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HISTORICAL TEMPORAL SHIPPING
(HITS)

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This report represents information on the temporal shipping densities in 1°x1° throughout the world. The basic data base was Lloyd's 1972 Shipping Index updated to 1978. The shipping routes used were reported i[illegible] PSI Report No. TR-036049 of 19 April 1977. The current study provides distributions on merchant vessels, tankers, super tankers, fishing boats and mobile oil rigs. The distributions are by month, season, and annual averages. The data is available in computer readable formats upon request.

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CHAPTER I

Introduction

1. Purpose.

It is the purpose of this report to provide information on the shipping densities in 1° x 1° squares throughout the world. This report explains the techniques and procedures by which these densities were generated. The data generated in meeting this objective is stored in machine readable format and is available from Planning Systems Incorporated.

2. Scope.

This report describes in rather substantial detail the procedures by which shipping densities in 1° x 1° squares are available. The basic data base which was employed was the 1972 Lloyd's Shipping Index indicating the disposition of 18,000 ships per week in the 2,425 Lloyd's ports. The 1972 data base was updated to 1977 using a trend and growth analysis which is discussed in some detail in the report. Five different types of vessels are considered in the analysis. These are merchant vessels, tankers, super-tankers, fishing vessels, and oil rigs. The distributions of the individual types of vessels are given for each month of the year, each quarter of the year, and an annual average. This results in 17 distributions per type of vessel.

The report describes the methodology for distribution of the updated port traffic throughout the world. It is heavily dependent upon a preceding volume issued by Planning Systems Incorporated "Ocean Route Envelopes", (ORE)[22] published on 19 April, 1977. The resulting distributions consist of well over 12,000,000 individual pieces of data. Due to this enormous data base, it is impossible to present all distributions and possible combinations in a printed format within the body of this report.

Therefore, only examples are presented. However, any distribution or combination of distributions may be obtained in machine readable format directly from Planning Systems Incorporated.

3. Background.

The primary purpose of this project was to quantify the distributions of all ships in the oceans of the world at various times of the year. One of the necessary tasks to accomplish this objective was to employ and develop seasonal route envelopes which would allow the movement of ships between the world's ports. The routes themselves are subject to a very detailed development and have been presented in a previous report: Ocean Route Envelopes published by PSI.

World shipping densities are seasonally dependent and are due to two primary factors:

1. The seasonal variation of the routes by which ships move between world ports .

2. The seasonal variation in port traffic.

The first part of this problem, addressed in the ORE report, dealt exclusively with the logic and mathematical quantification of the development of the temporal world shipping routes. The second part of the problem is the world port activity. This activity has been provided through a numerical quantification of 1972 Lloyd's Shipping Index. The index gives the locations of approximately 18,000 ships per week. In the preparation of this report it was necessary to update this 1972 data to the year 1978. A number of techniques were employed based upon industry-wide sources. Therefore, the shipping densitites are considered to be 1978 information. This report, HIstorical Temporal Shipping (HITS), discusses the existing Lloyd's data base, the trend and growth analysis, the distribution methodology to establish the shipping densities, and the type of outputs. In addition to the data, it provides information on the development of the computer programs which were necessary in developing such a large and extensive data base.

CHAPTER II

The Lloyd's Data Base

1. Logical Structure of Data Base.

The DOT Marine Traffic Generator Input Tapes provided the majority of the raw data on ship movements necessary to generate the shipping density for this study. These tapes were originally prepared by the Department of Transportation for use by the Marine Traffic Generator,[4] and included data from Lloyd's Shipping Index for 1972.

These tapes were used in the study by Program Gamma to accumulate the total time spent by ships passing between each pair of ports in the DOT Marine Traffic Generator port table. Later programs then converted this information into shipping density fields.

The Lloyd's Shipping Index contains a weekly record of movements of many merchant vessels (approximately 18,000). It records the egress port, entrance port, and port of last call for each ship, along with the date of egress. An additional date field may fill one of several purposes, depending upon the setting of various flags. Possible interpretations are date of arrival at entrance port, date of arrival at port of last call, date of departure from port of last call, date of passing port of last call, or date of presence in the port of last call. Each ship is identified by name, flag, gross tonnage, year built, and type (tanker or non-tanker), and is recorded each week in approximately the same position within the Shipping Register.[9]

Each of the 52 tapes contains movement reports received during the corresponding week of 1972. However, the actual date of the ship movements recorded can be as much as several months prior to the date of report itself. Frequently, the same data will be repeated in several successive weekly tapes without change. Furthermore, as the length of a voyage can be appreciably longer than the weekly reporting intervals, no one tape will necessarily contain sufficient data to permit reconstruction of the ship's route and travel time. At the opposite extreme, only one voyage with a maximum of three ports (only two with dates) could be included per ship per week, so that numerous short-haul trips were completely ignored. This latter phenomenon was aptly illustrated by ships that were recorded as having arrived in port in one weekly issue and then as departing from a different port in the following week's issue, with no intermediate voyage recorded.

A possible fundamental weakness in the data base used arises from the selective nature of the reporting. Lloyd's was almost completely dependent for its data upon sailing reports from the various harbour masters. The completeness of the data thus depends in most cases upon the diligence of a single reporting source and the completeness of his information. Numerous reports exist in the shipping index of ships sailing off to nowhere or arriving from points unknown. There are no checks against consistent under-reporting of traffic from a specific port and, in particular, sailing reports for Communist owned ships between most Communist ports are conspicuously absent. Date information, too, is frequently missing. This weakness in the data collection is reflected by the incompleteness of the final shipping index. The number of ships reported each week (approximately 13,000) is much smaller than the total number of elligible ships from Lloyd's and no one ship is necessarily monitored continuously throughout the course of the year.

In order to extract the maximum amount of information from Lloyd's shipping index, it was necessary to correlate corresponding reports from successive weekly issues. This was done by matching the ship reports on the basis of the identifying information (name, weight, type, flag, and year built). The reported ship movements could then be compared to eliminate overlapping reports, supplement incomplete information, and simulate some unreported voyages. As movement reports (except for expected destination) were normally received after the movements reported, the tapes were processed backwards, beginning with the shipping index tape for the last week of December 1972, and proceeding backwards to January of that year.

The nature of the data is illustrated by the first 50 records from the DOT input tapes for weeks 51 and 52 shown in Table 2-1. Some sample match-up procedures from these lists are shown in Table 2-2. An examination of the missing data list in the notes to Table 2-1 reveals 122 missing or antiquated items of data among the 100 reports, for an average of 1.21 missing or antiquated data per report. Quite clearly, it is only the exceptional report which is complete and up-to-date.

Table 2-1 Sample Listing for DOT Input Tapes

DOT INPUT TAPE FOR WEEK 51, 1972

A	B	C	D	E	F	G	H	I	J	K	L
A. E. S. [I]	0	DA	57	001579	ROTTE	DEC 11	LONDO	AR		DEC 12	
A. HELD [a]	0	GE	67	000211	KOTKA	DEC 05	MAAST	AR	ANTWE	DEC 14	4
A. N. KEMP [I]	1	LI	50	018127[e]	NEW Y	DEC 06	ARUBA				4
A. P. MOLLER [I]	1	DA	66	052673[c]	PHILA	NOV 29[5]	ESCRA				4
AAGE ANDREASEN	0	DA	66	000499	WESTE	NOV 17[5]	TORRE	AR		DEC 03	5
AAP	0	GE	32	000330[d]	HARTL	DEC 09	BREME				4
AASE HOJ	0	DA	55	000300	HULL	DEC 14	GUNNE	AR		DEC 14	
ABAGURLES	0	RU	62	004652[e]	GARST	SEP 22[5]	ARCHA				4
ABAKANLES	0	RU	61	004638	ANTWE	DEC 09	LENIN				4
ABASIN	0	PH[II]	64	008989	BANGK		[2] KARAC	AR	KARAC	JUL 25	5
ABAVA	1	RU	71	003468[f]	MALMO	DEC 13	KLAIP				4
ABBOTSFORD	1	BR	72	001584[c]	HAVRE	DEC 08	DAKAR	AR		DEC 16	
ABEL TASMAN	0	DU	71	027614	MELBO	NOV 14[5]	LONDO	AR		DEC 16	
ABERTHAW FISHER	0	BR	66	002355	ROTTE	NOV 29[5]	ASHDO	AR		DEC 18	4
ABIDA	1	DU	58	012226[d]	STANLO	DEC 06	CURAC				
ABIDIN DAVER	0	RU[II]	60	004449[c]	MERSI	DEC 03	ISTAN	AR		DEC 06	
ABIDJAN	0	LI	67	003048	DUALA	DEC 07	BREME	AR	ABIDJ	DEC 10	4
ABIQUA	0	AM	43	014640[f]	CHITT	OCT 25[5]	GALVE	AR	CORPU	DEC 08	4
ABLE REEFER	0	SG	61	002683[c]	KRIST		[2] TROND	AR		DEC 11	
ABLON	0	FR	61	006451	HAVRE	DEC 01	BUENO	SD	PALMA	DEC 12	4
ABOCOL	0	BR	40	001834[e]	CARTA	NOV 22[5]	TAMPA				
ABOISSO	0	IV	55	004939	AMSTE		[2] DUALA	SD	ANTWE	DEC 16	4
ABOTA	0	CY	58	000499	IZMIR	NOV 28	BREME	AR		DEC 14	
ABRENE	1	RU	64	003390[II][c]	LONDO	DEC 14	BALTI				4
ABU SIMBEL	0	EG	60	001946	LATTA		[2] ALEXA	AR		DEC 09	
ABUGAWA MARU	0	JA	65	001782[c]	[i]		[2] [3]	AR	SINGA	DEC 08	
ACADIA FOREST	0	NO	69	036862[c]	ROTTE	DEC 12	NEW O	SD	SHEER	DEC 13	4
ACAMAR	1	LI	59	016808[c]	CARAC	DEC 12	[3]				
ACAPULCO MARU	0	JA	51	006493	KOBE	NOV 05[5]	TOWN	AR	REUNI	DEC 14	4
AVACUS [II]	1	BR	58	012326[f]	SARNI	DEC 07	ARUBA	PD	ESCOU	DEC 13	4
ACHAIOS	0	LI	50	005455[c]	TARRA	DEC 12	KAISE	SD	CEUTA	DEC 15	4
ACHATINA	1	BR	58	012326	HAMILO		[2] [3]	SD	LANOR	DEC 14	
ACHILLE LAURO	0	IR[II]	47	023629	ARENA	NOV 29[5]	GENOA	SD	MALTA	DEC 18	4
ACHILLES	1	AM	60	024471[e]	FRANC	DEC 10	ALASK[6]				4
ACHILLES	0	BR	72	016406[c]	OSAKA	OCT 07[5]	[3]				4
ACHILLES	0	DU	59	006134	DEMER	DEC 08	BREME	SD	MICHA	DEC 16	4
ACHILLES	0	GE	64	000500	ROTTE	DEC 14	LISBO				4
ACHILLET	1	GR	56	031571	KARLS	DEC 12	MARSAB				4
ACRADINA [b]	1	IT	60	022955	UMM S	DEC 13	GENOA				4
ACHILLEUS	0	CY	39	002920	[i]		[2] [2]	[c] AR	PIRAE	OCT 08	99
ACHILLEUS	0	GR	65	021505	NAGOY	DEC 02	ARGEN	AR	MUROR	DEC 18	4
ACILA	1	DU	58	012221	MANIL	DEC 09	CURAC				4
ACMAEA	1	DU	59	012222	ROTTE	DEC 17	FREDE				4
ACONCAGUA	0	CH	65	010869	JOHN N	DEC 13	[3]	AR	PHILA	DEC 17	4
ACONCAGUA	0	FI	60	005402	HELSI	NOV 22[5]	CASAB	AR		DEC 14	
ACONCAGUA VALLEY	0	SW	68	009611	HAMBU	DEC 16	CASAB				4
ACORES	0	PO	58	002963	MOCAM	NOV 30[5]	BREME	AR	LISBO	DEC 15	4
ACQUARIUS	1	PA	58	020519[c]	EUROP	DEC 18	BANDA				4

?

Table 2-1 Sample Listing for DOT Input Tapes (contd)

DOT INPUT TAPE FOR WEEK 52, 1972

A	B	C	D	E	F	G	H	I	J	K	L
A.E.S.	0	DA	57	001579	LONDO	DEC 20					4
A.N.KEMP	1	LI	50	018127	ARUBA		NEW Y	AR		DEC 20	4
A.P.MOLLER	1	DA	66	052673	PHILA	NOV 29	ESCRA				
AAGE ANDREASEN	0	DA	66	000499	TORRE		MANTY	SD	COPEN	DEC 18	4
AAR	0	GE	32	000330	GOTHE	DEC 21	OLDEN				4
AASE HOJ	0	DA	55	000300	GUNNE	DEC 15	AALBO				4
ABAGURLES	0	RU	62	004652	GAR[illegible]	SEP 22	ARCHA				4
ABAKANLES	0	RU	61	004638	ANTWE	DEC 09	LENIN				4
ABASIN	0	PK	64	008989	BANGK		KARAC				
ABAVA	1	RU	71	003468	GOTHE	DEC 20	KLAIP				4
ABBOTSFORD	1	BR	72	001584	HAVRE	DEC 08	DAKAR	AR		DEC 16	
ABEL TASMAN	0	DU	71	027614	LONDO	DEC 22	MELBO	AR	HAMBU	DEC 23	4
ABERTHAW FISHER	0	BR	66	002355	ASHDO	DEC 20					
ABIDA	1	DU	58	012226	ANNA	DEC 18	SYDNE	PD	PANAM	DEC 22	4
ABIDIN DAVER	0	TU	60	004449	MERSI	DEC 03	ISTAN	AR		DEC 06	5
ABIDJAN	0	LI	67	003048	DUALA	DEC 07	BREME	SD	ABIDJ	DEC 14	4
ABIQUA	0	AM	43	014640	CORPU		EVERG	SD	FREEPB	DEC 20	4
ABLE REEFER	0	SG	61	002683	KRIST		TROND	AR		DEC 11	
ABLON	0	FR	61	006451	HAVRE	DEC 01	BUENO	SD	SALVA	DEC 22	4
ABOCOL	0	BR	40	001834	TAMPA		CARTAC	AR		DEC 16	
ABOISSO	0	IV	55	004939	AMSTE		DUALA	AR	DUNKI	DEC 16	4
ABOTA	0	CY	58	000499	BREME	DEC 16	BENGH				4
ABRENE	1	RU	64	003350	LONDO	DEC 14	BALTI				4
ABU SIMBEL	0	EG	60	001946	ALEXA	DEC 22	LATTA				4
ABUGAWA MARU	2	AL	50	01732				AR	SINGA	DEC 08	4 5
ACADIA FOREST	0	NO	69	036862	ROTTE	DEC 12	NEW O	SD	SHEER	DEC 13	4
ACAMAR	1	LI	59	016808	CARAC	DEC 12					
ACAPULCO MARU	0	JA	51	006493	KOBE	NOV 05	TOWN	SD	REUNI	DEC 19	4
ACAVUS	1	BR	58	012326	SARNI	DEC 07	ANNA	AR		DEC 21	
ACHAIOS	0	LI	50	005455	TARRA	DEC 12	KAISE	SD	CEUTA	DEC 15	4
ACHATINA	1	BR	58	012326	HAMILO			PD	ESCOU	DEC 15	4
ACHILLE LAURO	0	IT	47	023629	ARENA	NOV 29	GENOA	AR		DEC 20	
ACHILLES	1	AM	60	024471	ANCHO	DEC 12	LOS A				
ACHILLES	0	BR	72	016406	OSAKA	OCT 07					
ACHILLES	0	DU	59	006134	DEMER	DEC 08	BREME	AR	ANTWE	DEC 22	4
ACHILLES	0	GE	64	000500	ROTTE	DEC 14	LISBO	AR	LEIXO	DEC 20	4
ACHILLET	1	GR	56	031571	KARLS	DEC 12	MARSAB	SD	CORUN	DEC 22	4
ACHILLEUS	0	CY	39	002920				AR	PIRAE	OCT 08	99
ACHILLEUS	0	GR	65	021505	NAGOY	DEC 02	ARGEN	AR	MUROR	DEC 18	4
ACILA	1	DU	58	012221	MANIL	DEC 09	CURAC				4
ACMAEA	1	DU	59	012222	ROTTE	DEC 17	COPEN	AR		DEC 20	
ACONCAGUA	0	CH	65	010369	JOHN N	DEC 13	ARICA	AR	NEW Y	DEC 19	4
ACONCAGUA	0	FI	60	005402	HELSI	NOV 22	TRIPO	SD	LA GO	DEC 22	4
ACONCAGUA VALLEY	0	SW	68	009611	HAMBU	DEC 16	CASAB				
ACORES	0	PO	58	002963	MOCAM	NOV 30	BREME	AR	LISBO	DEC 15	4
ACQUARIUS	1	PA	58	020519	EUROP	DEC 18	BANDA				
ACRADINA	1	IT	60	022955	UMM S	DEC 13	GENOA	SD	DAS I	DEC 15	4
ACRITAS	0	GR	71	009868	DULUT	DEC 08		PD	TRACY	DEC 17	4

Notes to Table 2-1

(Samples from DOT Input Tapes for Weeks 51 and 52)

Column Headings

- A Ship's name
- B Ship's type (1 = tanker, 0 = non-tanker)
- C Ship's flag (abbreviated)
- D Ship's year built (last two digits)
- E Ship's weight (in gross tons)
- F Port of origin
- G Date of departure
- H Port of destination
- I Code determining meaning of column (k)
- J Port of last call
- K

Code IV column(I)	Contents of column(s)	Meaning
SD	used	date of departure from port of last call
PD	used	date when port of last call was passed
AR	used	date of arrival at port of last call
AR	empty	date of arrival at destination port
IN	used	ship was in port of last call on reported date

- L Tragedy code

Incomplete and Difficult-to-Handle Data

1	No departure port	(4 cases in samples)
2	No departure date	(17 cases in samples)
3	No destination port	(14 cases in samples)
4	No destination arrival date	(64 cases in samples)
5	Antiquated date	(22 cases in sample)
6	Generic port name, not precisely identifiable	(1 case)

Correspondence Difficulties Between Weeks 51 and 52

a	Ship omitted in records from other week	(1 case in sample)
b	Ship out-of place	(1 case in sample)
c	Duplicated data, no change	(12 cases in sample)
d	Unrecorded intermediate voyage	(2 cases in sample)
e	Departure or arrival date must be interpolated	(4 cases in sample)
f	Ambiguous route	(3 cases in sample)

Misspelled and Erroneous Data

I. Ship's name spelled both with and without blanks

II. Other divergences between data for successive weeks

Table 2-2 Illustrative Examples of Ship Match-up from Successive DOT Tapes (for weeks 51 & 52)

ACHILLES	0	DU	59	006134	DEMER	DEC 08	BREME	SD	MICHA	DEC 16
ACHILLES	0	DU	59	006134	DEMER	DEC 08	BREME	AR	ANTWE	DEC 22
ABOTA	0	CY	58	000499	IZMIR	NOV 28	BREME	AR		DEC 14
ABOTA	0	CY	58	000499	BREME	DEC 16	BENGH			
ABOCOL	0	BR	40	001834	CARTA	NOV 22	TAMPA			
ABOCOL	0	BR	40	001834	TAMPA		CARTAC	AR		DEC 16

1. Same voyage: Departure and destination ports are the same from both week's reports. Merging data may permit missing dates and other data to be filled in, and gains routing information through successive port-of-last-call reports.

2. Two voyages: Destination port from weeks 51 and departure port from week 52 match. Merging data from successive weeks allows for disjoint time interval of voyage, and reporting interval, and may permit interpolation of missing dates.

3. Three voyages: Destination port from week 51 does not match any port from week 52. An intermediate unrecorded voyage has occurred, which may be plausibly reconstructed.

2. Technical Structure of The Data Base.

The 52 DOT Marine Traffic Generator Input Tapes were transcribed by hand from the Lloyd's publications. After having been initially keypunched, the cards are edited and copied onto 52 reels of 7-track, unlabeled magnetic tape at a recording density of 800 BPI and even parity. Data is recorded in external BCD code in unblocked, 84-byte fixed-length records, with data fields as specified in the original DOT specification (Marine Traffic Generator Documentation, p.25) and as illustrated in Table 2-1.

Although originally prepared for use with an IBM 7094 computer, these tapes are fully compatible with most data processing systems, including the IBM 360/370 series. Much the same data is duplicated on the 52 Marine Traffic Generator output tapes; however, these are much harder to utilize, as they are recorded in an internal 7094 format and use a record format no longer recognized by IBM. Furthermore, having been processed previously by the Marine Traffic Generator, these tapes could not be reused without risking accumulation of errors through successive layers of programming.

These input tapes were edited by two DOT programs whose purpose was to identify and eliminate major keypunch errors. In particular, data punched in the wrong field, gross date errors, and unknown or misspelled port names, should have been detected and corrected by these programs. The tapes used in this study represent the output of these editing programs.

Nevertheless, many simple errors remain in the tapes. These include:

1. Variations in spelling of ship's name, particularly insertion or emission of blanks after abbreviations,

2. Right-or-left shifted data, i.e., '01782 ' as a ship's weight,

3. Substitution of an incorrect letter or digit,

4. Duplication of a record on the same tape, usually when an initially mis-punched record was corrected and the original not removed.

Such errors are particularly serious when they affect the ship's identifying information, as these fields are used to match-up ships from successive weeks. To minimize the extent of this problem ships were matched via a statistical correlation on the identifying data.

In principle, each tape should have contained data on the same ships, in the same order. In practice, however, several types of violations of this rule could (and did) occur:

1. Misplaced records, out of the regular order

2. Omitted and inserted records, when no data was reported for a particular ship during a particular week.

The final run statistics from program GAMMA gives a count of records rejected due to excessive keypunching errors and of the number of new records which could not be matched. The results for week 47 can be taken as typical. Here, out of a total of 13,130 input records, 1 was mispunched beyond recovery, 20 were duplicates, 815 were out of order, and 4,644 did not match any entries from the previously processed weeks. Hence, only 7,650 records, or slightly over half, did not suffer from a serious problem in interpretation or matching, even before problems of incomplete data are considered.

The data for certain weeks were however, much poorer, due to hardware failure. In particular, the tapes for weeks 37, 36, 35, 31, 30 and 29 contained far fewer readable records than expected, less than 10,000 each, and weeks 28 and 27 were completely unprocessible. This reflects the deterioration of the tapes with age, with non-readable records being dropped on input by the processing system. In addition, difficulties are known to have occurred when the copies of these tapes used in this study were initially prepared by DOT. Fortunately, the other tapes were in much better shape.

Since it was beyond the limitations of this study to replace the missing data by re-punching the 70,000 or so missing records, little could be done to correct these technical difficulties.

3. Auxiliary Tables.

The major auxiliary table associated with the DOT input tapes is The Port Table, containing a list of all ports referred to in the reports contained on these tapes. Each port was identified by an abbreviation, which associated it with a specific entry in The Port Table. The Port Table contained the latitude and longitude of the port, along with an identifying number.

The original DOT Port Table contained a few errors or inconsistencies which were corrected for use in this study. Some latitutde and longitude information were incorrect. Many ports had several entries in the port table corresponding to differently spelled abbreviations used in the Input Tapes. These were corrected by assigning the same port number to all such variants, since they could not be deleted.

4. Conclusions.

The DOT Marine Traffic Generator Input Tapes, compiled from Lloyd's Shipping Register, suffers from several weaknesses for the purpose of the present study. It is incomplete in regards to the number of ships monitored and the movement data for each ship. It is systemtically biased in this regard against short voyages and some classes of voyages between Communist ports. Technically, many of the tapes are in poor condition, two having been essentially unusable. Nevertheless, it was the best data available at the time of this study, and every effort was made to overcome its limitations.

Maximum information was extracted from the tapes by comparing data from successive weeks. The itinerary of each ship was reconstructed as well as practical, and the number of days spent by ships travelling between each pair of ports accumulated. This information was then used to produce the shipping distributions.

CHAPTER III

Trend and Growth Analysis

1. Discussion of Available Sources

There were a number of very informative sources available to use on the World's Tanker Fleet. The "Analysis of World Tank Ship Fleet"[1] for the years 1974, 1975 provided data on the physical characteristics of the fleet; size, weight, capacity, speed, age, country of registry, etc. as well as very useful information on the economic life of tankers and the number of new construction orders placed in each of the years for 1964 to 1975. Some analyses of special vessels (i.e., O/B/O's,O/O's) were also given.

The "Analysis of World Tank Ship Fleet" is a Sun Oil Company publication. The Sun Oil Company published its first fleet analysis in 1947 and has continued to issue its analysis yearly since 1953. Each year the report has included the results of a research effort on tank ship economics. The research for 1974 was in the area of total carrying capacity of the fleet and the impact of fuel costs on the industry. The 1975 report contains a special section describing a method for using available information to predict tanker rates in the spot market.

"Shipping in the Seventies"[18] is a background paper prepared by the United Nations in order to assist consideration of shipping problems in general and the position of the developing nations in relation to them. Part One addresses the perspectives and problems in world shipping concentrating on technological progress, freight rates, optimum ships and scheduling. Part Two discusses implementation of the international development strategy in shipping and ports, with specific measures for implementation outlined. This brochure provided some insights into the future distribution of ship ownership.

"An Investigation: U.S. Import Dependence for Mineral Resources; Super-Bulk Carriers, and Deepwater Ports Development"[7] is a Master's Thesis written by Lt. Commander Corydon Rouse Gifford as part of the requirements for his degree at the Naval Postgraduate School. His thesis examines "(1) the increasing import dependence of the United States on foreign sources of major bulk fuel and non-fuel mineral resources which appear to have potential requirements for deep-water ports or terminals, (2) principal bulk commodity ports and commodity movements, (3) trends in the construction of ocean bulk carriers, (4) the economics of "super" bulk carriers, (5) the consequences of the United States not providing adequate facilities to accomodate "super" bulk carriers and (6) recent events pertaining to deep-water port end terminal developments by the United States." We were quite interested in his assessments of the consequences of various courses of action the U.S. might be expected to pursue; for clearly the future distribution of tankers throughout the world, in fact the entire tanker industry will be ultimately related to the future course taken by the U.S.

"A Forecast of 1970-1985 World Shipping"[28] by Robert V. Wiederkehr, Sept., 1971 is a report prepared by SACLANT ASW Research Centre for NATO. This report is part of a study on the future use of shipping in the North Atlantic by NATO nations. It has the forecast numbers, average speeds, average tonnages, fleet capacities, annual trade, and fleet productivity of merchant shipping up to 1985.

"Trends in World Shipping with Particular Reference to Large Crude-Oil Carriers"[3] by Peter Burton, July 1974 is a second SCALANT ASW Centre manuscript. This document reviews and updates the previous SACLANT document. The forecast figures by Robert V. Wiederkehr were found to be low for tankers and bulk carriers and high for container ships. This paper studies the 1974 status and short term trends of World Shipping as a first step in estimating total numbers and types of ships, and their concentration routes and in areas of importance to NATO in the eighties.

"Shipping Statistics and Economics"[19] published monthly by H.P. Drewry (Shipping Consultants) Limited is a journal designed to provide shipping data and marketing trends to shipping companies. The November 1975 and March 1977 issues were used to provide us with insights into the changes in shipping trends from 1975 to 1977 and an overview of the market trends in those years. These journals included monthly tables on numbers of vessels by ship type. We used these numbers as part of our comparison analysis to arrive at realistic total ship numbers. The growth factors reflected there were instrumental in arriving at our own growth factors.

"Recent and Projected Trends in the Shipping Industry"[13] a technical paper produced July 28, 1976 by Tetra Tech, Inc. analyzes the effects upon shipping brought about by the various crises of the mid-70's. This paper updates a 1975, Tetra Tech report.

"A Statistical Analysis of the World's Merchant Fleets"[24] by the U.S. Department of Commerce is a world inventory of ocean-going vessels of 1,000 gross tons or more. The world totals for the various vessel types for the years 1972, 1974, and 1975 were taken from this source as it provided us with a consistant ship profile and data collection process.

The "Pacific Shipper"[11] is a weekly journal devoted to shipping schedules from and to the Pacific ports of the United States. It is a reliable gauge of the volume of shipping to major ports around the world from the U.S. Pacific ports.

In order to determine the volume of shipping to major ports around the world from the U.S. Pacific ports, an analysis of the "pink pages" of the Pacific Shippers was made. The following procedure was used:

1. The Pacific Shippers (dated weekly from July of 1973 through June of 1977) were used. Only the copy for the last week of each month was examined.

2. Traffic to the following ports from the U.S. Pacific Coast was examined: Kobe, Manila, London, Rio, Capetown, Naples, Piraievs, Bombay, Honolulu, Sydney, Balboa, Singapore, LeHarve, Rotterdam.

3. Since the traffic leaving the West Coast ports (San Francisco, Los Angeles, Portland, Seattle and Vancouver) is essentially identical, only traffic leaving the San Francisco - Oakland area was studied.

4. When the copy for the last week of a given month was analyzed, for example, the issue dated June 27, 1977, only ships leaving through the following month are recorded. For June 27, 1977, for traffic to London (page 130), there are 37 ships leaving San Francisco for London from July 1 through July 29. The 7 ships leaving between June 27-30 are not recorded for this issue (they were recorded for the May 30, 1977 issue). The 2 ships mentioned for August 2 and 4 are not recorded for this issue (they will be recorded for the July 25, 1977 issue).

Figures 3-1 to 3-14 are a collation in histogram form of the data extracted from the Pacific Shipper. A perusal of the histograms indicates:

a. Steady volume of traffic from '73-'77 to Kobe, Rio, Capetown, Honolulu, Sydney.

b. A steady increase in traffic from '73-'77 to Manila and Rotterdam.

c. Erratic traffic volume to Bombay.

d. London, Naples and Piraievo all experienced an increase in the volume of traffic arriving at their ports in August of 1975. This is probably due to an increase in the reporting net of the Pacific Shipper. Balboa shows a similar increase at the same time although it was less dramatic.

e. In October 1975, Singapore experienced the beginning of an increase in incoming traffic that has continued steadily. LeHarve showed the same phenomenon in September 1975.

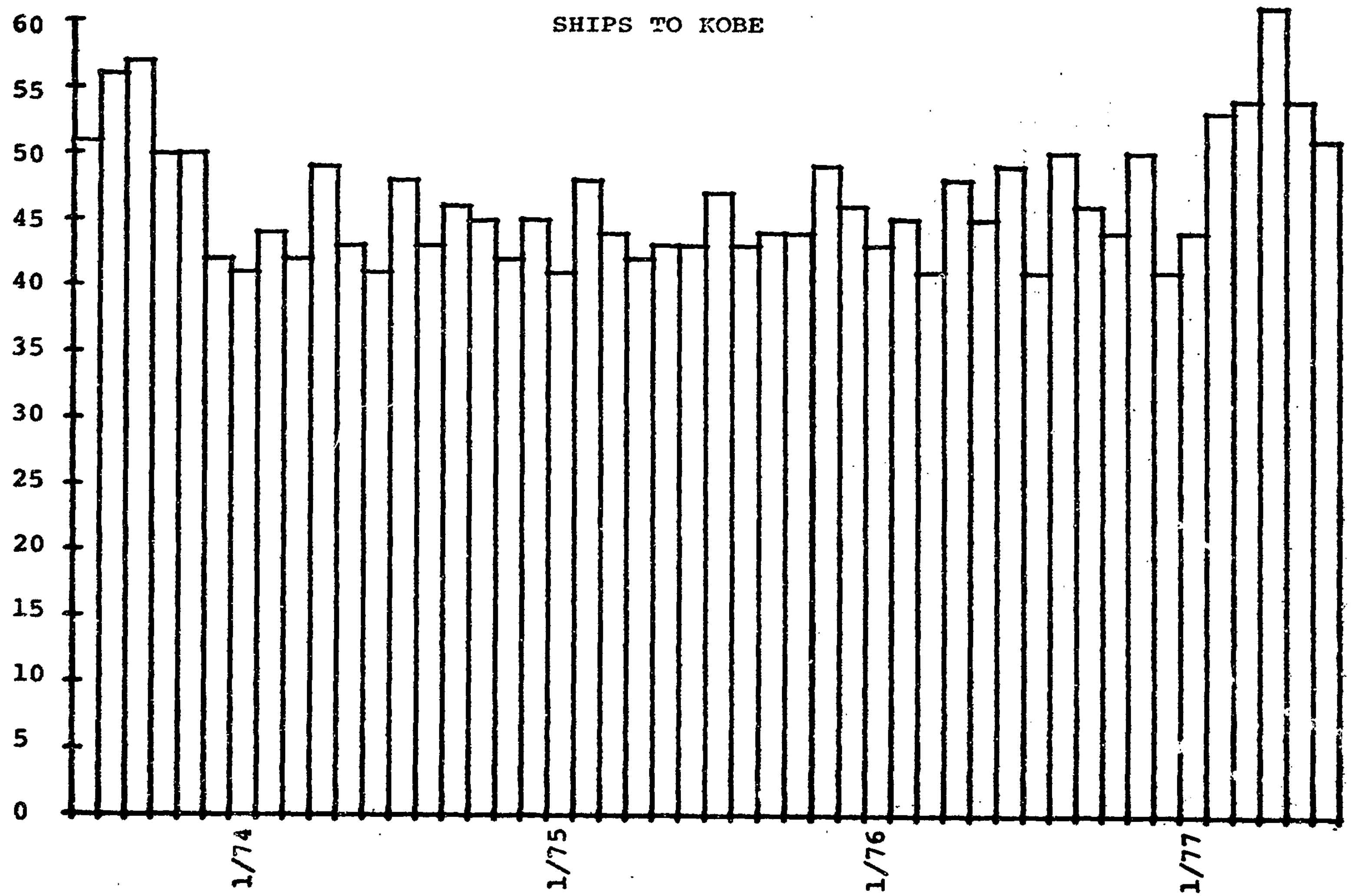


Figure 3.1. Histogram of Shipping Traffic from U.S. Pacific Coast to Kobe.

SHIPS TO MANILA

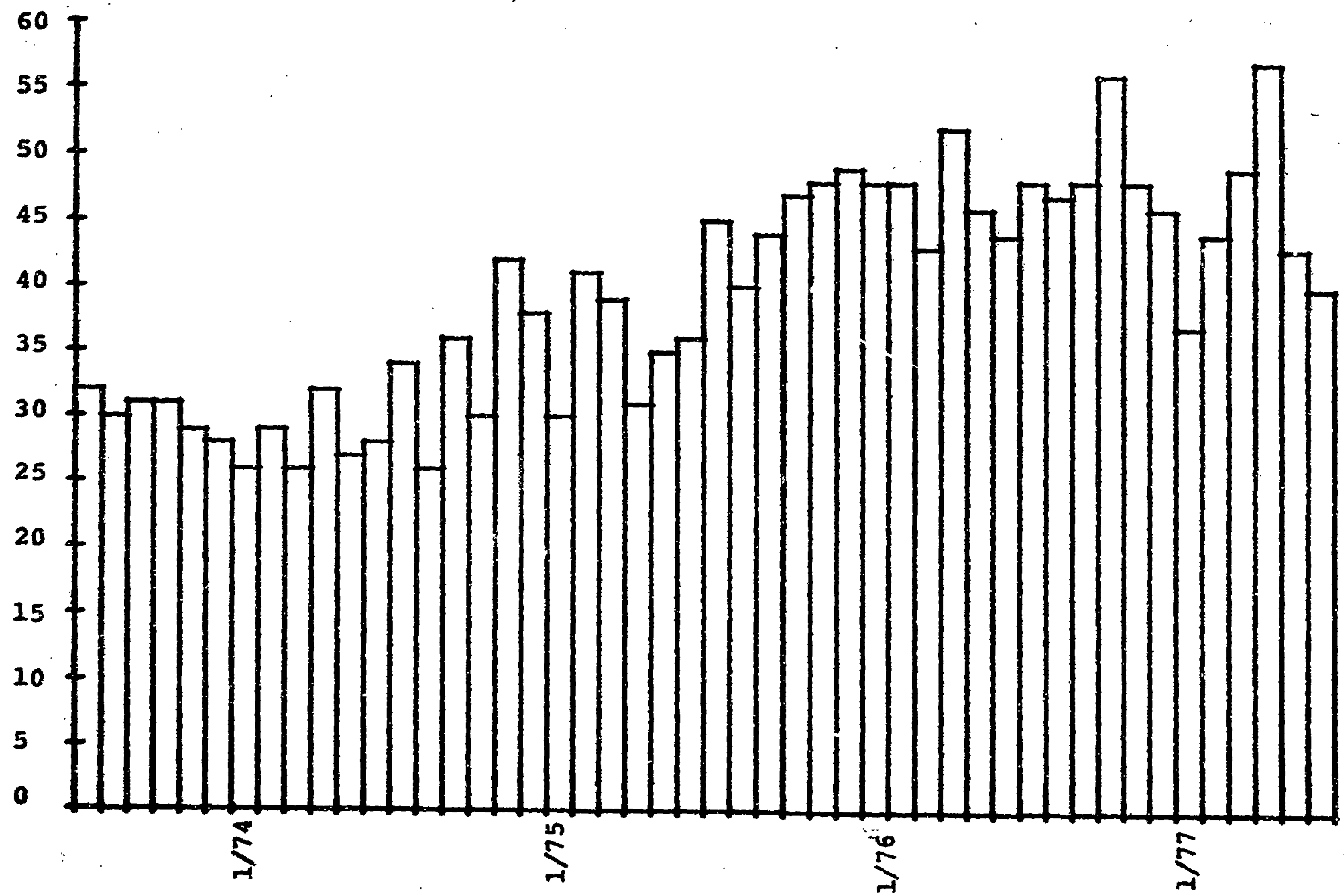


Figure 3.2. Histogram of Shipping Traffic from U.S. Pacific Coast to Manila.

