERNATIONAL JOINT COMMISSION
C
C     THIS PROGRAM CALCULATES THE TRANSPORTATION COSTS (IN MILLIONS
C     OF DOLLARS) OF COMMERCIAL NAVIGATION FOR U.S. AND CANADIAN
C     FLEETS BY COMMODITY, MONTH, TRAFFIC ROUTE, AND VESSEL CLASS.
C
C     ONE RUN PRODUCES COST FIGURES FOR A BASE CASE (THE FIRST FILE
C     SPECIFIED) AND THE COST DIFFERENCES BETWEEN THE BASE CASE AND
C     VARIOUS ALTERNATIVE PLANS UNDER CONSIDERATION.
C
C     IT IS USED TO ANALYZE THE EFFECTS OF WATER LEVEL REGULATION
C     ON THE COSTS OF TRANSPORTING SELECTED COMMODITIES ON THE
C     GREAT LAKES.
C
C     PROGRAM ORIGINALLY WRITTEN BY THE BUREAU OF MINES
C     EXTENSIVELY MODIFIED BY THE U.S. ARMY CORPS OF ENGINEERS,
C     NORTH CENTRAL DIVISION ADP CENTER (SHARON HECKMAN)  1980.
C
      INTEGER D
      COMMON /DOTN/ N,M,L
      COMMON /CTMP/ ARRAY(12,77,10)
      COMMON / COUNTRY/ COUNTRY(2)
      COMMON /CNMCLS/ NMCLAS(11)
      COMMON /  CMMCLS/ MMCLAS(11)
      COMMON /NCOM/ NPG,DPT,NCA(2,5),NCB(2,5),ITJ(10)
      COMMON /MCOM/ MON(13),ITI(10)
      COMMON /CSLR/ SLR(12,11)
      COMMON /MSAVE/ SAVE(30,8)
      DIMENSION ACC(15,5),HVC(11),CTS(12,12) ,TITLE(30)
      DIMENSION PERCT(3),TLU(11),VPT(11)
      DIMENSION VSC(11),VCH(11),VTM(24),VPC(33),RTF(11),IDATA(6)
      DIMENSION CTO(15,5),ATL(15,5),INKODE(11),SCTO(15,5)
C
C
      COMMON /CVLA/ VLA(12)
C
      COMMON /CXO/ XO (11, 10)
      COMMON /CVLB/ VLB (11)
      COMMON /CVLC/ VLC ( 11)
      COMMON /CVCP/ VCP (11)
      COMMON /CHRRTE/ HRRTE (10, 12)
      COMMON /VBC/VBC(12,12)
      COMMON /TOT/TOT(12,12)
      COMMON /TIME/ ITIME,BASE1(15,5),BASE2(10,12),BASE3(10,12),
     1   BASE4(10,12),BASE5(10,12),BASE6(12,12),BASE7(10,12),
     2   BASE8(12,12)
C
      DIMENSION  EYP(10,12), SHP(10,12)
      DIMENSION  REM(10,12), SME(10,12)
C
C     CANADIAN VESSEL CLASSES
```

```
      DATA NMCLAS/2H1 ,2H2 ,2H3 ,2H4 ,2H5 ,2H6 ,2H7 ,2H8 ,
     1        2H9 ,2H10, 2H11   /
C     U.S. VESSEL CLASSES
      DATA NMCLAS /2H5 ,2H6 ,2H6W,2H7 ,2H7W,2H8 ,2H8A,2H8W,
     1               2H9 ,2H10,2H11/
      DATA MON / 4HJAN ,4HFEB ,4HMAR ,4HAPR ,4HMAY ,4HJUNE,4HJULY,
     1               4HAUG ,4HSEP ,4HOCT ,4HNOV ,4HDEC ,5HTOTAL /
C     U.S. LAKE NAMES
      DATA NCA /6HSUPERI, 6HOR  US, 6HMICHIG, 6HAN  US,6HHURON ,
     1            6H    US, 6HERIE  , 6H    US, 6HONTARI, 6HO   US /
C     CANADIAN LAKE NAMES
      DATA NCB /6HSUPERI, 6HOR CAN, 6HMICHIG,6HAN CAN, 6HHURON ,
     1            6H   CAN, 6HERIE  ,6H   CAN, 6HONTARI, 6HO  CAN/
C
      DATA ILW,IEX,ITM,ITO/ 8HDOMESTIC, 8HEXPORT  ,8HIMPORT  ,
     1                               8HTOTAL        /
      DATA COUNTRY/ 3HUS , 3HCAN  /
C     INPUT CODES
      DATA INKODE /3HCAP,3HDRA,3HIMM,3HSPE,3HCOS ,3HCLA, 3HMON, 3HROU,
     1       3HUNL, 3HLOA, 3HTON /
      DATA NMONTH, NOVSCL, NOYEAR, NROUTE / 12, 11, 77, 10/
C
      PERCT(3)=1.0
      DO 5 I=1,30
      DO 5 J=1,8
    5 SAVE(I,J)=0.
C     SPECIFY THE NO. OF WATER LEVEL FILES TO BE PROCESSED
C       (EX.  BASE CASE + 5 ALTERNATIVE PLANS = 6 FILES)
      READ (5,*) NTAPE
C     READ A SHORT (10 CHARACTERS OR LESS) TITLE FOR EACH FILE.
C     THIS WILL ONLY BE USED FOR IDENTIFICATION IN THE SUMMARY REPORTS.
      DO 8 I=1,NTAPE
      READ (5,9) TITLE(I)
    9 FORMAT (A10)
    8 CONTINUE
      ICROP=1
C     PROGRAM IS PRESENTLY WRITTEN TO RUN A MAXIMUM OF 30 WATER
C     LEVEL FILES (TAPE11 TO TAPE40)
      IF (NTAPE .LE. 30) GO TO 3
      WRITE(6,920) NTAPE
  920 FORMAT (2X,"INPUT ERROR-MAX. NO. OF PLANS IS 30"/2X,
     1   "YOU INPUT",I4)
    2 ISHAL=0
      ICROP=ICROP+1
    3 IERROR=0
      ITIME=0
      DO 165 I = 1, NOVSCL
      DO 162 J=1,NMONTH
  162 CTS ( J,I ) = 0.0
      HVC ( I ) = 0.0
  165 CONTINUE
      DO 170 I = 1, NROUTE
      DO 170 J = 1, NMONTH
      HRRTE (I, J) = 0.0
      EXP(I,J)     =0.0
      SHP(I,J)     =0.0
      REM(I,J)     =0.0
  170 SMF(I,J)     =0.0
      DO 175 I = 1, NOVSCL
      DO 175 J = 1, NROUTE
```

