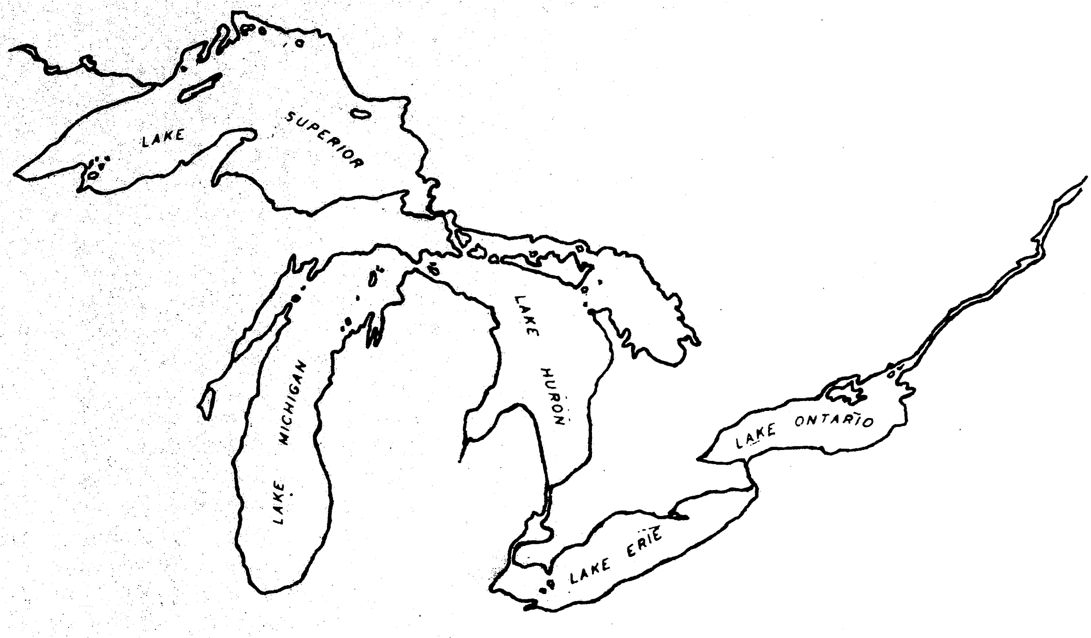
GREAT LAKES UNITIZED TRANSPORTATION SYSTEM



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GREAT LAKES UNITIZED TRANSPORTATION SYSTEM

PRESENTED BY

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ABSTRACT

This project deals with the design of a unitized barge transportation system to serve the overseas general cargo trade of the Great Lakes region. The system is intended to reduce the amount of port time resulting from the need to stop at many Great Lake ports in order to obtain a full cargo load while also permitting unitization of the cargo in a size suitable for much of the cargo.

System Characteristics

Number of Ships	3
Number of Barges	500
Frequency of Service	5 Day
Round Trips per Season	18

ACKNOWLEDGEMENTS

This paper was made possible through the efforts of many people other than the authors. We would like to express our special thanks to some of these people.

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CONTENTS

INTRODUCTION

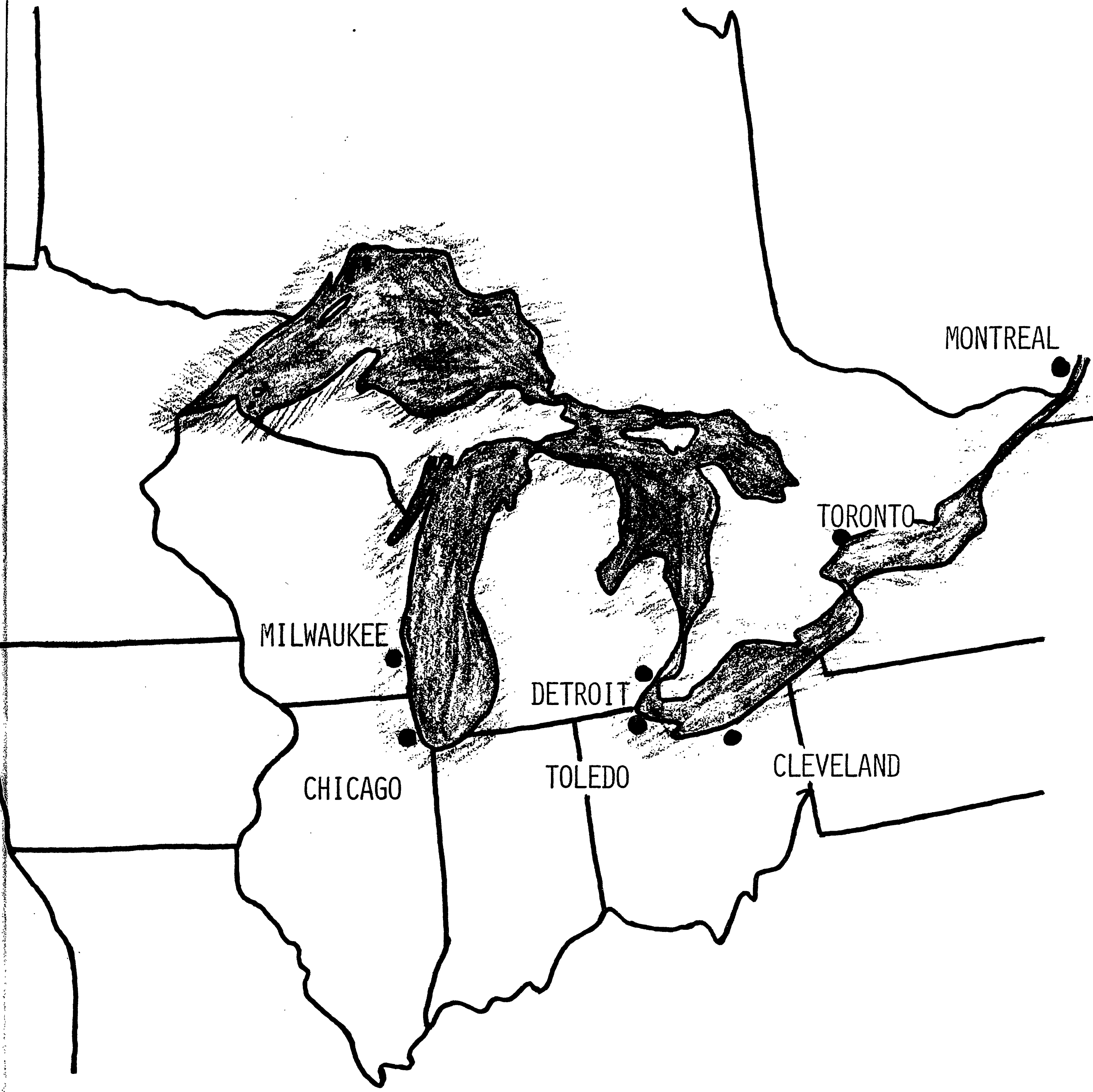
The Great Lakes Unitized Transportation System is the result of this project's purpose to develop a transportation system specifically designed for the Great Lakes-overseas trade. This trade's potential is quite impressive; the Great Lakes region is the export center of North America, and its population and industry provide a vast market for imported goods (see Fig. 1). Chicago is the leading export producing city in the nation, while Detroit is second, Rochester seventh, and Milwaukee tenth. Altogether, approximately forty percent of all American exports are produced within three hundred miles of Chicago.