SHIPS TO LONDON

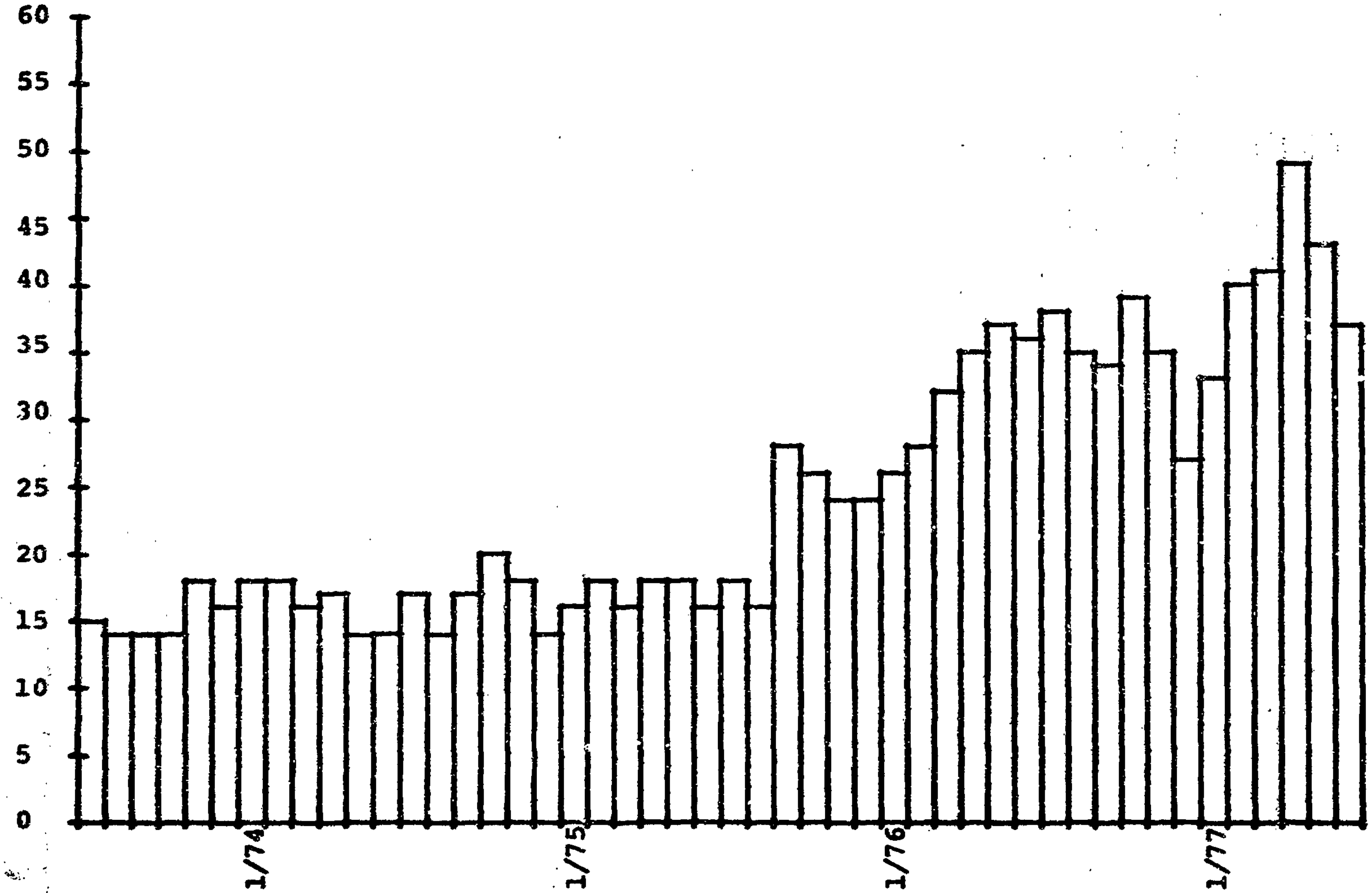


Figure 3.3. Histogram of Shipping Traffic from U.S. Pacific Coast to London.

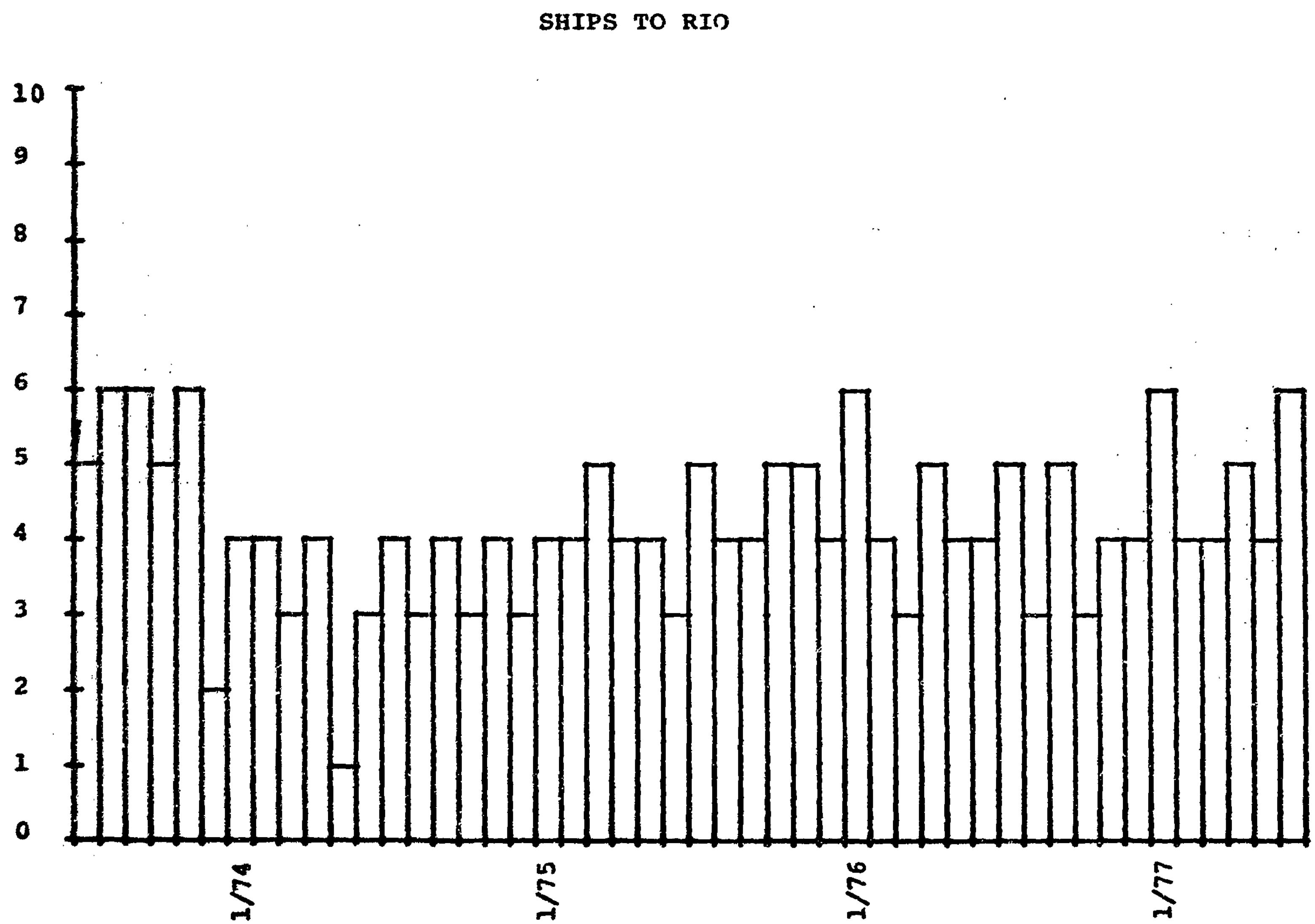


Figure 3.4. Histogram of Shipping Traffic from U.S. Pacific Coast to Rio.

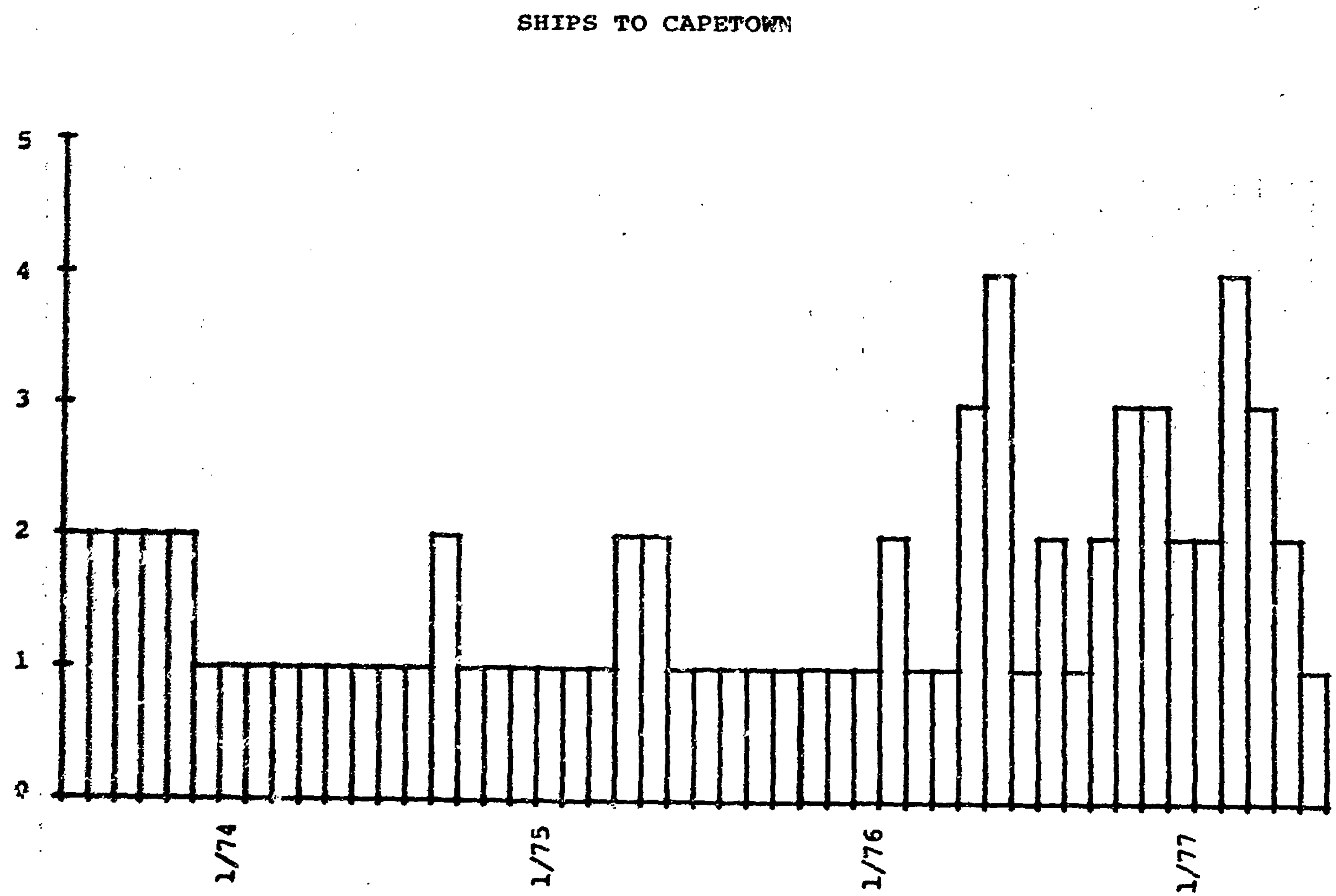


Figure 3.5. Histogram of Shipping Traffic from U.S. Pacific Coast to Capetown.

SHIPS TO NAPLES

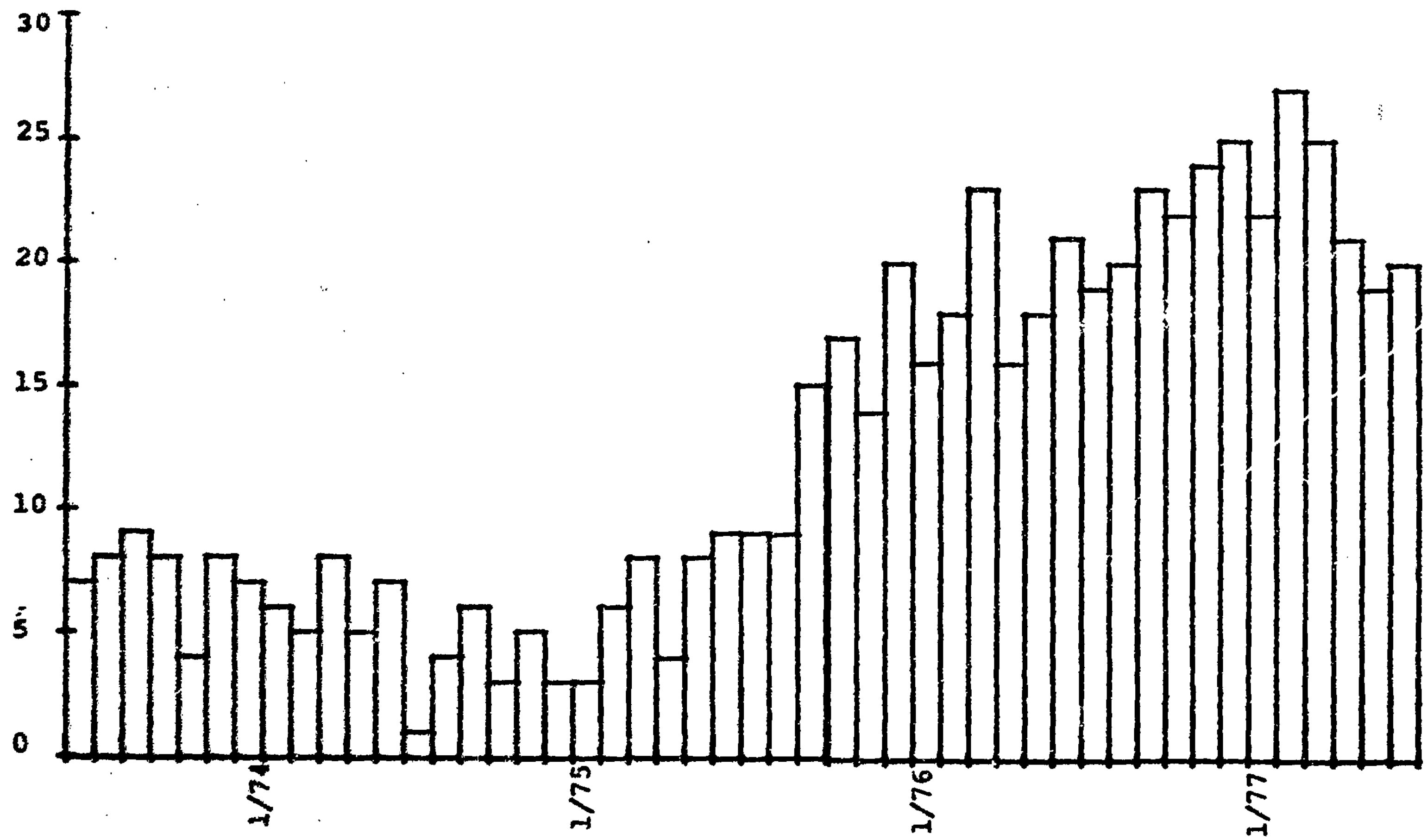


Figure 3.6. Histogram of Shipping Traffic from U.S. Pacific Coast to Naples.

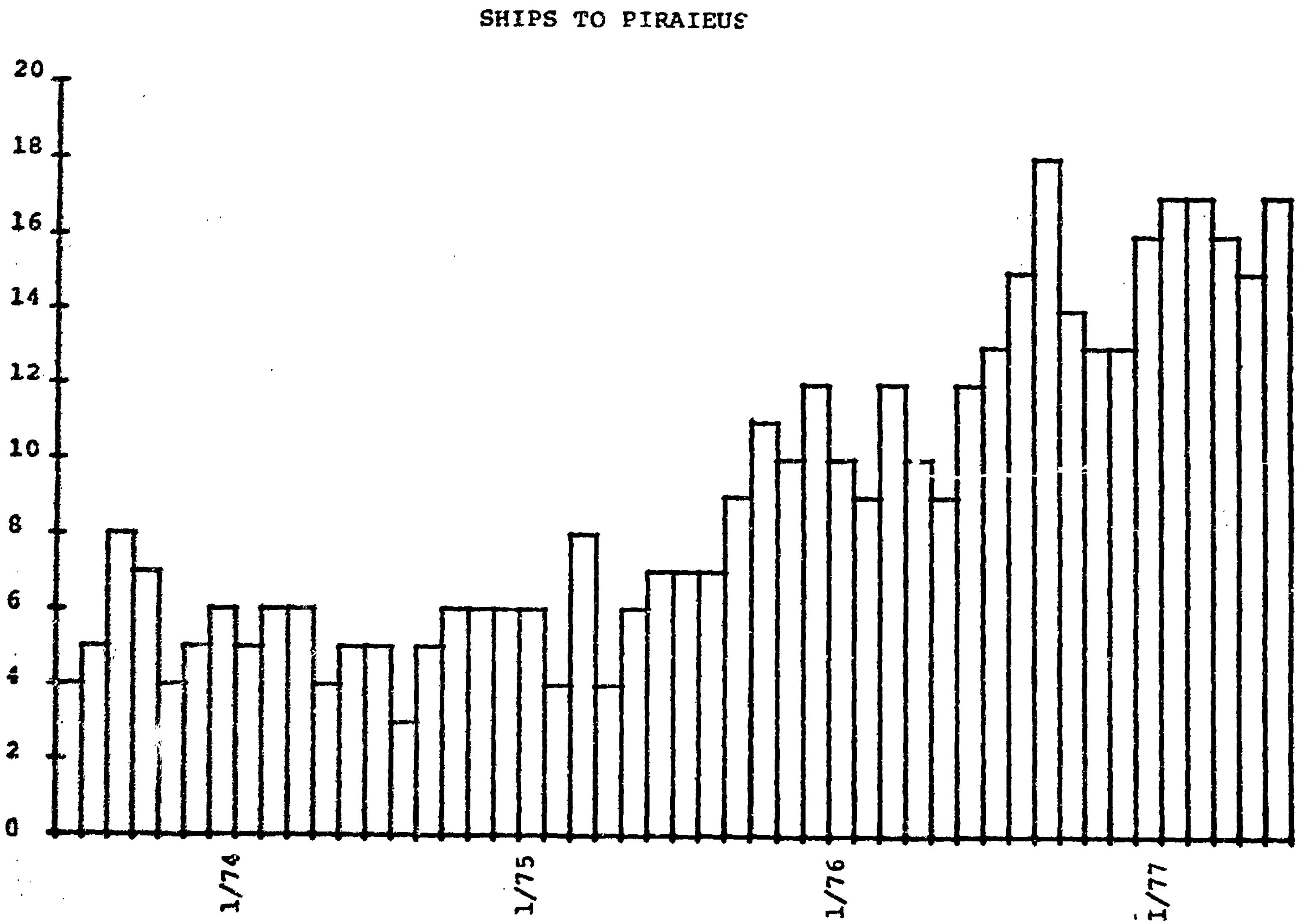


Figure 3.7. Histogram of Shipping Traffic from U.S. Pacific Coast to Piraieus.

SHIPS TO BOMBAY

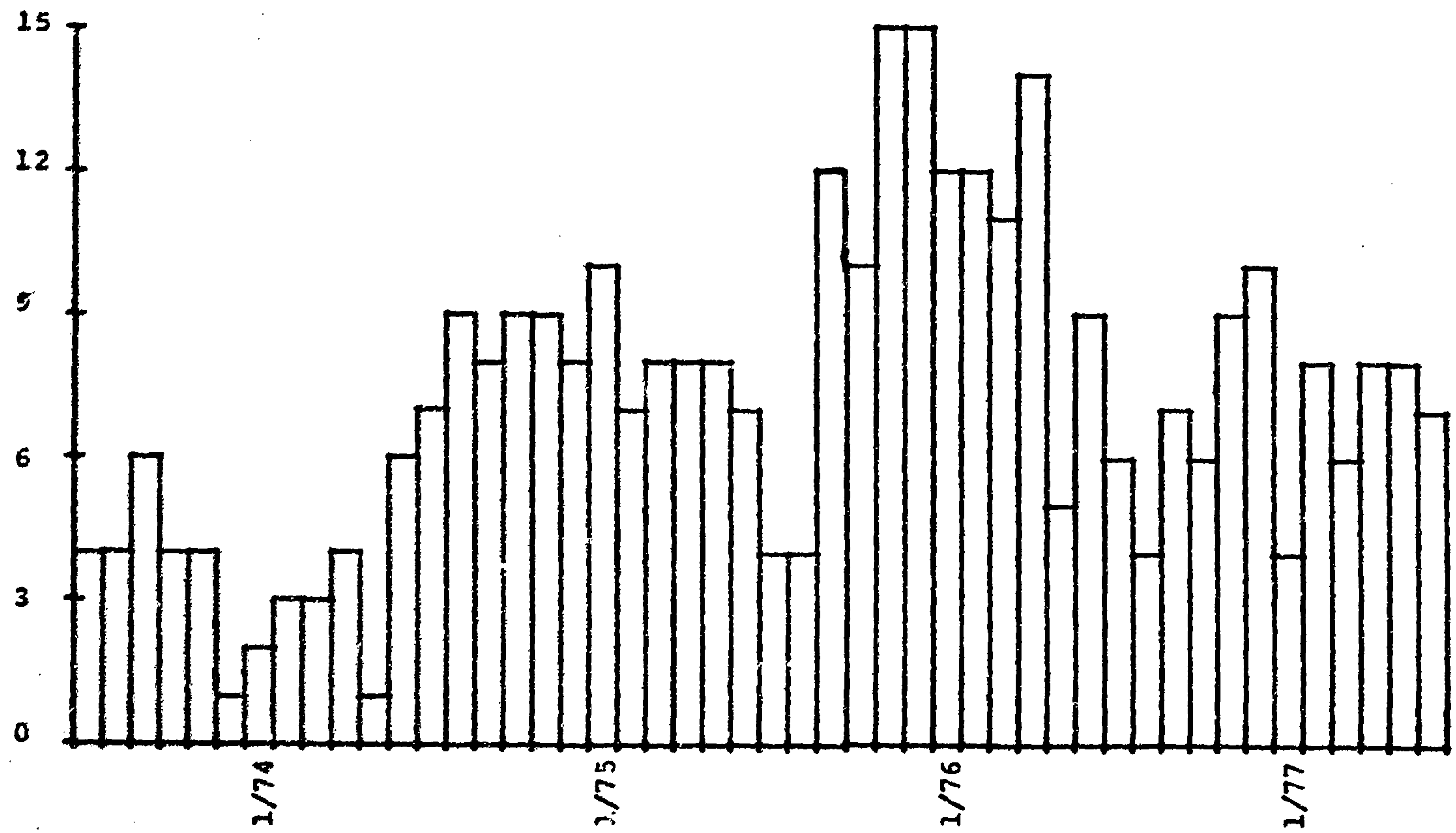


Figure 3.8. Histogram of Shipping Traffic from U.S. Pacific Coast to Bombay.

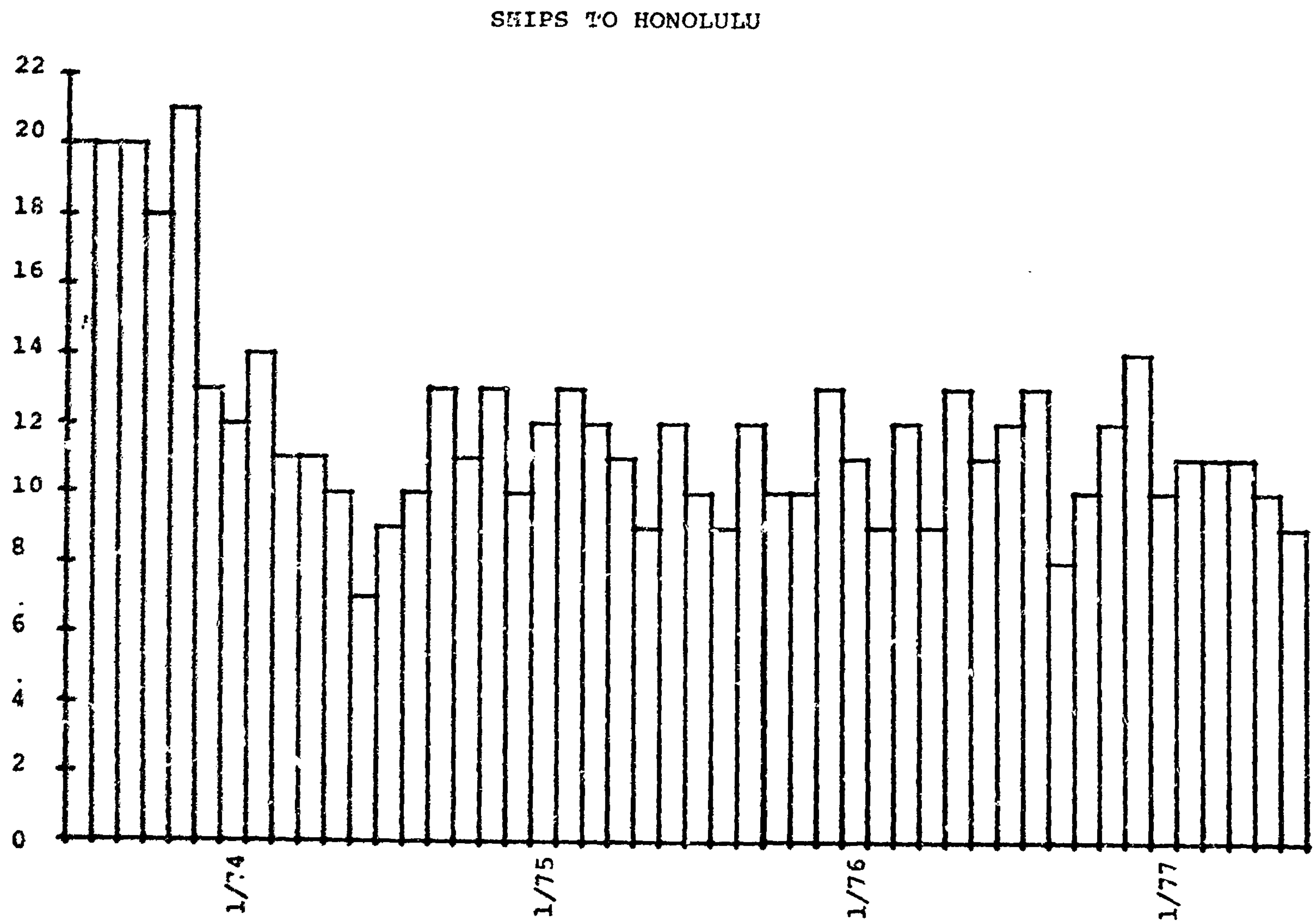


Figure 3.9. Histogram of Shipping Traffic from U.S. Pacific Coast to Honolulu.

SHIPS TO SYDNEY

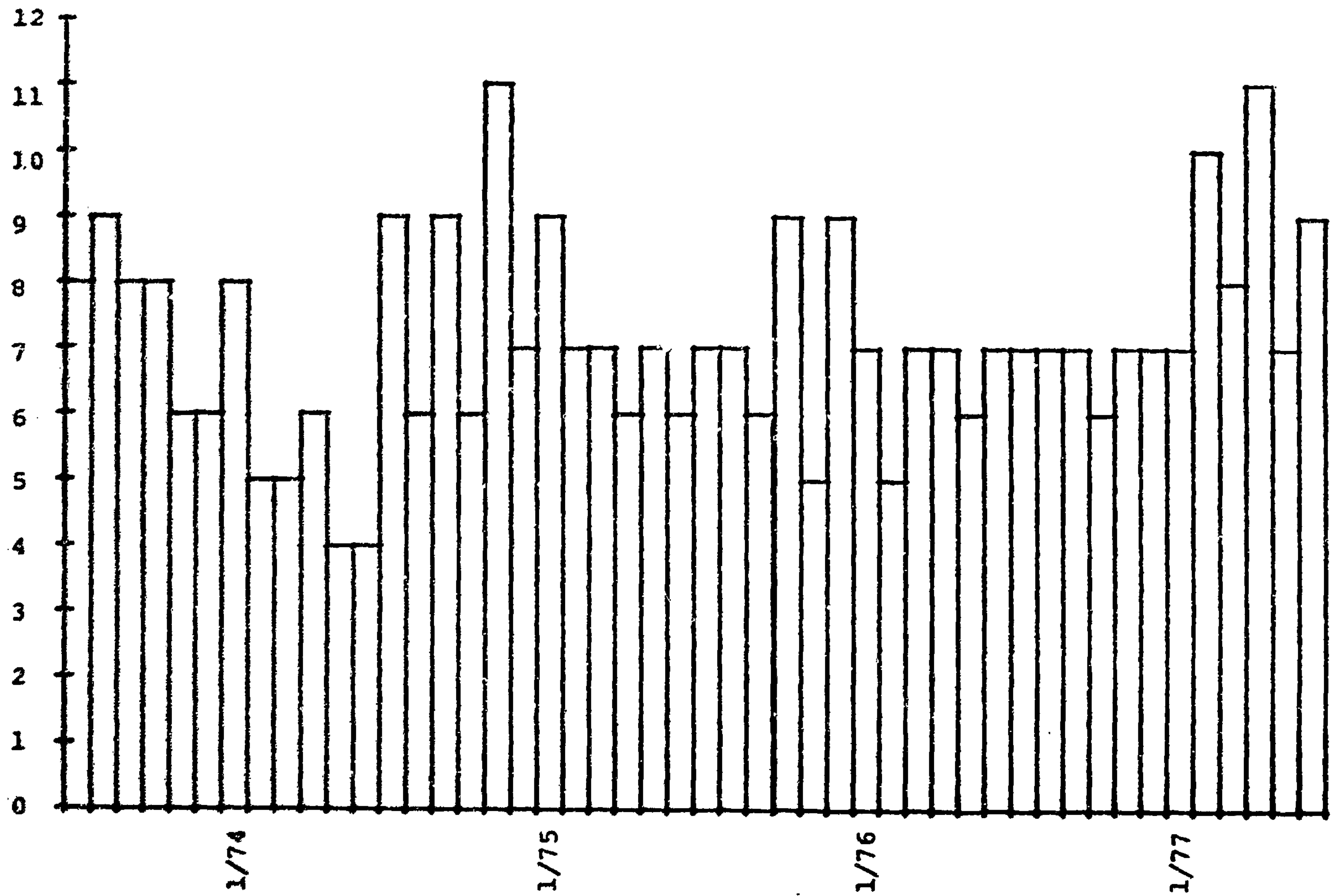


Figure 3.10. Histogram of Shipping Traffic from U.S. Pacific Coast to Sydney.

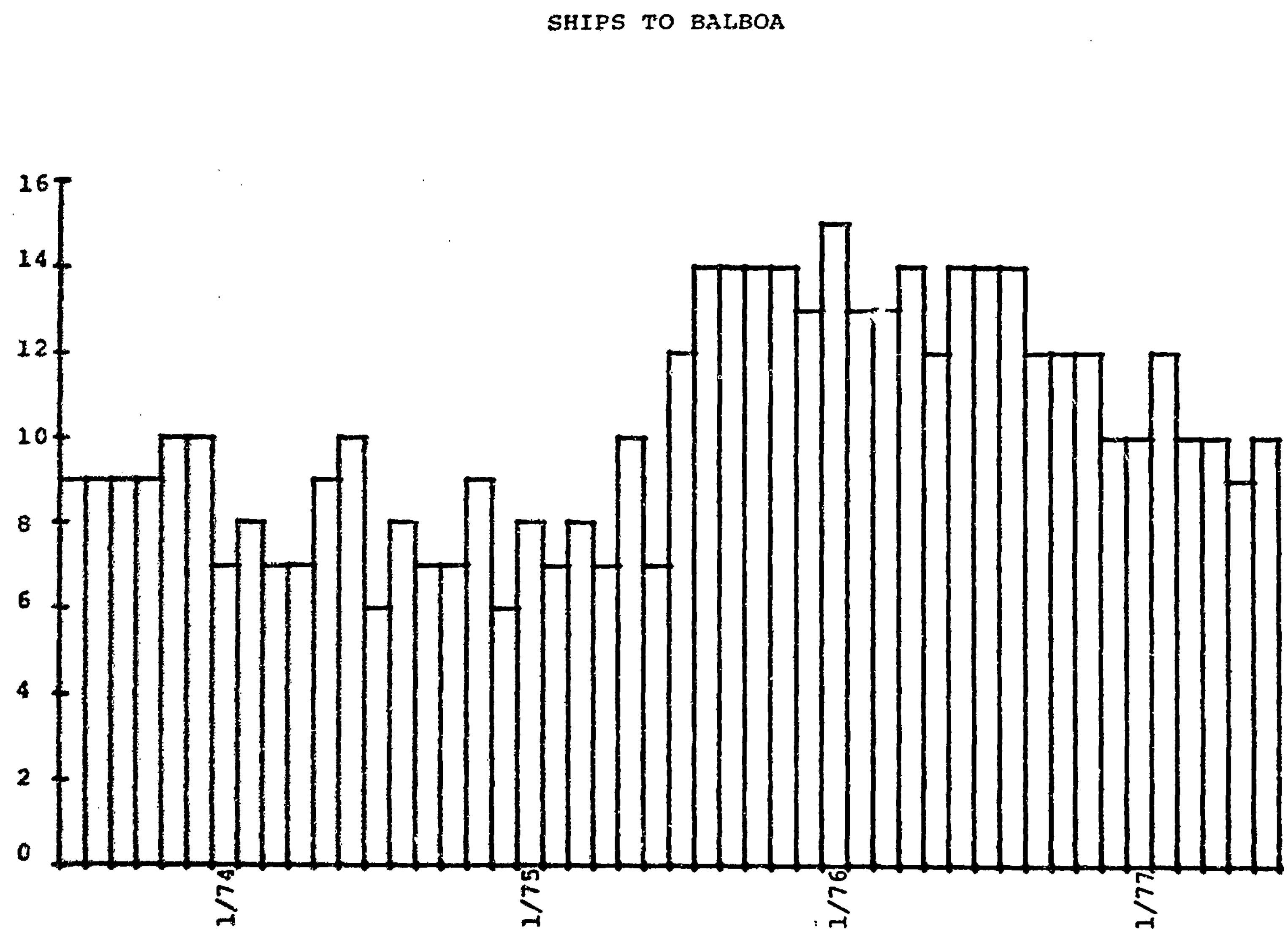


Figure 3.11. Histogram of Shipping Traffic from U.S. Pacific Coast to Balboa.

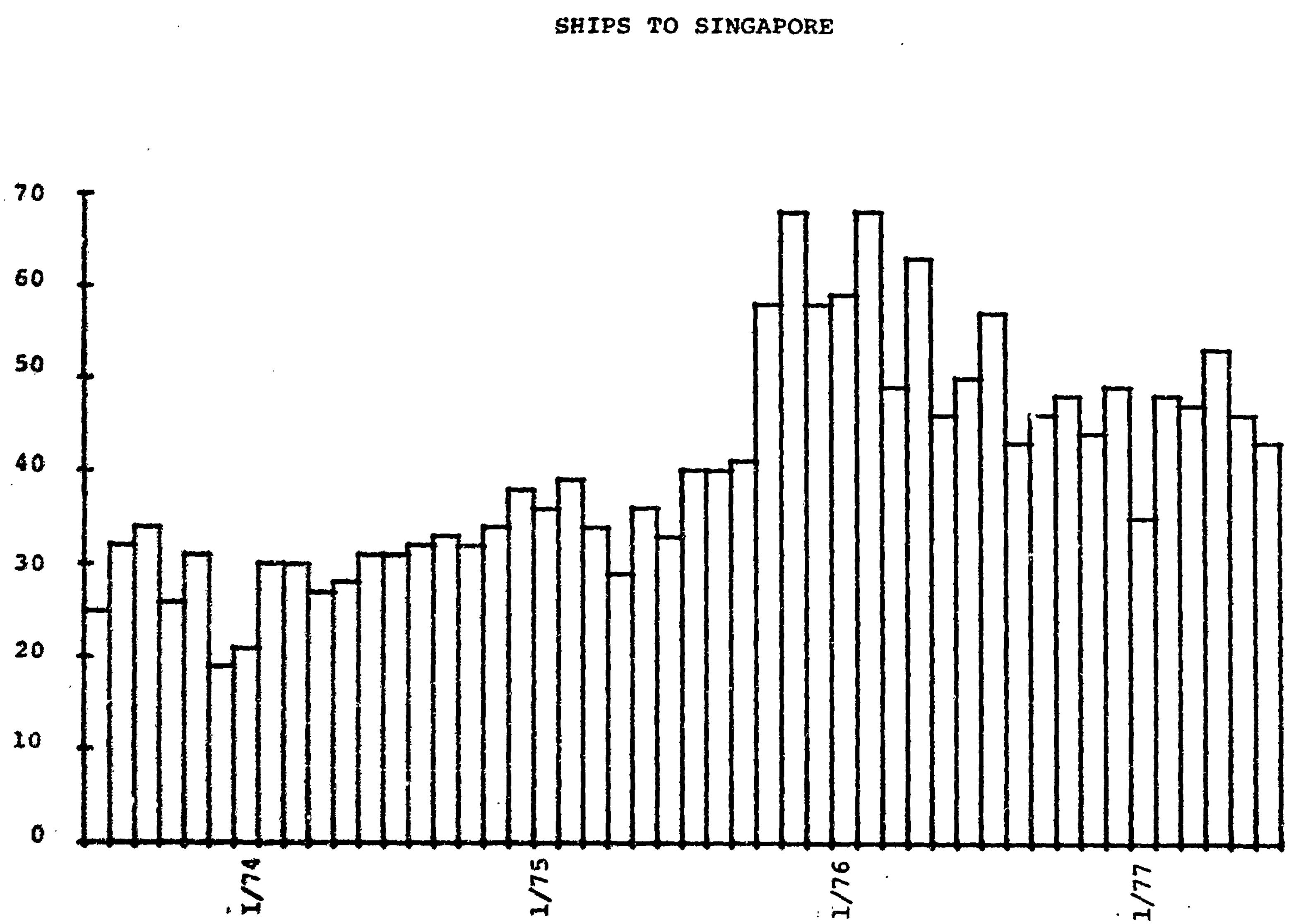


Figure 3.12. Histogram of Shipping Traffic from U.S. Pacific Coast to Singapore.