```
      XO (I, J) = 0.0
  175 CONTINUE
      IF (ISHAL .EQ. 1) GO TO 150
      DO 30 I=1,15
      DO 30 J=1,5
      CTO(I,J)=0.
      ATL(I,J)=0.
      ACC(I,J)=0.
      SCTO(I,J)=0.
   30 CONTINUE
C
C     TITLE CARD - MAY SPECIFY COUNTRY, COMMODITY, YEAR, DATE, ETC.
C        THIS INFORMATION WILL BE PRINTED AS PART OF THE PAGE HEADING
C            (MAXIMUM OF 80 CHARACTERS)
      READ (5,1000) ITI
      IF (EOF(5)) 401,31
 1000 FORMAT (10A8)
C
C     YEAR, DEEP DRAFT, SHALLOW DRAFT, AND PERCENTAGE OF CARGO CARRIED IN
C           U.S. SHIPS FOR EXPORTS AND IMPORTS
C     ALSO ENTER A 0 FOR A U.S. RUN OR A 1 FOR A CANADIAN RUN
C
   31 READ (5,*) IYR,HBD,SHBD,PERCT(1),PERCT(2),ICOUN
      HDP=HBD-1.5
C     READ IDENTIFIER OF TYPE OF DATA THAT IS TO FOLLOW
C     CAP, DRA, IMM, SPE, COS, CLA, MON, ROU, UNL, LOA, OR TON
   39 READ (5,1001) KODE
 1001 FORMAT (A3)
      DO 40 I=1,11
      IF (KODE .EQ. INKODE(I)) GO TO 45
   40 CONTINUE
      WRITE (6,1002) KODE
 1002 FORMAT (1X,"INPUT ERROR-DATA LABEL ",A3," IS NOT VALID")
      IERROR=1
      GO TO 39
   45 GO TO (51,52,53,54,55,56,57,58,59,60,96) I
C     CAP - MAX DESIGNED CARGO CAPACITY (NET TONS) FOR EACH VESSEL CLASS
C     INPUT 11 VALUES
   51 READ (5,*) VCP
      GO TO 39
C     DRA - DRAFT AT MAXIMUM CARGO CAPACITY (FT.) FOR EACH VESSEL CLASS
C     INPUT 11 VALUES
   52 READ (5,*) VLC
      GO TO 39
C     IMM - NET CAPACITY/FT. OF IMMERSION IN EXCESS OF 18 FT. (TONS)
C     INPUT 11 VALUES
   53 READ (5,*) VLB
      GO TO 39
C     SPE - VESSEL SPEED IN MILES/HOUR FOR EACH VESSEL CLASS
C     INPUT 11 VALUES
   54 READ (5,*) VSC
      GO TO 39
C     COS - VESSEL OPERATING COST PER HOUR (DOLLARS) FOR EACH VESSEL CLASS
C     INPUT 11 VALUES
   55 READ (5,*) VCH
      GO TO 39
C
C     CLA - PERCENTAGE OF ANNUAL SHIPMENT BY CLASS
C     US DATA-FIRST 11 VALUES FOR ROUTES THAT DO NOT USE ONTARIO OR SLS
C             SECOND 11 VALUES ARE USED  FOR SHALLOW DRAFT HARBORS AND
```

```
C                  ROUTES USING LAKE ONTARIO OR SLS
C         TOTAL OF 22 VALUES INPUT FOR U.S. RUNS
C
C      CANADIAN DATA-FIRST 11 VALUES ARE DISTRIBUTION BY CLASS FOR
C                              DOMESTIC TONNAGE
C                   -SECOND 11 VALUES ARE DISTRIBUTION BY CLASS FOR
C                              CANADIAN IMPORT TONNAGE
C                   -THIRD 11 VALUES ARE DISTRIBUTION BY CLASS FOR
C                              CANADIAN EXPORT TONNAGE
C        TOTAL OF 33 VALUES INPUT FOR CANADIAN RUNS
   56 I=1
   61 II=I+10
      READ (5,*) (VPC(IV),IV=I,II)
C     THE SUM OF EACH 11 PERCENTAGES INPUT MUST TOTAL 100.
      VSUM=0
      DO 63 J=I,II
      VSUM=VSUM+VPC(J)
      VPC(J)=VPC(J)/100.
   63 CONTINUE
C     IF SUM OF PERCENTAGES DOES NOT EQUAL 100%, PRINT ERROR MESSAGE
      IF (VSUM .LT. 100.01 .AND. VSUM .GT. 99.99) GO TO 65
      WRITE (6,64) VSUM
   64 FORMAT (1X,"INPUT ERROR-SUM OF PERCENTAGE DISTRIBUTION BY CLASS IS
     1 ",F6.1," AND SHOULD TOTAL 100")
      IERROR=1
   65 I=I+11
      IF (I .LT. 23) GO TO 61
      IF (ICOUN .EQ. 0) GO TO 39
      IF (I .LT. 34) GO TO 61
      GO TO 39
C
C     VUM - PERCENTAGE DISTRIBUTION OF TRAFFIC BY MONTH
C     FOR CANADIAN DATA, INPUT 12 VALUES
C     FOR U.S. DATA INPUT 24 VALUES
C          THE FIRST 12 VALUES WILL BE USED FOR DEEP DRAFT RUNS
C          THE SECOND 12 VALUES WILL BE USED FOR SHALLOW DRAFT RUNS
   57 I=1
   46 II=I+11
      READ (5,*)  (VTM(IV),IV=I,II)
      VSUM=0
      DO 62 J=I,II
      VSUM=VSUM+VTM(J)
   62 VTM(J)=VTM(J)/100.
C     IF SUM OF PERCENTAGES DOES NOT EQUAL 100%, PRINT ERROR MESSAGE
      IF (VSUM .LT. 100.01 .AND. VSUM .GT. 99.99) GO TO 47
      WRITE (6,49) VSUM
   49 FORMAT (1X,"INPUT ERROR-SUM OF MONTHLY PERCENTAGE DISTRIBUTION",
     1 " OF TRAFFIC IS ",F6.1,/"AND SHOULD TOTAL 100")
      IERROR=1
   47 I=I+12
      IF (ICOUN .EQ. 1) GO TO 39
      IF (I .LT. 25) GO TO 46
      GO TO 39
C     RTF - ROUND TRIP TIME FACTOR BY CLASS
C     INPUT 11 VALUES
   58 READ (5,*) RTF
      GO TO 39
C     UNL - UNLOAD TIME IN HOURS BY CLASS
C     INPUT 11 VALUES
   59 READ (5,*) TLU
```

```
      GO TO 39
C     LOA - SEASONAL LOAD LINE LIMITS
C     READ 4 SETS OF VALUES IN SEASONAL ORDER OF
C           WINTER, INTERMEDIATE, SUMMER, MIDSUMMER
C
C      WINTER CONSISTS OF JAN, FEB, MAR, NOV, AND DEC
C      INTERMEDIATE INCLUDES APRIL AND OCTOBER
C      SUMMER MONTHS ARE MAY AND SEPTEMBER
C      MIDSUMMER INCLUDES JUNE, JULY, AND AUGUST
C
   60 DO 20 I=3,6
      READ (5,*) (SLR(I,J),J=1,NOVSCL)
   20 CONTINUE
      DO 21 J=1,NOVSCL
      SLR(1,J)=SLR(3,J)
      SLR(2,J)=SLR(3,J)
      SLR(10,J)=SLR(4,J)
      SLR(9,J)=SLR(5,J)
      SLR(7,J)=SLR(6,J)
      SLR(8,J)=SLR(6,J)
      SLR(11,J)=SLR(3,J)
   21 SLR(12,J)=SLR(3,J)
      GO TO 39
C
C     PRINT INPUT DATA
C
   96 WRITE(6,700) ITI
      IF (ICOUN .EQ. 1) GO TO 97
      WRITE(6,701) IYR,HBD,SHBD,ICOUN,COUNTRY(ICOUN+1),PERCT(1),PERCT(2)
      WRITE (6,702) NMCLAS
      GO TO 98
   97 WRITE(6,701)IYR,HBD,SHBD,ICOUN,COUNTRY(ICOUN+1),PERCT(2),PERCT(1)
      WRITE (6,702) MMCLAS
   98 WRITE (6,703) VCP
      WRITE (6,704) VLC
      WRITE (6,705) VLB
      WRITE (6,706) VSC
      WRITE (6,707) VCH
      IF (ICOUN .EQ. 0) GO TO 101
      WRITE (6,718) VPC
      GO TO 102
  101 WRITE (6,708) (VPC(IV),IV=1,22)
  102 WRITE (6,709) RTF
      WRITE (6,710) TLU
      WRITE (6,711)
      WRITE (6,725) (SLR(3,J),J=1,NOVSCL)
      WRITE (6,726) (SLR(4,J),J=1,NOVSCL)
      WRITE (6,727) (SLR(5,J),J=1,NOVSCL)
      WRITE (6,728) (SLR(6,J),J=1,NOVSCL)
      IF (ICOUN .EQ. 1) GO TO 103
      WRITE (6,714) (MON(I),I=1,12),VTM
      GO TO 104
  103 WRITE (6,724) (MON(I),I=1,12),(VTM(I),I=1,12)
  104 WRITE (6,715)
      DO 149 NN=1,2
  149 PERCT(NN)=PERCT(NN)/100.
C
C     TON - FOR THREE DIFFERENT CATEGORIES (DOMESTIC, EXPORT, IMPORT)
C           READ ORIGIN, DESTINATION, TONNAGE(IN 1000 OF TONS), MILEAGE,
C           AND PERCENTAGE OF SHIPMENT THAT GOES TO SHALLOW DRAFT HARBOR
```