However, since the opening of the St. Lawrence Seaway, this trade has not developed as expected. Less than eighteen percent of the value of exports originating in this area are shipped through its ports. Instead, goods are shipped by railroad to seaboard ports where they can be loaded on container ships; leaving goods that generally are low value agricultural products or oversized machinery to be shipped from Great Lakes ports. Containers have not been applied to the Great Lakes because there is not enough potential traffic from a single city to support a one stop container service. Although the potential volume of the trade is large, the majority of the cargo shipped from the Lakes is unsuitable for containerization; only sixteen percent of the exports and a quarter of the imports, compared to the projected eighty to ninety percent for the New York-Northern Europe route.[1]

To serve the Great Lakes general cargo trade, the best ship type is the barge carrier since it is particularly suited for the route's characteristics. Other ship types such as the breakbulk or container ship cannot perform as well because of the need to stop at many ports, the lack of containerizable cargo, and the expensive terminal facilities required. Studies have shown the barge carrier to be more economical than either the general cargo

Figure 1

GREAT LAKES REGION



ONTARIO:

1/3 OF CANADA'S POPULATION

2/5 OF CANADA'S MANUFACTURING OUTPUT

GREAT LAKES STATES:

1/4 OF U.S. POPULATION

2/5 OF U.S. MANUFACTURING OUTPUT

or container ship when several ports are to be served.[2] The use of the barge also broadens the spectrum of cargo which can benefit from unitization. For example, dried milk and animal feed have too little value to justify the investment for containers but are suitable for barge size unitizing. The barge also provides the flexibility of cargo types required for the area since break-bulk, bulk, palletized, and containerized cargo can be carried in the barges, and containers and very large cargo can be carried on the ship's deck.

In this system, the barge carrier is to operate on a weekly schedule between Chicago and Montreal with intermediate cargo stops. At Montreal, the barges will be transshipped to an ocean-going barge carrier. The Great Lakes barge carrier is to be designed strictly to the requirements for Great Lakes service since numerous investigations have shown such a vessel to have a greater earning capacity than a dual purpose vessel. This design is greatly affected by the restrictions of the route. The size limitations of the Welland Canal and the St. Lawrence Seaway dicatate the size of both the barge and ship. The choice of engines and propellers must recognize the fact that the ship operates at full speed for only a small fraction of the time. Finally, any ship on the Great Lakes can enjoy only an eight to ten month season.

COST ESTIMATE BASIS

Investment Cost		
Steel Cost		
Medium Steel:	Cost/ton = $227	Ref. 5
	MH/ton = 90000 $(W_s/1000)^{.85}$	
Aluminum:	Cost/ ton = $450	Ref. 6
	MH/ton = 130	
Outfit Cost		
Outfit: Cost/ton = $1800, MH/ton = 280		Refs. 5,7
Gantry Crane: Cost and MH		Ref. 6
Machinery Cost: Cost and MH		Ref. 8
Indirect and Engineering Costs, Overhead:		Ref. 6
Barge Cost: $500/ ton completed		Ref. 6
Owner's Costs:		Ref. 5
Operating Costs		
Wages and Benefits: $25000 + $300d + $30cd		Ref. 7
c - number of crew = 30		
d - number of operating days = 270		
Subsistence: $800c		Ref. 5
Maintenance and Repair:		Ref. 5,7,10
Protection and Indemnity Insurance: $965c		Ref. 7
Hull and Machinery Insurance:		Ref. 5
$10000 + .007(Investment Cost)		
Fuel:		
Fuel Oil: $2.20/barrel, 9000 tons/year		
Diesel Oil: $3.60/barrel, 1800 tons/year		
Tolls:		
Welland: $800/passage x 36 passages		
St. Lawrence: [$.05(Gross Tonnage) +$.90(Cargo Tons)]x36		
Overhead: $65000 + 2(CN)		Ref. 5

COST ESTIMATE SUMMARY

INVESTMENT COST

Cost of Ships

Item	$ Material	Man-Hours Labor
Steel	$ 1,350,000	426,000
Medium Steel	$ 1,260,000	400,000
Aluminum	$ 90,000	26,000
Outfit and Hull Engineering	$ 4,010,000	509,000
Outfit and Hull Eng.	$ 3,060,000	476,000
Gantry Crane	$ 950,000	33,000
Machinery	$ 1,700,000	96,000
Subtotal	$ 7,060,000	1,031,000
Indirect Costs		
(3% Mat., 14% Labor)	$ 211,000	144,340
Engineering Cost		
(1% Mat., 30% Labor)	$ 70,600	309,300
Overhead (70% Labor)	$	721,700
Total Material Cost	$ 7,341,000	
Total Labor Cost @ $3.70/hr	$ 8,163,500	
Subtotal	$15,505,000	
10% Profit	$ 1,551,000	
First Ship Cost	$17,056,000	
Three Ship Cost		
(93.5% Learning Curve)	$46,980,000	$15,660,000 each
Cost of Barges (500 Barges)	$12,500,000	
Owner's Costs	$ 1,407,000	
TOTAL INVESTMENT -----------------	$60,887,000	$20,296,000 each

For a life of 35 years, tax rate of 50%, and an after tax profit of 10%, CR = 0.172

OPERATING COSTS PER SHIP	$1,581,000
Wages and Benefits -------------------------	$ 350,000
Subsistence ---------------------------------	$ 24,000
Protection and Indemnity Insurance ----------	$ 8,000
Hull and Machinery Insurance ----------------	$ 138,000
Maintenance and Repair, Winter Costs, Stores	$ 170,000
Fuel --	$ 187,000
Overhead ------------------------------------	$ 110,000
Tolls ---------------------------------------	$ 592,600
AVERAGE ANNUAL COST ----------------------------	$5,072,000
Cargo per year per ship (36 trips) (16200 long tons cargo per trip)	585,200 LT
REQUIRED FREIGHT RATE (100% capacity)	$ 8.70/ton
REQUIRED FREIGHT RATE (60% capacity)	$14.50/ton

HULL DEVELOPMENT

The St. Lawrence Seaway system was the determining factor in the selection of the ship size. The maximum ship size allowed through the Seaway is:

Extreme length .... 730 ft
Extreme breadth ...... 75.5 ft
Maximum draft .... 25.5 ft

The next factor considered was the hull form. Hull form for a barge carrying ship is dependent on the particular cargo handling system which is used. Three systems were considered in this study: the European proposed gantry crane combined with a well and side ports, the stern elevator, and the stern lift gantry crane. The stern lift gantry crane system was chosen for this application. This system dictates that the ship have its maximum beam carried to the stern, in order to provide for the gantry crane track extensions.

Speed is of course an important factor governing the hull form of any ship. Because this ship is to operate at very low speed for approximately fifty percent of any voyage a high speed hull form is unnecessary.

The above three factors and the desire to carry a maximum amount of cargo produced a ship of the principal characteristics listed in Table 1.

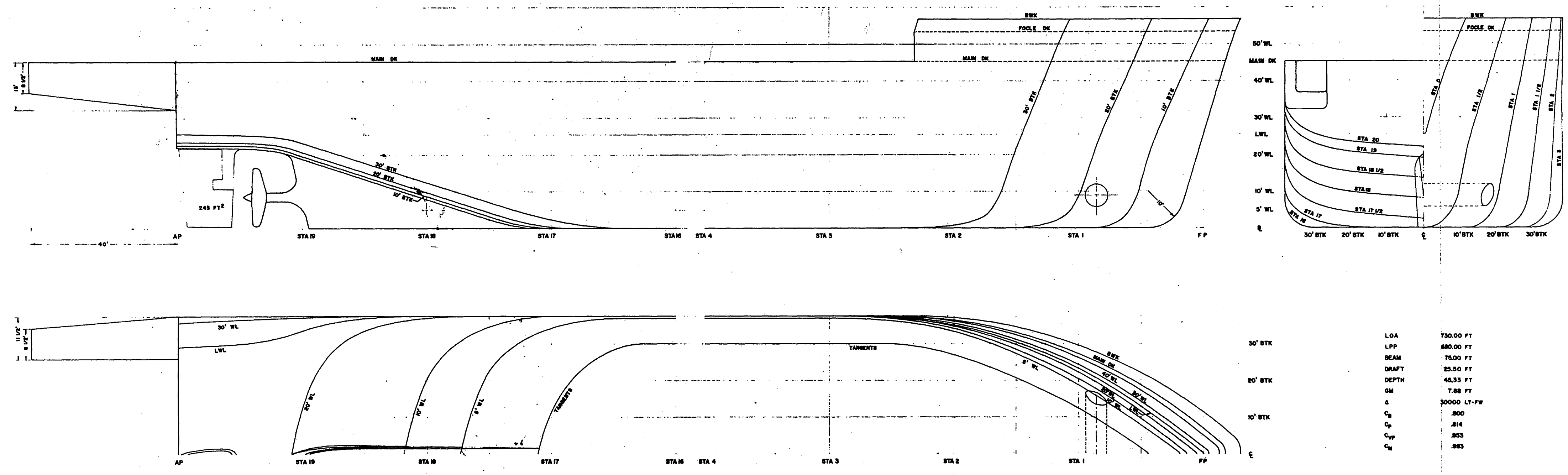
From the lines drawing can be seen the very full form of this ship. Parallel midbody extends over approximately seventy percent of the length between perpendiculars. The wide, flat transom stern allows for good flow to the propeller while providing the necessary width for the gantry crane track extensions. In order to further improve flow to the propeller and provide support for the propeller shaft, a skeg was added.