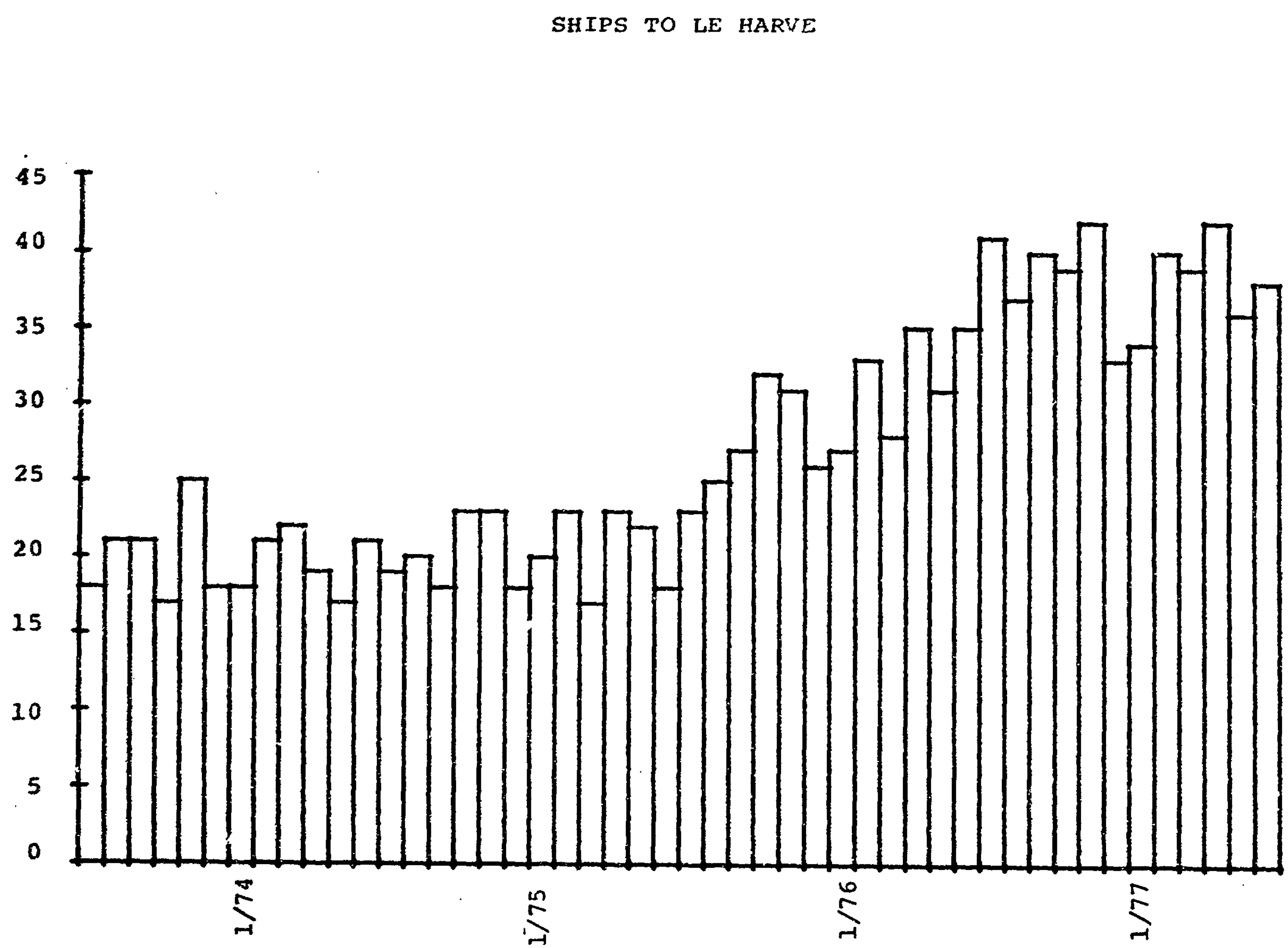


Figure 3.13. Histogram of Shipping Traffic from U.S. Pacific Coast to Le Harve.

SHIPS TO ROTTERDAM

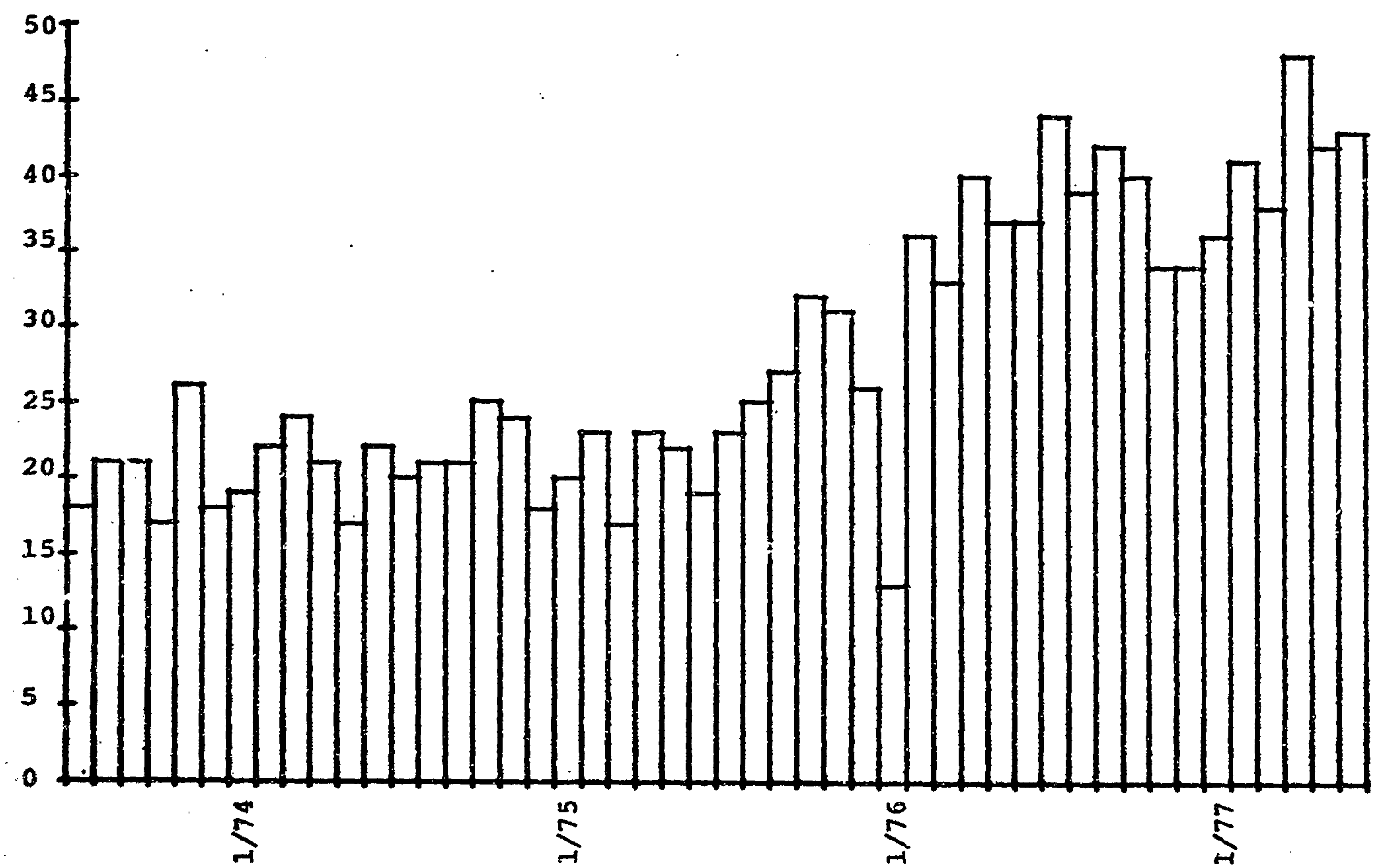


Figure 3.14. Histogram of Shipping Traffic from U.S. Pacific Coast to Rotterdam.

2. Methods and Sources Finally Used

In order to project our 1972 data from the Lloyd's tapes to the year 1978 we need to estimate growth factors for the various ship categories in the major ocean areas of the world. The objective is to compare the total number of ships of a given class in a particular ocean area in the year 1972 with the same measurement in the year 1978. The ratio of these two numbers then being the growth factor.

The difficulty with this procedure is that no single definitive source exists for these measurements. Some sources give measurements for years other than 1972 and 1978. Since this report is being generated before 1978 statistics are available on any measurements for that year are projected measurements. Each source has its own procedure for collecting data and its own breakdown of vessel type, making it far too inaccurate to use data from one source for 1972 and estimates for 1978 from a second source.

We are most interested in merchant vessels and three classes of tankers. Tanker I's are small tankers with 1,000 to 70,000 dwt, Tanker II's are large tankers and combined carriers in oil and are between 70,000 and 300,000 dwt, Tanker III's are super tankers, that is tankers of over 300,000 dwt.

Since it is sufficient to consider only a world wide growth figure for merchant vessels[10] (see PSI report, "Ship Density Estimates for Traffic Along Selected Routes in the Year 1990"[17]) we estimated the growth factor by using the number from "Statistical Analysis of World Merchant Fleet"[24] years 1972, 1974 and 1975 and extended them linearly to 1978. The growth ratio being the simple ratio of the 1972 figures and the projected 1978 numbers.

The tanker case is more complicated. The growth factors for these vessels are not uniform over the world. But while several of the sources[25,26] give world wide figures no source gives comprehensive data for specific ocean areas. Certain areas reflect the same growth pattern as the world in general, such as the North Atlantic (see PSI report referred to previously)

Tankers

World Totals

	1972	Projected 1978	Growth Factor
1,000 - 175,000 dwt	2,931	3,000	1.02
175,000 - 300,000 plus o/o	558	894	1.60

Specific World Areas

	Growth Factor	
	Tanker I	Tanker II
Honolulu	0.94	0.94
South Pacific	1.21	1.60
U.S. - Japan	1.08	1.08
Panama - West Coast	1.15	1.30
North Atlantic & Remainder of World	1.02	1.60

Merchants

1972	1974	Projected 1978	Growth Factor
12,889	13,253	13,600	1.06

but other areas do not follow the overall pattern of the world. To overcome this limitation two types of growth factors were computed. The first is growth factors for world wide shipping in specific tanker categories. The second is growth factors for total shipping in specific ocean areas for which we could obtain reliable data. Specifically we used the Pacific Shipper to calculate growth factors for traffic to U.S. western ports from Honolulu, South Pacific, Japan and Panama. We collated the available data for the years mid 1973 to mid 1976 and used curve fitting techniques to eliminate seasonal fluctuations and obtained the yearly trends. Next we extrapolate backward to 1972 as our growth factor for these ocean areas.

However since super tankers were a rarity in 1972 but have undergone a dramatic, but erratic growth pattern in the ensuing years we do not attempt to compute a growth factor for these vessels.

In computing the world wide growth factors for the two smaller categories of tankers we were fortunate to find that the "World Shipping Statistics 1976"[29] carries statistics for the year 1972 and projections for 1978. The projections for 1978 are based upon their figures for 1976 plus orders for ships scheduled to be delivered by 1978. The growth factor is a simple ratio between the two years.

CHAPTER IV

Distribution and Methodology

1. ORE Outputs and Cubic Splines.

This chapter deals with the problem of distributing the densities across the routes by one degree squares. Various input tables were needed to accomplish this task. The use of the Port Table, Route Trees, Routing Table, Sextile Points and various mathematical methods for distributing the densities were obtained from the ORE report. Because of the multitude of ports and the number of routes connecting them, the use of the above tables provided us with a systematic way of handling the data.

The Port Table is a listing of 2,425 ports that were taken from the Lloyd's data for 1972 by the Department of Transportation. Due to the number of ports in existance a simplification was warranted in order to provide a more manageable data base. Therefore, a small class of major ports were determined from the 2,425 ports. These 69 ports are known as canonical ports. Also, each non-canonical port will be associated to one and only one canonical port. This is determined by searching for the closest canonical port in the area.

The information on the Port Table is of the form:

684   FREEPB   FREEPORT, BAHAMAS   26N 78W 17 22

684 is the port number; FREEPB is the abbreviation of the port name and FREEPORT, BAHAMAS is the name of the port. On the right hand side we have the latitude and longitude of the ports location. The next integer, 17, corresponds to the canonical port to which Freeport, Bahamas is associated with. 22 represents the distance between the port and its canonical port. The units are that of a convenient metric.

Just as the number of ports were substantially reduced by considering a small set of canonical ports, so may the number of routes be reduced by considering a set of 85 canonical routes. The Routing Table is a 69 x 69 matrix whose (α,β) entry symbolically represents the route from port α to port β. The entries contain two pieces of information. The first is an alphanumeric followed by an integer, say m, which lies between 1 and 85. The possible entries in the table are as follows:

i) N=0 represents no route between the ports. This situation arises when $\alpha = \beta$, that is port α equals port β.

ii) P=m represents the case where port α and port β are not connected by a canonical route, that is, there exists at least one intermediate port between α and β. The port m is the first intermediate port encountered. As one would expect, the route between α and m is a canonical route. Thus, the first link of the overall route is from port α to port m. Now, one must examine the route from port m to port β. If there is a canonical route then one is done, if not, continue recursively until the destination is reached.

iii) B=m designates that multiple routing exists. This case occurs when the route taken is dependent upon the ship type. For example, the shortest route between the Persian Gulf and Northern Europe is via the Suez Canal, yet large tankers and supertankers must go around the Cape of Good Hope. In this case the integer m designates the mth line in the Multiple Routing Table. This line will contain two entries, the first entry is the first intermediate port for the non-supertankers, and the second is for supertankers. Then one would proceed as in case ii.

iv) If a blank exists for the alphanumeric field, then the following number indicates which direct route is to be taken.

The set of 85 routes can be found by looking at the Route Trees Table. In many routes, seasonal variations affect the distribution of traffic across the route, on the other hand entire route envelopes are shifted by the changing of seasons. Therefore, we have four sets of Route Trees, a separate one for each season. One must note that the structure of the route trees does not change with seasons; however, the parameters contained within the tree structure, such as the latitude and longitudes do.

In some cases, the traffic travelling in one direction uses a route quite different from the traffic moving in the opposite direction. One example of this is Route 23 (Punta Arenas - Torres Strait). The entrance route to Torres Strait is much farther north than the egress route. When this is the case, the tree is structured so that there are two routes between the ports. Since a tree is a graph without loops, this implies that there has to be two leaves for one of the ports. One leaf is the vertex used for egress routing, the other leaf is used for entrance routing. The distinction between entrance and egress routes is preserved in the tree structure by the ordering of the vertex indices. A binary branch is made with a terminal zero being added to the end of the egress branch point identifier, and a terminal one to the entrance branch point identifier. For example, Route 23 divides at Ident. 10 (Strait of Magellan). Ident. 100 is the egress branch point while Ident. 101 is the entrance branch point. All identifiers are written in base 2. Figure (4.1) shows the tree structure with identifiers for Route 23.

The identifiers describe the location of the turn point in the route tree structure. These identifiers are so linked that it is possible to progress either forward or backwards along the route in the tree structure. In order to move forward there are three possible circumstances: 1) You are at a turn point, in which case a zero is added after the last digit of your current vertex identifier in order to obtain the identifier for the next vertex along the route, 2) You are at a branch point, in which case a zero is added to continue down one branch of the route, or a one is added after the last digit of your current vertex iden-

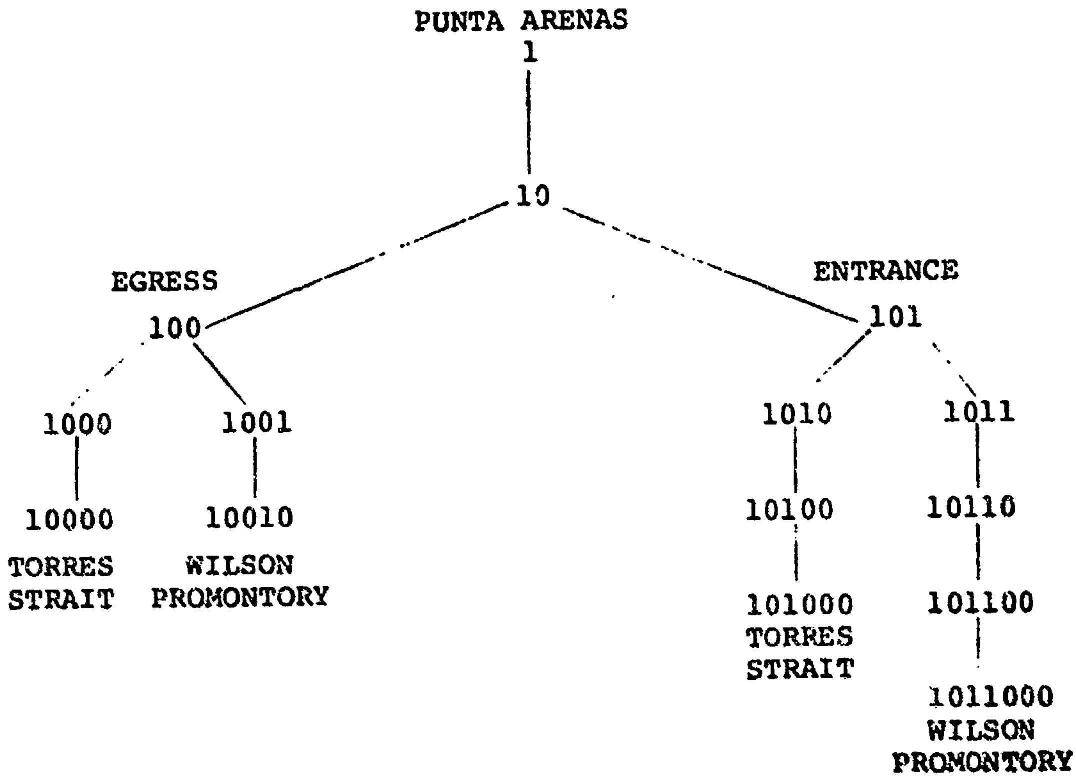


Figure 4.1

Tree Structures

tifier to continue down another branch, 3) You are at a route end point in which case you must reverse direction in order to move along the route.

To progress backwards along the route is much simpler than a forward progression. To retrace the route simply drop off the last digit of the current vertex identifier in order to obtain the identifier of the previous tree vertex.

The second and third columns of the Route Trees contain the latitude and longitude of the route point represented by the tree vertex.

The fourth column of the Route Trees refers to the vertex width. Its units are in latitudinal degrees, and it is a measurement of the routes width at the vertex.

The length of a route segment is contained in column five of the Route Trees. This length refers to the previous route segment when progressing forward through the route. The units are in latitudinal degrees.

The sixth column of the Route Trees contains the edge width which is again a measurement of the widest point on the previous segment. The units are also in latitudinal degrees.

The seventh and last column refer to the back pointers. When progressing backwards along a route the back pointers indicate the line in the Route Trees to which the present vertex is connected. Whenever one begins a new route the back pointer is set at zero.

An important factor in determining the route density is the route envelope. It is an area of the ocean between two ports where 95 percent of the ships will travel. The width of the route envelope may vary from route to route. In going from one port to another not all ships follow the best path. Different ship tracks will approximate the optimal path to a greater or lesser extent. The longer the distance between ports, the greater the probable deviation from the optimum. This is especially true for routes that cross large open oceans with no land navigation point available. Areas with unstable weather conditions also cause ships to deviate from the best path. Because of the effects of these variables, a route width is required in order to describe a route's envelope.

The distribution is found along a vertical cut. A vertical cut refers to a slice of the route taken along a fixed longitude. The reason for the cut is to take a look at the way the distribution function varies across the route. The densities along the section of the route under consideration are projected parallel to the route median and integrated to form the density distribution. The sextile points are points which divide the distribution into sixths. For a cut along a fixed longitude there are latitudes associated with these sextile points. The sextile points of the distribution and their corresponding latitudes are found and printed. These sextile point latitudes are used by a separate program to reconstruct the distribution using a Type I' cubic spline to connect the sextile points.

The Sextile Array, is a table containing the sextile points by route for a given season.

These sextile points are normalized to the interval [-1,1], and the five intermediate sextile points will describe the distribution (up to a linear transformation). On a route between 2 canonical ports the envelope is described by either a specific Type I' cubic spline for the given route or a general default spline.

In order to produce a histogram which represents the distribution of traffic across a route, it is first necessary to determine how the density varies across the route. The following method was used to accomplish this task.

Given a fairly well defined (e.g., Southern Hemisphere) route, and assuming the same distribution function is used along the entire route, choose a group of vertical columns of cells (Fig 4-2) which cross the route. These columns should be chosen in an area where there is a minimum of interference from other routes. There should be no cross routes in this region, nor should this area contain any other routes in close proximity. If only one vertical column is used, then this would automatically be a histogram, for the density histogram which we are seeking would merely be a projection of this column (assuming that the width of the route doesn't change). (Note: The histograms are somewhat more complex than shown, for to be exact the projection of a square of area onto the perpendicular of the route is not the standard step, but rather a trapezoid (Fig 4-3). This is probably sufficiently minor to be ignored, but is not computationally difficult.). As long as the route's distribution may be assumed locally constant, then the vertical column of Figure 4-4 is a cut of a "cylinder" type of distribution which is a function of only one variable, i.e., it is a slightly stretched version of the distribution, the elongation factor being sec θ. In the case of more than one column (which will have better statistical confidence for distribution prediction) the columns can be combined appropriately using tan θ to the histogram (Fig 4-5). With the elongation removed we now have the empirical representation of y(= $\frac{\delta}{2}$ G(w) sin $\pi\lambda$ say) so δ and G(w) are "determined", through a smoothing operation discussed below.

The histograms are discrete, empirical approximations to the true distribution. This underlying distribution function does not have the step function for the histogram. From the physics of the situation, one may safely assume that there exists a density function for the distribution, and that it is continuous. To obtain the underlying distribution function, it is necessary to "fit" a smooth curve (the density function) $\hat{h}(x)$ to the step function (i.e., the histogram). The density function will be the smallest closed set such that the density function is always zero outside that set.

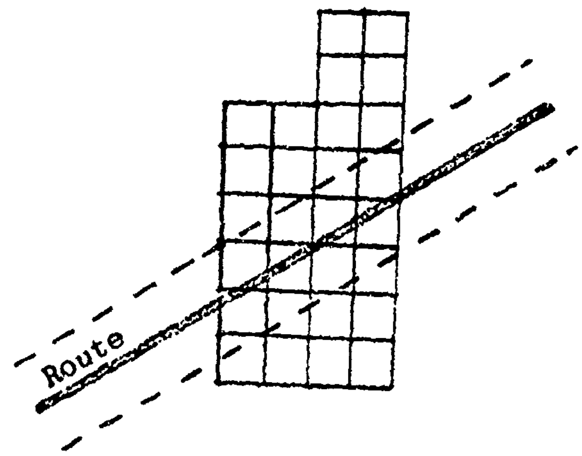


Figure 4-2. Route Histogram Cells

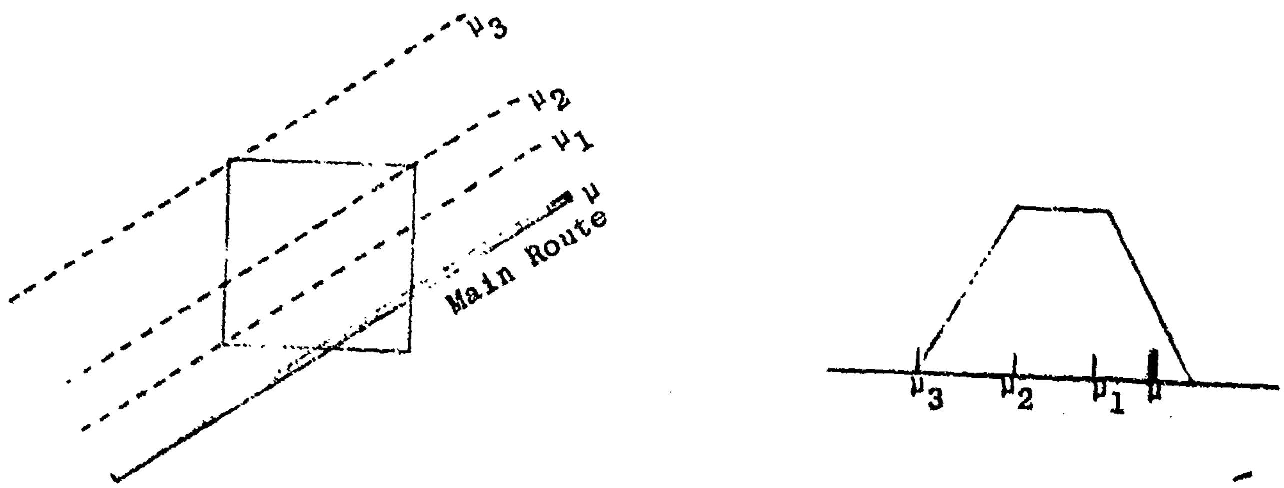


Figure 4-3. Projection of Area Onto Route Perpendicular

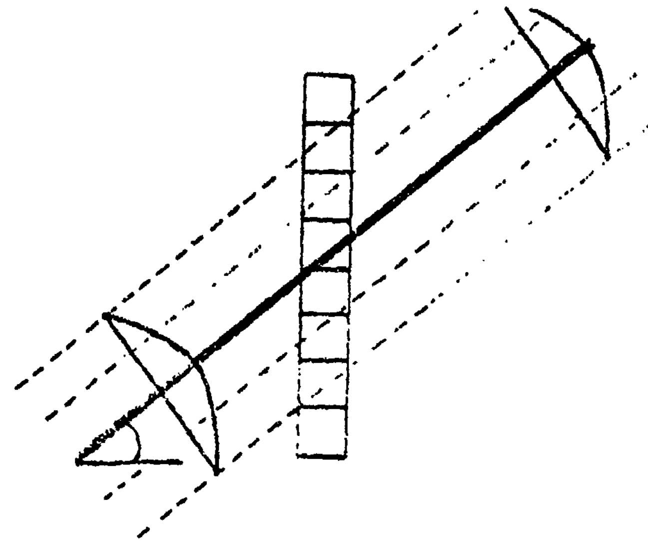


Figure 4-4. Single Column Cut of Route Envelope

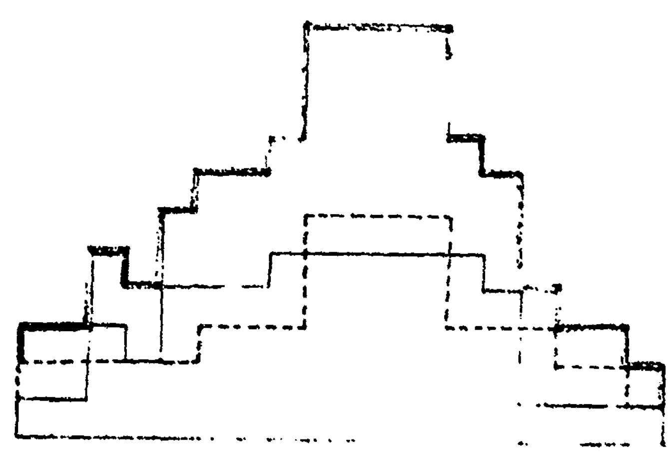


Figure 4-5. Histogram of Two Columns of Data
— and --- are individual columns,
▬ is the sum of both.

The use of interpolating functions are used to fit a smoothed distribution function $\hat{H}(x)$ to an empirical distribution $H(x)$. In order to use an interpolation function one only needs a net of points along the interval. Since the histogram itself is really a discrete data structure this approach is especially suitable.

Let $M = \{(x_i, H(x_i)\}_0^N$ be a mesh of points from the histogram's distribution, and assume that the net $\{x_i\}_0^N$ covers $[-1,1]$, i.e,

$$x_{i-1} < x_i$$

$$x_0 = -1$$

$$x_N = 1$$

The smoothed density function should be continuous (by the nature of open ocean routes), and it is not unreasonable to assume it is C^1 (i.e., has a continuous first derivative) on the interval $[-1,1]$. Thus the distribution function will be $C^2[-1,1]$, (i.e., it will have a continuous second derivative on the interval $[-1,1]$). Let the class of possible distributions D_3 consist of those functions which satisfy four criteria:

i. It is $C^2[-1,1]$

ii. It is a distribution function on $[-1,1]$

iii. It's extension to a distribution function on the real line is C^1

iv. It interpolates the mesh M

For an open ocean route envelope one would not expect a rapidly fluctuating density across a route cut. Based on this empirical observation and other inherent properties of the route, the criteria for minimization is chosen to be the integrated square derivative of the density function,

$$\int_a^b \{\hat{h}'(x)\}^2 dx$$

This analytical expression is a measure of the fluctuation in the density function. Thus the chosen interpolating function $\hat{H}(x)$ is that function from the set D_3 which minimizes the functional

$$\int_a^b \{\frac{d^2\hat{H}}{dx}\}^2 dx$$

Thus out of all functions satisfying conditions i through iv, that one which minimizes this functional will be the 'smoothed' distribution used to model the distribution of traffic across a route cut. Using the fundamental identity for cubic splines a generalization of Holladay's Theorem can be developed. This generalization implies that if the optimization is done over all functions satisfying i, iii and iv, then the minimizing function is a Type I' cubic spline. Furthermore, the minimizing function is unique. {A cubic spline is of Type I' if the first derivative is zero at the endpoints a and b.} If, in addition, the Type I' cubic spline is monotonic, then it is also a distribution function, which is condition ii. In other words, it will satisfy the four conditions for inclusion in D_3 and it will be the (unique) distribution which minimizes the above functional. The monotonicity was assumed, however, in actual data reduction the cubic spline turned out to be monotonic in every case.

The mesh is obtained by using seven sextile points uniformly located along the distributed mass - i.e., the seven sextile points, which are found by solving the following equation for x_i

$$H(x_i) = i/6 \qquad i = 0,1,2,\ldots,6$$

Now the equations of the cubic spline may be developed in an algorithmically implementable form. Since the interval [a,b] was defined to be the smallest closed interval containing the support of the distribution, it is immediately seen that

$$x_0 = -1$$

$$x_6 = 1$$

Let Δ denote the forward difference operator

$$\Delta x_j \equiv x_{j+1} - x_j$$

Define the fifteen quantities

$$\lambda_j = \frac{\Delta x_j}{\Delta x_j + \Delta x_{j-1}}$$

$$\mu_j = 1 - \lambda_j$$

$$c_j = \frac{1}{2} \{\frac{\Delta x_j}{\Delta x_{j-1}} + \frac{\Delta x_{j-1}}{\Delta x_j}\}/\{\Delta x_j + \Delta x_{j-1}\}$$

for $j = 1,2,3,4,5$

The cubic spline is given in terms of the seven coefficients $\{m_i : i = 0,1,\dots,6\}$. Since we are dealing with a Type I' cubic spline two of these coefficients are fixed, viz

$$m_0 = 0$$
$$m_6 = 0$$

The remaining coefficients are given by the linear system

$$\begin{bmatrix} 2 & \mu_1 & 0 & 0 & 0 \\ \lambda_2 & 2 & \mu_2 & 0 & 0 \\ 0 & \lambda_3 & 2 & \mu_3 & 0 \\ 0 & 0 & \lambda_4 & 2 & \mu_4 \\ 0 & 0 & 0 & \lambda_5 & 2 \end{bmatrix} \begin{bmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \\ m_5 \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{bmatrix}$$

This matrix is nonsingular, and the system may easily be solved by tridiagonal matrix algorithms. The density function $\hat{h}(x)$ of the distribution $\hat{H}$ is then given by

$$\hat{h}(x) = m_{j-1}\frac{(x_j-x)(2x_{j-1}+x_j-3x)}{(\Delta x_{j-1})^2}$$
$$- m_j\frac{(x-x_{j-1})(2x_j+x_{j-1}-3x)}{(\Delta x_{j-1})^2}$$
$$+ \frac{(x_j-x)(x-x_{j-1})}{(\Delta x_{j-1})^3}$$

$$\text{for } x\varepsilon[x_{j-1},x_j]$$

This equation will be refered to as equation 4.1.

Thus the development of the route envelope's distribution is completed, with the underlying distribution being modelled by a Type I' cubic spline.

Now we will address ourselves with the problem of mathematically modelling the route envelope outline and the distribution of traffic along a 'cut' across the route. Given two ports A and B the envelope between the two ports will be determined by two mappings. One is from the distance space, Δ, to a 'flat' earth (i.e., the plane R^2) and one from the 'flat' to the 'round' earth (i.e., the sphere S). Thus the total mapping is the composition of the two mappings.

The distance space, Δ, is

$$\Delta = \Lambda \times \Omega = \{(\lambda,\omega);\ 0\leq\lambda\leq 1,\ 0\leq\omega\leq 1\}$$

The parameter ω corresponds to the stochastic aspect of the envelope, i.e., which route is taken. The value $\omega = 0$ corresponds to the route along one edge of the envelope, and $\omega = 1$ corresponds to the route along the other edge. λ denotes the normalized distance along the route (i.e., distance divided by the total length). Thus $\lambda = 0$ corresponds to port A and $\lambda = 1$ corresponds to port B.

The mapping from Δ to R^2 will be considered in several cases, beginning with the most elementary and then generalizing.

<u>Case a:</u> <u>Port-to-Port Segment</u>.