```
C
C      EXPORTS = U.S. EXPORTS = CANADIAN IMPORTS
C      IMPORTS = U.S. IMPORTS = CANADIAN EXPORTS
   95 READ (5,100) IDATA
      IF (EOF(5)) 150,94
  100 FORMAT (6A10)
   94 DECODE (60,105,IDATA) I1,I2
  105 FORMAT (2A1)
      IF (I1 .NE. 1HD) GO TO 110
      INDEX=0
      GO TO 125
  110 IF (I1 .NE. 1HI) GO TO 120
      INDEX=10
      GO TO 125
  120 IF (I1 .NE. 1HE) GO TO 126
C      END INDICATES THE END OF TONNAGE DATA
C      WHEN THIS OCCURS, PROGRAM STARTS CALCULATING COSTS
      IF (I2 .EQ. 1HN) GO TO 150
      IF (I2 .NE. 1HX) GO TO 126
      INDEX=5
  125 WRITE (6,716) IDATA
      READ (5,100) IDATA
      IF (EOF(5)) 150,126
  126 DECODE (60,130,IDATA) IO,ID,TON,RMILE,SHAL
      IF (SHAL .LT. 0.1) SHAL=0.0
      WRITE (6,717) IO,ID,TON,RMILE,SHAL
  717  FORMAT (9X,A1,9X,A1,6X,F10.1,1X,F10.1,5X,F10.1)
C
C      TRANSLATE ORIGIN AND DESTINATION INPUT LETTERS TO NUMERIC
C          SUBSCRIPTS.
C                                 SUPERIOR = S = 1
C                                 MICHIGAN = M = 2
C                                 HURON    = H = 3
C                                 ERIE     = E = 4
C                                 ONTARIO  = O = 5
C      FIRST SUBSCRIPT MAY BE 1-15 RATHER THAN 1-5 BECAUSE
C              DOMESTIC = 1-5
C              U.S. EXPORTS = CANADIAN IMPORTS = 6-10
C              U.S. IMPORTS = CANADIAN EXPORTS = 11-15
      CALL FINDIT(IO,ID,I,J)
      IF (IO.EQ. 0 ) IERROR=1
      SHAL=SHAL/100.
C      DEEP DRAFT TONNAGE
      CTO(I+INDEX,J)=TON * 1000. * (1.-SHAL)
C      SHALLOW DRAFT TONNAGE
      SCTO(I+INDEX,J)=TON * 1000. * SHAL
      ATL(I+INDEX,J)=RMILE
  130 FORMAT (A1,1X,A1,3F10.0)
      GO TO 95
C
  150 IF (IERROR .EQ. 1) GO TO 399
      IF (HBD .LT. 0.1) GO TO 392
  152 ITIME=ITIME+1
      DO 153 I1=1,15
      DO 153 I2=1,5
  153 ACC(I1,I2)=0.
      DO 154 I1=1,10
      DO 154 I2=1,12
      HRRTF(I1,I2)=0.
      SME(I1,I2)=0.
```

```
      SHP(I1,I2)=0.
      EYP(I1,I2)=0.
  154 REM(I1,I2)=0.
      DO 155 I1=1,11
      DO 155 I2=1,12
  155 CTS(I2,I1)=0.
      DO 156 I1=1,11
      DO 156 I2=1,10
  156 XO(I1,I2)=0.
      IF (ITIME .GT. NTAPE) GO TO 399
      JERROR=0
C     READ WATER LEVEL DATA
C      NAVIGABLE CHANNEL DEPTHS IN THE GREAT LAKES ARE INPUT IN FEET
C      RELATIVE TO THE LOW WATER DATUM INPUT
      CALL WLD(ITIME,JERROR,ITJ)
      IF (JERROR .EQ. 1) GO TO 152
      NPG=0
C     77 YEARS OF DATA WERE USED IN STUDY AND REPORT OF 1980 (1900-1976)
      YRCON=1./FLOAT(NOYEAR)
      DO 280 N=1,NMONTH
      DO 270 M=1,NOYEAR
      DO 270 L=1,NOVSCL
      IF (VPC(L) .LE. 0.001 .AND. VPC(L+11) .LE. 0.001) GO TO 270
      HRCON=RTF(L)/VSC(L)
      IV=0
      IP=3
      DO 260 I=1,15
      IF (I .EQ. 6) GO TO 171
      IF (I .EQ. 11) GO TO 172
      GO TO 174
  171 IP=1
      IV=11
      GO TO 174
  172 IP=2
      IV=22
  174 DO 260 J=1,5
      IF (CTO(I,J) .LE. .01) GO TO 260
C
C     DETERMINE ROUTE NUMBER AND DEPTH OF CHANNEL
      CALL DEPTH(I,J,WATER,O,HDP)
C     ROUTES INCLUDING LAKE ONTARIO USE SAME VALUES AND PROCEDURES FOR
C       DEEP DRAFT RUNS AS ARE USED FOR ALL SHALLOW DRAFT CALCULATIONS
      IF (ICOUN .EQ. 1) GO TO 176
      IF (O .EQ. 4 .OR. O .EQ. 7 .OR. O .EQ. 9 .OR. O .EQ. 10) GO TO 187
      VTCON=YRCON*VTM(N)
      TRCON=VPC(L)*VTCON*PERCT(IP)
  184 IF (WATER - VLC(L)) 188,188,186
  176 VTCON=YRCON*VTM(N)
      TRCON=VPC(L+IV) * VTCON*PERCT(IP)
      IF (O .NE. 4 .OR. O .NE. 7 .OR. O .NE. 9 .OR. O
     1       .NE. 10) GO TO 184
      GO TO 190
  186 CAPAC=VCP(L)
      GO TO 189
  187 VTCON=YRCON*VTM(N+12)
      TRCON=VPC(L+11)*VTCON*PERCT(IP)
C     MAXIMUM DRAFT IN LAKE ONTARIO CANNOT BE GREATER THAN 26 FT.
  190 IF (WATER .GT. 26.) WATER=26.
      GO TO 184
C
```