Table 1

GREAT LAKES UNITIZED TRANSPORTATION SYSTEM

PRINCIPAL CHARACTERISTICS

LOA	730.00 FT
LBP	680.00 FT
BEAM	75.00 FT
DRAFT	25.50 FT
DEPTH	45.33 FT
C_B	.80
C_M	.983
$_{FW}$	29500 LT
CARGO CAPACITY	
BARGES	51
DWT	18900 LT
V_S	19 MPH
SHP	12000 HP
TONNAGE (GROSS)	25500 (EST)
CREW SIZE	29



LOA	730.00 FT
LPP	680.00 FT
BEAM	75.00 FT
DRAFT	25.50 FT
DEPTH	48.33 FT
GM	7.88 FT
Δ	30000 LT-FW
C_B	.800
C_P	.814
C_{VP}	.853
C_M	.983

DRAWING NO. 1

GREAT LAKES UNITIZED TRANSPORTATION SYSTEM

LINES DRAWING

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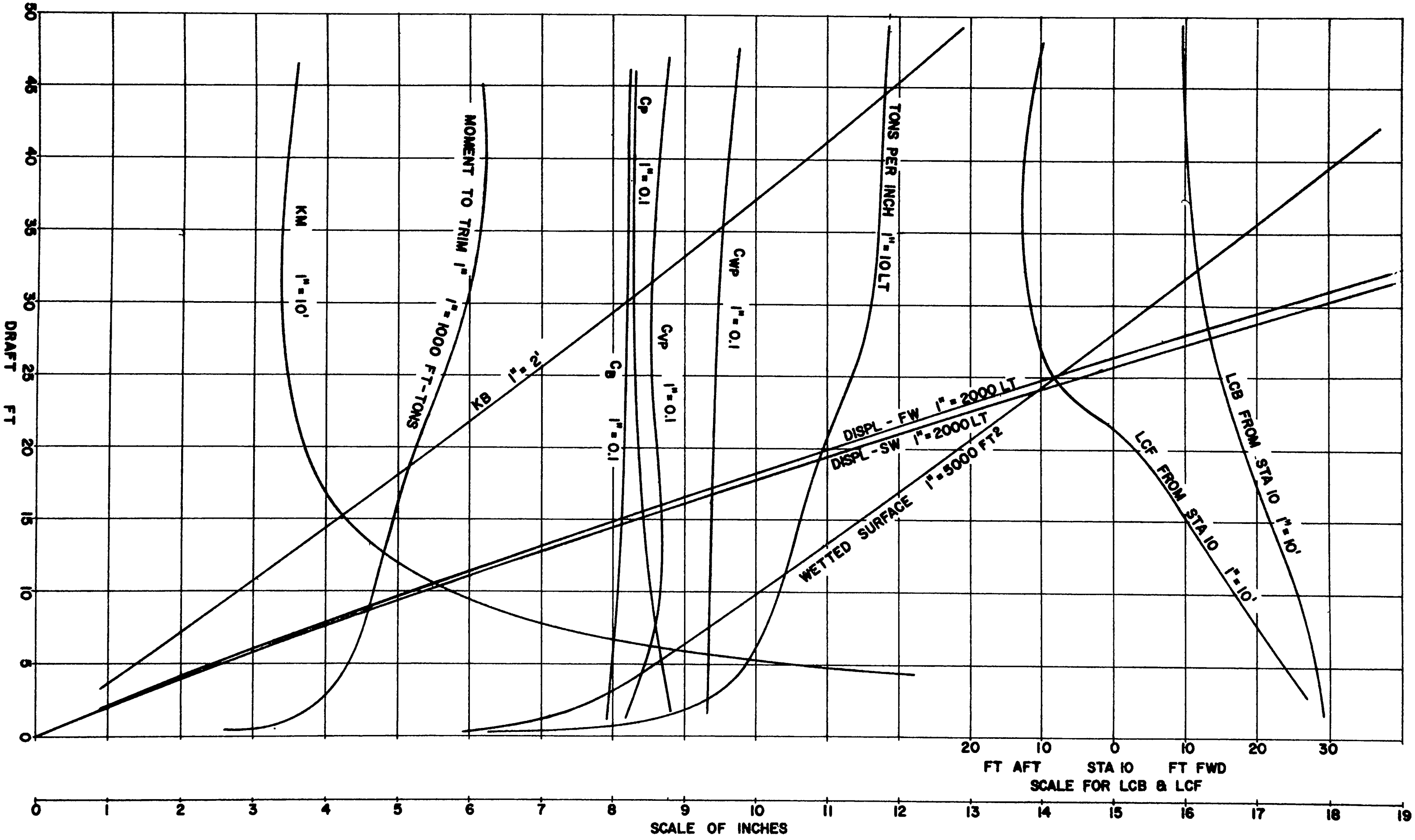
SCALE: 1" = 8'

HYDROSTATICS

After the lines were drawn a complete set of hydrostatic curves and Bonjean's curves were computed with the aid of a computer program. The hydrostatic curves are shown in Fig. 2. Table 2 shows all of the hydrostatic curves of form computer output for the load waterline (25.5 ft). Due to the very full bow and cut away stern, the ship has considerable trim problems in the full load condition. It was found necessary to carry the permanent ballast forward in order to correct the trim by the stern. It is also necessary that cargo hold 7 be loaded as lightly as possible and that any deck cargo and the gantry crane be carried well forward to reduce the aft trimming moments.



GREAT LAKES UNITIZED TRANSPORTATION SYSTEM

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Figure 2

Table 2

GREAT LAKES UNITIZED TRANSPORTATION SYSTEM

EVEN KEEL CONDITION,DRAFT = 25.500

WATER PLANE DATA

LENGTH(FT)	679.9998
AREA(FT**2)	0.4782978E 05
MOMENT ABOUT CENTER LINE(FT**3)	0.4349923E 06
MOMENT ABOUT ORIGIN(FT**3)	0.4231335E 06
MOMENT OF INERTIA ABOUT ORIGIN(FT**4)	0.1639244E 10
MOMENT OF INERTIA ABOUT LCF(FT**4)	0.1635500E 10
MOMENT OF INERTIA ABOUT CENTER LINE(FT**4)	0.2134496E 08
CENTER OF FLOTATION FROM ORIGIN(FT)	8.8467
CENTER OF HALF AREA FROM CENTER LINE(FT)	18.1892
WATER PLANE COEFFICIENT	0.937839
TRANSVERSE MOMENT OF INERTIA COEFFICIENT	0.892861
LONGITUDINAL MOMENT OF INERTIA COEFFICIENT	0.830546
MOMENT TO TRIM AN INCH(FT-LT)	0.5684320E 04
TONS PER INCH(LT)	0.1139569E 03
CHANGE OF DISPLACEMENT PER INCH TRIM AFT(LT)	0.1779065E 02
LCF AS PERCENT LWL FROM AMIDSHIPS	-1.300979
LCB AS A PERCENT OF LWL FROM AMIDSHIPS	2.167707