In this case both ends of the cresent are points and there are no protrusions of land to cause land avoidance. On the flat earth the route envelope is bounded by sine waves. A rectangular coordinate system is established such that port A is at the origin and port B lies on the positive x axis. Let

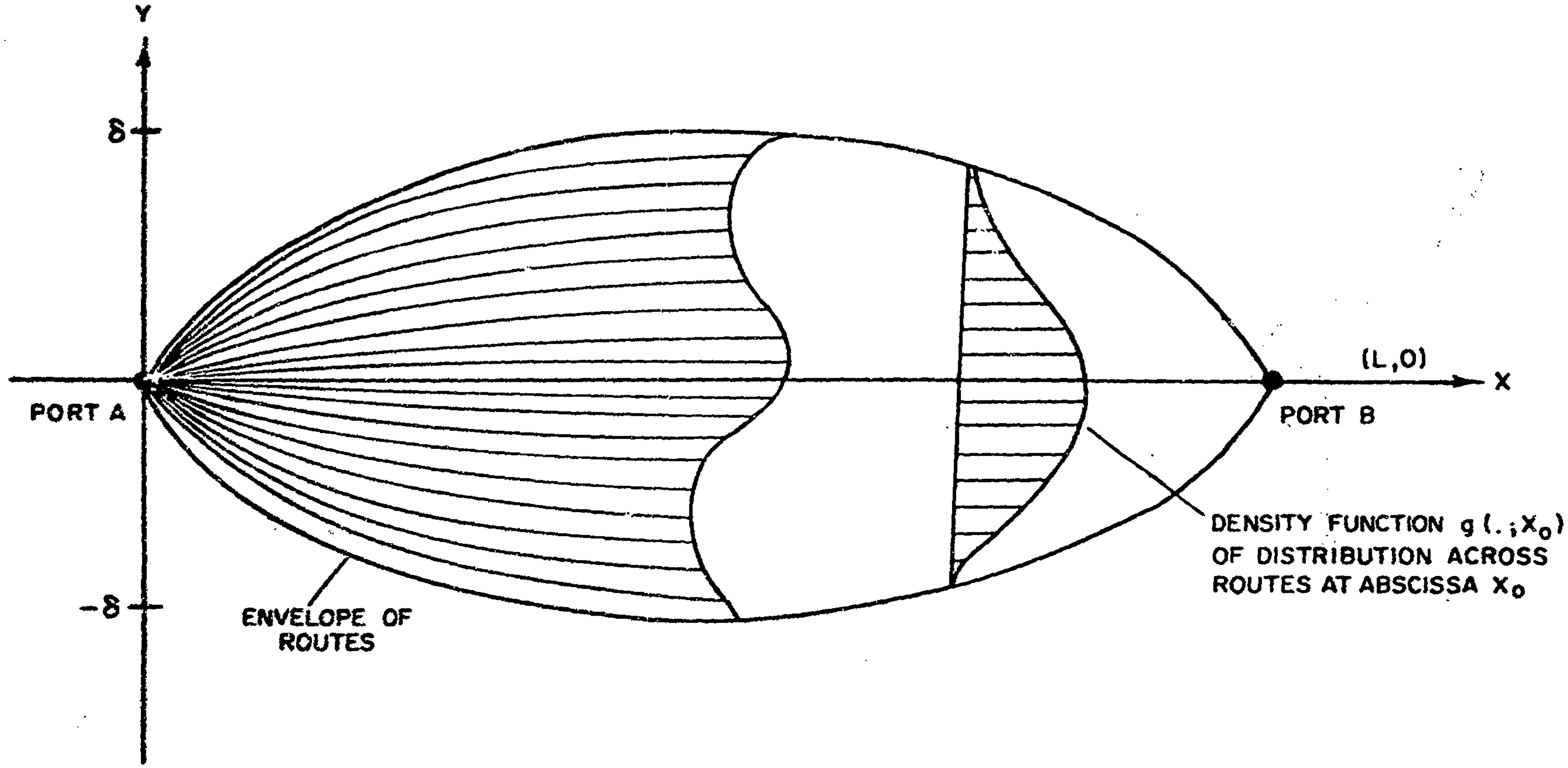


Figure 4.6 Envelope for Case a

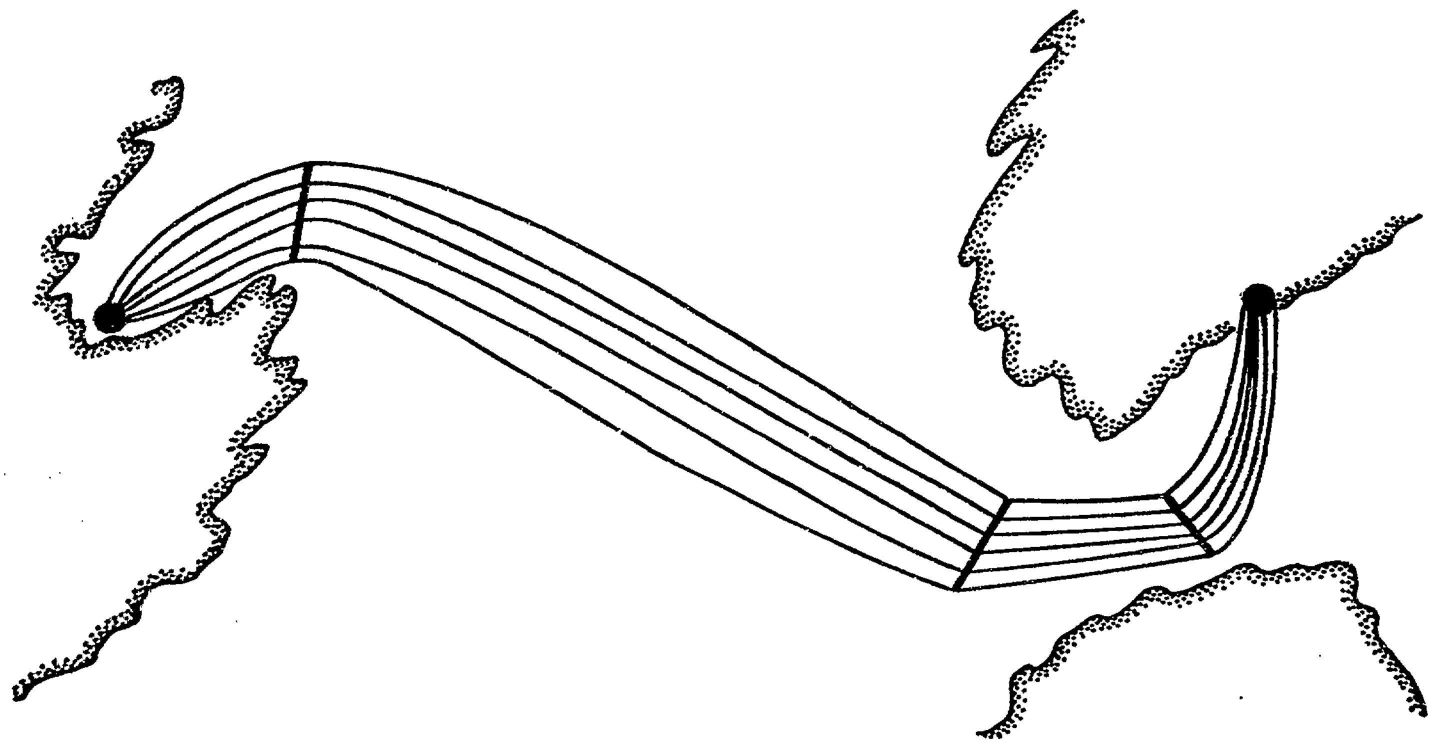


Figure 4.7 Example of a Route with Several Segments

2δ be the maximum width of the envelope. Let $g(y;x_0)$ be the density function of the distribution of traffic across the route at a fixed distance x_0 along the route $(0<x_0<L)$. Note that $g(.;x_0)$ is a density function concentrated on the interval $[-\nu,\nu]$ where

$$\nu = \delta \sin \frac{\pi x_0}{L}$$

Let $H(z;\lambda_0)$ be the distribution function, scaled between $[-1,1]$ so that

$$H(z;\lambda_0) = \int_{-\delta \sin \pi\lambda_0}^{+\delta z \sin \pi\lambda_0} g(y;L\lambda_0)dy \qquad -1\leq z\leq 1$$

and let $G(\omega;\lambda_0)$ be the inverse function of $H(z;\lambda_0)$. Thus, $G(.;\lambda_0)$ has domain $[0,1]$ and range $[-1,1]$. Therefore, the mapping for this case from (λ,ω) to (x,y) is

$$x = L\lambda$$

$$y = \delta G(\omega;\lambda)\sin \pi\lambda$$

Case b: Sloped End Condition.

In this case, the lefthand point is still port A but the route is merely a segment of the total route (Fig 4-8), thus it ends at a turnpoint (e.g., strait, cape) in the ocean. As before 2δ is the maximum envelope width, and now the end of the segment has a width of 2ε rather than zero. Let L be the distance to the midpoint of this end segment. Note that if the angle of the end segment to the axis (θ) is not $\pi/2$, then the 'cuts' across the route envelope corresponding to a fixed distance λ are no longer perpendicular to the axis. For each

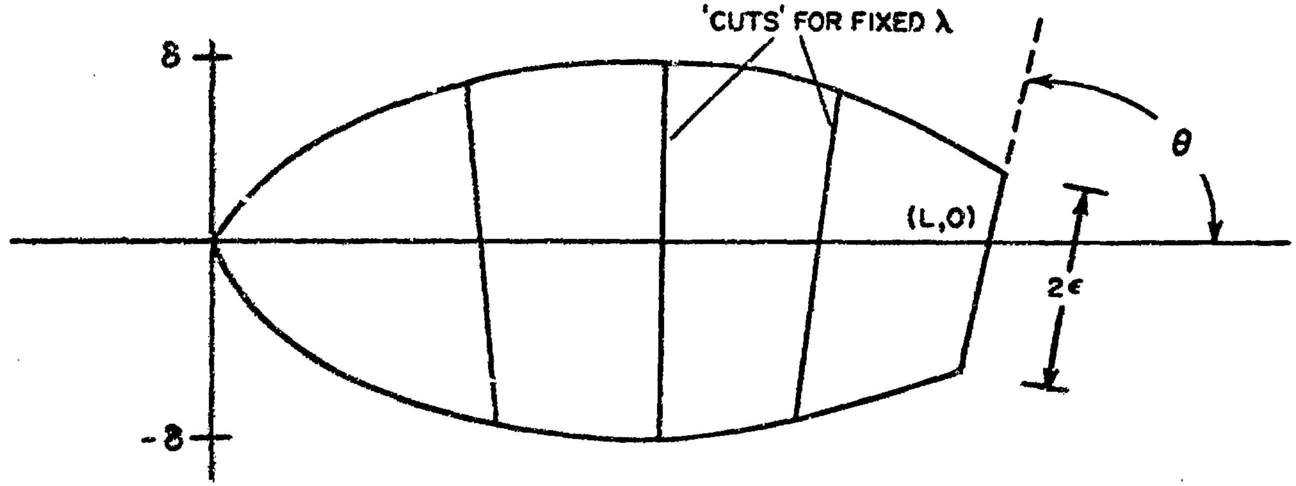


Figure 4.8 Outline of Envelope and Geometry for Case b

fixed $\lambda_0 \varepsilon (0,1)$ let $G(\cdot;\lambda_0)$ be the inverse of the scaled distribution across the routes at the cut $\lambda = \lambda_0$. As before, $G(\cdot;\lambda_0)$ maps [0,1] onto [-1,1]. The angle θ is measured counterclockwise from the exterior axis and is between 0 and π. Thus the mapping for case b from (λ,ω) to (x,y) is

$$x = (L+\varepsilon G(\omega;\lambda)\cos\theta)\lambda$$

$$y = \varepsilon G(\omega,\lambda)\lambda\sin\theta + \phi G(\omega;\lambda)\sin\pi\lambda$$

where the constant ϕ is determined from the following equation

$$\phi \simeq \gamma\left(1-\frac{\zeta^2}{2\pi^2\gamma^2}\right)$$

where $\gamma = (\delta-\zeta/2)$

and $\zeta = \varepsilon\sin\theta$

Case c: General End Conditions.

If both ends have nonzero width, the situation corresponds to Figure 4-9. Both angles θ and $\tilde{\theta}$ are measured counterclockwise from the exterior axis and are between 0 and π. The distance L is measured from the midpoint of one end to the midpoint of the other. The midpoint of one is taken as the origin, and the midpoint of the other as the positive x axis.

Let $\zeta = \varepsilon \sin\theta$

$\tilde{\zeta} = \tilde{\varepsilon}\sin\tilde{\theta}$

Then with previous definitions, the mapping is

$$x = \tilde{\varepsilon}G(\omega;\lambda)\cos\tilde{\theta} + (L+G(\omega;\lambda)(\varepsilon\cos\theta - \tilde{\varepsilon}\cos\tilde{\theta}))\lambda$$

$$y = G(\omega;\lambda)(\tilde{\zeta} + (\zeta-\tilde{\zeta})\lambda + \phi\sin\pi\lambda)$$

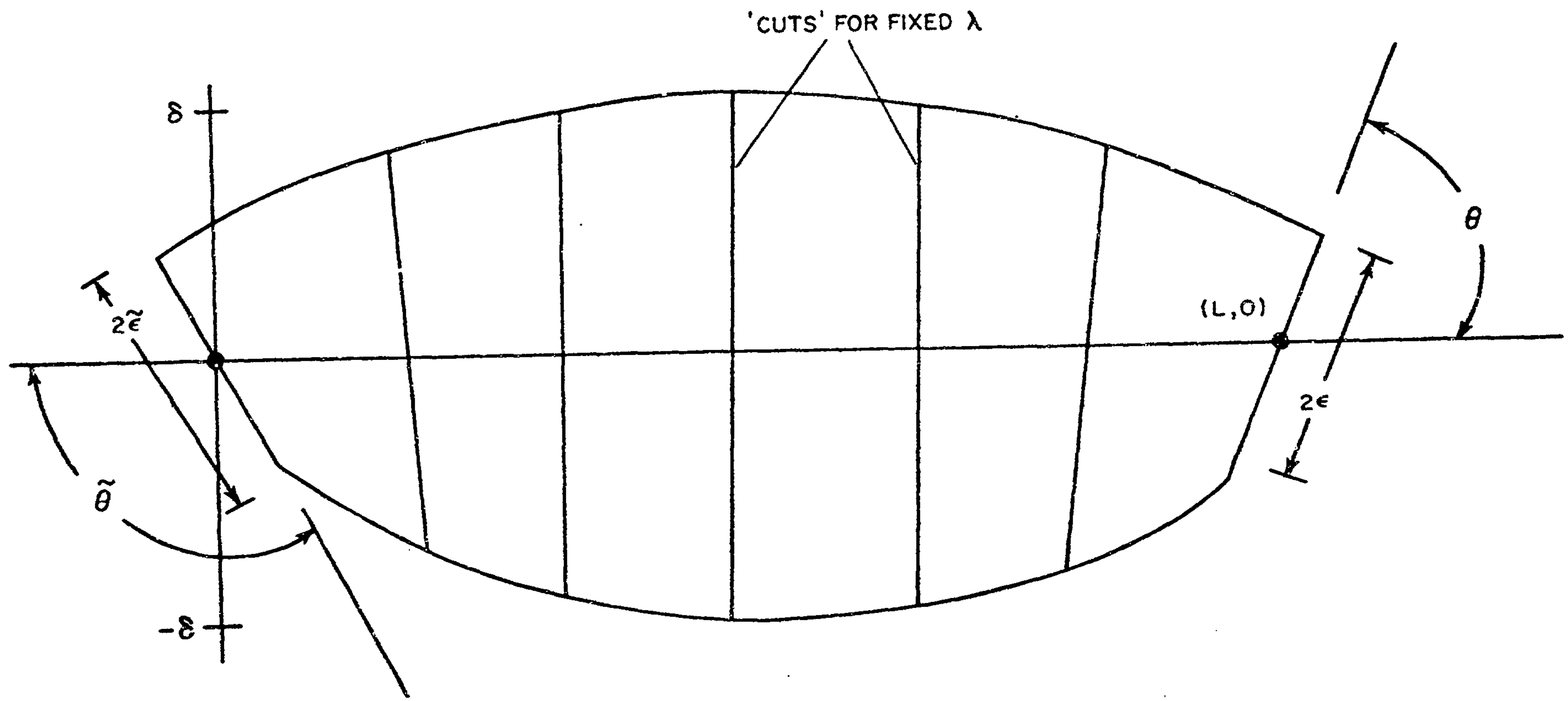


Figure 4.9 Outline of Envelope and Geometry for Case c

where ϕ is a constant. Proceeding as in Case b, we find that ϕ may be computed as

$$\phi \approx \gamma \left(1 - \frac{(\zeta - \tilde{\zeta})^2}{2\pi^2 \gamma^2} \right)$$

where

$$\gamma = \delta - (\zeta + \tilde{\zeta})/2$$

Thus the general mapping from Δ to R^2 has been developed. Next is the mapping from the image of Δ (in R^2) into S.

The plane R^2 had units of length attached to the parameters L, δ, ε and $\tilde{\varepsilon}$, but all equations were developed without recourse to specific dimensional units. References to angles will be made in terms of radian measure. The spherical earth has a well established coordinate system using latitude and longitude, which we will be using. Adopting the conventions that Southern latitudes and Eastern longitudes are negative, and that latitudes and longitudes is expressed in decimal degrees, we have the following coordinate representation of the earth (minus the two poles):

$$S \equiv \{(\alpha,\beta): -90<\beta<90, -180<\alpha<180\}$$

Let (α_1, β_1) and (α_2, β_2) be the two endpoints (longitude-latitude pairs) of the route segment, then the route in R^2 will have to be mapped such that its endpoints (or midpoints of end segments) map into these two points. The procedure used to do this is as follows.

Assume that the points are not diametrically opposed on the sphere, so that there is a unique geodesic between them. If the route is not vertical, (which would send the great circle through the poles) then the geodesic route is a segment of a great circle, which has an equation of the form

$$\tan \beta = \gamma \sin \alpha + \delta \cos \alpha$$

$$= \sqrt{\gamma^2+\delta^2} \sin (\alpha-\alpha_0)$$

where the positive square route is taken. Substituting the two endpoints in this equation gives

$$\gamma = \{\cos \alpha_2 \tan \beta_1 - \cos \alpha_1 \tan \beta_2\}/T$$

$$\delta = \{\sin \alpha_1 \tan \beta_2 - \sin \alpha_2 \tan \beta_1\}/T$$

where $\quad T = \sin (\alpha_1 - \alpha_2) \neq 0$

To parametrically map the segment (0,L) of the x axis in the R^2 space into the geodesic between the two points (α_1, β_1) and (α_2, β_2) consider three cases.

Case a. β_1, β_2 not both zero:

This is the general case, where at least one endpoint does not lie on the equator. The point where the great circle up-crosses the equator (i.e., $\frac{d\beta}{d\alpha} > 0$ at the crossing, see Figure

4.10) is $(\alpha_0, 0)$, and from the great circle equations we have

$$\tan \alpha_0 = -\delta/\gamma$$

The correct inverse function is given by the argument function

$$\alpha_0 = \text{Arg}(\gamma - i\delta)$$

Let the arc length s along the great circle be measured from the upcrossing point $(\alpha_0, 0)$, increasing the westward direction. Let it be measured in units of latitudinal degrees (1 degree = 60 nm), so that the arc length of the entire circle is 360°. We wish to parameterize the route segment of the great circle using $\sigma \varepsilon [0, 1]$ such that $\sigma = 0$ corresponds to the point (α_2, β_2) and

$$\frac{d^2 s}{d\sigma^2} = 0$$

Let s_i be the arc length (from the upcrossing) to (α_i, β_i), then by the law of cosines

$$\cos s_1 = \cos \beta_1 \cos (\alpha_1 - \alpha_0)$$

$$\cos s_2 = \cos \beta_2 \cos (\alpha_2 - \alpha_0)$$

To uniquely specify the value of $s_1 \varepsilon(-180°, 180°)$, use the relationship

$$\hat{s}_1 = \text{Arccos} \left(\cos \beta_1 \cos (\alpha_1 - \alpha_0)\right)$$

$$s_1 = \text{sgn} (\beta_1)\hat{s}_1$$

Specification of the correct value of s_2 is somewhat more complicated since the route must be traversed the 'right way'

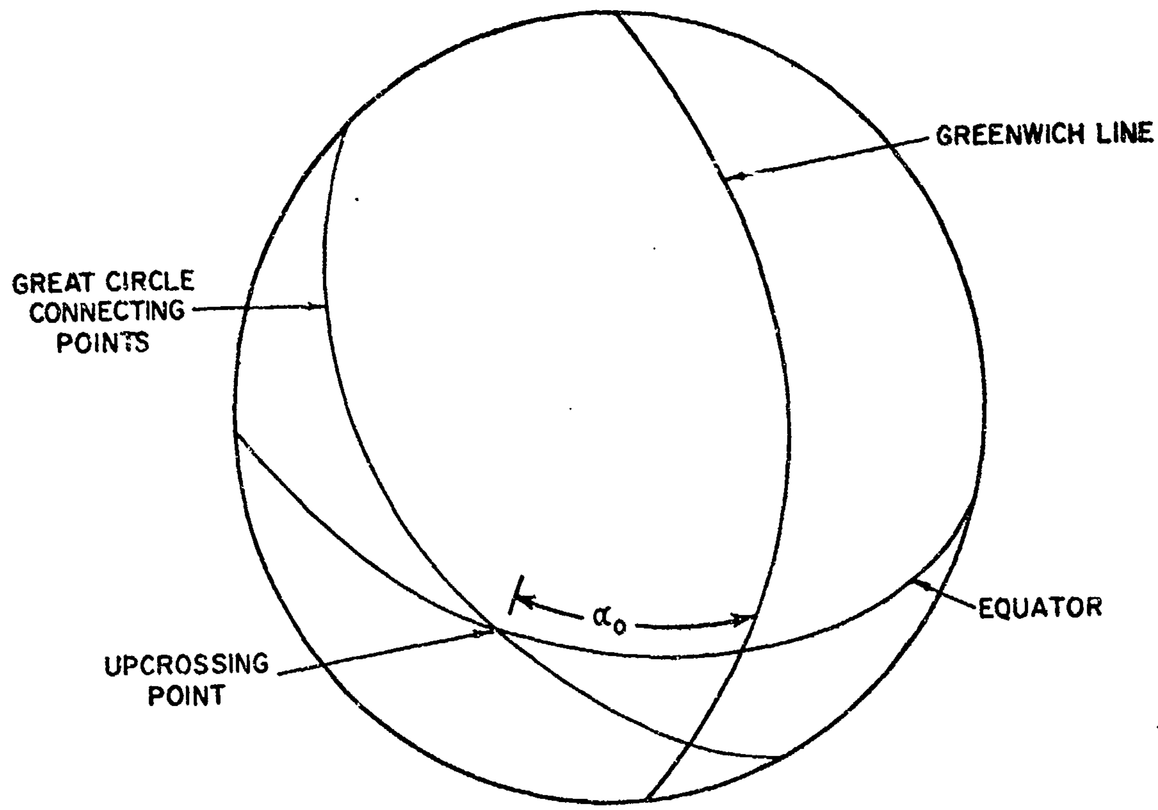


Figure 4.10 Definition of Angle α_0 and Upcrossing Point

around the earth, and there cannot be any discontinuities of 2π (or rather 360°) in the arc length function:

$$\hat{s}_2 = \text{Arccos}\left(\cos \beta_2 \cos (\alpha_2 - \alpha_0)\right)$$

$$s_2 = \text{sgn}(\beta_2)\, \hat{s}_2 + k.360°$$

where $k \varepsilon \{-1, 0, 1\}$ is chosen such that

$$|s_2 - s_1| < 180°$$

Given a $\sigma \varepsilon [0, 1]$, let the arc length parameterization of a third point be

$$s_3 = s_1 + (s_2 - s_1)\,\sigma$$

Then the corresponding point (α_3, β_3) along the segment of the great circle satisfies

$$\tan \beta_3 \sin(\alpha_2 - \alpha_1) + \tan \beta_1 \sin(\alpha_3 - \alpha_2) +$$

$$\tan \beta_2 \sin(\alpha_1 - \alpha_3) = 0$$

If β_i is not zero, then $\sin s_i$ is nonzero. Since not both β_1 and β_2 are zero, the following equation can be used to find β_3;

$$\sin \beta_3 = \sin s_3 \sin \beta_1 / \sin s_1$$

$$= \sin s_3 \sin \beta_2 / \sin s_2$$

The inverse sine function is unique since

$$|\beta_3| < 90°$$

The above relation follows from repeated application of the law of sines. Now, from the law of cosines

$$\cos(\alpha_3 - \alpha_0) = \cos s_3 / \cos \beta_3$$

thus α_3 is found using the relations

$$\upsilon = \text{Arccos}(\cos s_3 / \cos \beta_3)$$

$$\alpha_3 = \alpha_0 + \text{sgn}(\sin s_3)\upsilon$$

{Note that unlike the previous applications of the law of cosines, to resolve the ambiguities it is necessary to use the sign of the sine}.

Case b. Both β's zero.

In this case both points lie on the equator. Define

$$\hat{\alpha}_2 = \alpha_2 + k.360°$$

where the integer k is chosen such that

$$|\hat{\alpha}_2 - \alpha_1| < 180°$$

Then the parameterization of the route, in terms of $\sigma \varepsilon [0, 1]$ is

$$\alpha_3 = \alpha_1 + (\hat{\alpha}_2 - \alpha_1)\sigma$$

$$\beta_3 = 0$$

Case c. Equal α's.

In this case both points lie on the same meridian, and the parameterization is

$$\alpha_3 = \alpha_1$$

$$\beta_3 = \beta_1 + (\beta_2 - \beta_1)\sigma$$

Hence in each case the parameterization of the segment has been specified.

Our attention is now turned to the perpendicular to the mean route. By this we mean the family of great circles that cut the given route at right angles. Before determining the equations for the general case, it is first necessary to give some definitions.

In the planar projection of the earth, the slope of a great circle route is $\frac{d\beta}{d\alpha}$, and it is (naturally) not constant. This slope represents the ratio of an infinitesimal change in vertical (ordinate) degrees to an infinitesimal change in horizontal (abscissa) degrees. On the spherical earth, however, degrees are not a uniform measure of distance. The slope of the great circle (on S) is sec $\beta\frac{d\beta}{d\alpha}$, which represents the ratio of infinitesimal change in vertical (North-South) nautical miles to an infinitesimal change in horizontal (West-East) nautical miles. The slope of the perpendicular is the negative reciprocal of the slope of the great circle route (i.e., $-\cos\beta/\frac{d\beta}{d\alpha}$), thus changing back to a degree coordinate system (i.e., the planar projection), the slope of the perpendicular, $m_{\perp}$ (as a ratio of infinitesimal degrees) is

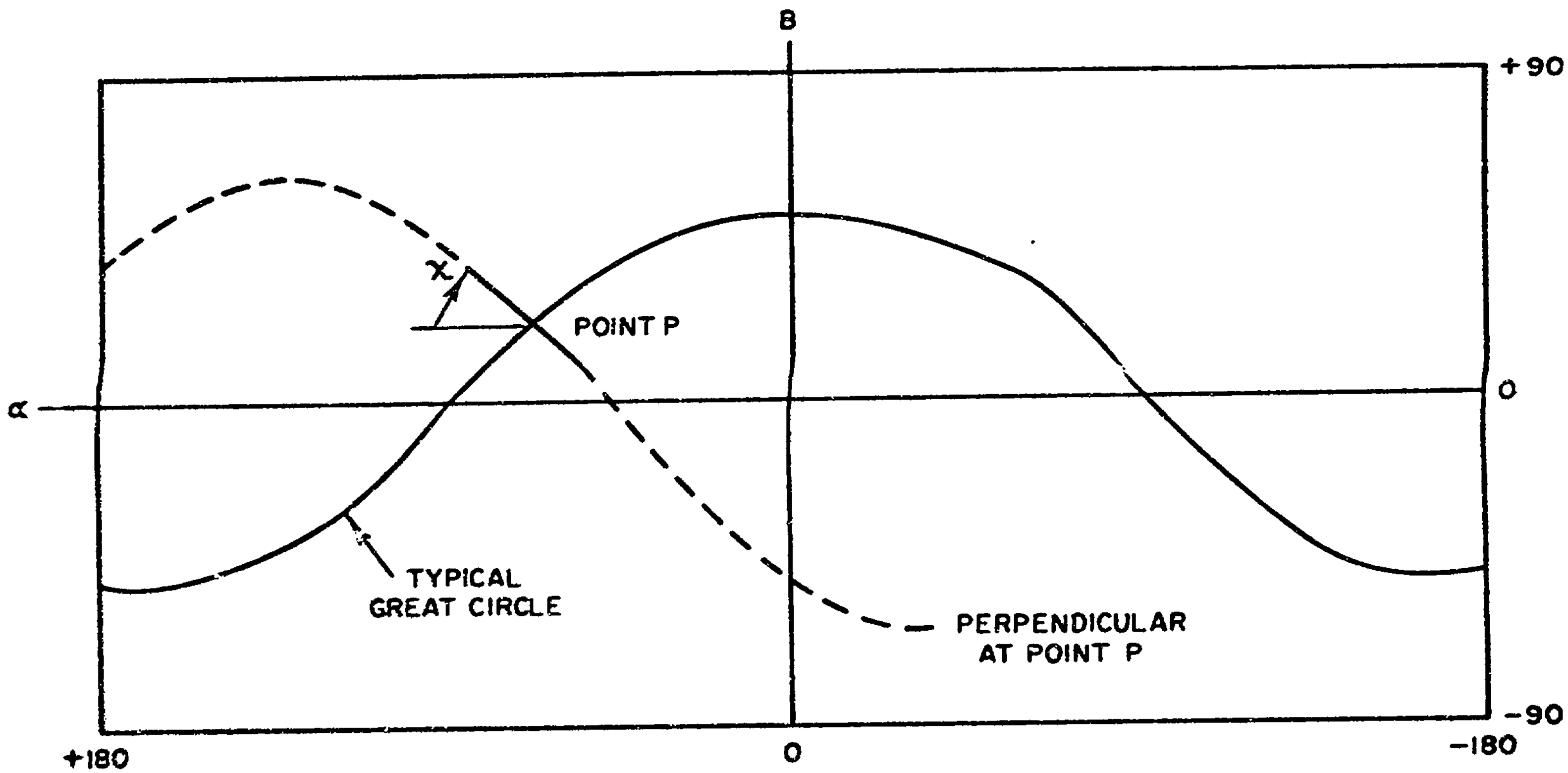


Figure 4.11 Planer Projection of the Earth, Degree Coordinate System

$$m_\perp = -\cos^2\beta \,/\, \frac{d\beta}{d\alpha}$$

$$= -\cos^2\beta \,\frac{d\tan\beta}{d\beta} \,/\, \frac{d\tan\beta}{d\alpha}$$

$$= -\cos^2\beta \sec^2\beta \,/\, (\gamma\cos\alpha - \delta\sin\alpha)$$

$$= 1 \,/\, \psi$$

where

$$\psi = \delta\sin\alpha - \gamma\cos\alpha$$

Let the angle the perpendicular makes with the horizontal (in the planar projection) at the intersection with the great circle route be χ as shown in Figure 4.11. Then

$$\cos\chi = \psi \,/\, \sqrt{1+\psi^2}$$

$$\sin\chi = 1 \,/\, \sqrt{1+\psi^2}$$

where positive square roots are taken. The great circle perpendicular to the route at the point (α_3, β_3) is given by the equation

$$\tan\beta_\perp = \tilde{\gamma}\sin\alpha_\perp + \tilde{\delta}\cos\alpha_\perp$$

where $\tilde{\gamma}$ and $\tilde{\delta}$ satisfy the equations

$$\tan\beta_3 = \tilde{\gamma}\sin\alpha_3 + \tilde{\delta}\cos\alpha_3$$

$$\sec^2\beta_3 \tan\chi = \tilde{\gamma}\cos\alpha_3 - \tilde{\delta}\sin\alpha_3$$

i.e.,

$$\tilde{\gamma} = \sin \alpha_3 \tan \beta_3 + \frac{\cos \alpha_3}{\psi_3 \cos^2 \beta_3}$$

$$\tilde{\delta} = \cos \alpha_3 \tan \beta_3 - \frac{\sin \alpha_3}{\psi_3 \cos^2 \beta_3}$$

where ψ_3 is ψ evaluated at the point (α_3, β_3).

Since the width of the route envelope will be small (compared to the radius of the earth) it may not be necessary to use great circles for the perpendicular displacements, but rather use rhumb lines. A rhumb line approximation to this perpendicular is given by the parametric equations

$$\beta_{\perp} = \beta_3 + \tau \sin \chi_3$$

$$\alpha_{\perp} = \alpha_3 + \tau \cos \chi_3$$

where τ is the parameter and χ_3 is χ evaluated at (α_3, β_3). This equation, of course, is much simpler than the great circle perpendicular.

Now we have the necessary tools to begin distributing the densities. By use of the Cubic Spline Table each route will have a designated Cubic Spline associated with it, where the number of ship days will be distributed across a normal (i.e., a 'cut') to the median of the route envelope. Ultimately the density will be distributed to 1° squares. When doing this, the cut of width h (where h = edgelength x 5) will intersect the one degree square boundaries in a manner indicated in Figure 4-12.

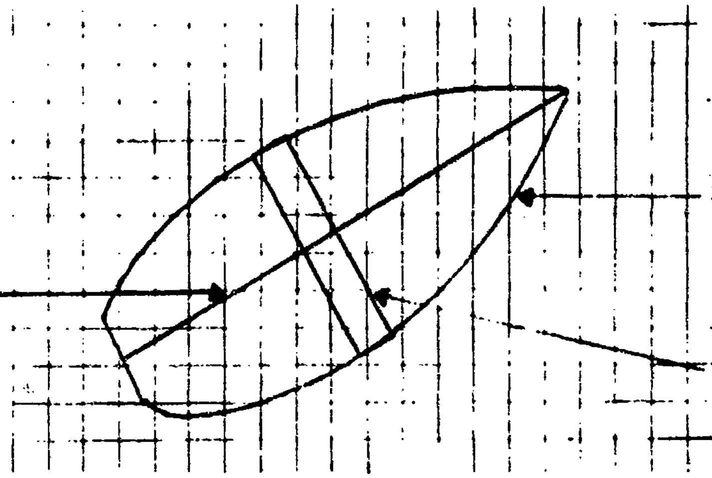


Figure 4-12. Components of a Typical Route Segment

It can be observed that various proportions of one degree squares are located within the cut. Now we will consider the various cases.

Case 1: Suppose that one edge of the 1° square lies in the cut, as in Figure 4-13. Given the coordinate of the vertices of the one degree square, the equation of the side which intersects the cut is,

$$y = \left(\frac{y_r - y_s}{x_r - x_s}\right)x + y_s - x_s\left(\frac{y_r - y_s}{x_r - x_s}\right)$$

or

$$y = \alpha x + \beta$$

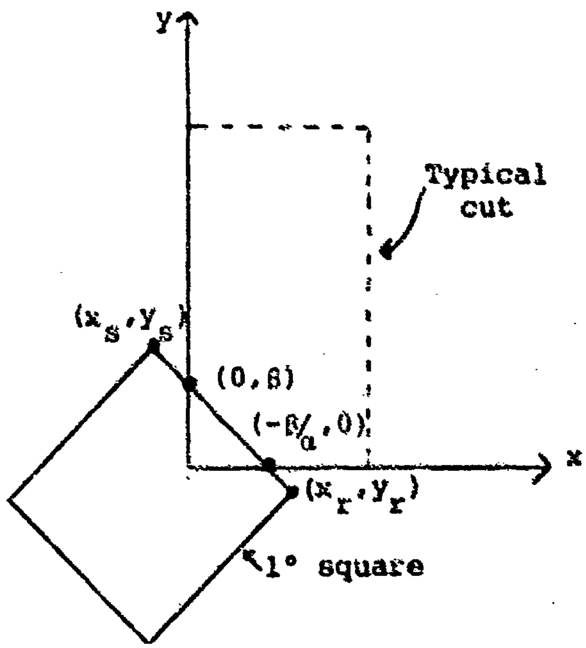


Figure 4-13. Case 1: One edge of the 1° square lies in the cut.

where

$$\alpha = \left(\frac{y_r - y_s}{x_r - x_s}\right), \quad \beta = y_s - x_s\left(\frac{y_r - y_s}{x_r - x_s}\right)$$

Let h(y) denote the density function indicated in eq. 4.1 for the interval $[y_{j-1}, y_j]$. Upon integrating the density function in both directions one obtains

$$\int_0^{\alpha x+\beta} h(y)\,dy = H(\alpha x+\beta) - H(0)$$

$$= a_0 + a_1 x + a_2 x^2 + a_3 x^3$$

where a_0, a_1, a_2, a_3, are constants dependent on the cubic spline, 1° sq. vertices, etc.

$$\text{Volume} = \int_0^{-\beta/\alpha} (a_0 + a_1 x + a_2 x^2 + a_3 x^3)\,dx =$$

$$= -a_0\frac{\beta}{\alpha} + \frac{a_1\beta^2}{2\alpha^2} - \frac{a_2\beta^3}{3\alpha^3} + \frac{a_3\beta^4}{4\alpha^4} = k_i$$

<u>Case 2</u>: Suppose that the cut lies inside a portion of the one degree square as in Figure 4-14. Similar to Case 1, $y = \alpha x + \beta$ represents the side of the square that intersects the interior of the cut. Let h(y) represent the density function. Upon integration in both directions one obtains:

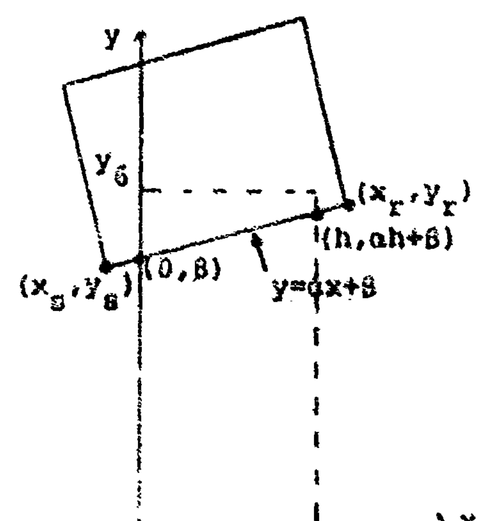


Figure 4-14. Case 2: The cut lies inside a portion of the 1° square.

$$\int_{\alpha x+\beta}^{y_6} h(y)\,dy = H(y_6) - H(\alpha x+\beta)$$

$$= a_0 + a_1 x + a_2 x^2 + a_3{}^3$$

a_0, a_1, a_2, a_3 are determined constants

$$\text{Volume} = \int_0^h (a_0+a_1x+a_2x^2+a_3x^3)\,dx = k_i$$

Case 3: Suppose a rectangular region lies in the cut. Then the volume is

$$\int_{y_r}^{y_p} h(y)\,dy = a_0$$

$$V = \int_{x_r}^{h} a_0 dx = a_0 x_s - a_0 x_r = k_i$$

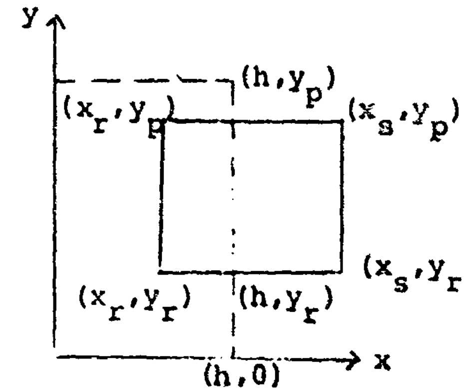


Figure 4-15. A rectangular region lies in the cut.

Case 4: Suppose that a triangular region lies in the cut. The equations of the two lines were determined as in Case 1. Then the volume is, after integrating in both directions

$$\int_{\gamma x+\delta}^{\alpha x+\beta} h(y)\,dy = a_0+a_1x+a_2x^2+a_3x^3$$

$$\text{Volume} = \int_0^{x_r} (a_0+a_1x+a_2x^2+a_3x^3)\,dx = k_i$$

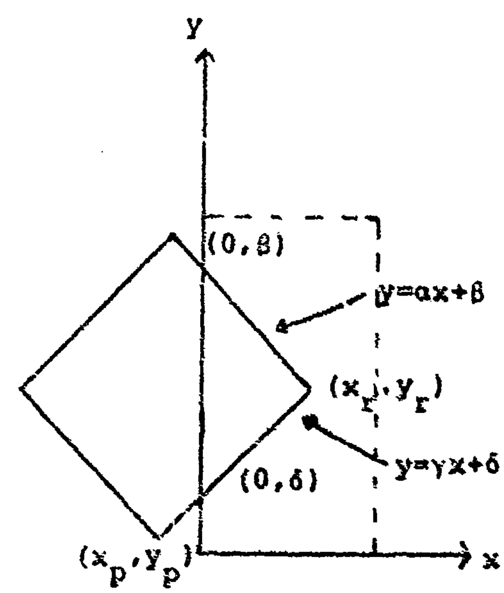


Figure 4-16. A triangular region lies in the cut.