```
C      VESSEL CAPACITY MUST BE ADJUSTED IF CHANNEL DEPTH IS LESS THAN
C       MAXIMUM DESIGNED VESSEL DRAFT.
  188 CAPAC=VCP(L)-(VLB(L)*(VLC(L)-WATER))
C
  189 TRIP=CTO(I,J)*TRCON/CAPAC
      RATLES=TRIP*ATL(I,J)
      HOURS=RATLES*HRCON + TRIP*TLU(L)
C     COST IS PRINTED IN MILLIONS OF DOLLARS
      COST=HOURS*VCH(L) /1000000.
C     ACCUMULATE TOTALS BY VARIOUS CATEGORIES
      HVC(L)=HVC(L)+HOURS
      HRRTE(O,N)=HRRTE(O,N)+HOURS
      CTS(N,L)=CTS(N,L)+COST
      ACC(I,J)=ACC(I,J)+COST
      SME(O,N)=SME(O,N)+COST
      XO(L,O)=XO(L,O)+COST
      IF (I-5) 400,400,410
C     TOTAL COST OF DOMESTIC SHIPMENTS
  400  SHP(O,N)=SHP(O,N)+COST
      GO TO 260
  410 IF (I-10) 420,420,430
C     TOTAL COST OF EXPORT SHIPMENTS
  420 EYP(O,N)=EYP(O,N)+COST
      GO TO 260
C     TOTAL COST OF IMPORT SHIPMENTS
  430 REM(O,N)=REM(O,N)+COST
  260 CONTINUE
  270 CONTINUE
    . CALL     NOV(N,HVC,ICOUN)
      CALL     CVC(N,CTS,ICOUN)
  280 CONTINUE
      IF (ITIME .EQ. 1) GO TO 281
C
C     COSTS FOR ALTERNATE PLANS ARE COMPARED TO BASE CASE COSTS
C     THE DIFFERENCES (BASE CASE - ALTERNATE PLAN) ARE PRINTED FOR
C     ALL THE PLANS UNDER CONSIDERATION.
C     TOTAL COSTS ARE ONLY PRINTED FOR THE BASE CASE.
C     NEGATIVE DIFFERENCES INDICATE THAT THE ALTERNATE COSTS MORE THAN
C       THE BASE CASE.
C     POSITIVE DIFFERENCES INDICATE THAT THE BASE CASE COSTS MORE THAN
C       THE ALTERNATE.
C
      DO 300 I=1,15
      DO 300 J=1,5
  300 ACC(I,J)=BASE1(I,J)-ACC(I,J)
      DO 310 I=1,NROUTE
      DO 310 J=1,NMONTH
      SHP(I,J)=BASE2(I,J)-SHP(I,J)
      EYP(I,J)=BASE3(I,J)-EYP(I,J)
      REM(I,J)=BASE4(I,J)-REM(I,J)
      SME(I,J)=BASE5(I,J)-SME(I,J)
  310 HRRTE(I,J)=BASE7(I,J)-HRRTE(I,J)
      DO 320 I=1,NOVSCL
      DO 320 J=1,NMONTH
      VBC(I,J)=BASE6(I,J)-VBC(I,J)
      TOT(J,I)=BASE8(J,I)-TOT(J,I)
  320 CONTINUE
C
. 281 CALL     HED(IYR,HBD)
      CALL     PTA(ACC, 13,ICOUN)
```

```
      CALL    HED(IYR,HBD)
      IF(ICOUN)282,282,284
C
C     U.S. PRINTOUT SEQUENCE
C
  282 WRITE(7,2000) COUNTRY(1),ILW
      CALL    SPT(SHP,ICROP,ITIME,ISHAL)
      WRITE (7,730)
      WRITE(7,2000) COUNTRY(1),IEX
      CALL SPT(EYP,ICROP,ITIME,ISHAL)
      CALL    HED(IYR,HBD)
      WRITE(7,2000) COUNTRY(1),IIM
      CALL    SPT(REM,ICROP,ITIME,ISHAL)
      GO TO 288
C
C     CANADIAN PRINTOUT SEQUENCE
C
  284 WRITE(7,2000) COUNTRY(2),ILW
      CALL    SPT(SHP,ICROP,ITIME,ISHAL)
      WRITE (7,730)
      WRITE(7,2000) COUNTRY(2),IEX
      CALL    SPT(REM,ICROP,ITIME,ISHAL)
      CALL    HED(IYR,HBD)
      WRITE(7,2000) COUNTRY(2),IIM
      CALL SPT(EYP,ICROP,ITIME,ISHAL)
  288 WRITE (7,730)
      WRITE(7,2000) COUNTRY(ICOUN+1),ITO
      CALL    SPT(SME,ICROP,ITIME,ISHAL)
      CALL    HED(IYR,HBD)
      CALL    NOV( 13,HVC,ICOUN)
      CALL    HED(IYR,HBD)
      WRITE(7,2000) COUNTRY(ICOUN+1),ITO
      CALL    CVC( 13,CTS,ICOUN)
      IF (ITIME .NE. 1) GO TO 152
C     SAVE THE TOTAL VALUES CALCULATED FOR THE BASE CASE
C     THESE VALUES WILL BE USED FOR COMPARISON OF ALTERNATE PLANS.
      DO 610 I=1,15
      DO 610 J=1,5
  610 BASE1(I,J)=ACC(I,J)
      DO 620 I=1,NROUTE
      DO 620 J=1,NMONTH
      BASE2(I,J)=SHP(I,J)
      BASE3(I,J)=EYP(I,J)
      BASE4(I,J)=REM(I,J)
      BASE5(I,J)=SME(I,J)
  620 BASE7(I,J)=HRRTE(I,J)
      DO 630 I=1,NOVSCL
      DO 630 J=1,NMONTH
      BASE6(I,J)=VRC(I,J)
  630 BASE8(J,I)=TOT(J,I)
      GO TO 152
C
  700 FORMAT (1H1, 50X,"INPUT DATA"//7X,"TITLE CARD:  ",10A8/)
  701 FORMAT (7X,"YEAR= ",I4,3X,"DEEP DRAFT DATUM= ",F6.2," FT." ,
     1 3X,"SHALLOW DRAFT DATUM=",F6.2," FT."/7X,
     1  "COUNTRY ",I1," = ",A3,2X,"EXPORT PERCENTAGE= ",F4.0,
     2  "  IMPORT PERCENTAGE= ",F4.0/)
  702 FORMAT ( 7X,"VESSEL CLASS",11X,A2,10(5X,A2))
  703 FORMAT ( 7X,"CAPACITY (TONS)",7X,11(F6.0,1X))
  704 FORMAT ( 7X,"DRAFT AT MAX CAPAC(FT)",2X,11(F4.1,3X))
```

```
  705 FORMAT ( 7X,"TONS/FT IMMERSION",6X,11(F5.0,2X))
  706 FORMAT ( 7X,"AVERAGE SPEED(MPH)",6X,11(F4.1,3X))
  707 FORMAT ( 7X,"OPERATING COST/HR ($)",2X,11(F5.0,2X))
  708 FORMAT (7X,"DISTRIBUTION BY CLASS",/,9X,
     1  "ROUTES ON S,M,H,E",4X,11(F5.4,2X)/9X,
     2  "ROUTES ON ONTARIO",4X,11(F5.4,2X))
  709 FORMAT (/7X,"ROUND-TRIP TIME FACTOR",1X,11(F5.2,2X))
  710 FORMAT ( 7X,"UNLOADING TIME(HRS)",6X,11(F3.0,4X))
  711 FORMAT ( 7X,"SEASONAL LOAD LINE LIMITS")
  714 FORMAT (/7X,"DISTRIBUTION OF TRAFFIC BY MONTH"/
     1 29X,12(A4,2X)/9X,"ROUTES ON S,M,H,E",2X,12(F5.4,1X)/
     2 9X,"ROUTES ON ONTARIO",2X,12(F5.4,1X))
  715  FORMAT (/,7X,"ORIGIN DESTINATION    TONS",
     1   ,"      MILES     SHALLOW DRAFT PERCENTAGE" )
  716 FORMAT (7X,6A10)
  718 FORMAT (7X,"DISTRIBUTION BY CLASS",/,9X,
     1 "FOR DOMESTIC USE",4X,11(F6.5,1X)/9X,
     2 "US EXP=CAN IMP",6X,11(F6.5,1X)/9X,
     3 "US IMP=CAN EXP",6X,11(F6.5,1X))
  724 FORMAT (/7X,"DISTRIBUTION OF TRAFFIC BY MONTH"/
     1 29X,12(A4,2X)/12X,"ALL ROUTES",6X,12(F5.4,1X)/)
  725 FORMAT (9X,"JAN FEB MAR NOV DEC",3X,11(F4.1,3X))
  726 FORMAT (15X,"APR OCT", 9X, 11(F4.1,3X))
  727 FORMAT (15X,"MAY SEPT",8X,11(F4.1,3X))
  728 FORMAT (12X,"JUNE JULY AUG",6X,11(F4.1,3X))
  730 FORMAT (//)
 2000 FORMAT(5X, 8HCOST OF , A3,1X,A9, 9HSHIPMENTS ,2X,
     1 "(IN MILLIONS OF DOLLARS)")
C
C ***********************************************************************
C
C      MAX. OF 4 DIFFERENT COMMODITIES MAY BE PROCESSED IN ONE RUN
C       (IRON ORE, COAL, LIMESTONE, AND GRAIN)
  393 IF (ICROP .GE. 4) GO TO 401
      GO TO 2
  399 DO 395 IR=1,NTAPE
      IRW=IR+10
      REWIND IRW
  395 CONTINUE
C     CALCULATIONS FOR SHALLOW DRAFT IMMEDIATELY FOLLOW DEEP DRAFT
C     CALCULATIONS FOR EACH COMMODITY
      IF (ISHAL .EQ. 1) GO TO 393
  392 ISHAL = 1
      IF (SHPD .LT. 0.1) GO TO 2
      HDP=SHRD-1.5
      HBD=SHRD
      IF (ICOUN .EQ. 1) GO TO 396
      DO 67 II=1,11
   67 VPC(II)=VPC(II+11)
      DO 42 II=1,12
   42 VTM(II)=VTM(II+12)
  396 DO 500 II=1,15
      DO 500 IK=1,5
  500 CTO(II,IK)=SCTO(II,IK)
      GO TO 3
C     PRINT SUMMARY REPORT
  401 WRITE (6,4000)
      WRITE (6,431) IYR
  431 FORMAT (62X,I4//)
      WRITE (6,440)
```