DISPLACED VOLUME DATA

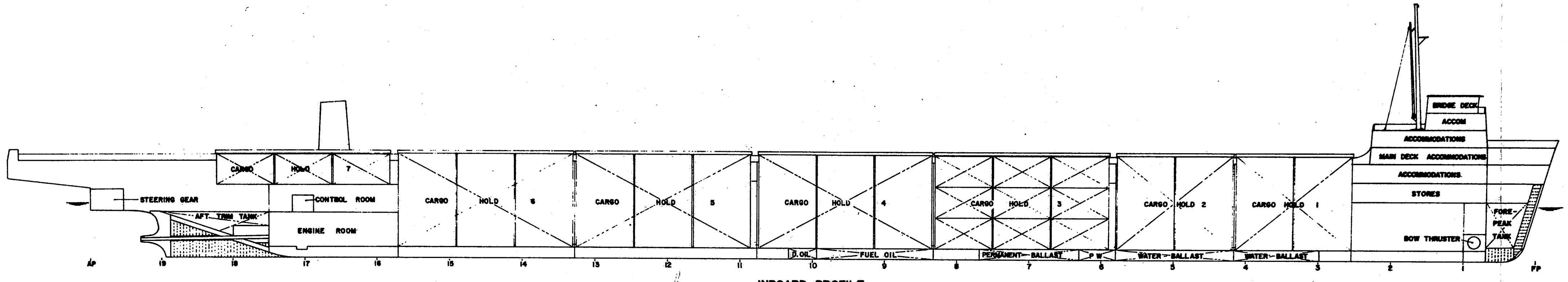
VOLUME(FT**3)	0.1040179E 07
SALT WATER DISPLACEMENT(LT)	0.2973936E 05
FRESH WATER DISPLACEMENT(LT)	0.2891697E 05
WETTED SURFACE(FT**2)	0.7174269E 05
LCB FROM ORIGIN(FT)	-14.7404
VCB FROM BASE LINE(FT)	13.9594
DISTANCE OF CENTROID FROM CENTER LINE(FT)	18.9457
MOMENT ABOUT ORIGIN(FT**4)	-0.1533267E 08
MOMENT ABOUT BASE LINE(FT**4)	0.1452026E 08
MOMENT OF HALF VOLUME ABOUT CENTER LINE(FT**4)	0.9853468E 07
BLOCK COEFFICIENT	0.799831
PRISMATIC COEFFICIENT	0.813795
VERTICAL PRISMATIC COEFFICIENT	0.852844
MIDSHIP SECTION COEFFICIENT	0.982840
BM (FT)	20.520
BM-LONGITUDINAL(FT)	1572.326
KM(FT)	34.480
KM-LONGITUDINAL(FT)	1586.285
GM(FT)	7.880
GM-LONGITUDINAL(FT)	1559.685
PRISMATIC COEFFICIENT FOR THE ENTRANCE	0.339032
PRISMATIC COEFFICIENT FOR THE FORE BODY	0.801709
PRISMATIC COEFFICIENT FOR THE AFTER BODY	0.825881
PRISMATIC COEFFICIENT FOR THE RUN	0.564703
VERTICAL PRISMATIC COEFFICIENT FOR THE ENTRANCE	0.473000
VERTICAL PRISMATIC COEFFICIENT FOR THE FORE BODY	0.864608
VERTICAL PRISMATIC COEFFICIENT FOR THE AFTER BODY	0.841727
VERTICAL PRISMATIC COEFFICIENT FOR THE RUN	0.609340

GENERAL ARRANGEMENTS

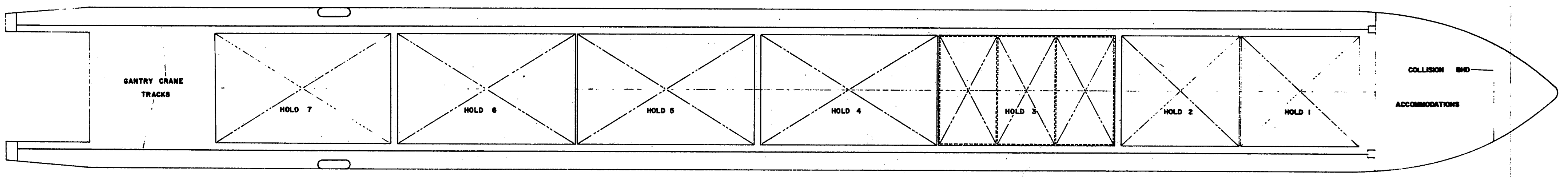
Barge carrying ships, like container ships and bulk cargo ships, require a long expanse of open deck. However, unlike these types, the barge carrier which uses a gantry crane cannot have a superstructure between the forwardmost hold and the stern. Therefore, in this design all accommodations are placed at the bow. There is an underdeck access alley along both sides of the ship to serve as a weathertight passage for the engineering crew.

Figures 3,4,5,6, and the profile drawing show the arrangements of the living spaces. These accommodations are designed for eleven officers and eighteen crewmen. Each officer is provided a stateroom of 225 sq. ft.,and each crew member has a stateroom of 200 sq. ft. These figures include toilet and shower. A large, enclosed recreation area is located on the main deck.

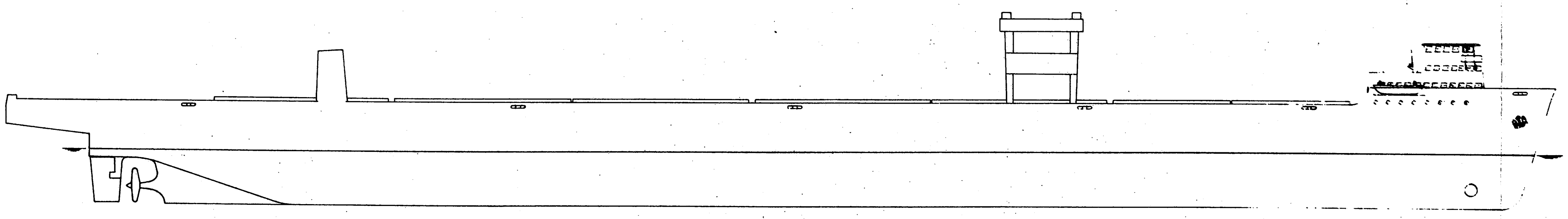
Ships stores are located below the accommodations. There is an elevator which is accessible from the galley and stores area and also from the top of the first superstructure deck. A mast and boom arrangement is used to bring the stores on board. Below the stores is space available for shops and ballast or trim tanks.