Case 5: Suppose the region appearing in Figure 4-17 lies completely in the cut on $[y_{j-1}, y_j]$. Then upon integrating the density function h(y) in two part, one obtains

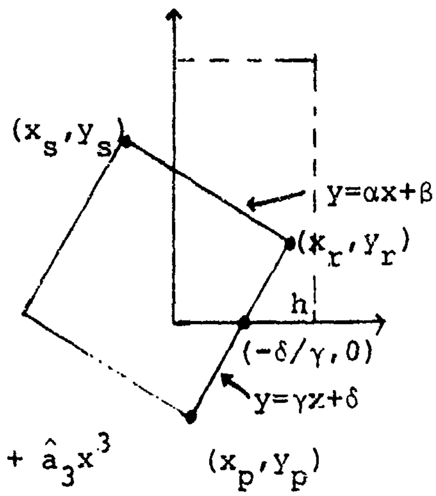


Figure 4.17. A polygonal region lies in the cut.

$$\int_0^{\alpha x+\beta} h(y)\,dy + \int_{\gamma x+\delta}^{\alpha x+\beta} h(y)\,dy$$

$$= \tilde{a}_0 + \tilde{a}_1 x + \tilde{a}_2 x^2 + \tilde{a}_3 x^3 + \hat{a}_0 + \hat{a}_1 x + \hat{a}_2 x^2 + \hat{a}_3 x^3$$

$$= a_0 + a_1 x + a_2 x^2 + a_3 x^3 \qquad \text{where } a_i = (\tilde{a}_i + \hat{a}_i) \quad i = 0,1,2,3$$

$$\text{Volume} = \int_0^{-\delta/\gamma} (a_0+a_1x+a_2x^2+a_3x^3)\,dx + \int_{-\delta/\gamma}^{x_r} (a_0+a_1x+a_2x^2+a_3x^3)\,dx = k_i$$

Case 6: Suppose that the region of the 1° square lies in the upper portion of the cut as in the following figure

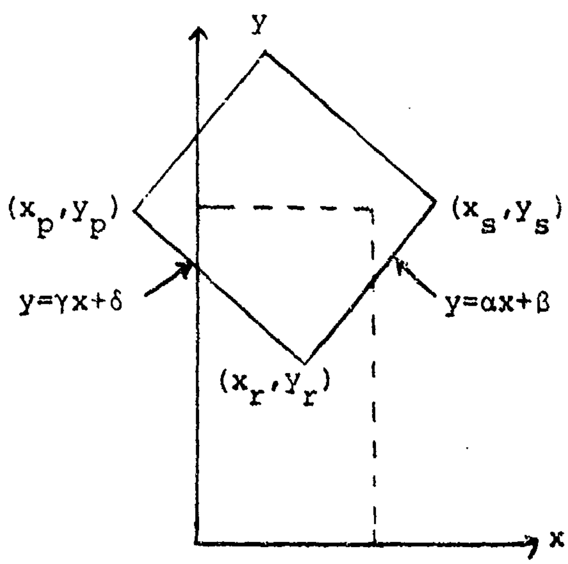


Figure 4-18. Case 6: Region of the 1° square lies in upper portion of the cut.

Given the density function h(y), the corresponding volume is

$$\int_{\gamma x+\delta}^{y_6} h(y)dy + \int_{\alpha x+\beta}^{y_6} h(y)dy$$

$$= a_0 + a_1x + a_2x^2 + a_3x^3 + \tilde{a}_0 + \tilde{a}_1x + \tilde{a}_2x^2 + \tilde{a}_3x^3$$

$$\text{Volume} = \int_0^{x_r} (a_0+a_1x+a_2x^2+a_3x^3)dx + \int_{x_r}^{h} (\tilde{a}_0+\tilde{a}_1x+\tilde{a}_2x^2+\tilde{a}_3x^3)dx$$

$$= k_i$$

Case 7: Suppose that three edges of the square lie in the cut, as given in the following figure

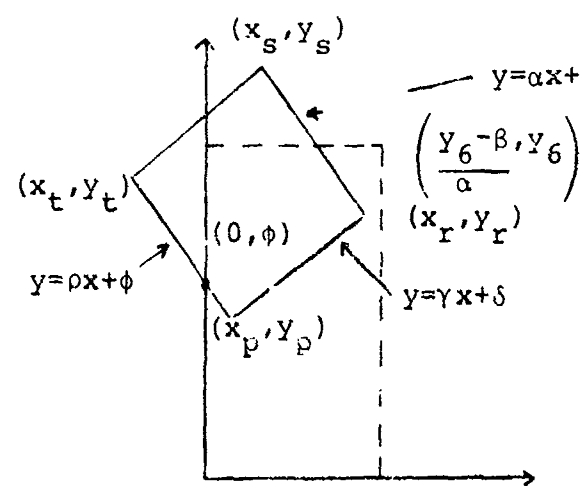


Figure 4-19. Case 7: Three edges of the square lie in the cut.

Let h(y) denote the corresponding density fucntion

$$\int_{\rho x+\phi}^{y_6} h(y)dy + \int_{\gamma x+\delta}^{y_6} h(y)dy + \int_{\gamma x+\delta}^{\alpha x+\beta} h(y)dy$$

Then the volume is

$$V = \int_0^{x_p} (a_0+a_1x+a_2x^2+a_3x^3)\,dx + \int_{x_p}^{\frac{y_6-\beta}{\alpha}} (\tilde{a}_0+\tilde{a}_1x+\tilde{a}_2x^2+\tilde{a}_3x^3)\,dx +$$

$$\int_{\frac{y_6-\beta}{\alpha}}^{x_r} (\hat{a}_0+\hat{a}_1x+\hat{a}_2x^2+\hat{a}_3x^3)\,dx$$

$$= k_i$$

Case 8: Suppose that the whole 1° square lies in the cut. Then the corresponding volume will be determined in the following manner

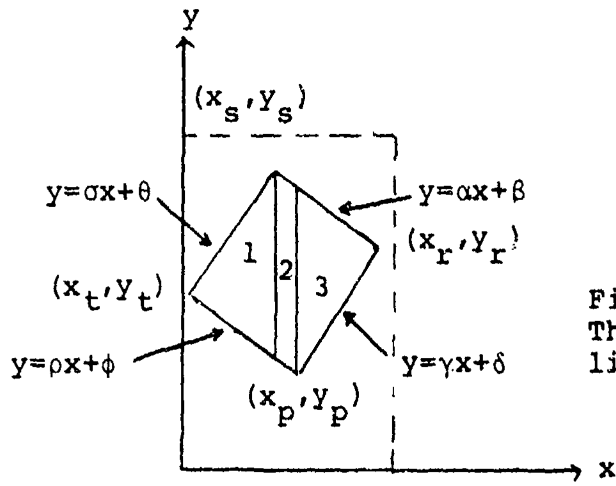


Figure 4-20. Case 8: The whole 1° square lies in the cut.

$$\overset{①}{\int_{\rho x+\phi}^{\sigma x+\theta} h(y)\,dy} + \overset{②}{\int_{\rho x+\phi}^{\alpha x+\beta} h(y)\,dy} + \overset{③}{\int_{\gamma x+\delta}^{\alpha x+\beta} h(y)\,dy}$$

$$V = \int_{x_t}^{x_s} (a_0+a_1x+a_2x^2+a_3x^3)\,dx + \int_{x_s}^{x_p} (\tilde{a}_0+\tilde{a}_1x+\tilde{a}_2x^2+\tilde{a}_3x^3)\,dx +$$

$$\int_{x_p}^{x_r} (\hat{a}_0+\hat{a}_1x+\hat{a}_2x^2+\hat{a}_3x^3)\,dx = k_i$$

Case 9: Suppose that the following region lies in the cut. Then the volume is

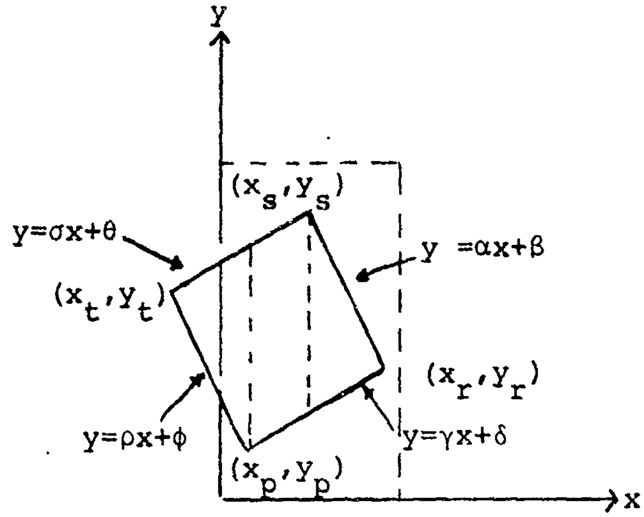


Figure 4-21. Case 9: A polygonal region lies in the cut.

$$\int_{\rho x+\phi}^{\sigma x+\theta} h(y)\,dy + \int_{\gamma x+\delta}^{\sigma x+\theta} h(y)\,dy + \int_{\gamma x+\delta}^{\alpha x+\beta} h(y)\,dy$$

Then integrating in the x direction,

$$\text{Volume} = \int_0^{x_p} (a_0+a_1x+a_2x^2+a_3x^3)\,dx + \int_{x_p}^{x_s} (\tilde{a}_0+\tilde{a}_1x+\tilde{a}_2x^2+\tilde{a}_3x^3)\,dx +$$

$$\int_{x_s}^{x_r} (\bar{a}_0+\bar{a}_1x+\bar{a}_2x^2+\bar{a}_3x^3)\,dx$$

$$= k_i$$

Case 10: Given the region below the volume is:

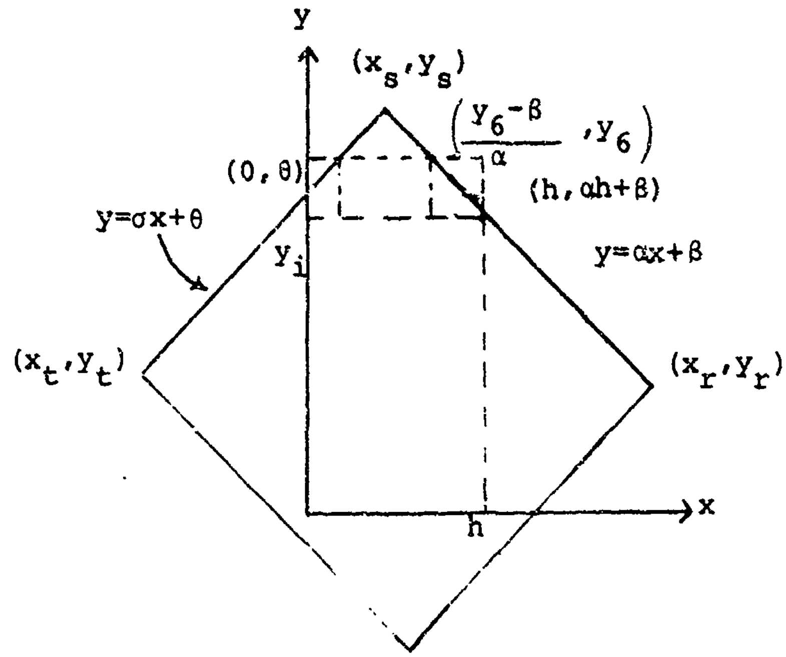


Figure 4-22. Case 10: The cut lies completely in the 1° square.

The volume of the rectangular region is

$$\int_0^{y_i - y_{i-1}} h(y)\,dy = a_0$$

then Volume $= \int_0^h a_0 dx = a_0 h$

The volume of the remaining region can be delt with as in Case 6.

Case 11: Suppose the following region occurs then the volume is

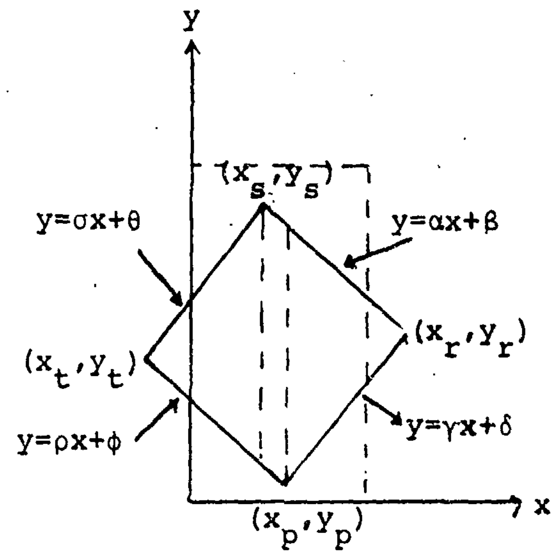


Figure 4-23. Case 11: A polygonal region lies in the cut.

$$\int_{\rho x+\phi}^{\sigma x+\theta} h(y)dy + \int_{\rho x+\phi}^{\alpha x+\beta} h(y)dy + \int_{\gamma x+\delta}^{\alpha x+\beta} h(y)dy$$

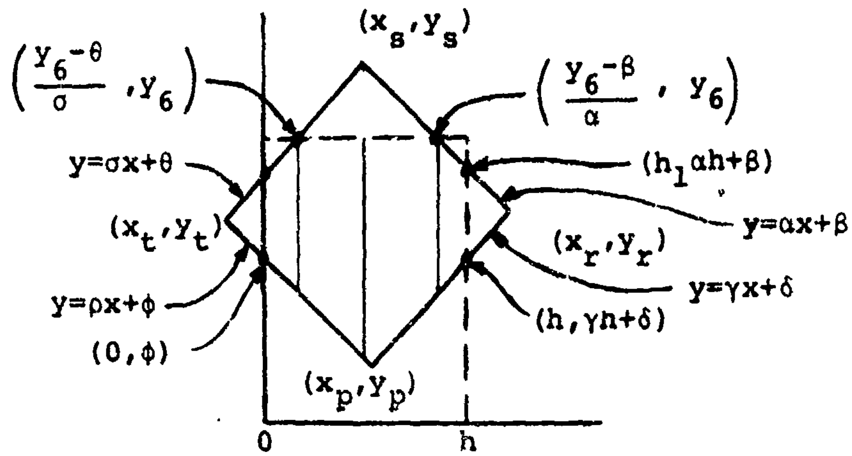
Then

$$\text{Volume} = \int_0^{x_s}(a_0+a_1x+a_2x^2+a_3x^3)dx + \int_{x_s}^{x_p} (\tilde{a}_0+\tilde{a}_1x+\tilde{a}_2x^2+\tilde{a}_3x^3)dx +$$

$$\int_{x_p}^{h} (\bar{a}_0+\bar{a}_1x+\bar{a}_2x^2+\bar{a}_3x^3)dx$$

$$= k_i$$

Figure 4-24. Case 12: Three regions of the 1° square lie outside the cut.



$$\int_{\rho x+\phi}^{\alpha x+\theta} h(y)\,dy + \int_{\rho x+\phi}^{y_6} h(y)\,dy + \int_{\gamma x+\delta}^{y_6} h(y)\,dy + \int_{\gamma x+\delta}^{\alpha x+\beta} h(y)\,dy$$

$$\text{Volumn} = \int_0^{\frac{y_6-\theta}{\sigma}} (a_0+a_1x+a_2x^2+a_3x^3)\,dx + \int_{\frac{y_6-\theta}{\sigma}}^{x_p} (\hat{a}_0+\hat{a}_1x+\hat{a}_2x^2+\hat{a}_3x^3)\,dx$$

$$+\int_{x_p}^{\frac{y_0-\beta}{\alpha}} (\bar{a}_0+\bar{a}_1x+\bar{a}_2x^2+\bar{a}_3x^3)\,dx + \int_{\frac{y_6-\beta}{\alpha}}^{x_1} (\tilde{a}_0+\tilde{a}_1x+\tilde{a}_2x^2+\tilde{a}_3x^3)\,dx$$

Now all the densities have been distributed across the route. Then to find the total volume in the one degree square, you would sum up all the components comprising it.

Oil and Fishing Rigs

Next the question of distributing the Oil Rigs arises. The main data sources are the Register of Offshore Units Submersibles and Diving Systems 1977-1978[14] and The Ocean Industry[5]. In The Ocean Industry, the oil rigs are categorized according to types: submersibles, semi-submerisibles, jack-ups, drillships and barges. They also provide us with the geographical location in which they are presently working and the depth capability of the rig. This information is also given in the Register of Offshore Units. Therefore by correlating the two sources for the geographical location, one was better able to pin-point the location of the oil rig. According to Ocean Industry there are 439 units in existance right now. This figure also takes into account those oil rigs under construction, and those available for contract. Therefore the number of oil rigs in use is approximately 360. Most of the oil rigs tend to lie in distinct geographical locations, namely the Gulf of Mexico, the North Sea, the Caribbean, Suez, Red Sea, and the Persian Gulf.[12]

The sources of data for the fishing vessels are as follows: Soviet Fisheries Investigations in the Northeastern Pacific,[23] Fisheries Statistics of the United States 1970,[6] The Fish Resources of the Ocean,[8] Yearbook of Fishery Statistics,[30] 1971 Atlas of the Living Resources of the Seas,[2] Trends in Merchant Shipping[15] (1969-1980). In order to determine the actual distribution the total number of fishing vessels and the thousand of tons of catch is required. In order to illustrate the magnitude of fishery resources and their present state of exploitation, the available data have been grouped by regions in accordance with the breakdown adopted by FAO in the Yearbook of Fishery Statistics, 1971 Maps show the catch for each statistical area according to the four main groups: demersal or bottom-living fish, pelagic fish, crustaceans and cephalopods, and whales.

The count for the total number of fishing vessels is obtained from Lloyd's Register of Ships. There are presently 21,261 fishing vessels, of which 76% of them are at sea yielding 16,159 vessels. The total world catch is 70,481,700 tons; therefore, the thousand tons of fish per catch per vessel is 2.43.

The Yearbook of Fishery Statistics designates the total number of thousand tons of fish for each geographical area in the world. By using this information we are able to determine the number of vessels in each ocean area necessary to procure this catch.

Knowing the various times of the year in which the 4 classes of fishes are caught, enabled us to determine the seasonality factor. The fishing vessel distributions are done for the winter and summer for each one degree square.

Additional data was obtained by NOSIC, Naval Ocean Surveillance Information Center. The Red Flag Shipping data was used to supplement the Lloyd's Register tapes, in various geographical regions. The use of Red Flag Shipping data enabled us to more accurately depict the total shipping distributions.

CHAPTER V

Outputs

1. Availability - Administrative:

Any types of data which can be culled from the description of the data base is available in machine readable format. The data can be provided upon request in any type of machine readable format: punched cards, magnetic tape, or disc pack. A request for data should be sent by letter to:

Dr. Louis P. Solomon
Suite 600
7900 Westpark Drive
McLean, Virginia 22101
Tel: (703)790-5950

2. Availability - Technical:

The technical data is available on 7 track, 800 bpi magnetic tape. All the numbers will be available in E format. The actual distributions and their descriptors can be understood by considering not only the printout of the data, but also in conjunction with the body of this report.

CHAPTER VI

Discussion of Validity of Results and Sample Outputs

The questioi. concerning the validity of the 1° x 1° square distribution is the next problem that must be addressed. Presently, there is a paucity of data available exhibiting shipping distributions, which restricts the number of cases that can be checked. However, there has been extensive studies of shipping traffic in the North Pacific. They are: Church Anchor, Aircraft Surveillance of Shipping,[21] Church Opal: Surveillance of Shipping,[27] and the RMS study, Navy Interim Shipping Distribution.[16,20]

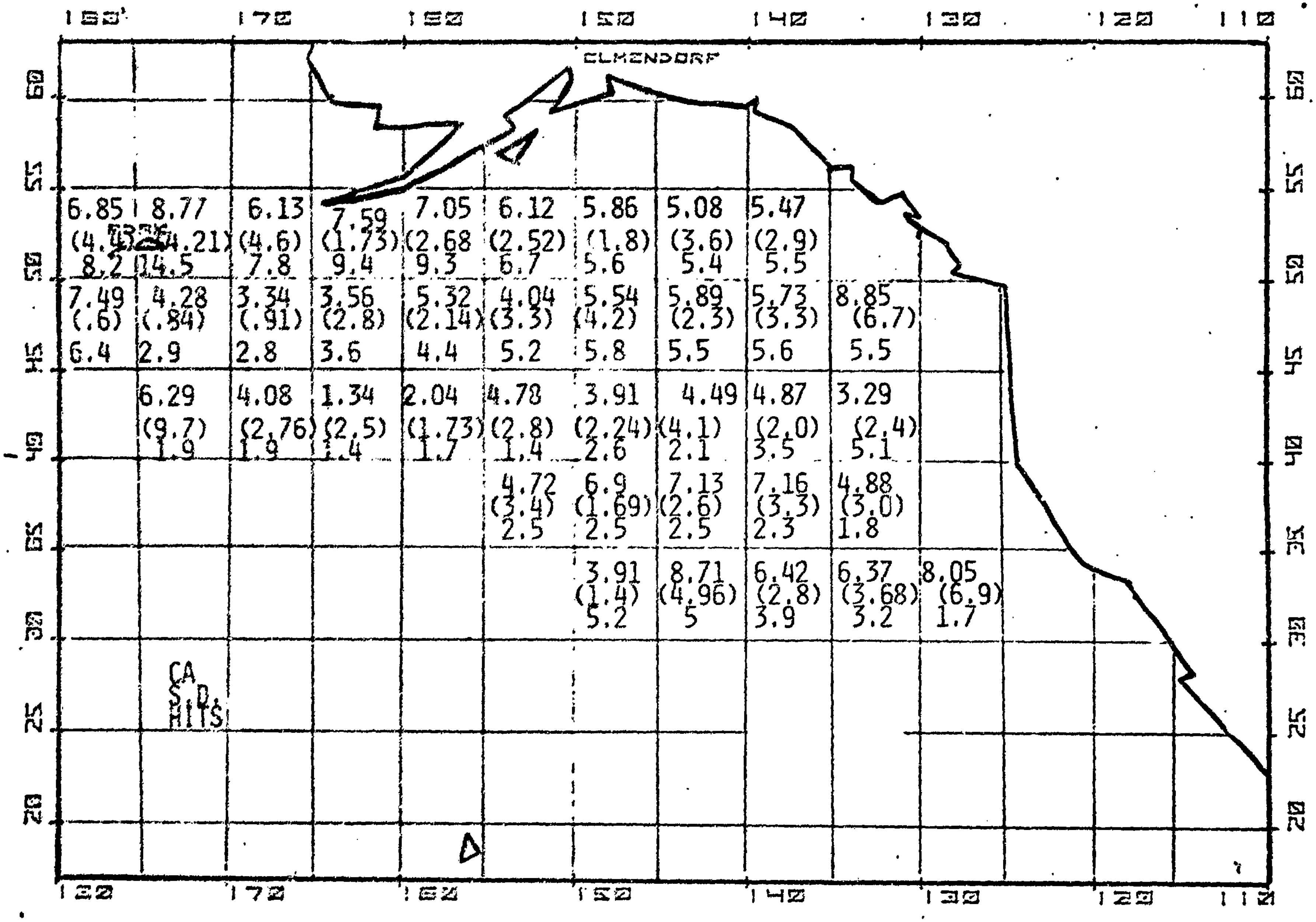
The Church Anchor Exercise presents the results of extensive aircraft surveillance of merchant vessels at sea in the North East Pacific during the month of September 1973. Sufficient observations were made to enable a statistical analysis of the data to be perfoi.aed. The resolution of the Church Anchor Exercise is by 5° squares. The data for HITS by 5° squares in the same area, as that of Church Anchor, were analyzed and compared. The region considered is between 30° N to 55°N and 125°W to 180°W as shown in Figure 6-1. The top numbers in Figure 6-1, of each 5° x 5° square represents the number of ships observed in the Church Anchor exercise. The number directly beneath it represents the standard deviation of the observed results, and the bottom represents the HITS results. We have found that the HITS distribution to be statistically consistent with that of Church Anchor. The following observations were found:

a. 30% of the data lies with 0.25 standard deviation by 5° square.

b. 58% of the data lies wt-hin 0.75 standard deviation by 5° square.

c. 79% of the data lies within 1.0 standard deviation by 5° square.

d. 87% of the data lies within 1.25 standard deviation by 5° square.



5 x 5 ° Comparisons of CHURCH ANCHOR Versus HITS with Standard Deviations

Figure 6-1

Histogram of Normalized HITS Densities Relative to CHURCH ANCHOR Densities

where σ = Standard Deviation of CHURCH ANCHOR Densities by EACH 5° Square

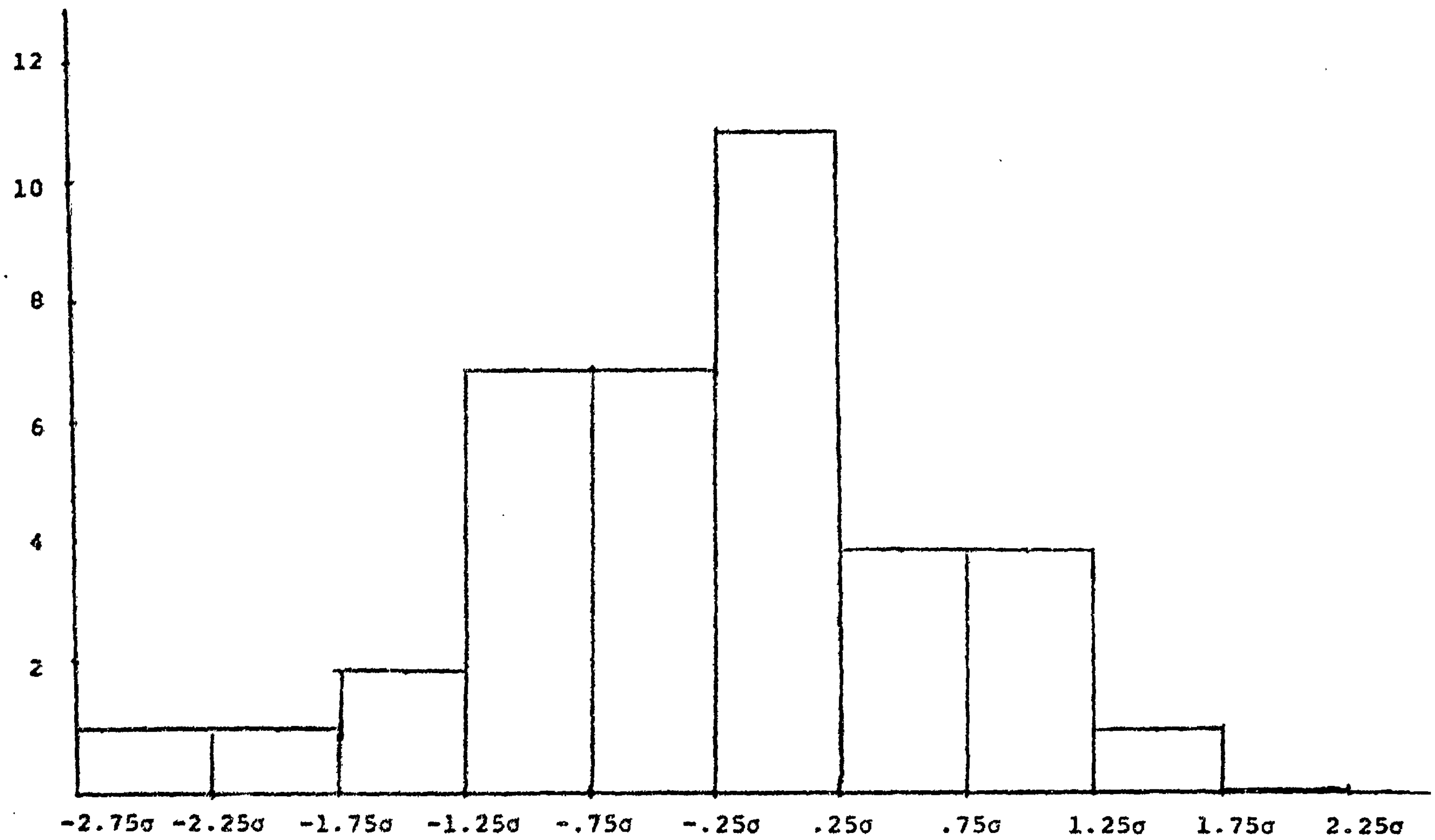


Figure 6-3

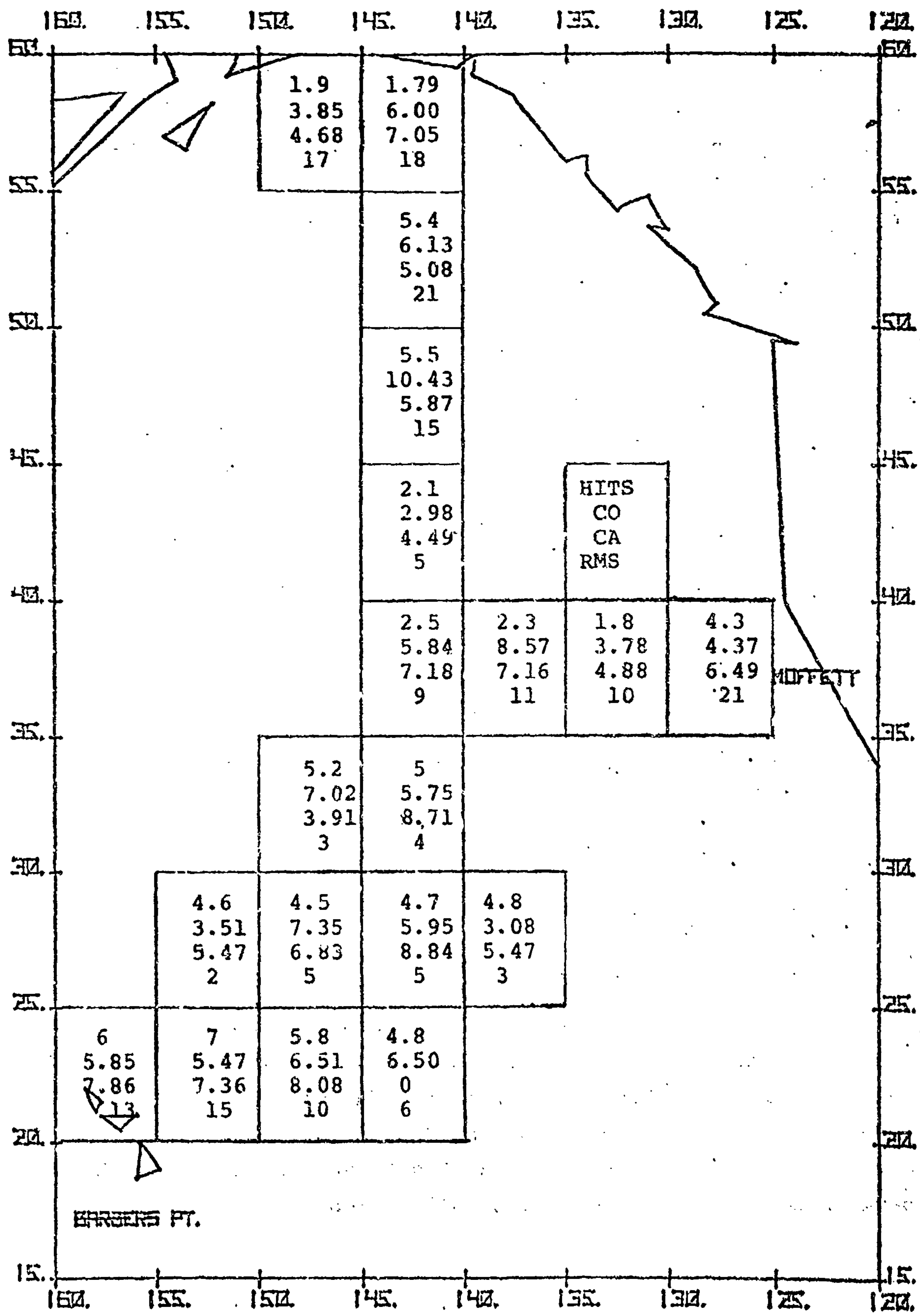
Next the ratio of the HITS data to the Church Anchor data was considered. We can observe from the histogram, in Figure 6-2, that a majority of the data ratios lie within .75 and 1.25. This indicates that the HITS results are remarkably close to those of Church Anchor's.

Further analysis was done comparing the Church Anchor to the HITS data. In Figure 6-3 we have a histogram representing the normalized HITS density relative to Church Anchor's densities. This was obtained by the following method:

$$\frac{\text{HITS Data} - \text{Church Anchor data}}{\text{CA standard deviation for the square}}$$

This demonstrated that the data behaves like the normal standard deviation curve. This again validates the accuracy of the HITS results.

The Church Opal Exercise performed similar missions as that of Church Anchor. The surveillance of merchant vessels took place in September of 1975 in the North East Pacific. The number of merchant vessels were tabulated and analyzed. Figure 6-4 illustrates the findings of various studies for 5° x 5° square designated in the North East Pacific. Reading from top to bottom in a square, one can observe the results of the HITS, Church Opal, Church Anchor and RMS findings. The HITS results compared very well to that of Church Opal data.



5 x 5° SQUARES COMPARISON OF HITS, CHURCH ANCHOR, RMS, AND CHURCH OPAL

Figure 6-4

The correlation coefficients were next performed on the Church Anchor, Church Opal, RMS and the HITS data. The following equation was used to determine the zero based correlation coefficient.

$$\rho_0^2 = \frac{(\Sigma x_i y_i)^2}{\Sigma x_i^2 \Sigma y_i^2}$$

Studies	CHURCH OPAL REGION	CHURCH ANCHOR Mid Region	CHURCH ANCHOR Full Region
Church Anchor-Church Opal versus RMS	.704		
Church Anchor-Church Opal versus HITS	.839		
RMS versus HITS	.626	.724	.543
Church Anchor versus HITS		.839	.799
RMS versus Church Anchor		.898	.785

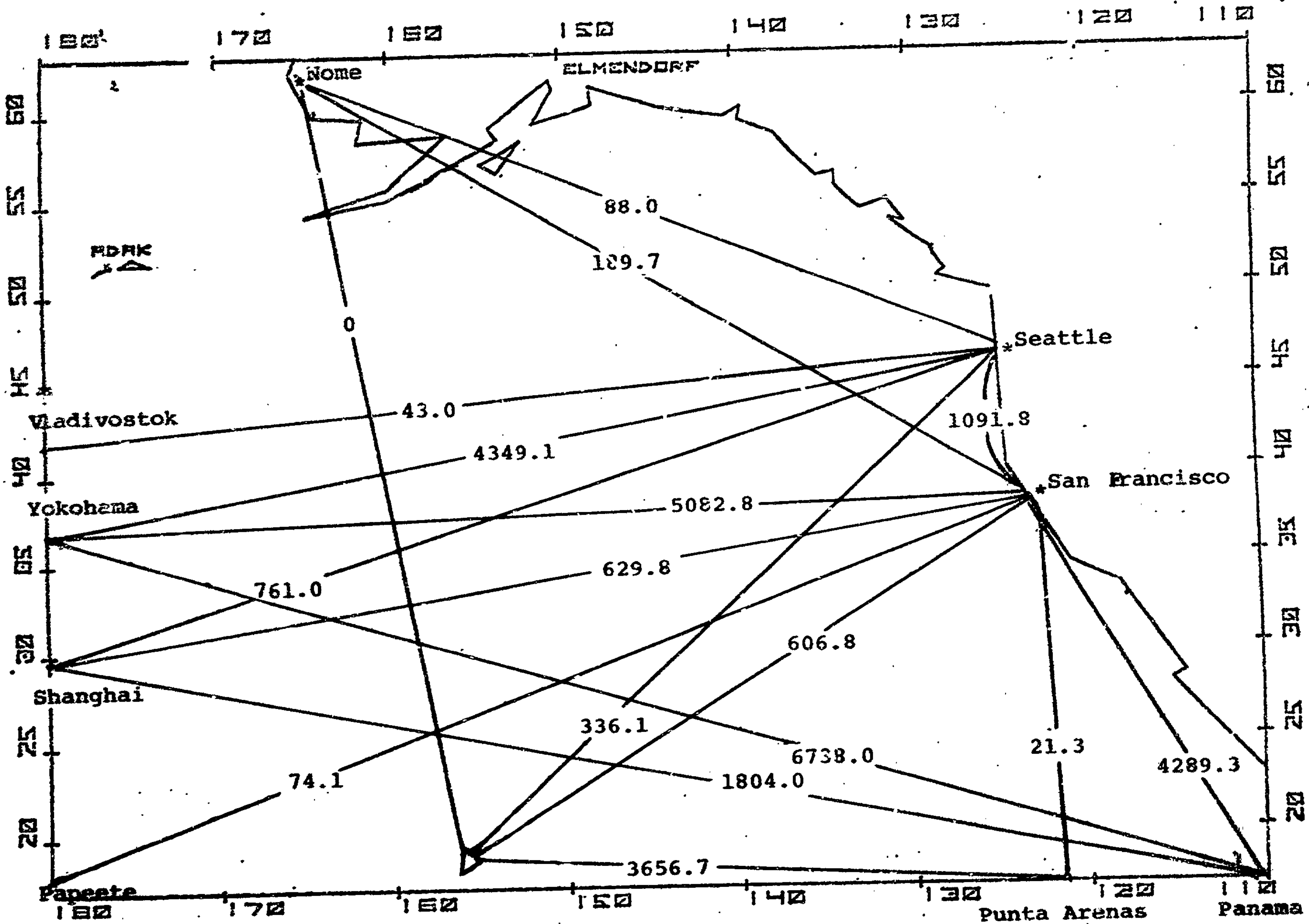
Table 6-1 Correlation Coefficients (ρ_0^2) among various studies.

In the above table the Church Anchor-Church Opal entry signifies that the most reliable data between the two of them for each square was chosen for the Church Opal region. One can observe that the HITS data correlates better in the Church Opal region than RMS when compared to Church Anchor and Church Opal data. There is also a very high correlation in the HITS data versus the Church Anchor data in both the mid-region and full region.

In conclusion, based on the data sources available and the analysis of the data, the HITS results have successfully modeled the actual shipping densities.