```
  440 FORMAT (35X, "DEEP DRAFT",36X,"SHALLOW DRAFT",22X,"TOTAL"/
     1  3X,"PLAN",12X,"IRON",8X,"COAL",6X,"LIMESTONE",5X,"GRAIN"
     2  ,7X,"IRON",8X,"COAL",6X,"LIMESTONE",5X,"GRAIN"/)
      DO 450 I=1,NTAPE
      TSAVE=0.
      DO 444 J=1,8
  444 TSAVE=TSAVE+SAVE(I,J)
      WRITE (6,460)  TITLE(I),(SAVE(I,K),K=1,8),TSAVE
  450 CONTINUE
  460 FORMAT (3X,A10,3X,8(F10.6,2X),2X,F12.6/)
 4000 FORMAT (//1H1,30X,46HWATER LEVELS OF THE GREAT LAKES--INTERNATIONA
     /L,31H JOINT COMMISSION SPECIAL STUDY, /,
     / 30X,34H EFFECT OF LAKE LEVEL REGULATION--,
     / 29HBY SUBCOMMITTEE ON NAVIGATION, 37X //)
      STOP
      END
      SUBROUTINE NOV(N,HVC,ICOUN)
C
C     THIS SUBPROGRAM COMPUTES THE NUMBER OF VESSELS REQUIRED BY CLASS
C     FOR EACH MONTH.
C
      COMMON /NCOM/  NPG,DPT,NCA(2,5),NCB(2,5),ITJ(10)
      COMMON /VBC/ VBC(12,12)
      COMMON /MCOM/ MON (13), ITT (10)
      COMMON /CNMCLS/ NMCLAS (11)
      COMMON /CHRRTE/ HRRTE (10, 12)
      COMMON / CMMCLS/ MMCLAS(11)
C
      DIMENSION HVC (11),  HPM (12)
C     NUMBER OF HOURS PER MONTH (JAN. - DEC.)
      DATA NMONTH, NOVSCL,  NROUTE / 12, 11,  10/
      DATA HPM/744.,672.,744.,720.,744.,720.,744.,744.,720.,744.,720.,
     1     744./
      IF(N-13) 100,120,140
  100 DO 110 I=1,NOVSCL
      VBC(I,N) = HVC(I) / HPM(N)
  110 HVC(I) = 0.0
C
C     NUMBER OF VESSELS REQUIRED BY CLASS BY ROUTE
C
      DO 200 I = 1, NROUTE
      HRRTE (I,N) = HRRTE(I,N) / HPM (N)
  200 CONTINUE
      RETURN
  120 IF (ICOUN .EQ. 1) GO TO 122
      WRITE (7,2000)  NMCLAS
      GO TO 124
  122 WRITE (7,2000) MMCLAS
  124 DO 130 J=1,NMONTH
      WRITE (7,2010) MON(J),(VBC(K,J),K=1,NOVSCL)
  130 CONTINUE
      WRITE (7,3000)
 3000 FORMAT(//1H ,15X,"NUMBER OF VESSELS REQUIRED  (BY ROUTE) "
     1 //1H ,"MONTH",8X,1HS,9X, 2HMH,
     210X,1HE,10X,1HO,8X,4HS-MH,6X,6HS-MH-E,4X,8HS-MH-E-O,
     35X,4HMH-E,6X,6HMH-E-O,8X,3HE-O/)
      DO 310 J = 1, NMONTH
      WRITE (7,3010)  MON(J), (HRRTE(I,J), I = 1, NROUTE)
 3010 FORMAT( 1H , 1X, A4, 10F11.4/)
  310 CONTINUE
```

```
      RETURN
  140 WRITE (7,2020) N
      RETURN
 2000 FORMAT(1H ,15X,"NUMBER OF VESSELS REQUIRED (BY VESSEL CLASS)",
     //1H ,34X,"VESSEL CLASS"//1H ,"MONTH",5X,A1,11(8X,A2)/)
 2010 FORMAT(1H , 1X, A4, 12F10.4/)
 2020 FORMAT(1H1,"THE VALUE FOR THE MONTH IS",I5," BUT SHOULD NOT EXCEED
     $ 12",///)
      END
      SUBROUTINE CVC(N,CTS,ICOUN)
C
C     THIS SUBPROGRAM TOTALS AND WRITES THE COST OF TOTAL SHIPMENTS BY
C     VESSEL CLASS BY MONTH
C
      DIMENSION CTS (12,12), TOTAL(11)
      COMMON /NCOM/  NPG,DPT,NCA(2,5),NCB(2,5),ITJ(10)
      COMMON /MCOM/ MON (13), ITI (10)
      COMMON /CNMCLS/ NMCLAS (11)
      COMMON /CMMCLS/ MMCLAS(11)
      COMMON /TOT/ TOT(12,12)
      DATA DSH/6H------/
      DATA NMONTH, NOVSCL / 12, 11/
      IF(  N -  13) 100,120,160
  100 DO 102 IS=1,NOVSCL
 102   TOT(N,IS)=0.
      DO 110 I=1,NOVSCL
      TOT(N,I) = TOT(N,I) + CTS(N,I)
  110 CTS(N,I) = 0.0
      RETURN
  120 IFL = 4
  130 IF (ICOUN .EQ. 1) GO TO 132
      WRITE (7,2000)  NMCLAS
      GO TO 134
  132 WRITE (7,2000)  MMCLAS
  134 DO 140 I=1,NOVSCL
  140 TOTAL(I) = 0.0
      DO 150 J=1,NMONTH
      IF (IFL .EQ. 4) GO TO 145
      DO 142 IK=1,NOVSCL
  142  CTS(J,IK)=TOT(J,IK)
  145 WRITE (7,2010) MON(J),(TOT(J,IJ),IJ=1,NOVSCL)
      DO 150 I=1,NOVSCL
      TOTAL(I) = TOTAL(I) + TOT(J,I)
  150 CONTINUE
      WRITE (7,2020) (DSH,I=1,21),TOTAL
      RETURN
  160 IF(N - 14) 180,170,180
  170 IFL = 5
      GO TO 130
  180 WRITE (7,2030) N
      RETURN
 2000 FORMAT(1H0,53X,"VESSEL CLASS"//,1H ,"MONTH",4X,A2,11(9X,A2)/)
 2010 FORMAT(1H0,1X,A4,11F11.6)
 2020 FORMAT(1H0,1X,21A6,/,1H ,"TOTAL",11F11.6)
 2030 FORMAT(1H1,"THE VALUE FOR THE MONTH IS",I5," BUT SHOULD NOT EXCEED
     $ 12",///)
      END
      SUBROUTINE  HED(IYR,HBD)
C
C     HEADING PRINTOUT ROUTINE
```