INBOARD PROFILE



MAIN DECK PLAN



OUTBOARD PROFILE

DRAWING NO. 2

GREAT LAKES UNITIZED
TRANSPORTATION SYSTEM
INBOARD PROFILE,
MAIN DECK PLAN, AND
OUTBOARD PROFILE

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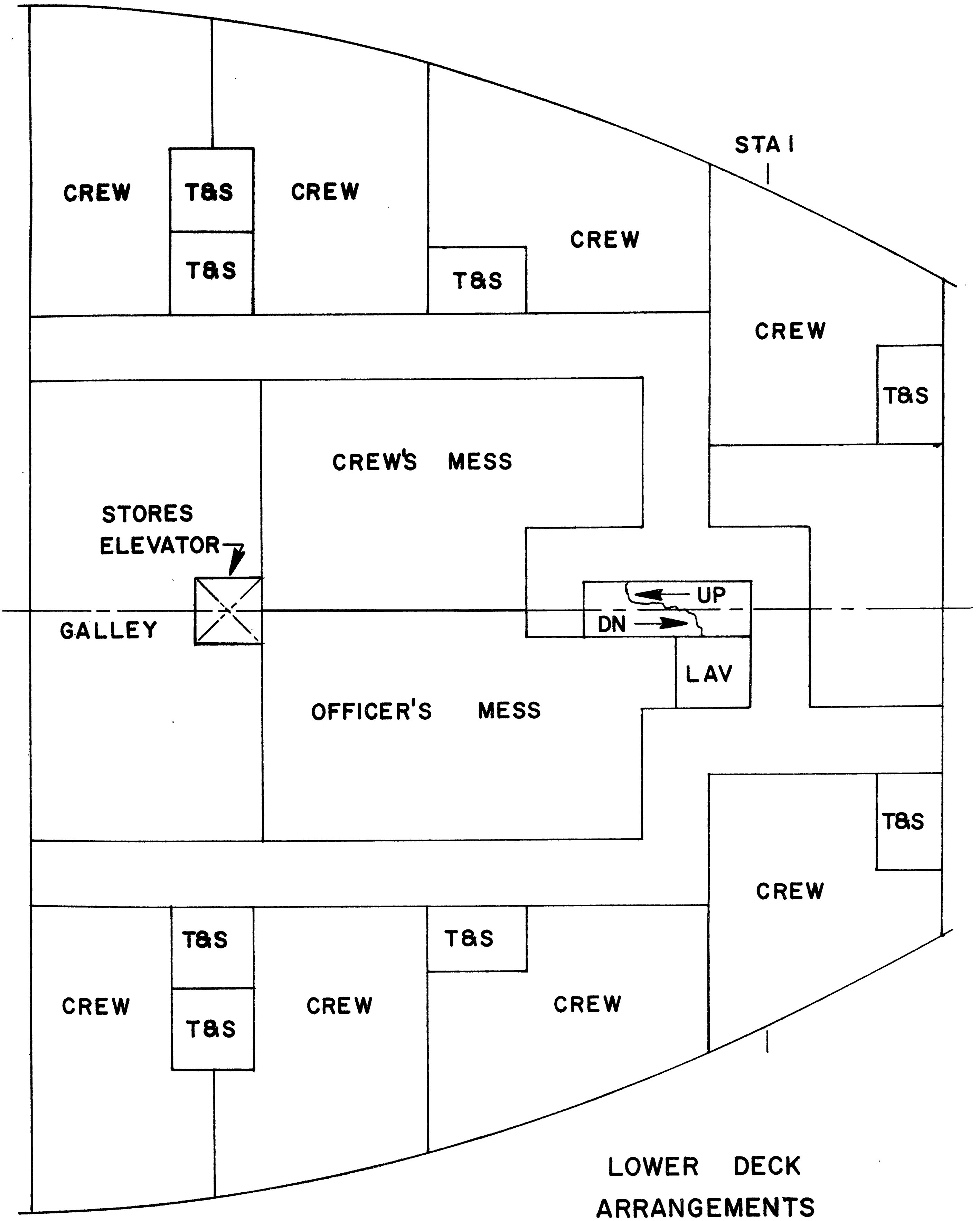
SCALE: 1" = 16'

Figure 3



LOWER DECK ARRANGEMENTS
1" = 8'

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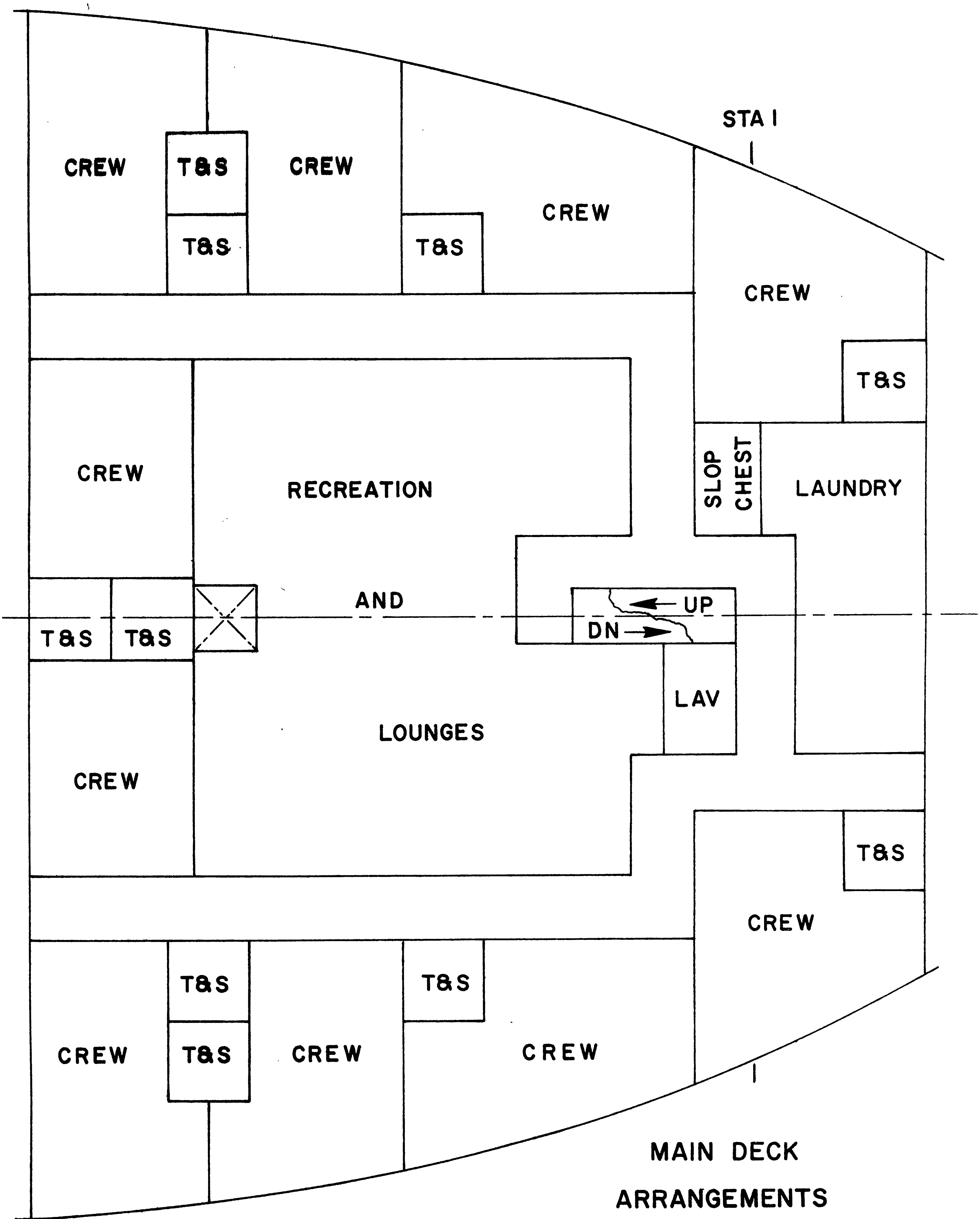

MAIN DECK
ARRANGEMENTS
1" = 8'