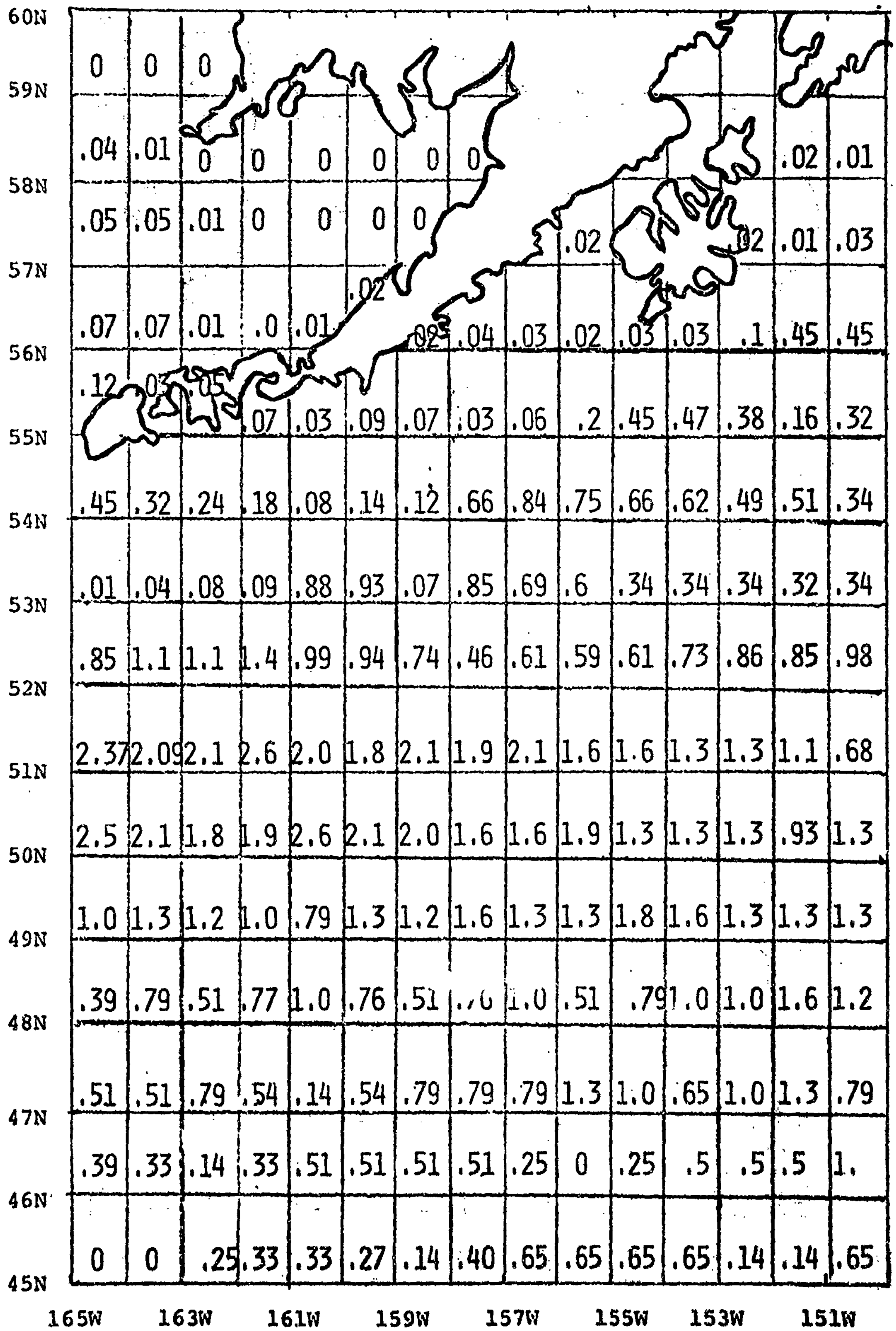
This last part deals with some of the sample outputs of this study. Figure 6-5 designates the routes from the West Coast, U.S. to Vladivostok, Yokohama, and Shanghai. The number, 1539, between the route Shanghai and Seattle represents the ship traffic in total number of ship days for the month of October. Program Gamma produced the number of ship days of traffic from the Lloyd's tape between each of the 69 canonical ports for three class types. This output is placed in a table called the Proto-Routing Table. Next Program Epsilion further reduces this 69 x 69 array to ship days between canonical ports that are connected by a direct route. Therefore, Figure 6-5 represents the total number of ship days in the North East Pacific between the illustrated canonical ports. The next step is to distribute the number of ship days across the route by 1° square. This is done in Program Theta. This is shown in Figure 6-6. This is the 1° x 1° square distribution of merchant ships for October in the Aleutian Islands. The distribution is done by processing one route at a time and storing the densities in a (180 x 360) array called the Merchant Counts Array. This is again by class and by month.

Figures 6-7 and 6-8 show the number of oil rigs and fishing vessels in the Gulf of Mexico. The fishing vessel's distributions are done for the summer and winter, while the oil rigs are done annually. The oil rigs consist of jack-up, submersible, semi-submersible, drill ship and barges.

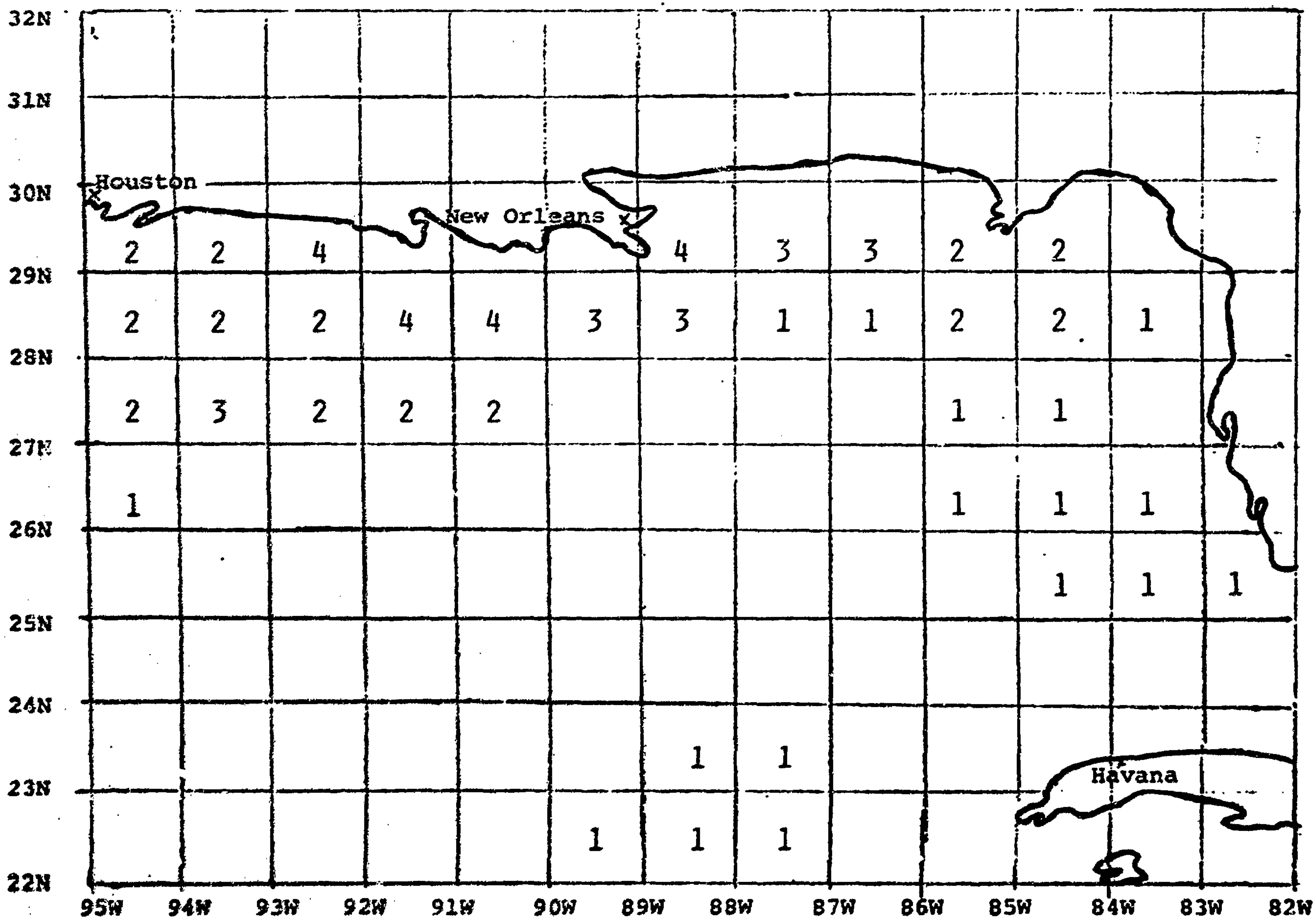


TOTAL SHIPDAYS BETWEEN CANONICAL PORTS VIA DIRECT ROUTES (DECEMBER)
Figure 6-5

Figure 6-6

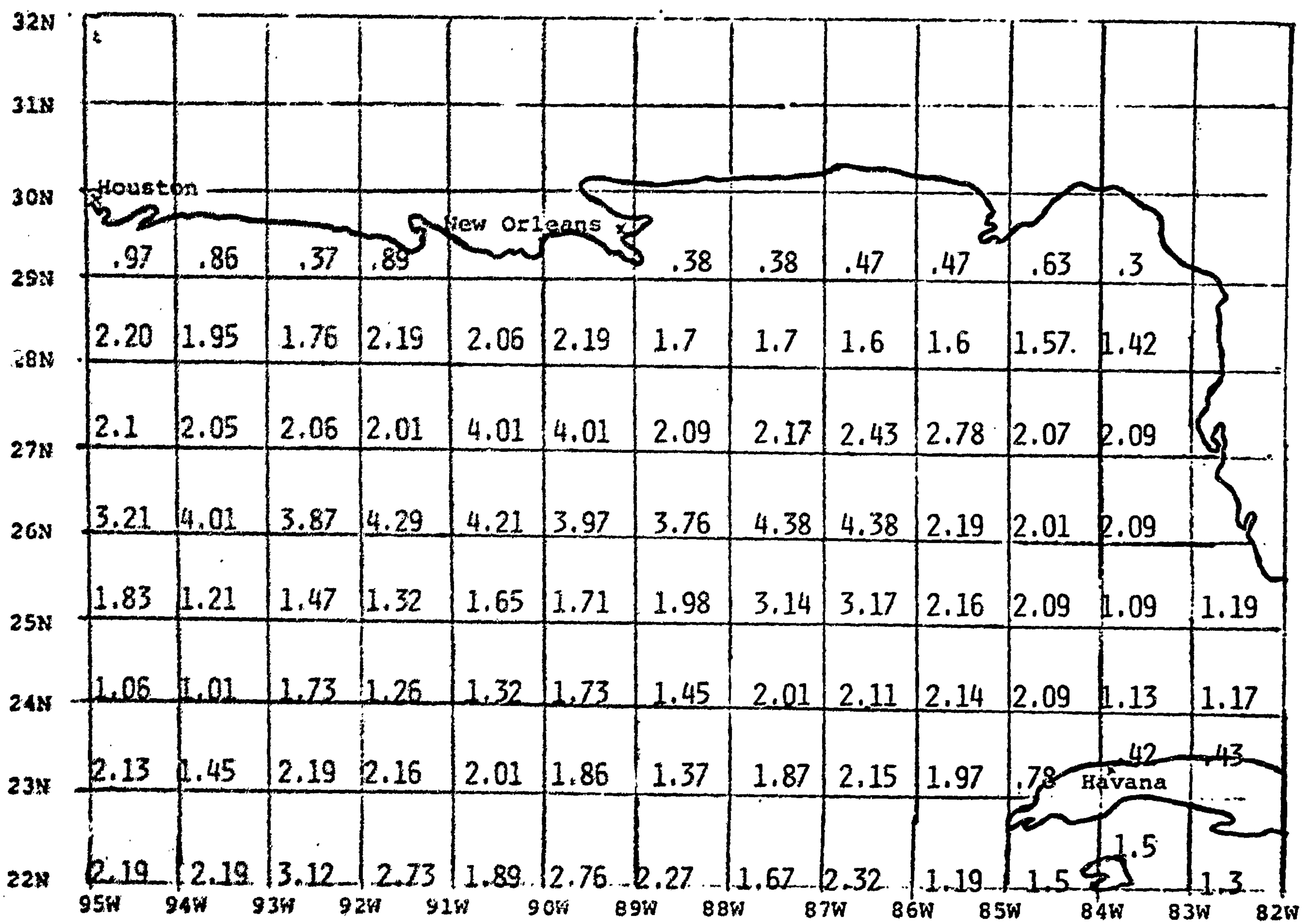


DISTRIBUTION IN THE ALEUTIAN ISLANDS BY 1 x 1° SQUARE (MERCHANTS)



OIL RIGS IN THE GULF OF MEXICO

Figure 6-7



FISHING VESSELS DISTRIBUTION FOR THE GULF OF MEXICO (SUMMER)

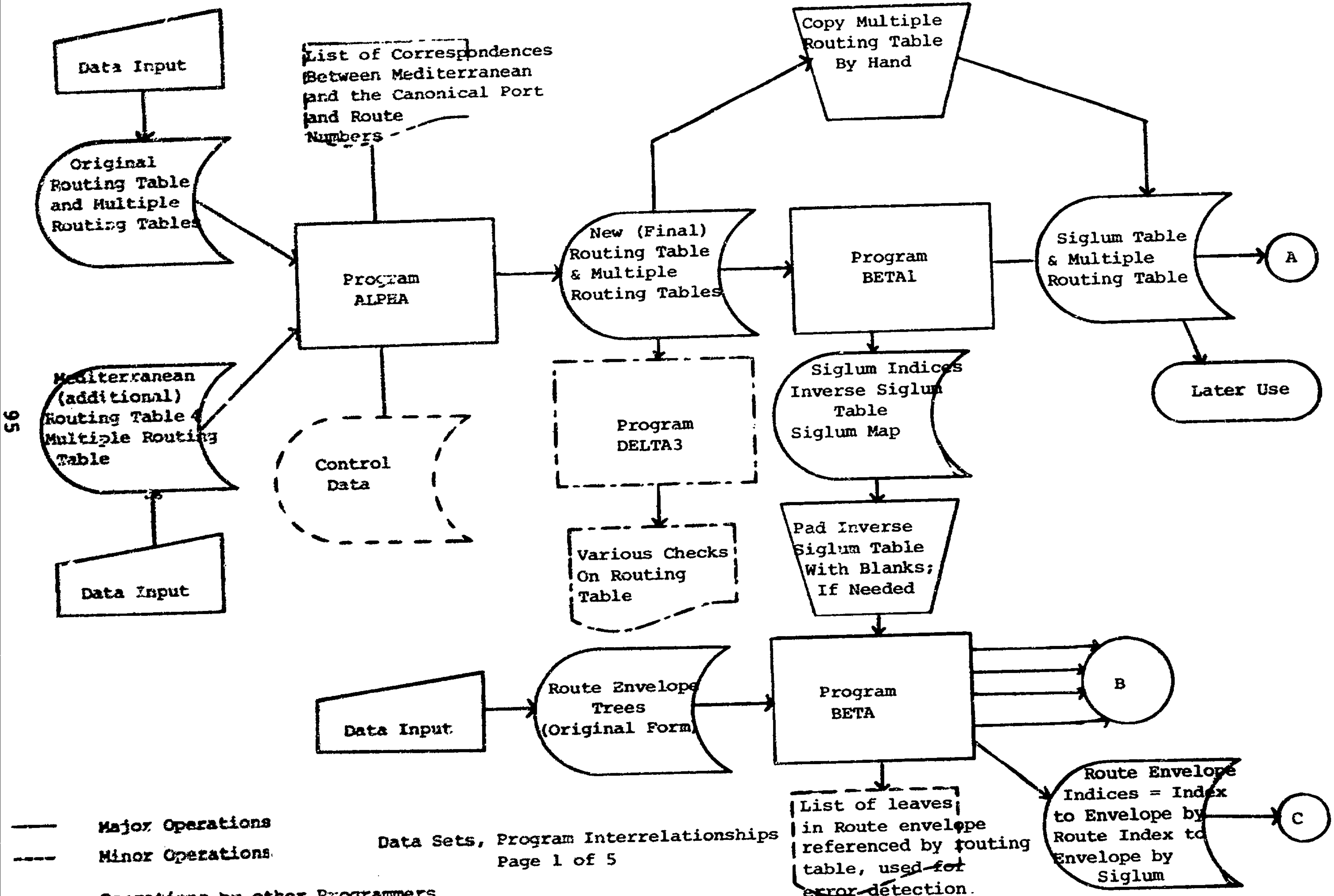
CHAPTER VII

Computer Programs

1. Overview and Program Flow.

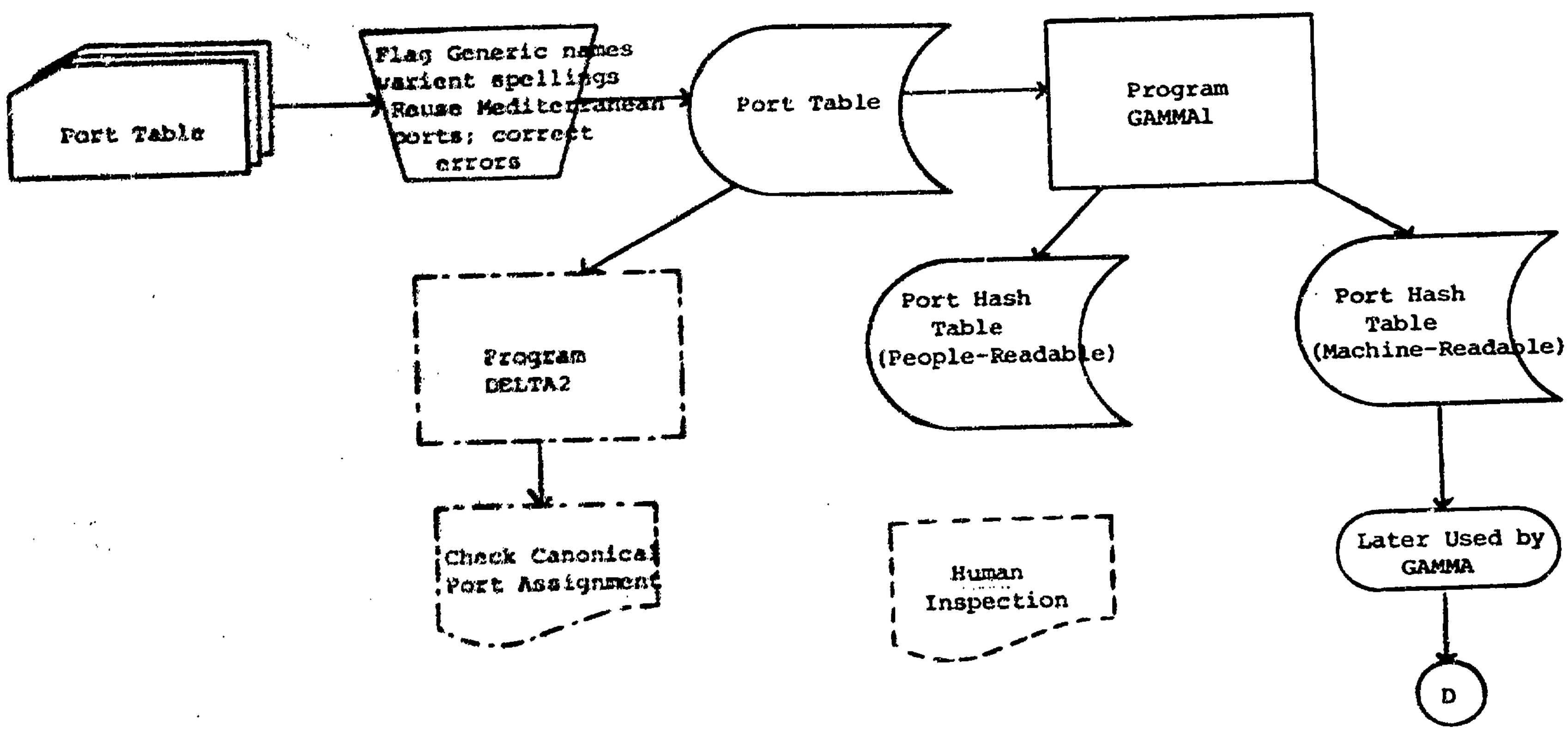
This chapter deals with the various aspects of the programs implemented in this project. The program flow, function of each program, mathematical logic, and various checks and cases are considered.

The flow charts on the following pages depict data set and program interrelationships.



Data Sets, Program Interrelationships
Page 1 of 5

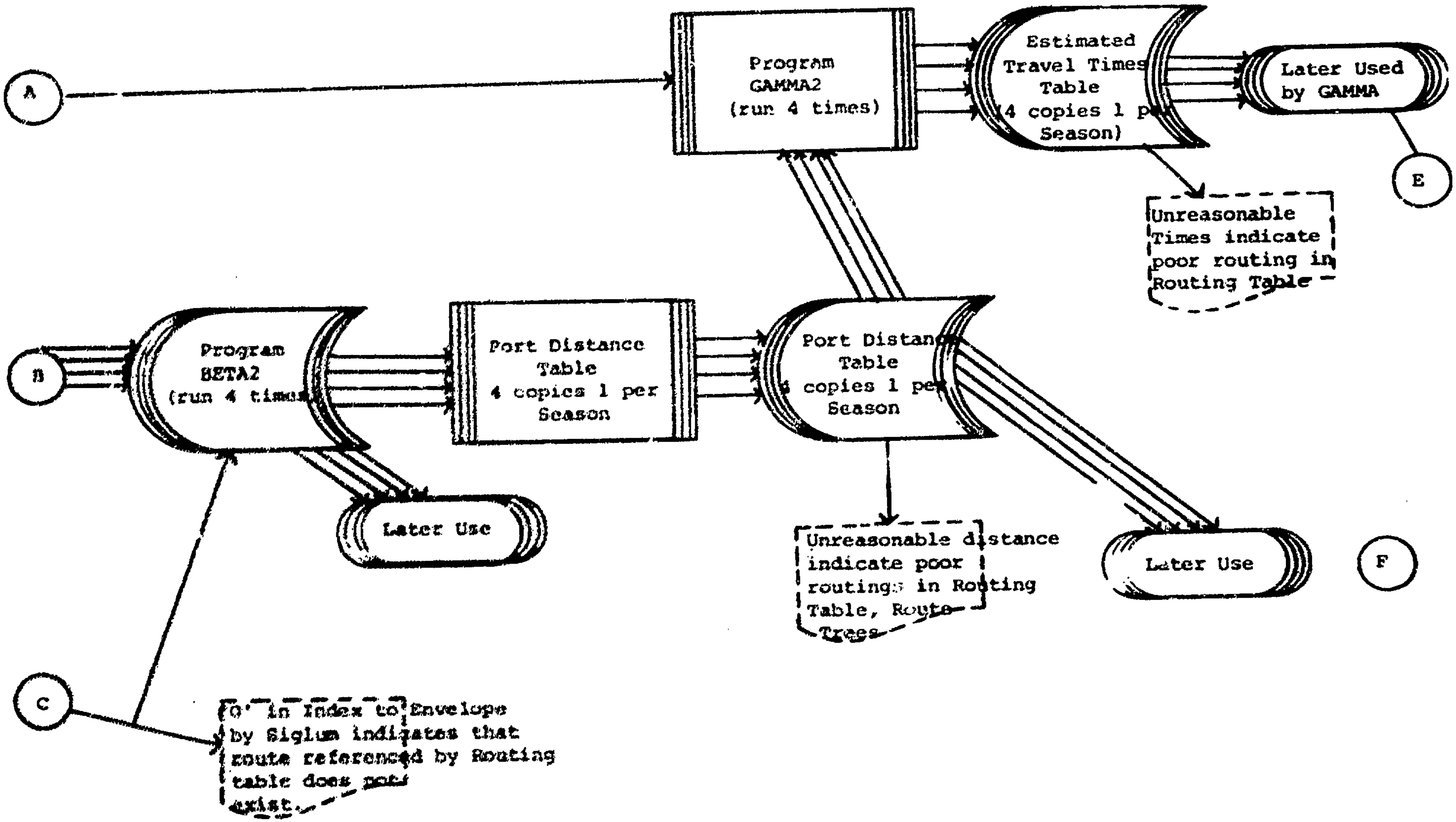
Figure 7.1



Data Sets, Program Interrelationships

Page 2 of 5

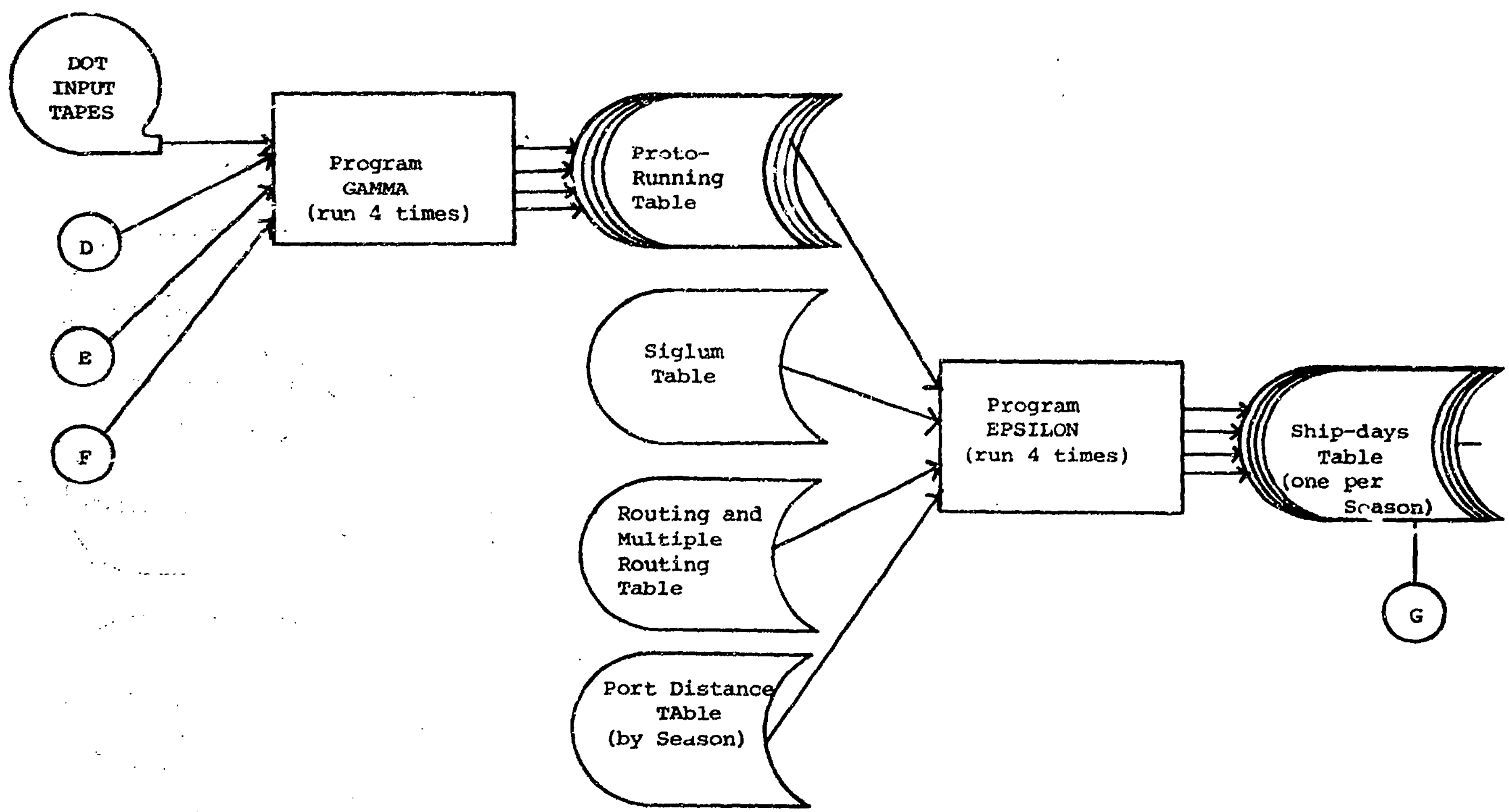
FIGURE 7.1 (Continued)



Data Sets, Program Interrelationships

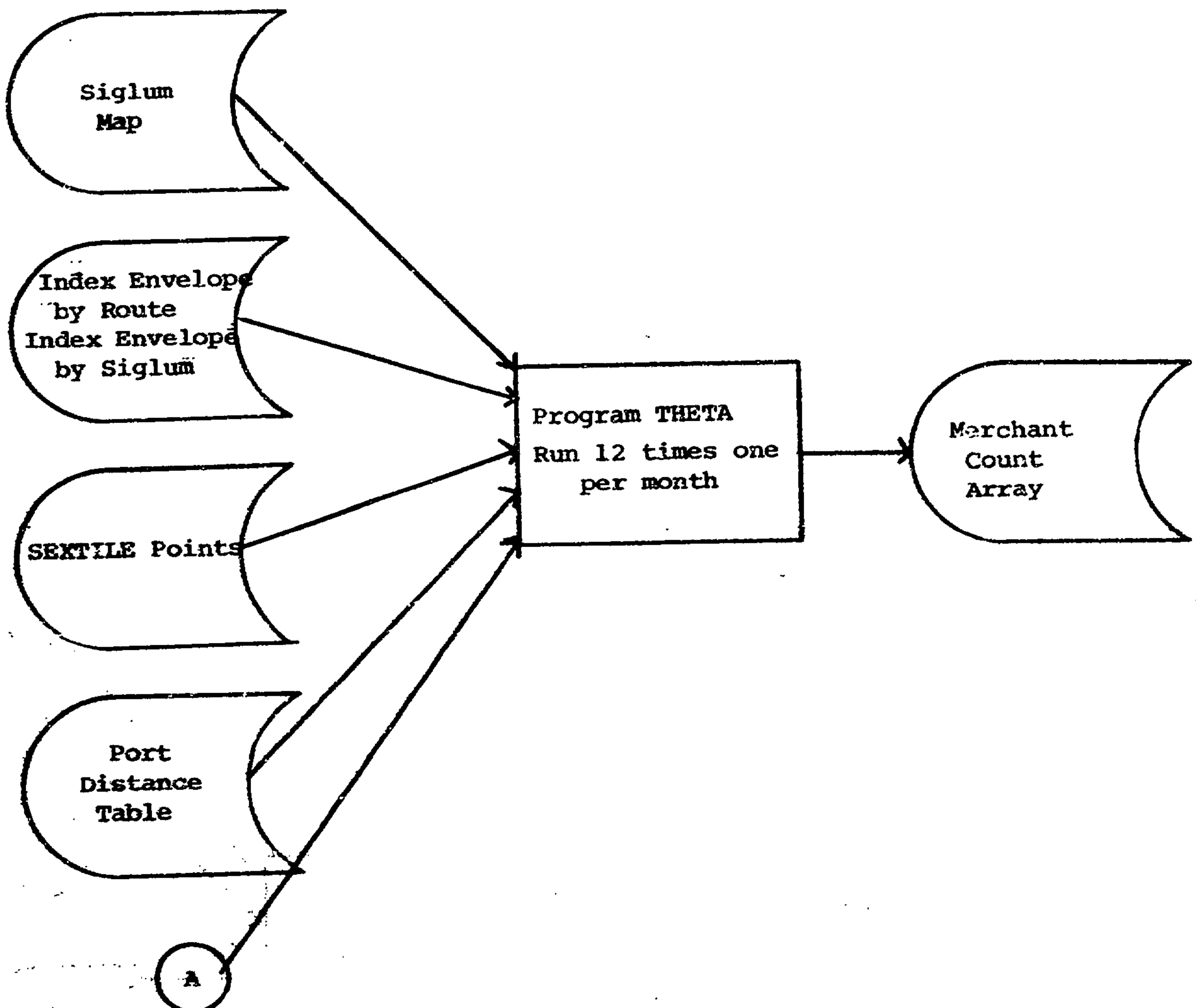
Page 3 of 5

Figure 7.1 (Continued)



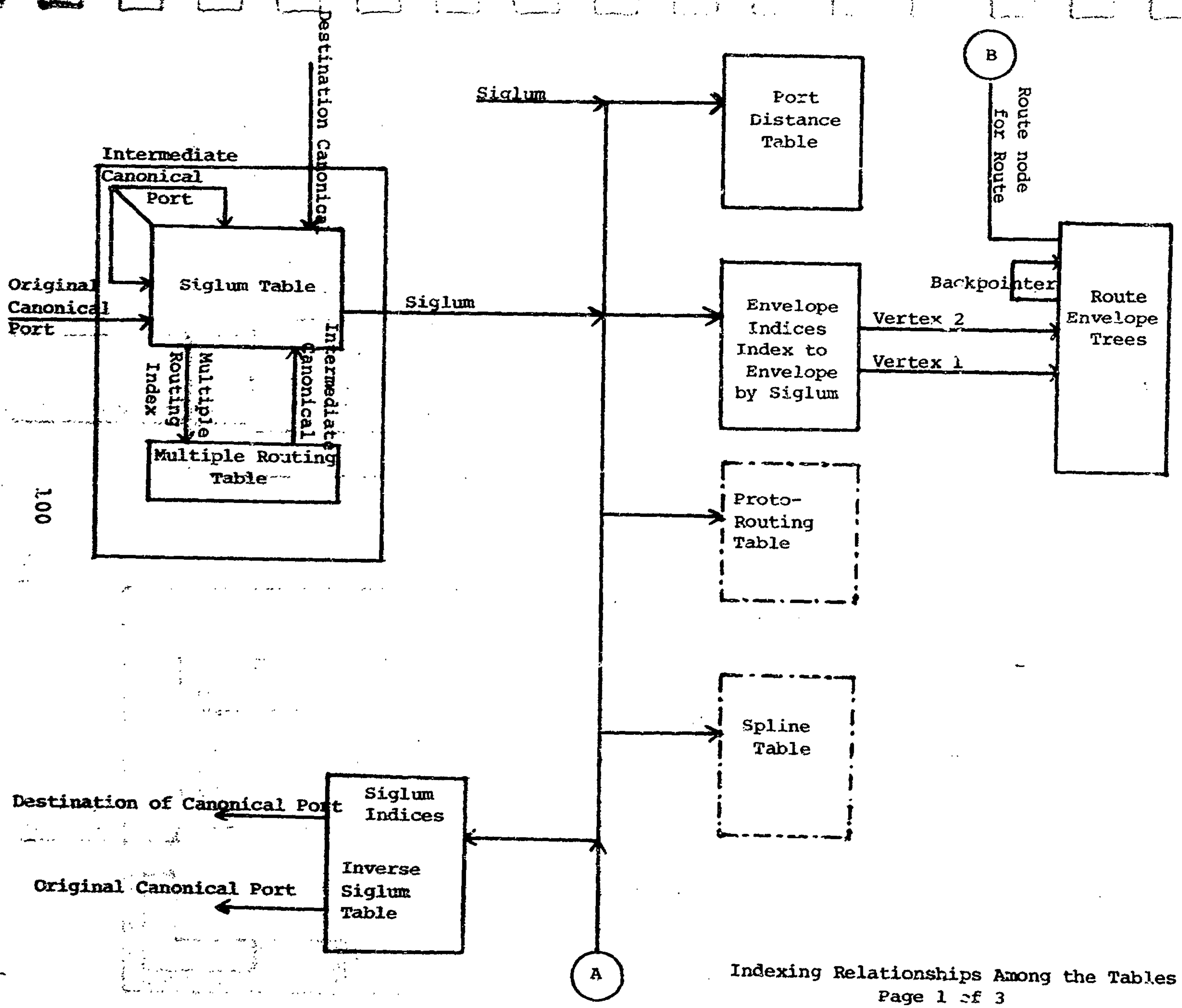
Data Sets, Program Interrelationships
Page 4 of 5

Figure 7.1 (Continued)



Data Sets, Program Interrelationships
Page 5 of 5

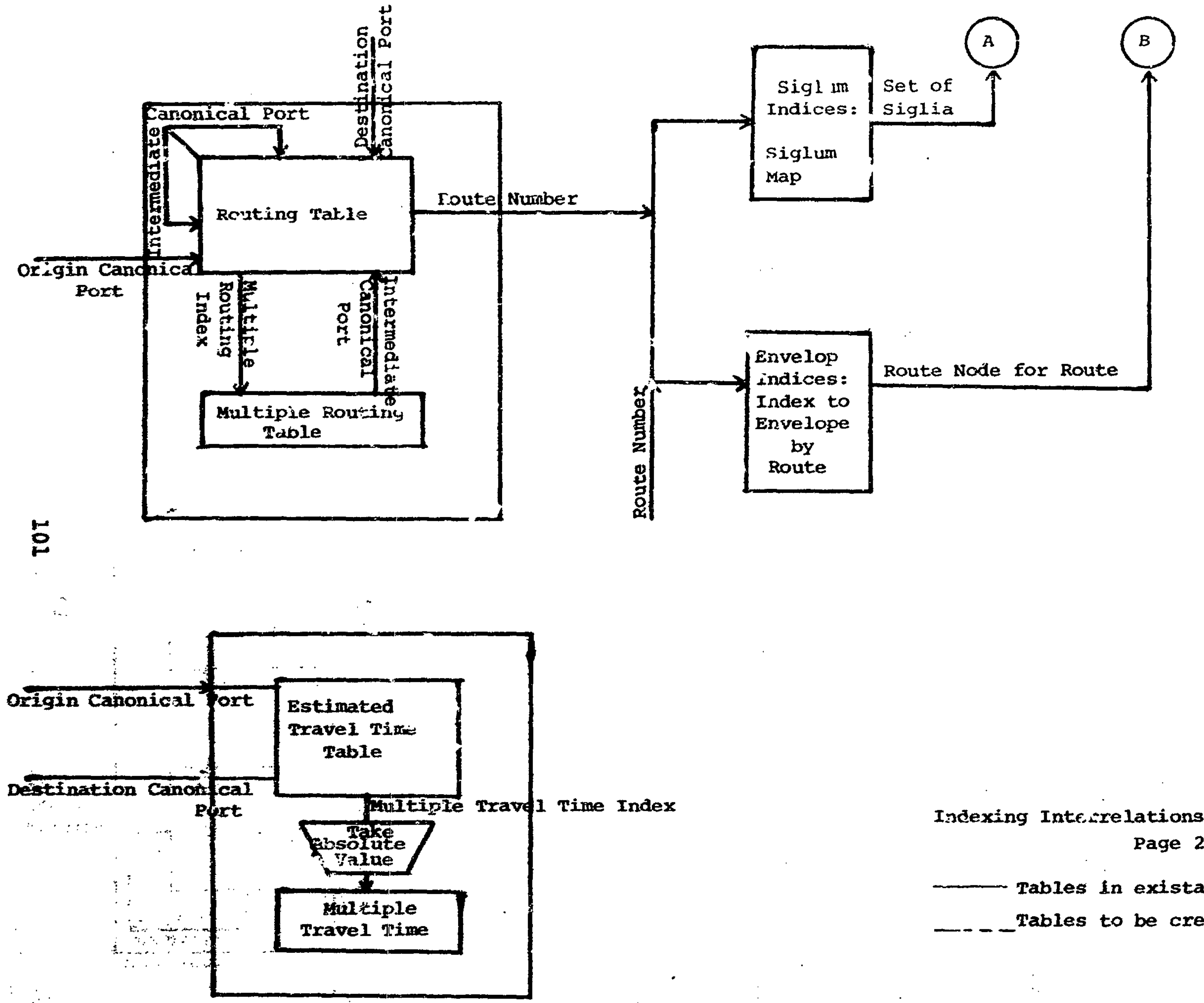
FIGURE 7.1 (Continued)



Indexing Relationships Among the Tables
Page 1 of 3

Figure 7.2

——— Tables in existance
-·-·- Tables to be constructed

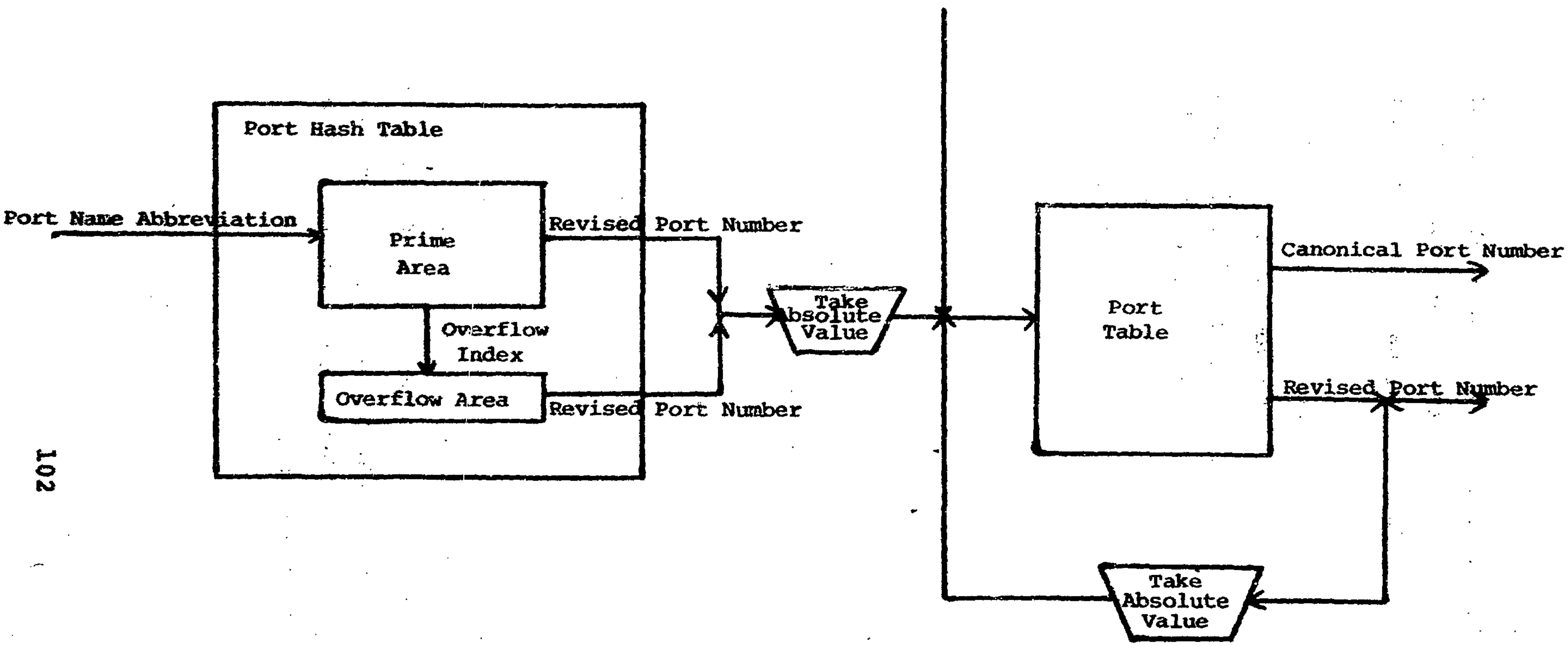


Indexing Interrelationships Among the Tables
Page 2 of 3

——— Tables in existance

- - - Tables to be created

Figure 7.2 (Continued)



Indexing Interrelationships Among The Tables
Page 3 of 3

Figure 7.2 (Continued)

2. Function of Each Program

Program Alpha: It obtains the ORE Routing Table (50x50) the Mediterranean Routing Table (24x24), and constructs the total Routing Table (69x69). Prints it out and stores it on a data set.