```
C
      COMMON /NCOM/  NPG,DPT,NCA(2,5),NCB(2,5),ITJ(10)
      COMMON /MCOM/ MON (13), ITI (10)
      NPG=NPG+  1
      WRITE (7,1000) NPG,ITI,IYR
      WRITE (7,1010) ITJ,HBD
      RETURN
 1000 FORMAT (47H1WATER LEVELS OF THE GREAT LAKES--INTERNATIONAL,
     / 31H JOINT COMMISSION SPECIAL STUDY, /,
     / 34H EFFECT OF LAKE LEVEL REGULATION--,
     / 29HBY SUBCOMMITTEE ON NAVIGATION, 37X, 5HPAGE , I5, //,
     / 10X, 50HCOST ANALYSIS OF TRANSPORTATION ON THE GREAT LAKES, /,
     / 10X, 10A8,I8)
 1010 FORMAT(1H ,10A8,/,1H ,16X,"HARBOR DEPTH =",F5.1," FEET"/)
      END
C
      SUBROUTINE  PTA(AAA,NEW,NPL)
C
C     PRINTOUT ROUTINE FOR UNITED STATES AND CANADIAN TRAFFIC
C
      DIMENSION   AAA(15,5)
      COMMON /NCOM/  NPG,DPT,NCA(2,5),NCB(2,5),ITJ(10)
      COMMON /MCOM/ MON (13), ITI (10)
      COMMON /COUNTRY / COUNTRY(2)
        N=NEW
C
C     TEST IF US OR CANADIAN RUN
C
      IF(NPL) 100,100,200
C
C     PRINTOUT FOR U.S. TRAFFIC
C
  100 WRITE (7,1000)  COUNTRY(1),NCA
      DO  110   J=  1,5
  110 WRITE (7,1010) MON(N),(NCA(I,J),I=1,2),
     /                 (AAA(J,I), I=  1,5)
      WRITE (7,1020)  COUNTRY(1),NCB
      DO  120   J=  1,  5
  120 WRITE (7,1010) MON(N),(NCA(I,J),I=1,2),
     /                 (AAA(J+5,I), I=  1,  5)
      WRITE (7,1030)  COUNTRY(1),NCA
      DO  130   J=  1,5
  130 WRITE (7,1010) MON(N),(NCB(I,J),I=1,2),
     /                 (AAA(J+10,I), I= 1,5)
      RETURN
C
C     PRINTOUT FOR CANADIAN TRAFFIC
C
  200 WRITE (7,1040)  COUNTRY(2),NCB
      DO  210   J=  1,  5
  210 WRITE (7,1010) MON(N),(NCB(I,J),I=1,2),
     /                 (AAA(I,J), I=  6,10)
      WRITE (7,1050)  COUNTRY(2),NCB
      DO  220   J=  1,  5
  220 WRITE (7,1010) MON(N),(NCA(I,J),I=1,2),
     /                 (AAA(J,I), I=  1,  5)
      WRITE (7,1060)  COUNTRY(2),NCA
      DO  230   J=  1,  5
  230 WRITE (7,1010) MON(N),(NCB(I,J),I=1,2),
     /                 (AAA(I,J), I= 11,15)
```

```
      RETURN
 1000 FORMAT (//,3X,A3,1X,19HDOMESTIC  SHIPMENTS,28X,11HDESTINATION,/,
     / 20X, 5(2X, 2A6), /, 2X, 2HMO, 7X, 6HORIGIN, /)
 1010 FORMAT (1X, A5, 3X, 2A6, 3X, F10.6, 4(4X, F10.6))
 1020 FORMAT (//,3X,A3,1X,19HEXPORT  SHIPMENTS  ,28X,11HDESTINATION,/,
     / 20X, 5(2X, 2A6), /, 2X, 2HMO, 7X, 6HORIGIN, /)
 1030 FORMAT (//,3X,A3,1X,19HIMPORT   RECEIPTS  ,28X,11HDESTINATION,/,
     / 20X, 5(2X, 2A6), /, 2X, 2HMO, 7X, 6HORIGIN, /)
 1040 FORMAT (//,3X,A3,1X,19HDOMESTIC  SHIPMENTS,28X,11HDESTINATION,/,
     / 20X, 5(2X, 2A6), /, 2X, 2HMO, 7X, 6HORIGIN, /)
 1050 FORMAT (//,3X,A3,1X,19HIMPORT    RECEIPTS ,28X,11HDESTINATION,/,
     / 20X, 5(2X, 2A6), /, 2X, 2HMO, 7X, 6HORIGIN, /)
 1060 FORMAT (//,3X,A3,1X,19HEXPORT  SHIPMENTS  ,28X,11HDESTINATION,/,
     / 20X, 5(2X, 2A6), /, 2X, 2HMO, 7X, 6HORIGIN, /)
      END
      SUBROUTINE  SPT(VAR,ICROP,ITIME,ISHAL)
C
C     SUMMARY PRINTOUT ROUTINE
C
      DIMENSION VAR (10,12), TCL (10), SUM (12)
      COMMON /NCOM/  NPG,OPT,NCA(2,5),NCR(2,5),ITJ(10)
      COMMON /MSAVE/ SAVE(30,8)
      COMMON /MCOM/ MON (13), ITI (10)
      DATA DSH/6H------/
      DATA NMONTH,  NROUTE / 12,  10/
      WRITE (7,1000)
      DO  100   I=  1, NROUTE
  100 TCL(I) = 0.0
      TOT=0.0
      DO  130   J=  1,  NMONTH
      SUM(J) = 0.0
      DO  120   I=  1, NROUTE
      TCL(I) = TCL(I) + VAR(I,J)
  120 SUM(J) = SUM(J) + VAR(I,J)
      TOT = TOT + SUM(J)
  130 CONTINUE
      DO 110 J = 1, NMONTH
  110 WRITE (7,1010) MON(J), (VAR (I,J), I=1,NROUTE),SUM(J)
      ICR=ICROP
      IF (ISHAL .EQ. 1) ICR=ICROP+4
      SAVE (ITIME,ICR)=TOT
      WRITE (7,1020)  (DSH    , I = 1, 22), TCL,TOT
      RETURN
 1000 FORMAT(/1X,5HMONTH,5X,1HS,9X,2HMH,10X,1HE,10X,1HO,8X,4HS-MH,6
     /X, 6HS-MH-E, 4X, 8HS-MH-E-O, 5X, 4HMH-E, 6X, 6HMH-E-O, 8X, 3HE-O,
     / 7X,"TOTAL"/)
 1010 FORMAT (  1X, A4, 2X, F9.6, 9(2X, F9.6),2X,F11.6)
 1020 FORMAT (1H0,22A6,/1H ,5HTOTAL,F10.6,9F11.6,F13.6)
      END
      SUBROUTINE DEPTH(I,J,WATER,O,HDP)
C     ASSIGN ROUTE NUMBER ACCORDING TO ORIGIN AND DESTINATION
      INTEGER O
      COMMON /DOTN/ N,M,L
      COMMON /CTMP/ ARRAY(12,77,10)
      COMMON /CSLR/ SLR(12,11)
      COMMON /CVLC/ VLC(11)
      DIMENSION IROUTE(5,5)
      DATA IROUTE /1,5,5,6,7,5,2,2,8,9,5,2,2,8,9,6,8,8,3,10,7,9,9,10,4/
      IJ=I
   50 IF (IJ .LT. 6) GO TO 100
```