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Figure 5

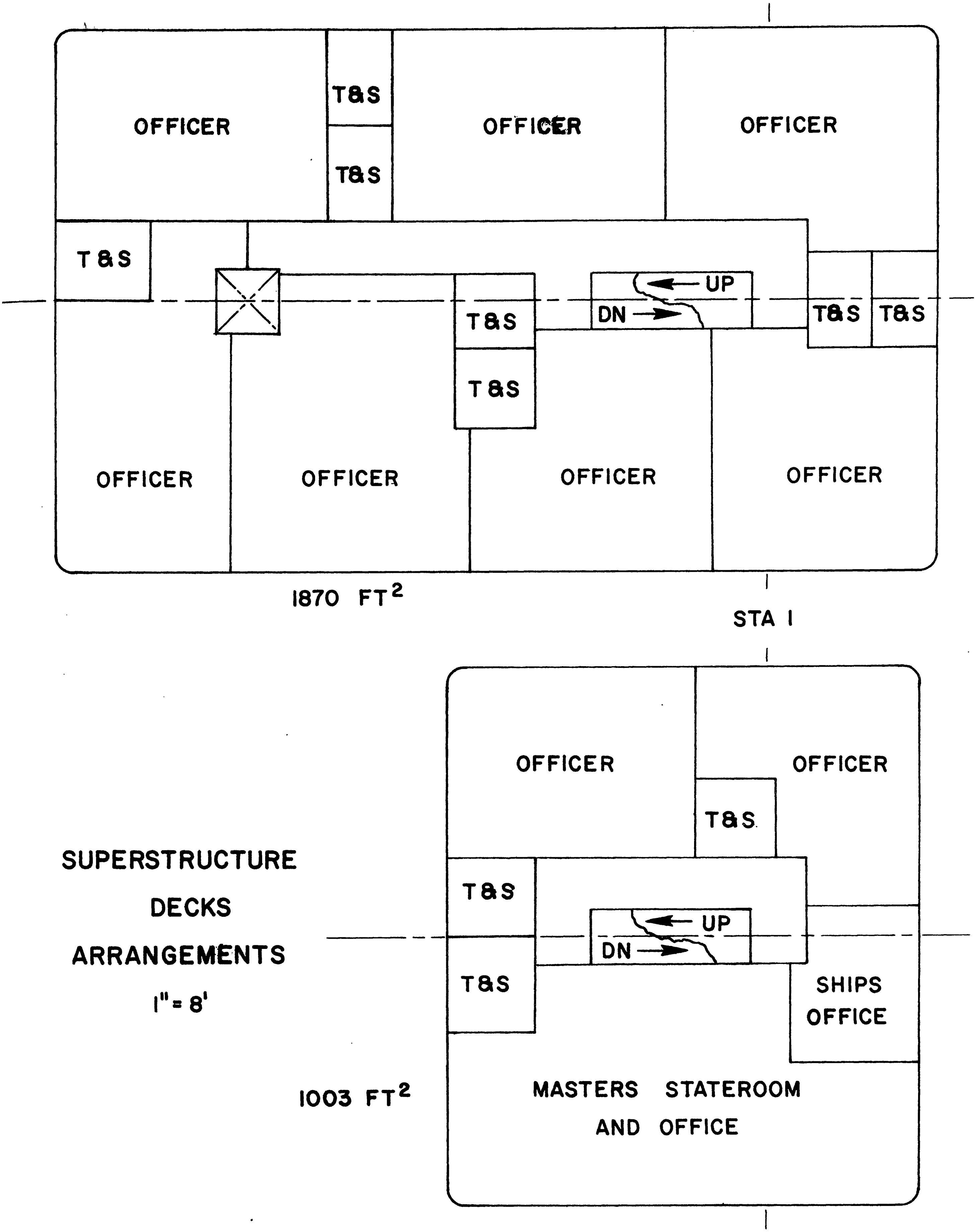

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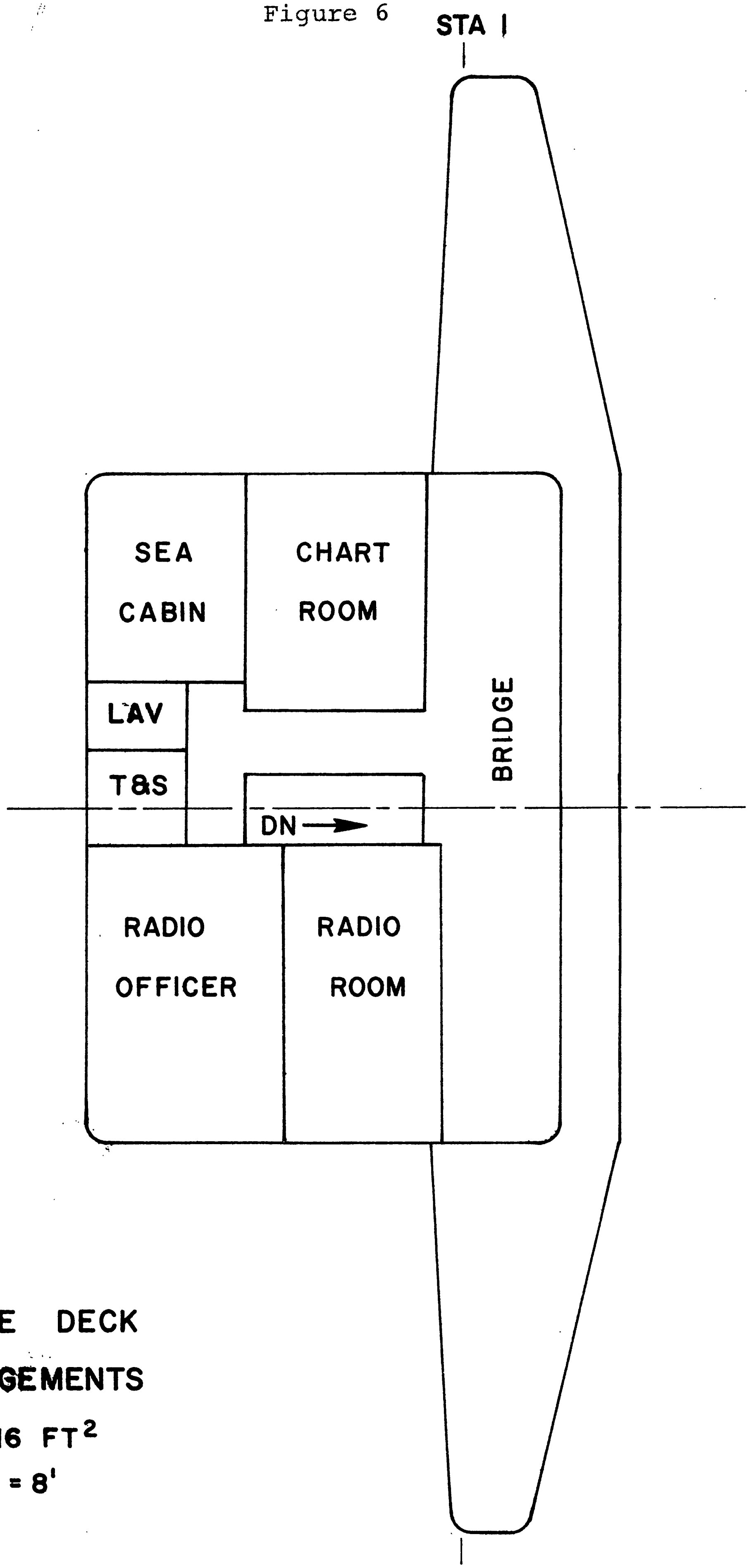
Figure 6



BRIDGE DECK
ARRANGEMENTS
816 FT^2
1" = 8'

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STRUCTURES

Time did not permit a detailed structural design of the Great Lakes barge carrier. However, the structure of the ship is similar to that of a container ship since these two types are very much alike in arrangement of cargo holds, i.e., cells uninterrupted by deck, and with full width hatches. Figure 7 is a representative midship section with the following framing system:

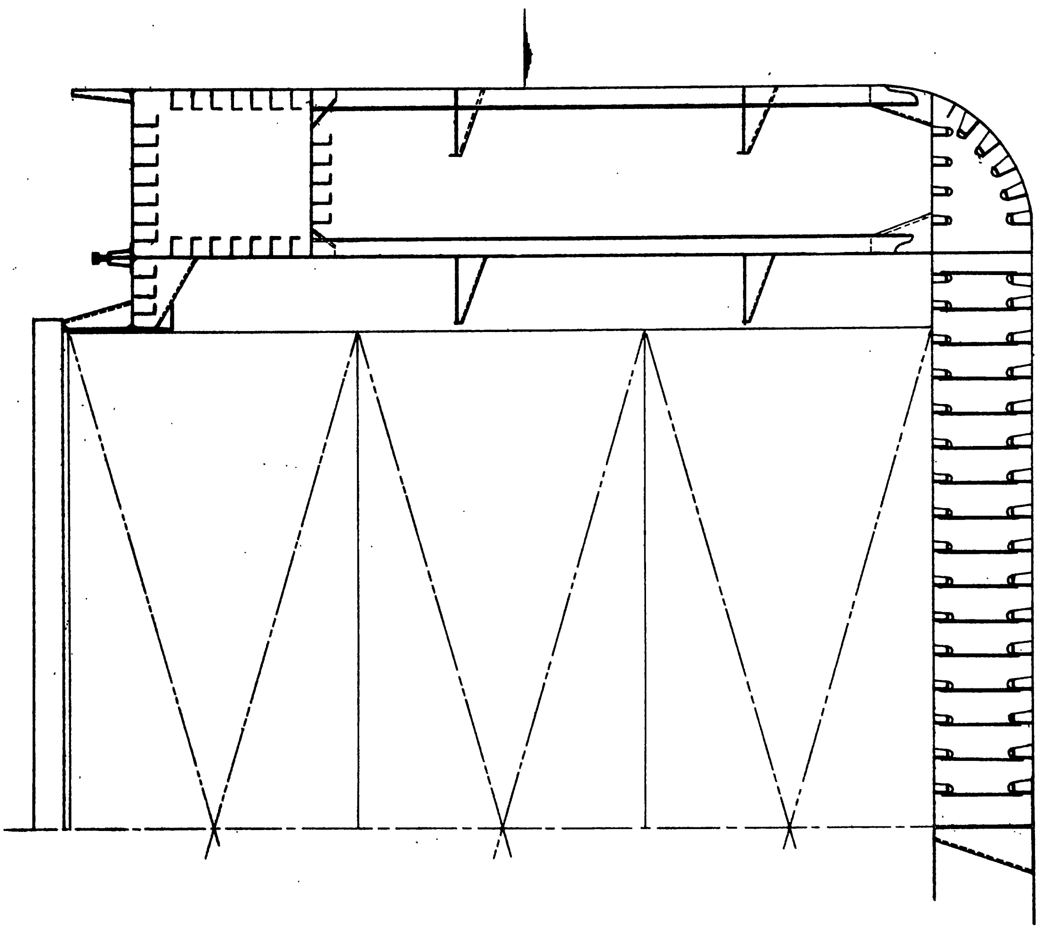
Bottom	Longitudinal
Inner Bottom	Longitudinal
Side Shell	Transverse
Wing Bulkhead	Transverse
Box Girder	Longitudinal
Deck	Longitudinal