Program Beta: Converts original form of route envelope trees to the final form by converting degrees/minutes to decimal degrees, calculating edge lengths, inserting back pointers, and collecting leaf and route identifiers into two indices. These indices are the Index to Envelope by Route and the Index to Envelope by Siglum. A separate output tree is generated for each season.

Program Beta 1: Builds Siglum Table and Siglum Indices (Siglum Map and Inverse Siglum Table) from the Routing Table, except for moving the Multiple Routing Table from the Routing Table to the end of the Siglum Table.

Program Beta 2: It sums the edge lengths from the Route Envelope Trees (final form) to build the Port Distance Table. It determines the total path length for each Siglum. It must run once for each season.

Program Gamma 1: Constructs the Port Hash Table from the Port Table. The Port Name Abbreviation is converted to Hash Index by taking its S/370 numeric value, dividing by 2999, and using the remainder.

Program Gamma 2: Builds the Estimated Travel Times Table by tracing the Siglum Table and totaling Port Distances from the Port Distance Table. Assume a speed of 12 knots. For ships traveling from one canonical port to itself, a travel time of 0 days is recorded. This program must be run 4 times, once for each season.

Program Gamma: It reads the Lloyds Tapes by week, in reverse order (i.e., week 52 is first). It compares the tape with the ships from the previous tape (i.e., the following week) for error control. Uses the (updated) Canonical Port Mapping Table to find the two associated canonical ports. If three ports are given (i.e., an intermediate port), determine which segment the ship will be on during the week. [If it is on both, it is treated as two separate voyages]. If the associated canonical port indices for egress and entrance ports are α and β respectively, and the type is $\Gamma \varepsilon [1,3]$ (corresponding to the various ship types), then increment the (α,β,Γ)-th component of the Proto-Routing Table by the number of days in that week which the ship spent at sea. After processing all weeks for that month, write the Proto-Routing Table on disk. Zero out the matrix and begin to accumulate for the "next" (i.e., previous) month.

Program Delta 1: Provides a visual check on the Route Trees to catch transcription errors. It plots each vertex of the given route and designates canonical ports by a C and a non-canonical port by a V. The great circle path is generated and displayed between each pair of vertices. A 5° allowance is allotted on either ends of the route for clarity. The program was used for each of the four seasons on all 85 routes.

Program Delta 2: Checks the canonical port mapping. The non-canonical ports are plotted using symbols to denote the various associated canonical ports. This provides a quick checking procedure to determine if in a given area there are more than one canonical port associated to it. It also spots typographical errors occurring in the port table. An example of this is the occurrence of a port in the middle of a large landmass. The program is run in two parts, once for canonical ports 1-34 and is repeated for canonical ports 35-69.

Program Delta 3: Checks the Routing Table. Prevents the occurrence of infinite loops, and does various checks on non-direct routes. In the case of multiple route the check was done manually. When an error is spotted, a corresponding message is written.

Program Theta 1: Generates a set of x values to be used in Theta for the distribution. It takes a set of data points and determines the Type I' Cubic Spline in which it interpolates. Then it uses two iterations of Newton's Method to determine intermediate values between any two successive sextile points. Thus producing a set of 13 x values. This is done for each season.

Program Epsilon: This program reads a monthly Proto-Routing Table and from it generates a Ship-Days-Table.

Program Zeta: Inputs the oil rig densities in the one degree squares. It produces an 180x360 array containing the densities. (Only the yearly field is produced.)

Program Theta: Takes the Ship-Days-Table, created by Epsilon, applies the growth factor to the ship populations and converts the data from ship-days per route to ship-days per one degree square. The distributions are done between canonical ports, for the various types of vessels for each month. The array is known as the Merchants Count Array.

Program Iota: Reads the Merchant Counts Arrays (180x360) for all the various types of vessels. It then sums them up to produce the seasonal and yearly Merchant Counts Arrays.

3. **Detailed Table Description**

a. Port Table: Consists of a listing of 2,425 ports that were taken from Lloyd's data base for 1972 by the Department of Transportation. The information on the Port Table is in the form of Table 7-1 below.

Table 7-1 Sample of Port Table

509	DEMER	DEMERARA RIVER & DEMERARA	6N	58W	22	440
510	DEN H	DEN HELDER	52N	4E	33	44
511	DENMA	DENMARK	52N	4E	33	44
512	DERBY	DERBY	17S	123E	6	348
513	DERIN	DERINCE & DERINCJE	40N	29E	38	1
514	DESEA	PUERTO DESEADO	47S	65W	27	217
515	DETRO	DETROIT & DETROIT RIVER	42N	83W	20	56
516	DEVON	DEVONPORT (TASMANIA)	41S	146E	12	4
517	DEVONT	DEVONPORT (TASMANIA)	41S	146E	12	4
518	DHABI	ABU DHABI	24N	54E	40	77

The description of the fields are as follows: the port number, the abbreviation of the port name, the actual name of the port. On the right side we have the latitude and longitude of the port's location, the canonical port number to which the port is associated and the distance between the port and its canonical port. From the 2,425 ports, 69 major ports were extracted. They are listed in Table 7-2, along with their latitude and longitude.

b. Routing Table: Consists of a 69 x 69 matrix entered in 69 groups of 69 elements. Each group spans three lines with 24 elements each on lines 1 and 2, and 21 elements on line 3. Each entry contains either a letter code or a two digit number. If a two digit number appears then that is the route number that connects the two ports, namely, port a and port b. If a letter appears then it can be one of the following:

Table 7-2

Canonical Ports

Number	Name	Lat.	Long.
1	Bombay	18° 56'N	72° 51'E
2	Colombo	6° 57'N	79° 51'E
3	Calcutta	22° 33'N	88° 19'E
4	Singapore	1° 16'N	103° 50'E
5	Sunda Strait	6° 34'S	105° 50'E
6	Cape Leeuwin	34° 32'S	115° 08'E
7	Manila	14° 35'N	120° 58'E
8	Shang-hai	31° 14'N	121° 29' 30"E
9	Vladivostok	43° 06' 30"N	131° 53'E
10	Yokohama	35° 27'N	139° 39'E
11	Torres Strait	10° 33'S	142° 08'E
12	Wilson Promontory	39° 10'S	146° 26'E
13	Honolulu	21° 18' 30"N	157° 52' 15"W
14	Papeete	17° 32'S	149° 34'W
15	Seattle	47° 36'N	122° 22'W
16	San Francisco	37° 48' 30"N	122° 24'W
17	Havana	23° 08'N	82° 20' 30"W
18	New Orleans	29° 57'N	90° 03' 30"W
19	Straits of Florida	24° 25'N	83° 00'
20	New York	40° 42'N	74° 01
21	Montreal	45° 30' 10"N	73° 33'W
22	Panama	8° 53'N	79° 31'W
23	Valparaiso	33° 02'S	71° 38'W
24	Punta Arenas	53° 10'S	70° 54'W
25	Belém	1° 27'S	48° 30' 20"W
26	Rio de Janeiro	22° 53' 30"S	43° 11'W
27	Montevideo	34° 54' 30"S	56° 13' 30"W
28	~~Pentland Firth~~	58° 42'N	3° 20'W
29	Fastnet	51° 20'N	9° 36'W
30	Bishop Rock	49° 45'N	6° 35'W
31	Strait of Gibraltar	35° 57'N	5° 45'W
32	Marseille	43° 19' 10"N	5° 21' 17"E
33	Skagins Odde	57° 48'N	10° 44'E
34	Napoli	40° 50' 19"N	14° 16' 20"E
35	Cape of Good Hope	34° 22'S	18° 23'E
36	Leningrad	59° 55'N	30° 15'E

Table 7-2 (CONTD)

Number	Name	Lat.	Long.
37	Arkhangel'sk	64° 32'N	40° 31'E
38	Istanbul	41° 01' 15"N	28° 59' 09"E
39	Port Said	31° 16'N	32° 19'E
40	Al Basrah	30° 31' 30"N	47° 50' 30"E
41	Nome	64° 29'N	165° 25'W
42	Straits of Malacca (NW)	6° 50'N	95° E
43	Tiksi	71° 50'N	130° E
44	Cheluskin	77° 50'N	105° E
45	Churchill	58° 46'N	94° 11'W
46	Reykjavik	64° 09'N	21° 56'W
47	Dakar	14° 41'N	17° 26'W
48	Guayaquil	2° 12'S	79° 53'W
49	Petropavlovsk	53° N	158° 38'E
50	Nagayevo	59° 33'N	150° 45'E
51	Barcelona	41° 23'N	2° 10'E
52	Genova	44° 25'N	8° 57'E
53	Livorno	43° 31'N	10° 18'E
54	Messina	38° 15'N	15° 40'E
55	Oran	35° 40'N	0° 39'W
56	Strait of Bonifacio	41° 18'N	9° 11'E
57	Tarabulus	32° 52'N	13° 12'E
58	Alexandria	31° 15'N	29° 55'E
59	Venice	45° 28'N	12° 23'E
60	Trieste	45° 40'N	13° 45'E
61	Piraievs	37° 55'N	23° 40'E
62	Thessalonica	40° 38'N	22° 53'E
63	Izmir	38° 24'N	27° 04'E
64	Dardanelles	40° 03'N	26° 05'E
65	Iskenderun	36° 40'N	36° 05'E
66	Beirut	33° 58'N	35° 30'E
67	Tel Aviv	32° 04'N	34° 42'E
68	Strait of Otranto	40° 17'N	18° 34'E
69	Strait of Sicily	37° 15'N	11° 15'E

- P means that ports a and port b are connected by an intermediate port namely the number that follows P.
- Blank means that port a and port b are connected by a direct route namely the number following it.
- B means that a multiple route can be taken. The number following the B represents the line number in the Multiple Routing Table. It will consist of 2 entries, the first number is the first intermediate port to be taken by super-tankers while the second number is the first intermediate port to be taken by tankers.
- N means that there is no route between ports. This arises when port a equals port b.

Below is a sample listing of the Routing Table.

Table 7-3

```
N 0 69P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P39P39P39P39P39P39P35P35
P39P39P39P39P39P39P39P39P39P39P39 61P39P39P39 58 69P 2P 2P39P39P39P39P39P39
P 2P 2P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39
 69N 0 62 59 59P 5P 4P 4P 4P 4P 4P 5P 4P 4P 4P42P39P39P39P39P39P39P35P35
P39P35P35P39P39P39P39P39P39P39 62P39P39P39 59 59P 4 59P39P39P39P39P39P39
P 4P 4P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39
P 2 62N 0 29P 4P 4P 4P 4P 4P 4P 4P 4P 4P 4P 4P 4P 2P 2P 2P 2P 2P 2P35P35
P 2P35P35P 2P 2P 2P 2P 2P 2P 2 62P 2P 2P 2P 2P 2P42 29P 2P 2P 2P 2P 2P 2
P 4P 4P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2P 2
P 2 59 29N 0 59P 5 71 72P 7 28 27P 5 14P11P10P13P39P39P39P39P39  4P11P11
P39P 5P 5P39P39P39P39P39P39P39 62P39P39P39 59 59P10 29P39P39P39P39P39P22
P10P10P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39
P 2 59P 4 71N 0 25 72 72P 4P 4 71P 6P 4P11P 4P 4P 4P 4P 4P 4P 4P 4P11P35
P 2P35P35P39P39P39P39P39P39P39 63P39P39P39 63 59P 4P 4P39P39P39P39P39P 4
P 4P 4P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39P39
```

c. <u>Route Trees</u>: There are four versions of the Route Trees, one for each season. There are presently 85 routes connecting the 69 pairs of canonical ports. The table contains various information. Field one contains the vertex identifier which is in binary form, field two contains the latitude and longitude of the vertex identifier in decimal degrees. Southern and eastern hemisphere are designated by a negative sign and North and West are positive. The third field represents the vertex width; i.e., the width of the envelope at the vertex. Field four is the edge length, which is the length of the previous route segment when progressing forward through the route. Field five is the edge width, which is the widest part of the envelope on the previous route segment while traveling forward through the route. The last field is the back-pointers, they indicate how the vertices are linked together. When progressing backwards along a route, the back pointers indicate the line in the Route Trees to which the present vertex is connected. Whenever one begins a new route the backpointer is set to zero and the identifier is 1. Table 7-4 is a sample of the Route Trees.

Table 7-4 Sample of Route Trees

Line #	I	II	III	IV	V	VI
28	1	+45.00+170.00	0.00	000.00	0.00	0000
29	10	+45.00+160.00	4.00	007.30	4.00	0028
30	100	+46.50+124.66	0.00	025.02	4.00	0029
31	1000	+47.00+122.36	0.00	001.78	0.00	0030
32	101	+37.90+122.40	0.00	029.45	5.00	0029
33	11	+45.00-130.00	2.00	028.77	3.00	0028
34	110	+35.45-139.65	0.00	010.99	3.00	0033
35	111	+31.00-131.00	0.25	019.28	2.00	0033
36	1110	+31.00-130.83	0.25	000.14	0.25	0035
37	11100	+31.23-121.46	0.00	008.37	1.00	0036
38	1	+03.25+079.75	0.00	000.00	0.00	0000
39	10	+03.01+079.41	0.00	000.47	0.10	0038
40	100	+07.00+080.10	0.25	002.04	0.25	0039
41	1000	+06.91+081.41	0.33	001.24	0.33	0040
42	10000	+17.30+105.00	1.00	025.92	1.50	0041
43	100000	+10.91-125.83	0.12	021.54	4.00	0042
44	1000000	+10.93-125.50	0.25	000.33	0.25	0043
45	10000000	+09.91-125.33	0.25	000.93	0.12	0044
46	100000000	+09.00-123.75	0.12	001.40	0.12	0045
47	1000000000	+07.60-116.50	0.25	007.29	0.50	0046
48	10000000000	+01.20-103.63	0.00	014.15	1.00	0047
49	1	+21.30+157.86	0.00	000.00	0.00	0000
50	10	+54.33+165.00	0.12	033.47	4.00	0049
51	100	+60.00+167.86	1.00	005.87	2.00	0050
52	1000	+64.48+165.41	0.30	004.62	2.00	0051

d. <u>Siglum Table</u>: This table is again a 69 x 69 matrix entered in 69 groups of 69 entries. Each group spans 4 lines with 18 entries on the first three lines and 15 entries on the last. The codes for the entries are exactly like those of the Routing Table except for the case where port a and port b are connected by a direct route; i.e., no intermediate stop. In this table the route numbers have been replaced by Siglia. To every ordered pair of canonical ports that are linked by a direct route a different siglum is assigned. Presently there are 501 siglia. The first pair of canonical ports that are connected by a direct route is the first siglum, the second pair is siglia number 2 and so forth. Table 7-5 is a sample of the Siglum Table.

Table 7-5 Siglum Table Sample

N	0	1P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	39P	39
P	39P	39P	39P	39P	35P	35P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39	2P	39
P	39P	39	3	4P	2P	2P	39P	39P	39P	39P	39P	39P	2P	2P	39P	39P	39P	39
P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39			
	5N	0	6	7	8P	5P	4P	4P	4P	4P	4P	5P	4P	4P	4P	42P	39P	39
P	39P	39P	39P	39P	35P	35P	39P	35P	35P	39P	39P	39P	39P	39P	39P	39	9P	39
P	39P	39	10	11P	4	12P	39P	39P	39P	39P	39P	39P	4P	4P	39P	39P	39P	39
P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39			
P	2	13N	0	14P	4P	4P	4P	4P	4P	4P	4P	4P	4P	4P	4P	4P	2P	2
P	2P	2P	2P	2P	35P	35P	2P	35P	35P	2P	2P	2P	2P	2P	2P	2	15P	2
P	2P	2P	2P	2P	42	16P	2P	2P	2P	2P	2P	2P	4P	4P	2P	2P	2P	2
P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2P	2			
P	2	17	18N	0	19P	5	20	21P	7	22	23P	5	24P	11P	10P	13P	39P	39
P	39P	39P	39	25P	11P	11P	39P	5P	5P	39P	39P	39P	39P	39P	39P	39	26P	39
P	39P	39	27	28P	10	29P	39P	39P	39P	39P	39P	22P	10P	10P	39P	39P	39P	39
P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39			
P	2	30P	4	31N	0	32	33	34P	4P	4	35P	6P	4P	11P	4P	4P	4P	4
P	4P	4P	4P	4P	11P	35P	2P	35P	35P	39P	39P	39P	39P	39P	39P	39	36P	39
P	39P	39	37	38P	4P	4P	39P	39P	39P	39P	39P	4P	4P	4P	39P	39P	39P	39
P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39P	39			

e. Siglum Indices: This table consists of two sub-tables; Inverse Siglum Table and Siglum Map. The Inverse Siglum Table is headed by 'INV#SGLM#TBL' followed by a list of number pairs. Each pair corresponds to a successive siglum, and contains two (2) digit numbers specifying the pair of canonical ports. The first entry, " 1 2", says that ports 1 and 2 are connected by a direct route and is designated as siglia 1. There are presently 501 sigla. The Siglum Map is headed by 'SGLM#MAP' and it contains 85 routes each requiring three lines. Each group contains a header entry plus 45 entries (15 per line). The header entry (the first entry of each group) specifies the number of port pairs linked by that route (or equivalently, the number of sigla assigned to each route). Table 7-6 is a sample of the two tables.

Table 7-6 Sample Data from Inverse Siglum Table and Siglum Map

INV#SGLM#TBL

1 2	135	139	140	2 1	2 3	2 4	2 5	235	239	240	242
3 1	3 4	335	342	4 2	4 3	4 5	4 7	4 8	410	411	413
422	435	439	440	442	5 2	5 4	5 6	5 7	5 8	511	535
537	540	6 5	6 7	612	635	637	7 4	7 5	7 6	7 8	710
711	713	749	750	8 4	8 5	8 7	8 9	810	813	815	816
822	850	9 8	915	949	950	10 4	10 7	10 8	1012	1013	1015
1016	1022	1041	1047	1050	11 4	11 5	11 7	1112	1113	1114	1122
1123	1124	1135	12 6	1210	1211	1213	1214	1222	1223	1224	1235

SGLM#MAP

12	303	304	305	337	338	339	340	349	350	351	352	353	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	64	65	117	372	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	59	60	72	73	116	118	122	123	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	25	101	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

f. Port Distance Table: This table consists of 6 pairs of numbers per line. The first number in each pair is the number of the Siglum to which the pair corresponds. The second is the distance (in units of latitudinal degrees) between the pair of canonical ports corresponding to that siglum. There are 4 Port Distance Tables, one for each season. Below is a partial listing of the Port Distance Table for the fall.

Table 7-7 Sample Data from Port Distance Table
Fall

1	15.00	2	78.36	3	51.29	4	26.23	5	15.00	6	20.94
7	27.44	8	35.46	9	86.35	10	57.07	11	42.08	12	17.03
13	20.94	14	27.02	15	101.93	16	17.20	17	27.44	18	27.02
19	8.02	20	22.00	21	37.69	22	47.79	23	43.21	24	98.16
25	175.82	26	94.96	27	34.51	28	65.94	29	10.42	30	55.46
31	12.65	32	29.73	33	26.49	34	41.73	35	39.23	36	86.27
37	86.66	38	73.96	39	29.73	40	50.32	41	25.34	42	60.15
43	105.91	44	22.00	45	26.49	46	50.32	47	18.76	48	29.74

g. Estimated Travel Time Table: This table is a 69 x 69 matrix where each entry corresponds to every possible canonical port pair, whether linked by a direct route or not. These entries are arranged in 69 groups of 69 entries spanning 4 lines. The entries represent the expected travel time in integral days betweeen the two ports. If the entry is negative, the absolute value of this number is an index to the Multiple Travel Time Table, which follows immediately. This table consists of a pair of numbers, giving the estimated travel time for both super-tankers and non-super-tankers. This table is also seasonally dependent, one for each of the four seasons. Table 7-8 is a sample of the Estimated Travel Time Table for the spring.

Table 7-8 Sample of Estimated Travel Time Table (Spring)

23	25	29	31	31	35	35	38	42	41	39	40	34	33	32	29	15	16
14	10	8	18	28	27	17	25	29	0	2	3	6	8	2	9	23	5
8	12	13	-8	38	28	15	13	15	2	10	21	45	46	8	9	9	10
7	9	10	13	12	12	11	12	12	12	13	14	13	10	9			
21	23	27	29	29	33	33	36	40	39	37	38	32	31	30	27	15	17
15	11	8	16	26	25	15	23	27	2	0	1	4	6	3	7	21	7
10	10	11	-9	37	26	17	15	15	20	8	19	43	44	6	7	7	8
5	7	8	11	10	10	9	10	10	10	11	11	11	8	7			
21	22	27	28	28	32	33	36	40	38	36	38	31	31	29	26	15	16
14	10	9	15	25	24	15	17	21	3	1	0	3	6	3	7	20	6
9	10	10	-10	36	26	16	14	16	4	8	18	43	44	5	6	6	7
4	6	7	11	9	9	9	9	9	9	11	11	11	8	6			
17	19	23	25	25	29	29	32	36	35	33	34	31	31	29	26	14	16
14	11	15	15	25	22	11	19	23	6	4	3	0	2	6	3	18	10
13	6	7	-11	36	22	20	18	21	7	5	18	39	40	2	3	3	4
1	3	4	7	6	6	5	6	6	6	7	8	7	4	3			

h. <u>Proto-Routing Table</u>: This table consists of three 69 x 69 arrays; the first for merchants, the second for tankers less tahn 70,000 gt, and the third for tankers greater than 70,000 gt. The first line indicates which month is being processed, for example in Table 7-9 we are processing Week 48 i.e., month December. The second line indicates the ship type; for example; Tau = 1 for merchants. The 69 x 69 elements spans 5 lines. The entries represent the number of ship days traveled between any pair of canonical ports of a given ship type in a given month. There exists 12 Proto Routing Tables, one per month. Table 7-9 is a sample of Proto 48.

Table 7-9 Sample Data from Proto 48

WEEK=48
TAU=1

213	162	226	205	22	0	52	30	0	500	0	51	0	0	8	32
0	15	0	46	22	0	0	0	0	37	0	10	50	0	17	0
212	0	144	0	0	56	0	310	0	7	0	0	0	0	15	35
0	0	0	0	0	0	0	0	14	0	0	25	0	0	0	0
0	0	0	0	0											
84	105	152	102	14	28	10	70	0	68	15	13	0	0	43	0
11	167	67	60	39	34	0	0	0	19	0	0	103	0	0	0
241	0	180	0	19	69	0	205	0	0	0	0	0	0	66	9
0	0	0	0	0	0	0	0	14	0	0	34	0	0	0	0
0	0	0	0	0											
70	128	249	240	0	0	20	54	0	123	0	0	0	0	0	87
0	46	0	0	0	0	35	0	0	0	0	0	40	0	0	0
67	0	174	0	0	76	0	105	0	8	0	0	0	0	0	0
0	0	0	0	0	0	0	0	16	14	0	74	0	0	0	0
0	0	0	0	0											
176	78	120	388	50	94	700	987	168	1510	18	209	13	20	62	198
76	66	0	136	21	269	0	0	0	41	51	20	266	28	144	54
990	16	763	33	0	400	39	775	7	90	0	0	0	0	562	0
0	0	0	23	13	0	22	0	21	9	0	115	0	0	0	0
0	0	0	63	42											
0	7	8	72	68	0	42	108	0	104	8	75	0	0	0	0
0	6	0	24	0	0	0	0	0	0	0	0	0	0	0	0
147	0	0	0	0	0	0	15	0	35	0	0	0	0	60	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	19	0	0	0											

i. Ship Days Table: The format is similar to that of The Proto Routing Table; namely, that it consists of three tables each having 501 entries. These are again three different ship types, TAU = 1, TAU = 2, TAU = 3. The elements are listed according to sigla; i.e., canonical ports linked by a direct route, which represent the total number of ship days for the sigla; i.e., between the pairs of canonical ports. Following it lies the Residual Table, again by ship type. The Residual Table stores the number of ship days to be distributed for local traffic and 'non-route' traffic about the canonical ports. Table 7-10 is a sample of the ship days table for month 48; i.e., December

Table 7-10 Sample Ship Days Table

TAU = 1

450.2	144.0	265.4	310.0	280.8	481.3	493.9	68.9
191.7	607.0	275.1	6.8	265.1	334.0	191.9	8.0
435.3	245.6	145.6	1162.9	1838.2	3485.5	198.3	332.6
269.0	1180.9	3800.8	1569.1	252.3	43.5	402.9	318.3
164.1	203.2	28.6	55.8	139.7	191.5	269.4	964.1
792.1	42.0	1694.9	1106.2	36.0	674.0	537.0	1128.3
87.6	766.9	0.0	0.0	294.0	36.0	515.0	354.8
532.9	108.1	268.0	223.0	281.9	0.0	169.3	43.0
0.0	0.0	2619.6	1154.4	698.1	699.0	763.2	1725.1
2236.0	1115.0	90.2	0.0	5.8	975.6	0.0	55.5
295.7	42.6	110.1	289.6	8.1	0.0	72.0	794.3
924.0	308.6	358.2	45.0	875.1	75.0	18.7	218.2

CHAPTER VIII

Conclusions

This report provides shipping distribution by 1° square throughout all the ocean areas in the world. The distributions are temporally divided by month, season, and annual average. The ships are broken down into 5 classes: merchants, tankers, super tankers, fishers, and oil rigs.

The temporal variation is clearly area dependent. Some areas, such as the North Pacific are very seasonal dependent; other areas, such as the Indian Ocean are almost seasonal independent.

Fishing vessels are distributed for only winter and summer. These distributions are based on nutrient distribution and area catch tonnage. There is no raw data describing at-sea positions which allowed a refinement for densities.

The merchant and tanker distributions are heavily based upon Lloyd's Shipping Index for 1972, with growth factors applied to update the port traffic to 1978. The 1972 data base was rather spotty in inherent quality. Considerable care was taken in polishing and editing the individual data entries. A new data base of better quality would provide better absolute numbers; however, the basic shipping patterns would almost assuredly remain unchanged.

Multiple sources were used for trend and growth analysis of the 1972 data base. The growth is definitely geographically dependent. The merchant vessel population increased rather slowly; tanker population increased by 60 percent from 1972 to 1978. Both populations changed in character; i.e., ship type, size, tonnage, speed, power plant, and construction technique.

The predicted data base was verified by comparison with results of naval exercises. Agreement within a rather large area of the North Pacific is within one standard deviation of the measured result. Additional comparisons should be made as more statistically reliable data becomes available. Until that time it is believed that the results are easily correct within a factor of two (2) and can be used with confidence for a number of analyses.

APPENDIX

Program Documentation

A. PROGRAM: ALPHA (RTNGMRGE)

REFERENCE PARAMETERS - PROGRAMS;

DSNAME = CN5054.PS1.ALPHA

VOL = SER = PUBL03

UNIT = 3330

DCB = (BLKSIZE = 3120, LRECL = 80, RECFM = FB)

Sequenced 73/80. (Wylbur line numbers)

REFERENCE PARAMETERS - JCL and CONTROL DATA SET:

DSNAME = CN5054.PS1.JCL(ALPHA)

VOL = SER = PUBL03

UNIT = 3330

WYLBUR EDIT format

FUNCTION: Merges the original Routing Table and the Mediterranean Routing Table to form the final routing table. It determines the correspondence between the Mediterranean route and port numbers and those used in the final routing table. The program is written in a generalized form to allow use for other, similar applications with different numbers of points, routes, and multiple routing tables, and also difference function points between the original and additional routing tables. Similar routes and ports from additional and original routing tables are overlayed.

INPUT DATA SETS:

FILENAME	DSNAME	CONTENTS
ORG	RTNGTBL.ORG	Routing Table (original version) including Muliple Routing Table.
ADD	RTNGTBL.ADD	Routing Table (Mediterranean additions), including Multiple Routing Table (if any).

FILENAME	DSNAME	CONTENTS
ADD	RTNGTBL.ADD	(Both ORG and ADD may contain any number of entries per line, provided that the LRECL specified by JCL or Volume Table-of-Contents is exactly equal to the line length with no extra padding blanks at the end. Each run of the routing table must start on a new line; in that case only the preceding line may be truncated. The format is otherwise under control of the Control Data Set parameters, (discussed below). The multiple Routing Tables should immediately follow the main routing tables, with one pair per line and no spaces between them, with the same number of digits as specified for the main routing table.
SYSIN	-	Control Data Set Parameters: ORG#NO#PORTS (Number of ports in the original routing table) ORG#NO#ROUTES (Number of routes in the original routing table) ORG#NO#MRTS (Number of multiple routing tables in the original routing table) ORG#NO#DIGITS (Number of digits in the routing table used for recording ports, routes, and multiple-routing-table numbers) ADD#NO#PORTS (Number of ports in the additional routing table)

FILENAME	DSNAME	CONTENTS
SYSIN	-	ADD#NO#ROUTES (Number of routes in the additional routing table) ADD#NO#MRTS (Number of multiple routing tables in the additional routing table) ADD#NO#DIGITS (Number of digits in the additional routing table used for recording ports, routes, and multiple-routing table numbers). NEW#NO#PORTS[1] (Number of port for which space should be allocated in the new routing table). NEW#NO#DIGITS (Number of digits to be used in the new routing table for recording ports, routes, and multiple routing table numbers)

These parameters are read in Data-directed format.
This is followed by a list giving the port in the original routing table which is closest to the port in the additional routing table. There is one line for each port in the additional routing table, and two entries per line. The first giving the number of the closest port in the original routing table, the second a code (enclosed in single quote) which is 'IDENT' if ports are identical, and 'ADJCN' if they are merely adjacent. Otherwise, this list may be in free format.
This is followed by a list of number pairs specifying which routes from the additional routing table are to be overlayed on routes, from the original routing table. The first element of each pair gives the additional route number, and the second the original number. The list is terminated by two '0's. At least one space or a comma must be inserted between entries, otherwise, this list may be in free-form format.

[1]May be omitted if equal to 2.

OUTPUT DATA SETS:

FILENAME	DSNAME	CONTENTS
NEW	RTNGTBL.NEW	New routing table, along with the multiple routing table.
SYSPRINT	SYLIB (PORTNO)	Error messages, along with the table of correspondence between additional and new port numbers, and the multiple routing table numbers (original numbers are carried over unchanged).

JCL USAGE: Assumes that a load module has been placed by the linkage editor specifying the NCAL option in LINKLIB (ALPHA) and is now to be reprocessed by the loader.

MAJOR VARIABLES:	CONTENTS
PORT#INDX.NEW#PORT#NO	An array referenced by an additional port number containing corresponding new port numbers.
PORT#INDX.ADD#PORT#NO	Array referenced by new port number containing corresponding additional port number, or '0' if none.
ROUTE#INDX.NEW#ROUTE#NO	Array referenced by additional route number, giving number of corresponding route in new routing table.
PORT#MAP	Array referenced by additional port numbers containing port number of closest original port, and code (either "IDENT" or 'ADJCN')
ORG#RTNG#TBL,ADD#RTNG#TBL, NEW#RTNG#TBL	Two dimensional arrays referenced by original, additional, and new port numbers, respectively, containing routing tables.

MAJOR VARIABLES:	CONTENTS
MRT#TBL	Array used to hold multiple routing tables, referenced by new multiple routing table number.
(RTNG#ELEMENT, RTNG#ELMNT#1 (#2,#3) MRT#ELMNT)	Various temporaries, used while building tables.

PROGRAM STRUCTURE

LINES	FUNCTION
5/35	Reads in control parameter, checks for consistency
38/141	Reads in list of original ports closest to additional ports, and determines the correspondence between additional ports, routes, and multiple routing table numbers and those used in the new routing table. Builds PORT#INDEX and ROUTE#INDEX for later use.
145/368	Reads in original and additional routing tables, builds new routing table, and writes it out. (More details are provided by comments in the program.)

PROGRAM MESSAGES: (apart from new/additional routing table correspondence list)

'SEVERAL ADDITIONAL PORTS HAVE BEEN IDENTIFIED WITH THE ORIGINAL PORT NO XXX INDICATING ERROR IN PORT MAPPING SECTOR. EXECUTION TERMINATING.'

Response: Correct control data set

'INVALID LINKAGE CODE IN PORT MAPPING VECTOR, ADD PORT NO XXX EXECUTION TERMINATING.'

Response: Correct control data set

SYSTEM MESSAGES: (Probable meaning)

'CONVERSION' CONDITION RAISED, 'ONFILE' = {ORG / ADD}

Response: Make sure that the control data set parameters correspond to the actual format of the input routing tables. Make sure LRECL of input routing tables allows for no blanks at end of each line (except for truncated lines at end of the row). Checks the numeric fields for invalid character in the input routing tables.