```
      IJ=IJ-5
      GO TO 50
  100 O=IROUTE(IJ,J)
      WATER=ARRAY(N,M,O) + HDP
      IF (WATER-SLR(N,L)) 120,120,110
  110 WATER=SLR(N,L)
 120  IF (WATER-VLC(L)) 140,140,130
  130 WATER=VLC(L)
  140 RETURN
      END
      SUBROUTINE WLD(ITIME,JERROR,ITJ)
C     READ WATER LEVEL DATA
      COMMON /CTMP/ ARRAY(12,77,10)
      DIMENSION TEMP(10),ITJ(10)
      ICNT=0
      IT=ITIME+10
      READ(IT,1001) ITJ
 1001 FORMAT (10A8)
  900 READ (IT,1000) IMON,IYR,(TEMP(I),I=1,10)
      IF (EOF(IT)) 999,901
 1000 FORMAT (7X,I2,2X,I2,17X,10F5.2)
  901 IF (IMON .LE. 0) GO TO 900
      IF (IMON .EQ. 99) GO TO 999
      IF (IMON .GT. 12) GO TO 900
      IF (IYR .GT. 76) GO TO 900
      DO 800 I=1,10
  800 ARRAY(IMON,IYR+1,I)=TEMP(I)
      ICNT=ICNT+1
      GO TO 900
  999 IF (ITIME .NE. 1) GO TO 997
      WRITE (3,998) ICNT,ITJ
  998 FORMAT (/7X,20HRECORDS READ IN WLD ,I5,4X,10A8)
      ISAVE=ICNT
      RETURN
  997 WRITE (3,996) ICNT,ITJ
  996 FORMAT ( /7X,20HRECORDS READ IN WLD ,I5,4X,10A8)
      IF (ISAVE .EQ. ICNT) RETURN
      WRITE (3,990) ISAVE
  990 FORMAT (8X,"THIS DOES NOT EQUAL THE ",I4,
     1 " RECORDS READ FOR THE BASE CASE"/8X,
     2 "ANALYSIS SKIPPED -PLEASE CORRECT THIS PROBLEM"/)
  995 JERROR=1
      WRITE (3,1002)
      WRITE (3,1000) IMON,IYR,(TEMP(I),I=1,10)
 1002 FORMAT (2X,"***  DATA ERROR  ***")
      RETURN
      END
      SUBROUTINE FINDIT (IO,ID,I,J)
      DIMENSION LAKE(5)
C     CONVERT ALPHA CHARACTERS INPUT FOR LAKE ORIGIN AND DESTINATION
C      TO NUMERIC SUBSCRIPTS TO BE USED WITHIN PROGRAM
      DATA LAKE / 1HS, 1HM, 1HH, 1HE, 1HO /
      I=0
      J=0
      DO 10 K=1,5
      IF (IO .EQ. LAKE(K)) GO TO 20
   10 CONTINUE
   45 WRITE (6,50) IO,ID
   50 FORMAT (/1X,"INPUT DATA ERROR-ORIGIN OR DESTINATION IS INCORRECT",
     1  2A3/)
```

```
      ID=0
      GO TO 60
   20 I=K
      DO 30 K=1,5
      IF (ID .EQ. LAKE(K)) GO TO 40
   30 CONTINUE
      GO TO 45
   40 J=K
   60 RETURN
      END
```

```
00080 BASE 0
00090  DIM P(500)
00100  FOR L=0 TO 500
00110  LET P(L)=0
00120  NEXT L
00130 PRINT   USING "NUMBER OF YEARS";
00140  INPUT N1
00150 PRINT "NUMBER OF YEARS";
00160 PRINT
00170 REM
00180 PRINT "ENTER A 1 FOR CONSTANT ABSOLUTE CHANGE OR ";
00190 PRINT "ENTER A 2 FOR A CONSTANT"
00200 PRINT "RATE OF CHANGE IN DETERMINING INTERPOLATED YEARS";
00210  INPUT I1
00220  IF I1>3 THEN 160
00230  IF I1<1 THEN 160
00240 PRINT
00250 PRINT "ENTER THE PROJECT YEAR ALONG WITH THE VALUE "
00260 PRINT "ASSOCIATED WITH THAT YEAR"
00270 PRINT "IN ASCENDING PROJECT YEAR ORDER. IF VALUES ARE NOT "
00280 PRINT "IN ASCENDING ORDER"
00290 PRINT "ERROR WILL OCCUR IN THE ANALYSIS."
00300 REM
00310  LET N8=0
00320  LET P4=0
00330  LET P5=0
00340  INPUT I9,P6
00350  IF I9>0 THEN 390
00360  LET P4=P6
00370  LET P5=P6
00380  GOTO 340
00390  LET K9=I9-N8
00400  LET P(I9)=P6
00410  IF I1=2 THEN 530
00420  IF I1=3 THEN 490
00430  LET Z=(P6-P5)/K9
00440  LET M=K9-1
00450  FOR Z1=1 TO M
00460  LET Z2=N8+Z1
00470  LET P(Z2)=P5+Z1*Z
00480  NEXT Z1
00490  IF I9>= N1 THEN 660
00500  LET N8=I9
00510  LET P5=P6
00520  GOTO 340
00530  IF P5=0 THEN 550
00540  GO TO 560
00550  LET P5=.001
00560  IF P6=0 THEN 580
00570  GOTO 590
00580  LET P6=.001
00590  LET R2=EXP(1/K9*LOG(P6/P5))-1
00600  LET M=K9-1
00610  FOR Z1=1 TO M
00620  LET Z2=N8+Z1
00630  LET P(Z2)=P5*(1+R2)^Z1
00640  NEXT Z1
00650  GOTO 490
00660 PRINT "ENTER YEAR & COST"
00670  INPUT I9,P6
```

```
00680  IF I9>N1 THEN 710
00690  LET P(I9)=P(I9)-P6
00700  GOTO 670
00710  LET I2=0
00720  LET N4=0
00730  GOSUB 870
00740  GOSUB 920
00750  LET N4=N4+1
00760  IF ABS(S2) < .001  THEN 790
00770  LET I2=I2-.5*S2/D2
00780  GOTO 730
00790 PRINT
00800 PRINT
00810 PRINT "ITERATIONS ";
00815 PRINT USING "#####", N4;
00820 PRINT "  I/R/R IS ";
00825 PRINT USING "###.####", I2
00830 PRINT "ANOTHER RUN (Y OR N)";
00840  INPUT Y$
00850  IF Y$ = "Y" THEN 100
00860  GOTO 970
00870  LET S2=0
00880  FOR L=0 TO N1
00890  LET S2=S2+P(L)/(1.+I2)^L
00900  NEXT L
00910  RETURN
00920  LET D2=0
00930  FOR L=1 TO N1
00940  LET D2=D2-L*P(L)/(1.+I2)^(L+1)
00950  NEXT L
00960  RETURN
00970  END
```

SAMPLE INPUT

```
/JOB
/NOSEQ
KWAN,T400,CN277000,P02.
USER,ACCT. *,PASSWORD. LARSEN/3-1157/NCD-ADP
GET,MOD6LGO.
GET,TAPE11=JK3BAS2.
GET,TAPE12=JK36L2.
GET,TAPE13=JK315S2.
GET,TAPE14=JK325N2.
MAP,OFF.
MOD6LGO,PL=1000000.
EXIT,U.
COST,LO=F.
REWIND,OUTPUT.
COPY,OUTPUT,CNOT20.
REPLACE,CNOT20.
ROUTE,CNOT20,DC=PR,UN=CEF2RJ,P=02.
REWIND,TAPE3.
REWIND,TAPE7.
REPLACE,TAPE3=CLCN203.
REPLACE,TAPE7=CLCN207.
ROUTE,TAPE7,DC=PR,UN=CEF2RJ,P=02.
DAYFILE,DYCN20.
REPLACE,DYCN20.
/EOR
4
PLN77ADJ B
77PLN6LCT3
77PN15SCT3
77PN25NCT3
CANADA IRON ORE  2000 DEEP DRAFT (EX=M=O=M), (EX=E=O=E), (EX=O=O=O)
2000 27. 23.4  98 87 1
CAPACITY
6063 10892 10752 13455 19604 24098 31548 0 0 0 0
DRAFT
19.82 24.11 20.63 22.12 25.17 26.71 28.22 0 0 0 0
IMMERSION
504 804 804 948 1200 1344 1548 0 0 0 0
SPEED
14 14 14 14 14 14 14 0 0 0 0
COST
720 850 1050 1410 1510 1650 2040 0 0 0 0
CLASS DISTRIBUTION
0 0 0 .5 8.1 8.7 82.7 0 0 0 0
0 0 0 .54 8.26 8.87 82.33 0 0 0 0
0 0 0 .11 9.2 9.2 81.49 0 0 0 0
MONTHLY DISTRIBUTION
0 0 0 10.17 13.6 12.79 12.79 11.2 11.84 10.84 10.7 6.07
ROUND TRIP FACTOR
2 2 1.6 1.35 1.38 1.34 1.43 0 0 0 0
UNLOADING TIME
20 20 20 20 22 22 22 0 0 0 0
LOAD LINE LIMITS
18.82 22.54 18.98 20.09 23.23 25.12 26.45 0 0 0 0
19.13 22.88 19.79 20.91 23.78 25.89 26.65 0 0 0 0
19.52 23.56 20.44 21.68 24.57 26.14 27.53 0 0 0 0
19.82 24.11 20.63 22.12 25.17 26.71 28.22 0 0 0 0
TONNAGE, MILEAGE, AND SHALLOW HARBOR PERCENT
DOMESTIC
S S  1800.     266.      100.
```