The side shell is transversely framed for two reasons. First, transverse framing is very good in way of the light side shell plating, and second, the ship will not suffer significant damage when it collides with lock walls if it has transverse framing.

There are transverse, watertight bulkheads forward of the superstructure (collision bulkhead), at the forward end of hold 1, between each cargo hold, and at the forward and aft ends of the engine room. Transverse access walkways are provided between holds 2 and 3, 4 and 5, and 6 and 7.

The ship's bow is strengthened for navigation in ice since the ship is expected to be sailing when ice is present on the Great Lakes.

Figure 7



DRAWING NO. 3

GREAT LAKES UNITIZED
TRANSPORTATION SYSTEM

MIDSHIP SECTION

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SCALE: 1" = 4'

MACHINERY

The design of the machinery centers upon the selection of the type of machinery best suited for the requirements of the ship and the operating conditions of the route. For this system, medium-speed,geared diesels were chosen. For the power and range required by the ship, this engine has the least combined weight of machinery and fuel, the lowest installed cost (about seventy five percent that of a comparable steam turbine), and fuel consumption higher only than the direct drive diesel.[9] The machinery weight is important because of the trim problems arising from the aft engine room location. The medium-speed diesel also can be fitted in a shorter engine room than either the direct drive diesel or the steam turbine, permitting a longer cargo hold in this length-limited ship.

A dual engine installation as well as a controllable-pitch propeller was used because of the wide range of powers at which the ship operates. For about fifty percent of the voyage, the ship is travelling at eight miles per hour or less because of the locks and canals. By using two engines, one engine can be disengaged in these conditions, saving on both fuel and engine wear. The use of the controllable pitch propeller allows the engine to run at a constant rpm and drive a generator,and also offers the low speed maneuverability and improved stopping ability necessary to negotiate the locks. The machinery arrangement is shown in Figures 8 and 9.

Machinery Characteristics

2	6 cyl. medium speed diesels	6000 hp each
1	main engine-driven 1000kw generator	
1	1000 kw diesel generator	
1	16 ft diameter controllable pitch propeller	

Figure 8

MACHINERY SCHEMATIC

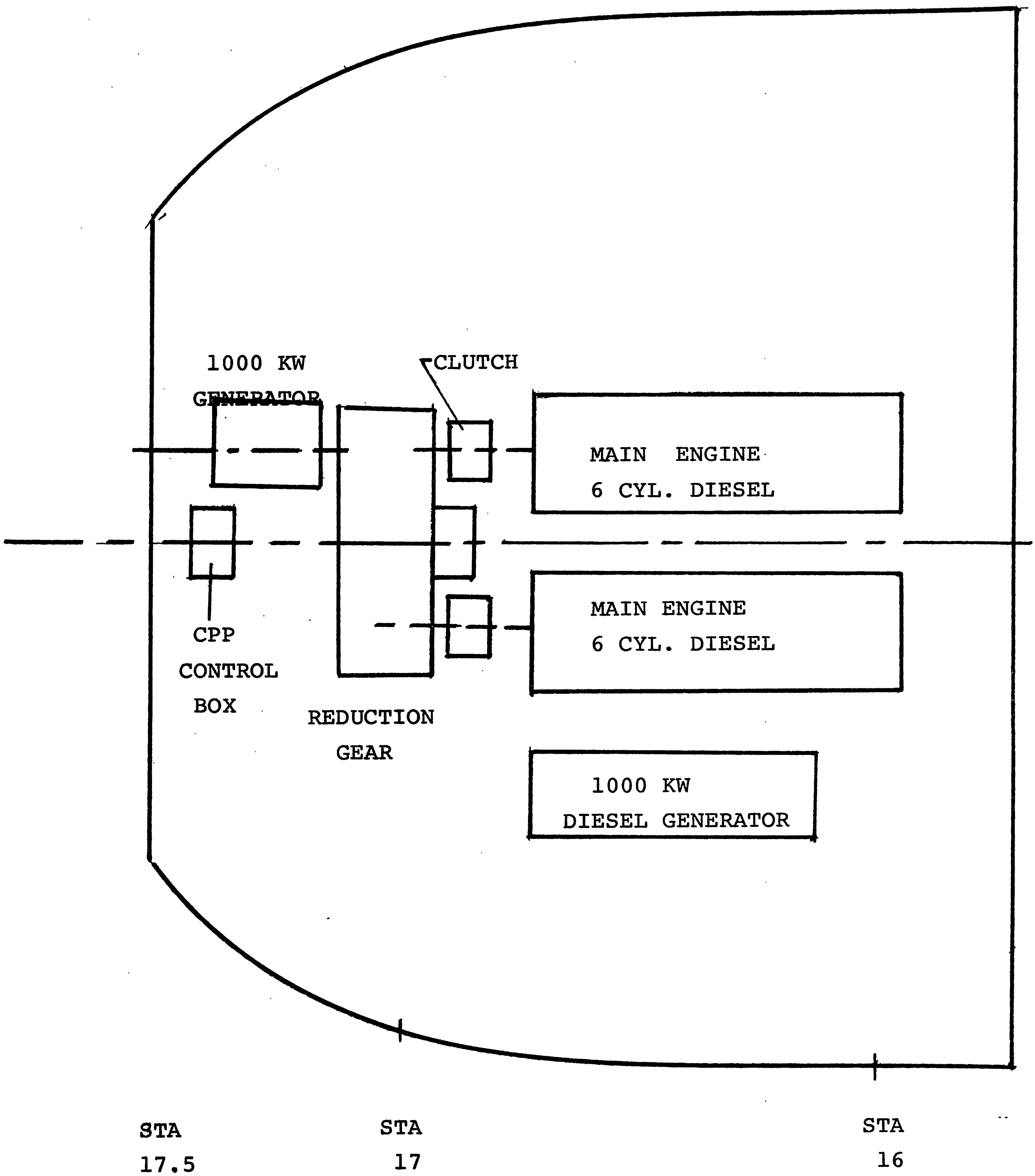
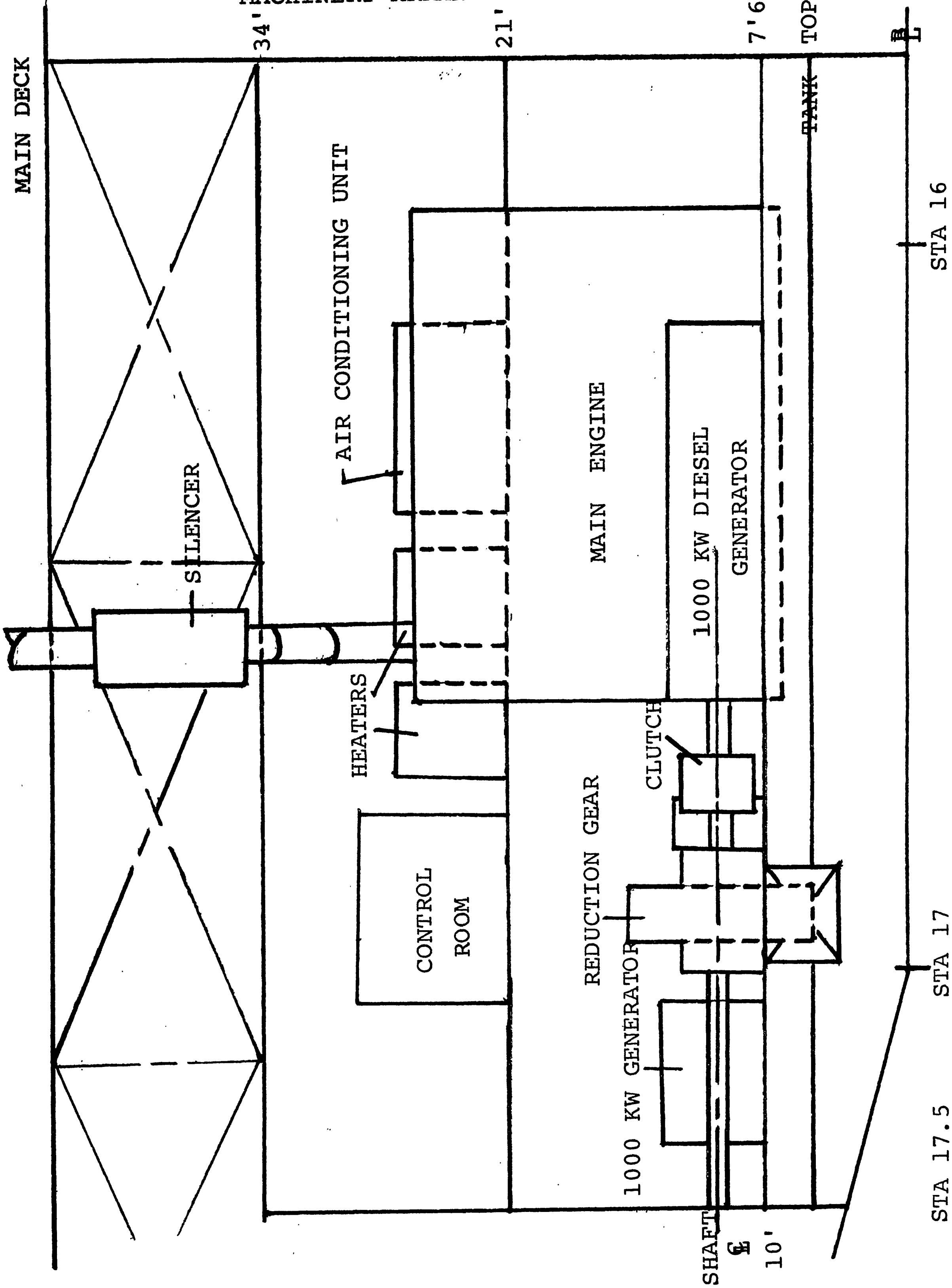


Figure 9

MACHINERY ARRANGEMENT



WEIGHT ESTIMATE BASIS

Light Ship Weight

Steel Weight: Ref. 7

$W_s = [857 + 266(CN/1000)]\ C_{L/D}\ C_{CB}$

$C_{L/D} = (L/D + 2)/20$

$C_{CB} = 0.565 + 0.5\ C_B$

Also checked by CN and CF ratios with other barge ships

Outfit Weight:

Outfit:

$W_o = -.71 \left(\frac{CN}{1000}\right)^2 + 93.5 \left(\frac{CN}{1000}\right) - 104$ Ref. 5

Gantry Weight Ref. 11

Machinery Weight: Ref. 8

Permanent Ballast: from Stability calculations

Margin: $.02(W_s + W_o + W_m)$

Operating Deadweight

Fuel: Specific Fuel Consumption Ref. 8

Crew Weight, Stores weight, Fresh Water, Reserve Cooling Water Ref. 12

Cargo Deadweight

Loaded Barge is 350 tons

WEIGHT SUMMARY

Light Ship	9900 LT
Steel Weight	5750
Outfit and Hull Engineering Weight	2150
Machinery Weight	900
Margin	175
Permanent Ballast	925
Operating Deadweight	700 LT
Fuel Oil	500
Diesel Oil	100
Lubricating Oil	5
Crew and Effects	5
Stores	5
Fresh Water	70
Reserve Cooling Water	15
Cargo Deadweight	18900 LT
Barges	17850
Deck Cargo	1050

BARGES

The size of barge used by the Great Lakes Unitized Transportation System was decided by two factors. First, the beam restriction of the St. Lawrence Seaway does not permit the athwartship loading of the American size barges and leave sufficient deck plate area. Second, the transshipping at Montreal would probably be done with a European barge carrier. Therefore, in order to have a barge size compatible with the restrictions on size, yet able to be interchangeable with other barge ships, the European Common Barge System Type 1 barge was chosen. Its characteristics are summarized in Table 3.

Table 3

GREAT LAKES UNITIZED TRANSPORTATION SYSTEM

BARGE CHARACTERISTICS

LENGTH ----------------- 50.52 FT

BEAM --------------------- 26.90 FT

DEPTH ------------------- 12.80 FT

DWT ------------------------- 275 LT

CUBIC CAPACITY - 14600 FT^3

CONTAINER
CAPACITY
(20 FT * 8 FT * 8 FT) ----- 6

CONCLUSION

As a result of this project, it is believed that the barge carrier ship can replace the break-bulk cargo ship as the mainstay of the Great Lakes-overseas trade. It provides improved service while reducing handling costs to which the route's low value cargo is quite sensitive. The low shipping costs should also attract cargo that presently is shipped by rail to the East coast; increasing the percentage of the area's exports shipped through its ports.

There are several changes or innovations which should be made or investigated, but which time did not permit. The ship's hull form should be modified in order to move the LCB aft to reduce the trim problem. This could be done, at the possible expense of cargo capacity, by having a finer forebody. The possibility of hinging or retracting the cantilever arms to add another cargo hold and lessen the problems of locking should be studied. Devices to reduce the amount of time spent in the locks could be developed, although the locks themselves should be improved rather than the ships. There are other possible refinements as well, but the basic fact remains that the barge carrier is the ship type best suited for the Great Lakes-overseas general cargo trade.

APPENDIX 4

U. S. Overseas General Cargo Movement on the Seaway System
(thousands of short tons)

	1966	1980
Exports		
Dried Milk	53.3	95.0
Wheat Flour and Semolina	109.0	110.0
Other Grain Mill Products	758.1	155.0
Prepared Animal Feeds	146.3	120.0
Fresh Meat and Meat Products	49.0	85.0
Other Animal Products	261.5	650.0
Motor Vehicles and Parts	66.9	75.0
Machinery excluding Electrical	44.1	45.0
Chemicals and Chemical Products	35.9	50.0
Vegetables and Preparations	99.6	120.0
Soybean Meal	254.0	1420.0
Residual	364.3	325.0
	2242.0	3250.0
Imports		
Nonmetallic Minerals and Manufactures	91.0	105.0
Motor Vehicles	78.5	130.0
Liquors and Wines	74.0	170.0
Crude Rubber	61.4	186.0
Machinery excluding Electrical	58.9	115.0
Glass and Glass Products	47.9	60.0
Wood Pulp	45.2	55.0
Chemicals and Chemical Products	27.5	150.0
Veneer and Plywood	40.5	100.0
Fruit and Preparations	39.9	75.0
Residual	320.3	350.0
	885.1	1396.0

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