```
S E  1500.      750.         8.
S D  2000.      913.
D D  4900.      867.
H E  100.       536.       100.
EXPORTS          US EX AND CANADIAN IMPORT
S S 1300.       180.       100.
S F  900.       636.         8.
S D  2100.      952.
M D  300.       725.
IMPORTS  US IMPORT AND CANADIAN EXPORT
S M  2900.      695.
S E  300.       690.        8.
H H  1000.      305.
H M   400.      469.       100.
H E   800.      430.       100.
D M  4400.      1777.
D E  14500.    1008.       30.8
END
CANADA COAL 2000 DEEP DRAFT (D-E=EX-E) DOM (D-E=E-SLS) EXP
2000 27. 22.3  98 98 1
CAPACITY
5647 9675 9590 12526 17554 20897 28952 0 0 68000.  0
DRAFT
18.83 22.16 18.77 20.84 23.23 24.26 26.67 0 0 28.  0
IMMERSION
504 804 804 948 1200 1344 1548 0 0 2930.  0
SPEED
14 14 14 14 14 14 14 0 0 14.9  0
COST
720 850 1050 1410 1510 1650 2040 0 0 3110  0
CLASS DISTRIBUTION
3.06 0 0 .11 3.06 .83 83.86 0 0 9.08 0
3.06 0 0 .11 3.06 .83 83.86 0 0 9.08 0
3.06 0 0 .11 3.06 .83 83.86 0 0 9.08 0
MONTHLY DISTRIBUTION
0 0 0 13.21 13.6 13.99 10.97 9.07 9.77 10.99 10.49 7.91
ROUND TRIP FACTOR
2 2 2 2 2 2 2 0 0 2  0
UNLOADING TIME
20 20 20 20 22 22 22 0 0 28  0
LOAD LINE LIMITS
18.83 22.16 18.77 20.09 23.23 24.26 26.45 0 0 28.  0
18.83 22.16 18.77 20.84 23.23 24.26 26.65 0 0 28.  0
18.83 22.16 18.77 20.84 23.23 24.26 26.67 0 0 28.  0
18.83 22.16 18.77 20.84 23.23 24.26 26.67 0 0 28.  0
TONNAGE, MILEAGE, AND SHALLOW HARBOR PERCENT
DOMESTIC
S H   100.       807.       100.
S E  5100.      807.        50.
S D   300.      913.        50.
D E   200.     1167.
EXPORTS          US EX AND CANADIAN IMPORT
E S  4400.      400.        99.
E H  6300.      230.        25.
E E  7000.       84.
E D 10600.      218.        3.5
D E   200.      568.
END
CANADA LIMESTONE 2000 DEEP (H-SLS=H-D) (SLS-D=D-D) OCT, 1980
2000 27. 22.5  97 100 1
```

```
CAPACITY
6063 12376 10304 14104 25019 25835 33897 0 0 0 0
DRAFT
17.34 22.58 20.63 21.65 23.54 24.88 28.23 0 0 0 0
IMMERSION
504 804 804 948 1200 1344 1548 0 0 0 0
SPEED
14 14 14 14 14 14 14 0 0 0 0
COST
720 850 1050 1410 1510 1650 2040 0 0 0 0
CLASS DISTRIBUTION
0 0 0 3.2 16.1 4.6 76.1 0 0 0 0
0 0 0 3.36 15.58 4.74 76.32 0 0 0 0
0 0 0 3.2 16.1 4.6 76.1 0 0 0 0
MONTHLY DISTRIBUTION
0 0 0 11.26 13.29 12.72 11.74 10.85 10.85 11.44 11.49 6.36
ROUND TRIP FACTOR
2 2 2 2 2 2 2 0 0 0 0
UNLOADING TIME
20 20 20 20 22 22 22 0 0 0 0
LOAD LINE LIMITS
16.98 21.08 18.98 19.52 21.67 23.28 26.56 0 0 0 0
16.98 21.58 19.79 20.45 22.26 23.36 26.73 0 0 0 0
17.34 22. 20.44 21.19 22.99 24.28 27.53 0 0 0 0
17.34 22.58 20.63 21.65 23.54 24.88 28.23 0 0 0 0
TONNAGE, MILEAGE, AND SHALLOW HARBOR PERCENT
DOMESTIC
D D  3500.      367.
EXPORTS         US EX AND CANADIAN IMPORT
H S  1300.      113.        100.
H H  1900.      179.         84.
H E   600.      258.         90.
H D   300.      870.
M H   200.      389.
IMPORTS    US IMP AND CANADIAN EXPORT
E E  1700.     145.         90.
END
CANADA GRAIN 2000    DEEP DRAFT    OCT, 1980
2000 27. 23.2  93. 98. 1
CAPACITY
4995 8680 12180 12468 17164 21478 28997 0 0 0 0
DRAFT
17.28 20.57 19.62 20.75 22.86 24.71 26.7 0 0 0 0
IMMERSION
504 804 804 948 1200 1344 1548 0 0 0 0
SPEED
14 14 14 14 14 14 14 0 0 0 0
COST
720 850 1050 1410 1510 1650 2040 0 0 0 0
CLASS DISTRIBUTION
2.5 .1 0 0 7.4 8.3 81.7 0 0 0 0
2.68 .11 0 0 6.74 8.21 82.26 0 0 0 0
14.7 0 0 0 8.47 0 76.83 0 0 0 0
MONTHLY DISTRIBUTION
0 0 0 9.75 11.88 12.14 12.16 9.42 9.86 13.17 12.03 9.59
ROUND TRIP FACTOR
2 2 1.6 1.37 1.3 1.32 1.37 0 0 0 0
UNLOADING TIME
20 20 20 20 22 22 22 0 0 0 0
LOAD LINE LIMITS
```

```
17.28 20.57 18.5 20.09 22.86 24.71 26.45  0 0 0 0
17.28 20.57 19.25 20.75 22.86 24.71 26.7  0 0 0 0
17.28 20.57 19.62 20.75 22.86 24.71 26.7  0 0 0 0
17.28 20.57 19.62 20.75 22.86 24.71 26.7  0 0 0 0
TONNAGE,MILEAGE, AND SHALLOW HARBOR PERCENT
DOMESTIC          CANADIAN
S O  4100.        1206.      .9              S-O=S-SLS
O S  9000.        1692.      0.              O-S=S-EX
H O   200.         650.    100.              H-O=H-SLS
O H   300.        1278.    100.              O-H=H-EX
E O   100.         421.     53.              E-O=E-SLS
O E   100.         800.     5.7              O-E=E-EX
O O   200.         525.     0.               O-O=SLS-EX
EXPORTS
S O   300.       1320.       .9              SAME SUBSTITUTIONS
O S   900.       1835.                       AS ABOVE
H O   100.        797.     100.
O H   200.       1363.     100.
M O   100.       1219.       0.              M-O=M-SLS
O M  1200.       1740.      11.2             O-M=M-EX
E O   300.        540.      53.
O E  2000.       1097.      5.7
END
```

DATE
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