COMPLETION CODE SZZZ TIME LIMIT EXCEEDED

Response: Checks for infinite recurive loop in additional routing table that are triggered in lines 257/351.

B. PROGRAM: BETA1

REFERENCE PARAMETERS (SOURCE PROGRAM)

DSNAME = CN5054.PS1.BETA1

VOL = SER = PUBL03

DCB = (RECFM = FB, BLKSIZE = 3120 LRECL = 80)

Sequenced 73/80 WYLBUR line numbers.

REFERENCE PARAMETERS (LOAD MODULE):

DSNAME = CN5054.PS1.LINKLIB(BETA1)

VOL = SER = PUBL03

UNIT = 3330

Load module may be invoked by // EXEC PGM = BETA1

REFERENCE PARAMETERS (JCL), (For load module invocation)

DSNAME = CN5054.PS1.JCL(BETA1),

VOL = SER = PUBL03

UNIT = 3330

Wylbur EDIT format

FUNCTION: Builds Siglum Table and Siglum Indices (Siglum Map and Inverse Siglum Table) from Routing Table, except for moving the Multiple Routing Table from the Routing Table to end of the Siglum Table, which must be done by hand.

INPUT FILES:

DDNAME	DSNAME	CONTENTS
RTNGTBL	CN5054.PS1.RTNGTBL.NEW	Final version of Routing Tables, must be precisely in format specified in table descriptions

OUTPUT FILES:

SGLMNDX	CN5054.PS1.SGLMNDX	Inverse Siglum Table and Siglum Map
SGLMTBL	CN5054.PS1.SGLMTBL	Siglum Table

MAJOR VARIABLES:

INV#SGLM#TBL	Inverse Siglum Table
SGLM#MAP	Siglum Map
SGLM#TBL,RTNG#TBL	Routing Table, on input, converted to Siglum Table in place.

PROGRAM PARAMETERS:

The following parameters are set implicitly by the program structure and will necessitate program modification if changed.

PARAMETER	REFERENCES (LINE NUMBERS)
Number of Canonical Ports (69)	24,27 Dimension 52,74 I/O Format 54, DO loop limit
Number of Canonical Routes (85)	19 Dimension 20,21 Repetition factor in INITIAL attribute 75,4 I/O Format 72,22 DO Loop Limit
Maximum Number of Sigla (600)	16 Dimension
Maximum Number of Sigla per Route (45)	21 Dimension 21 Repetition factor in INITIAL attribute 75.4,75.5 I/O Format (Note: overflow of this number may be easily detected by examining the Siglum Map. The first entry per route is the actual number of the Sigla for that route. If this is greater than 45, this parameter must be increased.)

PROGRAM STRUCTURE:

LINES	FUNCTION
50/52	Reads in the Routing Table.
54/60.6	Converts all entries flagged as representing direct routes to Sigla, building simultaneously the Inverse Siglum Table and Siglum Map.
601/end	Writes out Siglum Table, Inverse Siglum Table, Siglum Map

PROGRAM MESSAGES: None

SYSTEM MESSAGES (WITH PROBABLE CAUSE):

'CONVERSION' CONDITION RAISED, 'ONFILE' = RTNGTBL

Response: Check the Routing Table for invalid code. Make sure that the format corresponds to that given in table descriptions.

C. PROGRAM: BETA

REFERENCE PARAMETERS - SOURCE PROGRAM;

DSNAME = CN5054.PS1.BETA

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB,BLKSIZE=3120,LRECL=80)

sequenced 73/80 with WYLBUR line numbers.

REFERNECE PARAMETERS - LOAD MODULE;

DSNAME = CN5054.PS1.LINKLIB (BETAF) Note Suffix

VOL = SER = PUBL03

UNIT = 3330

Load module read for execution via PGM parameter of EXEC card; no link-editing necessary.

REFERENCE PARAMETERS - JCL

DSNAME = CN5054.PS1. JCL(BETA)

VOL = SER = PUBL03

UNIT = 3330

Wylbur EDIT format

FUNCTION: Converts the original form of the route envelope trees to the final form by converting degrees/minutes to decimal degrees, calculating edge length, inserting back pointers, and collecting leaf and route identifiers into two indices, the Index to Envelope by Route and the Index to Envelope by Siglum. A separate output tree is generated for each season.

As a secondary by-product, it effectively compares all direct-route linkages in the routing table through the intermediary of the Siglum Map and Inverse Siglum Table to the associated route envelope trees. It prints an error message if a branch of a route tree is never referenced by the route table. Inspection of the Index to Envelope by Siglum will also reveal any direct-route linkage for which no associated branch in the route Envelope Tree exists, as the indicated line number, will be '999.99'.

A '999.99' for latitude or longitude in the output route envelope trees means that a vertex has been omitted for some season in input.

INPUT DATA SETS:

DDNAME	DSNAME	CONTENTS
SGLMNDX	CN5054.PS1.SGLMNDX	Inverse Siglum Table and Siglum Map
INENV	CN5054.PS1.ENVELOPE	Original Version of Route Trees

OUTPUT DATA SETS:

ENVINDX	CN5054.PS1.ENVINDX	Index to Envelope by Route and Index to Envelope by Siglum
OUTENVP	CN5054.PS1.OUTENV. SPRING	Final version of Route Envelope, one per season.
OUTENVS	CN5054.PS1.OUTENV. SUMMER	
OUTENVF	CN5054.PS1.OUTENV. FALL	
OUTENVW	CN5054.PS1.OUTENV. WINTER	

JCL USAGE: Assumes that the load module has been placed in CN5054.PS1.

PROGRAM PARAMETERS:

The values of the following parameters, are set implicitly via program structure. The program must be revised and recompiled if they are changed:

PARAMETERS	REFERENCES (POSSIBLY NOT COMPLETE) BY LINE
Maximum # of routes (85)	13,48 Dimension
	14 Repetition factor in INITIAL attribute
	78,245 Repetition factor in FORMAT

PARAMETERS	REFERENCES (POSSIBLY NOT COMPLETE) BY LINE
Maximum # of Siglum (506)	15,46 Dimension 16 Repetition factor in INITIAL attribute (2X number of Sigla) 77,246 Repetition factor in FORMAT
Maximum # of Sigla per route (45)	50 Dimension 78 Number of lines read by FORMAT from Siglum Map (3)
Maximum # of Output Vertices per Route (75)	16.3,17 Dimension 16.5,16.6 Repetition factor in INITIAL attribute

PROGRAM MESSAGES:

'PORT W ROUTE ENVELOPE DOES NOT OCCUR IN ROUTING TABLE, ROUTE NO = XXX YYYYY'

XXX is Route number

YYYY is print out of leaf, as taken from original form of Route Tree.

Message may be printed twice for the same leaf, if it is marked in the input Route Trees as being used for both entrance and egress and is used in Routing Table for neither purpose.

Response: Correct Route Trees by eliminating unused branch of the route, or correct the Routing Table by finding some use for the route, or ignore it if certain that the error is harmless, (Note: Route 21 and and one branch of route 12 are currently unused).

SYSTEM MESSAGES AND LIKELY MEANINGS:

IBM 780I: NO 'OTHERWISE' CLAUSE AND NO 'WHEN' CLAUSES SATISIFED.

Response: Check for Season Code other than 'P', 'S', 'F', 'W', or Hemisphere code other than 'N', 'S', 'E', 'W' in the input Route Tree Envelope.

IBM 5371 DATA EXCEPTION

(Program uses decimal arithmetic in many calculations.)

Response: Check for illegal code in the alphanumeric field in the input route tree envelopes. Also make sure input matches picture specifications in lines 27/37, 43/45.2.

?'TRANSMIT' CONDITION RAISED, 'ONFILE' = {INENV / SGLMNDX

(DCB parameters are specified within program and cannot be modified by JCL or volume table of contents)

Response: Check that INENV or SGLMNDX are associated with data sets with LRECL = 72, BLKSIZE = 3096. If not, reformat data set (it may have been accidently stored in WYLBUR EDIT format) by using it and saving it with LRECL=72.

'CONVERSION' CONDITION RAISED, 'ONFILE' = SGLMNDX

Response: Make sure Inverse Siglum Table contains no more than the maximum number of Sigla (currently 506) expected by program BETA. If it contains less, pad with extra blanks or blank lines to simulate 506. (Note: If a terminal error occurs in processing a route, the envelope output file will contain all previously processed routes.)

MAJOR VARIABLES:

INDX_ENVLP_BY_ROUTE, INDX_ENVLP_BY_SGLM	Contain Envelope Indices
INV_SGLM_TBL, SGL_MAP	Contain Siglum Indices
IN_VERTEX, IN_ENVELOPE	Alternative dummy variables describing record from the input route envelope trees, overlayed upon input buffer, depending upon whether record is vertex descriptor or route header.

OUT_ENVELOPE	Array used for storing the final forms of the route envelope trees. It holds the verticies corresponding to all four seasons, but one route only (it is written out after processing each route)
OUT_ENVELOPE_INIT	Array used to reinitialize OUT-ENVELOPE at the start of processing each route, setting latitudes and longitudes to the impossible '999.99'
OUT_VERTEX_BUF	Dummy variable overlayed on OUT - ENVELOPE to facilitate output.

PROGRAM STRUCTURE

LINES	FUNCTION
75/78	Reads in Siglum Indices Establishes ENDFILE on-unit to terminate processing after all input trees have been read.
101/108	If this is the beginning of processing a new route, write out envelope tree for preceeding route, Record vertex number in INDEX - TO ENVELOPE - BY - ROUTE and re-initialize
109/144	Check if this vertex is a leaf corresponding to a canonical port, and if so, update INDEX TO ENVELOPE BY SIGLUM.
144/172	Convert degrees - minutes to decimal degrees, and moves the fields which do not need to be changed to the output variables.

173/184.7 185/206	Locates predecessor node and sets back the pointer. If the same vertex is used for all four seasons, copy it to all four copies of OUT_ENVELOPE. Calculate edge length, and if latitude/longitude of both main vertex and its predecessors are the same for each season copy it.
206.5/229	If the vertex differs for the various seasons, search the seasons previously calculated to see if both main vertex and its predecessors have same latitude/longitude, in which case copy edge length, otherwise, calculate it over. Go back to 100 for next vertex.
232/end	Write out last route.

D. PROGRAM: BETA2

REFERENCE PARAMETERS (SOURCE PROGRAM)

DSNAME = CN5054.PS1.BETA2

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

Sequenced 73/80 WYLBUR line numbers

REFERENCE PARAMETERS (OBJECT MODULE)

DSNAME = CN5054.PS1.LINKLIB(BETA2)

VOL = SER = PUBL03

UNIT = 3330

Objective Module must be reprocessed by Linkage Editor/Loader specifying entry point PLISTART

REFERENCE PARAMETERS (JCL) (For object module execution)

DSNAME = CN5054.PS1.JCL(BETA2)

VOL = SER = PUBL03

UNIT = 3330

WYLBUR EDIT format

FUNCTION:

Sums the edge lengths from the Route Envelope Trees (final form) to build the Port Distance Table, determining the total path length for each Siglum. It must be run once for each season.

INPUT FILES

DDNAME	DSNAME	CONTENTS
ENV	CN5054.PS1.OUTENV.SPRING SUMMER FALL WINTER	Route Envelope Trees, for appropriate season
ENVINDX	CN5054.PS1.ENVINDX	Index to Envelop by Siglum

OUTPUT FILES:

PRTDIST	CN5054.PS1.PRDIST.SPRING SUMMER FALL WINTER	Port Distance Table, for the appropriate seasons

MAJOR VARIABLES:

ENVELOPE	Array holding needed subfields of the Route Envelope Trees
INDEX#ENVLP#BY#SGLM	Array holding the index to Envelope by
LENGTH	Siglum used for summing up the edge lengths

PROGRAM PARAMETERS:

The following parameters are built into the logical structure of the program and if changed will necessitate program modifications:

PARAMETER	REFERENCE (LINE NUMBER)
Number of routes (84)	56.2 I/O Format (skipped over)
Maximum number of Sigla (506)	12 Dimension 56.3 I/O Format 100 DO loop limit
Maximum Number of Vertices in Route Envelope Tree (900)	8 Dimension

PROGRAM MESSAGES

'ERROR, SGLM = XXXX'

Response: The Index to Envelope by Siglum containes an '0' instead of a line number in the Route Envelope Trees. Correct the Routing Table or the Route Envelope Trees (original form) as necessary and re-run everything.

PROGRAM STRUCTURE:

LINES	FUNCTION
51/56.3	Read in Tables
100/112	Sum lengths
108.4/111.6	Write out length

E. PROGRAM: GAMMA1

REFERENCE PARAMETERS (SOURCE PROGRAM)

DSNAME = CN5054.PS1.GAMMA1

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)

Sequenced 73/80 WYLBUR line numbers

REFERENCE PARAMETERS (OBJECT MODULE)

DSNAME = CN5054.PS1.LINKLIB(GAMMA1)

VOL = SER = PUBL03

UNIT = 3330

Object Module - must be reprocessed by Linkage Editor/ Loader specifying entry point PLISTART

REFERENCE PARAMETERS (JCL)

DSNAME = CN5054.PS1.JCL(GAMMA1)

VOL = SER = PUBL03

UNIT = 3330

Wylbur EDIT format

FUNCTION: Constructs the Port Hash Table from the Port Table. The Port Name Abbreviation is converted to a Hash Index by taking its S/370 numeric value, dividing it by 2999, and using the remainder.

REVISION STATUS: Make certain JCL specifies most recent revision of PORTTBL before running.

INPUT FILES:

DDNAME	DSNAME	CONTENTS
PRTTBL	CN5054.PS1.PORTTBL	Port Table

OUTPUT FILES:

PRTHSH	CN5054.PS1.PRTHASH	Machine-readable Hash table

HASHOUT	CN5054.PS1.HASHOUT	Human-readable Hash Table

MAJOR VARIABLES:

PORT#HASH#TBL	Port Hash Table
PORT#HASH#TBL#BUF	Dummy variable overlayed on PORT#HASH#TBL during output.
PORT#DSCRPTN	Array storing the needed fields from the Port Table
PORT#NAME#A, PORT#NAME#B PORT#NAME#C	Various formats of the temporary variables used during conversion of the port name abbreviation to the Hash Index
NEXT#AVL#SPACE	Cursor used to manage loading of overflow area in the Hash Table

PROGRAM STRUCTURE:

Line	Format
40/47	On-unit to enable an error causing Port to be printed out.
50	On-unit to end the program after all records from Port Table are read.
51/68	Loop for each sucessive port
52/55	Render Port name, and convert to Hash Index
56/66	If another Port already has that Hash Index determine the proper bin to use in the overflow indices.
67/68	Store the port name and number in the Port Hash Table.

75/83 Write out Port Hash Table

PROGRAM MESSAGES:

Following any system error message is a print-out of Port Table entry being processed when the error occurred, the Hash Index calculated (if any), and NEXT#AVL#SPACE cursor.

F. <u>PROGRAM:</u> GAMMA2

REFERENCE PARAMETERS (SOURCE PROGRAM)

DSNAME = CN5054.PS1.GAMMA2

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB, BLKSIZE = 3096 LRECL=72)

Sequenced 73/80 WYLBUR line numbers.

REFERENCE PARAMETERS (OBJECT MODULE)

DSNAME = CN5054.PS1.LINKLIB(GAMMA2)

VOL = SER = PUBL03

UNIT = 3330

(Object module must be reprocessed by the linkage editor/ loader specifying entry point PLISTART).

REFERENCE PARAMETERS (JCL for Object Module execution)

DSNAME = CN5054.PS1.JCL(GAMMA2)

VOL = SER = PUBL03

UNIT = 3330

Wylbur EDIT Format

FUNCTION:

Builds the Estimated Travel Times Table by tracing the Siglum Table and totaling the port distances from the Port Distance Table. It assumes a speed of 12 knots. For ships traveling from one canonical port to itself, it assumes a travel time of 0 days (which may later be modified by Wylbur EDIT commands). It must be run 4 times, once for each season. Also it constructs the Multiple Travel Time Tables and places the additive inverse of a pointer to them in the proper place in the Estimated Travel Time Table.

<u>FILES:</u>

INPUT:

DDNAME	DSNAME	CONTENTS
SGLMTBL	CN5054.PS1.SGLMTBL	Siglum and Multiple Routing Tables
PORTDST	CN5054.PS1.PRTDIST.SPRING SUMMER FALL WINTER	Port Distance Tables, as appropriate for season.

OUTPUT:

TRAVTME	CN5054.PS1.TRAVTME.SPRING SUMMER FALL WINTER	Travel Time Tables
SYSPRINT	Intermediate checks.	

UPDATE STATUS: '(CHECK)' prefixes and line 75.5 used during the checkout may be removed, but are harmless except for producing lots of output. Otherwise, the program is finished.

PROGRAM PARAMETERS:

Changes in the following parameters will require program modification.

PARAMETER	REFERENCE (LINE NUMBER)
Number of Cononical Ports (69)	15,20 Dimension 52,100 I/O Format 58 DO Loop limit
Maximum number of Sigla (506)	21.5 Dimension 56 I/O Format
Maximum number of Multiple Travel Time Tables generated (100)	21 Dimension 100 I/O Format
Estimated Inverse Speed (Days/Degree Latitude)	64,68,80,85,91 Multiplier

MAJOR VARIABLES:

SGLM#TBL	Siglum Table
MULT#RTNG#TBL	Multiple Routing Table
TRAV#TME#TBL	Travel Time Table
MULT#TRAV#TME#TBL	Multiple Travel Time Table
PORT#DIST	Port Distance Table
PORT#1,PORT#2	Origin and Dest. Ports numbers
PORT, PORTM	Intermediate Port numbers
TIME, TIMEM	Accumulators for travel time
BRANCH	Multiple Routing Table branch

PROGRAM STRUCTURE

LINE	FUNCTION
50/56	Reads in the Table
58/97.5	Loops through the Siglum Table using all possible port combinations
59/60	Initializes for each origin and destination port pair
61/73	Traces the Siglum Table recursively until the Multiple Routing Table is encountered
76/78.5	Initializes the Multiple Routing Table, trace for each of the two branches
79/96	Traces the Siglum Table recursively, choosing the proper multiple routing table, branch for each time through.

G. **PROGRAM**: DELTA1

REFERENCE PARAMETERS - SOURCE PROGRAM;

DSNAME = CN5054.PS2.DELTA1
VOL = SER = PUBL03
UNIT = 3330-1
DCB = (RECFM = FB,BLKSIZE = 3120, LRECL = 80)

REFERENCE PARAMETERS - JCL

DSNAME = CN5054.PS2.DELTA1.JCL
VOL = SER = PUBL03
UNIT = 3330-1
WYLBUR EDIT format

FUNCTION: Provides a visual check on the Route Trees to catch transcription errors. It plots each vertex of the given route and designates canonical ports by a C and a non canonical port by a V. The great circle path is generated and displayed between each pair of vertices. A 5° allowance is allotted on either ends of the route for clarity. The program was used for each of the four seasons on all 85 routes.

INPUT DATA SETS:

DSNAME	CONTENTS
CN5034.PS2.LANDSEA	World in terms of periods and blanks
CN5054.PS1.SGLMNDX	Inverse Siglum Table and Siglum Map
CN5054.PS1.ENVINDX	Index to Envelope by Route and Index to Envelope by Siglum
CN5054.PS1.OUTENV.SPRING	Final version of Route
CN5054.PS1.OUTENV.Fall	Envelope, one per season
CN5054.PS1.OUTENV.WINTER	
CN5054.PS1.OUTENV.SUMMER	

MAJOR VARIABLES:

LSEA4, WORLD1	Contains Landsea table
SIGMAP	Contains Siglum indices
INSIG	Index Envelope by Siglum

PROGRAM STRUCTURE

Lines	Function
1/17	Dimensions various arrays, i.e., Route Trees, Landsea, Siglum Map, Index Envelope by Siglum
18/37	Reads in all the necessary files. A factor of 90.5 is added to the latitudes and 181 to the longitudes
38/70	Checks if we are beginning a new route, and if so, writes out the previous route. Determines the minimum and maximum longitudes
71/115	Determines the great circle path between pairs of vertices according to the vertex widths.
115.1/281	Stores the corresponding code for canonical ports, non canonical ports, and great circle paths.

H. PROGRAM: DELTA2

REFERENCE PARAMETERS - (SOURCE PROGRAM)

DSNAME = CN5054.PS2.DELTA2

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB,LRECL = 80,BLKSIZE = 3120)

REFERENCE PARAMETERS - JCL

DSNAME = CN5054.PS2.DELTA2.JCL

VOL = SER = PUBL03

UNIT = 3330

WYLBUR EDIT FORMAT

FUNCTION: Checks the canonical port mapping. The noncanonical ports are plotted using symbols to denote the various associated canonical ports. This provides a quick checking procedure to determine if in a given area there are more than one canonical port associated to it. It also spots typegraphical error occurring in the Port Table. An example of this is the occurrence of a port in the middle of a large landmass. The program is run in two parts, once for canonical ports 1-34 and is repeated for canonical ports 35-69.

INPUT FILES:

DSNAME	CONTENTS
CN5034.PS2.LANDSEA	The world stored in terms of periods and blanks
CN5054.PS4.PORTTBL	Table of all the ports and the corresponding latitude, longitude and associated canonical port.

MAJOR VALUABLES:

SUMTAB	Vector containing the code for the canonical ports.
WORLD	Array containing the landsea table.

PROGRAM STRUCTURE

LINES	FUNCTION
1/14	Dimensioning various arrays
15/20	Read in the port table with the correspon- ding latitude, longitude and associated canonical port.
21/32	Determines if the assoicated canonical port lies in the range of this run. Then it deals with the North, South, East, West by adding or subtracting the appro- priate value.
23/53	Checks if two different canonical port codes lie in the same 1° x 1° square, and if so, designates it on the output by an asterick. It also displays the full world.

I. PROGRAM: DELTA3

REFERENCE PARAMETERS: SOURCE PROGRAM;

DSNAME = CN5034.PS2.DELTA4

VOL = SER = VOL = PUBL03

UNIT = 3330

DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)

REFERENCE PARAMETERS - JCL

DSNAME = CN5034.PS2.DETLA4.JCL

VOL = SER = VOL = PUBL03

UNIT = 3330

DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)

FUNCTION: Checks the routing table. Prevents the occurrence of infinite loops, and does various checks on non-direct routes. In the case of a multiple routes the check was done manually. When an error is spotted a corresponding message is written.

INPUT DATA SETS:

DSNAME	CONTENTS
CN5054.PS1.RTNGTBL.FINAL	69x69 array called Routing Table.

MAJOR VARIABLES

ROUTEM	Alphanumeric array containing the code ' ' for direct route, 'P' for intermediate port and 'B' for multiple route
ROUTEM	Array containing the various routes between 2 ports

PROGRAM STRUCTURE

LINE	FUNCTION
1/10	Dimensions various arrays
11/19	Reads in the Routing Table and declares some logical variables
20/end	Reads a pair of canonical ports. It traces through the path and undergoes various checks along the way. If there are inconsistancies an error message is written.

J. PROGRAM: GAMMA

REFERENCE PARAMETERS: (Source Programs)	(OBJECT MODULE)
DSNAME=CN5054.PS1.GAMMA	DSNAME=CN5054.PS1.LINKLIB(GAMMA)
VOL=SER=PUBL03	VOL=SER=PUBL03
UNIT=3330-1	UNIT=3330-1
DCB=(RECEM=FB,LRECL=80, BLKSIZE=3120)	Must be reprocessed by loader

Sequenced 1/834 WYLBUR line numbers

MACROS INVOKED:

- DEFINE#MONTH#TBL
- DEFINE#PORT#HASH#TBL
- TEST
- SET#INVALID#FIELD#LIMIT
- COMPARE
- SEARCH#PORT#HASH#TBL
- SEARCH#MONTH#TBL
- GET#DATE
- SHPDYS

MAJOR VARIABLE (other than those limited to use in macros)

NEW#INPT#SHP	Overlayed on each record from SHPINPT in buffer
INPT#SHP	Contains data moved from NEW#INPT #SHP (both variables are needed to maintain synchronization since 2 sequential input records must be compared to check for duplicated records).
VAL#FLGS,NEW#VAL#FLGS	Validity flags to ID fields in NEW#INPT#SHP, INPT#SHP respectively.
TRNS#SHP	Contains data obtained by translating INPT#SHP by converting port name abbreviations to port numbers and month abbreviations/day of month to day of year.

SHP(J)	J=1 to 20 Search table contains 15 to 20 ships from OLDSDT.
BETA	Index of first ship in search table
W	Index of last ship in search table
P	Points at last ship in search table matched.
GAMMA (J)	Points to ship preceding SHP(J) in search table. GAMMA(BETA) = 0 .
PHI(J)	Points to ship succeeding SHP(J) in search table. PHI(W)=99,
F(J)	0 indicates position J empty in search table. 1 not empty
C(J)	0 indicates SHP(J) unmatched 1 SHP(J) matched
RHO	Counts inserts to the search table.
SUM	Counts comparisons.

PROGRAM STRUCTURE:

<u>LINES</u>:	<u>FUNCTION</u>
238/261	Initialization for the first processed week or the 13th week of the season.
262/293	Initialization for each week of processing.
294/330	Move previous NEW#INPT#SHP,NEW#VAL#FLGS, and NEW#ERR#INT, respectively. Read new NEW#INPT#SHP, check ID fields for validity via TEST macro and simultaneously set NEW#VAL#FLGS. Invoke COMPARE macro to test NEW#INPT#SHP and INPT#SHP for duplication. Maintain COUNTER.INPT#SHP, and synchronize TRANSMIT and ENDFILE conditions with INPT#SHP processing.

	Branch to ERR#WPT#SHP if too many errors, or TRANSMIT condition raised, and to FINISH on ENDFILE condition.
331/413	Translate PEE (Port Entrance/Egress Data) from INPT#SHP to internal form and store in TRNS#SHP, simultanteously setting validity flags.
332/352	Translate origin port data.
353/399	Translate port of last call data. If port name is missing, but other data given, then ship has arrived at its final destination, so use port of destination name and flag this field in TRNS#SHP as being the final destination. Use Last Call Code ('AR', 'IN', 'PD', 'SD') to determine whether LCALL date should be interpreted as arrival or departure date.
400/413	Translate port of destination name, if it has not been moved to LCALL field. Port name abbreviations must be translated to DOT port number (modified), and month/day-of-month pairs to day-of-year.
415/680	Sets up the search tables for all the weeks. Searches and matches the ships. Calls MACRO SHPDYS which actually calculates the days between ports and increments PRTRT.
415/426	Minor bookkeeping to make the two parts of the program more compatible and programming somewhat easier as values are transferred from one variable to

	a second variable that will be used in this part of the program.
426/431	Test for week 13, that is the 13th week of the season.
432/464	Two functions: sets up the initial search file for the 13th week of the season,does the initial calculations for any ship that makes its first appearance after the 13th week of the season.
465/507	Loads the search file at the beginning of each week. Reloads the search file as comparisons are made.
508/532	Compares, takes a TRNS#SHP and searches the file for a match. If a match occurs, goes to calculations.
533/597	Inserts new ships into search file.
598/656	Determines if the data on a ship fits into one of six categories available. Then sets the data up in a form compatible with MACRO SHPDYS. SHPDYS is called and actual days calculated and the proto-routing table incremented. Once the calculations are done, test on SUM. If SUM is still less than 10 control is sent back to GET#INPT#SHP
657/662	If SUM is greater than 10, test to see if the pointer is within 5 of the last ship on the list. If pointer is not, send control to GET#INPT#SHP. If pointer is within 5 then send control to WRITE#OUT.
663/680	Writes out the top of the search file.

	Resets the chain and various pointers and sends control back to LOAD where the search file is again filled with new ships.
681/733	ERR#INPT#SHP program segment for processing the errors not correctable by program logic.
734/767	ENDFILE. Closes ship input file, writes out error messages, on file ERRMSG and SYSPRINT.
768/781	Writes out the last of the search file, makes sure all ships have been taken off of the input file and written out on the new file for next week.
782/798	If INDX is equal to 1, sends control back to INITIALIZE, closes the appropriate file. If INDX does not equal 1, dumps proto-routing table for that week onto a temporary file. If also MOD(INDX,4) = 1, sends control to DUMP#PRTRT.
799/834	Dumps proto-routing table onto a file for the appropriate week. Sends control back to initialize it, unless it is the first week of the season, i.e., the last week processed and then closes down all the files, writes out a message saying 'normal' and ends the program.

<u>INTERNAL TABLES</u>

PORT#HASH#TBL	Used for translating port name abbreviation to DOT port number. Documentation elsewhere.
CAN#PORT	MAPS DOT PORT number to canonical port number.

DAYS	Contains travel time table for the season. Documentation elsewhere.
IDAYS	Contains multiple travel time table for the season. Documentation elsewhere.
PRTRT	The proto-routing table. A 3x69x69 table containing the cummulative days spent by each of the three ship types traveling between any two canonical ports.

CONTROL VARIABLES

VAL#FLGS.TO#ID

OCCURENCES:

NAME	HOW SET	APPLIED TO
VAL#FLGS.TO#ID	By TEST macro	INPT#SHP.ID
NEW#VAL#FLGS.TO#ID	By TEST macro	NEW#INPT#SHP.I
	By LOAD#TBL#SHP macro using VAL#FLGS.TO#ID	

FUNCTION:

BIT 1	Name Field	'1'B - Valid; '0'B - invalid
BIT 2	Not used - reserved for TYPE field	
BIT 3	Flag Field	'1'B - valid; '0'B - invalid
BIT 4	Year built field	'1'B - valid; '0'B - invalid
BIT 5	Type and weight fields	'1'B - both valid; '0'B - at least one invalid

SPECIAL FUNCTIONS (VAL#FLGS. TO#ID,NEW#VAL#FLGS)

'00000000'B	ENDFILE Condition
'00000000'B	TRANSMIT Condition
'00000000'B	First Record (void)

CONTROL VARIABLES

VAL#FLGS.TO#PEE

FORMAT: BIT(8)

OCCURENCES:

NAME	HOW SET	APPLIED TO
TRNS#SHP.VAL#FLGS.	By Search #MONTH#TBL.	TRNS#SHP.PEE PRT#OR
TRNS#SHP.VAL#FLGS. TO#PEE.PORT#CALL	GET#DATE, and SEARCH#PORT#HASH#TBL	TRNS#SHP.PEE PRT#CALL
TRNS#SHP.VAL#FLGS. TO#PEE.PRT#DST	SEARCH#PORT#HASH#TBL macros and surrounding code	TRNS#SHP.PEE PRT#DST

FUNCTION:

BITS 1&2	Port number field	'11'B - fully valid '10'B - valid, but port number corresponds to a port name flagged as a generic term in the port table '00' - invalid or blank
BITS 3&4	Arrival data field	'11' - fully valid
	Departure date field	'10' - upper limit, obtained by correlation on month name or by use of day-of-report, - when month name invalid, or actual data in arrival field of PRT#LCALL if LCALL code was invalid. '01' - lower limit, obtained by using first day of month when day of month invalid, or actual date in Departure field of PRT#LCALL if LCALL field was invalid '00' - filed missing or totally invalid, when in Departure field or Arrival field at PRT#DST probably means that ship has not yet left or arrived.
BIT 7		'1' indicates that this port was designated as a destination port in input data '0' indicates that it was not so designated

CONTROL VARIABLES

NAME	TESTED ON	VALUES
GATE	By SECOND#PART to control loading of the search table	'0' - have first TRNS#SHP of week Need to load the search table for the first time

NAME	TESTED ON	VALUES
		'1' - have a TRNS#SHP initial loading. Has started '-1' - need to get a TRNS#SHP after refilling of the search table
KFLG	By SECOND#PART WEEK#13 to transfer control after initial calculations on ship	'0' - we are in week 13 of the season '1'- we are in OTHER week than 13
TAG	By SECOND#PART to indicate if we are searching forward or backward through the search table	'0' - forward '1' - backward
K	By SECOND#PART Transfer of control during loading of search table	'0'- filling the tables for the first time this week '1' - refilling the table
INDX	By SECOND#PART WRAP#UP	Counts no. of weeks processed this season. Sends control to DUMP #PRTRT at INDX ≠ 1 but MOD (INDX,4)=1

INPUT DATA SETS:

FILENAME = SHPINPT

DDNAME = DOTINP52, DOTINP51, etc. Determined dynamically during execution by concatenating WK#OF#RPRT to "DOTINP'.

CONTENTS: DOT Marine Traffic Generator Input Tape for appropriate week.

ENVIRONMENT Specification: F RECSIZE (84) TOTAL BUFFERS (10)

DCB Specifications (on DD card): TRTCH = ET, OPTCD = C

FILENAME, DDNAME = PRTHSH

CONTENTS: Port Hash Table

Referenced by DEFINE#PORT#HASH#TBL macro

FILENAME, DDNAME = NEWPRT

CONTENTS: Canonical Port Numbers

ENVIRONMENT Specification: FB

RECSIZE (200) BLKSIZE (5000)

FILENAME = TRAV

DDNAME = TRAVTME.FALL
TRAVTME.WINTER
TRAVTME.SPRING
TRAVTME.SUMMER

CONTENTS: Number of shipdays between any two canonical ports. Also multiple route table for voyages that pass through the canals

ENVIRONMENT Specification: FB

RECSIZE (80) BLKSIZE (3120)

OUTPUT DATA SETS:

FILENAME, DDNAME = ERRMSG

Print file (SYSOUT=A) containing all error messages generated.

FILENAME,DDNAME = SYSPRINT

CONTENTS: System error messages, copies of certain important error messages from ERRMSG, system debugging output .

Print File (SYSOUT=A)

FILENAME=PROTO

DDNAME = PROTO48
PROTO44
PROTO40

CONTENTS: The Proto-Routing table for each month.

ENVIRONMENT Specification: FB

RECSIZE (72) BLKSIZE (3120)

FILENAME = PRO#TEM

DDNAME = PRO.TEMP

CONTENTS: Temporary proto-routing table to be used in case a restart is necessary. At the end of normal execution contains the cumulative list for ports of origin.

ENVIRONMENT Specification: FB

RECSIZE (80) BLKSIZE (3120)

MACRO FUNCTIONS:

TEST	TEST	Checks ID field of input record and sets corresponding validity flags.
COMPARE	COMPARE	Compares ID fields of two records and checks for identity.
SIFL	SET#INVALID#FIELD#LIMIT	

		Used with TEST, DPHT, SMT, AND GD macros to limit total number of invalid fields to be allowed before branching to error routine.
DPHT	DEFINE#PORT#HASH#TBL	Reads in Port Hash Table and contains declarations for associated variables.
SPHT	SEARCH#PORT#HASH#TBL	Searches Port Hash Table for a given port name abbreviation.
DMT	DEFINE#MONTH#TBL	Initializes Month Table to optimum sequence for linear searching.
SMT	SEARCH#MONTH#TBL	Obtains starting day of given month from the Month Table.
GD	GET#DATE	Adds day of month to starting day of month to obtain day of year.
SHPDYS		Calculates ship days between canonical ports. If canonical ports are identical assigns max. value of 2. Increments Proto-Routing table.

SYSTEM OPERATIONS

MACRO DEFINITIONS:

REFERENCE PARAMETERS:

DSN = CN5054.PS1.PLI.MACLIB

VOL = SER = PUBL03

UNIT = 3330-1

DCB = (DSORG=PO,RECEM=FB,BLKSIZE=3120,LRECL=80)
Sequenced 73/80 WYLBUR line numbers

ACCESS METHOD:

1. Include

```
//PL1.SYSLIB DD DSN = CN5054.PS1.PL.MACLIB
//              VOL = SER=PUBL03,UNIT=3330-1,DISP=SHR
```

card among complier DD cards.

2. Include

%INCLUDE (BNTS), (DST),...(GTS); card specifying short form of all macro names to be used in the source text for each external procedure.

I. If Gamma is to be modified.

1. Make changes in source code.
   DSN = CN5054.PS1.GAMMA
   VOL = SER=PUBL03

2. RECOMPILE and Linkedit. Gamma, JCL to accomplish this is located in Data set:
   DSN = CN5054.PS1.GAMMA.COMPLIN
   VOL = SER=PUBL03

3. The load module is placed in a library.
   DSN = CN5054.PS1.LINKLIB(GAMMA)
   VOL = SER=PUBL03

4. To execute the load module Gamma the JCL is located in GAMMA.JCL.EXEC.
   DSN = CN5054.PS1.GAMMA.JCL.EXEC
   VOL = SER=PUBL03

The JCL for the data set name GAMMA.COMPLIN is as follows:

```
// EXEC PL1OPCL,PARM.PLI=('CHARSET(48),NOINSOURCE,OPT(TIME)',
//    'NEST,STORAGE,OFFSET,AGGREGATE'),
//     PARM.LKED='LIST,MAP'
//PLI.SYSIN DD DSN=CN5054.PS1.GAMMA,UNIT=3330-1,
//   VOL=SER=PUBL03,DISP=(SHR,KEEP)
//PLI.SYSLIB DD DSN=CN5054.PS1.PLI.MACLIB,VOL=SER=PUBL03,
//   UNIT=3330-1,DISP=(SHR,KEEP)
//LKED.SYSLMOD DD DSN=CN5054.PS1.LINKLIB,UNIT=3330-1,
//      VOL=SER=PUBL03,DISP=(MOD,KEEP)
```

The JCL for GAMMA.JCL.EXEC

```
//JOBLIB DD DSN=CN5054.PS1.LINKLIB,UNIT=3330-1,
//   VOL=SER=PUBL03,DISP=SHR
//GO EXEC PGM=GAMMA,PARM='ISA(102K)/D'
//SYSPRINT DD SYSOUT=A
//EVEN DD DSN=CN5054.PS1.TEMP.PORT.SHP.FILE1,UNIT=3330-1,
//     VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,LRECL=38)
//ODDS DD DSN=CN5054.PS1.TEMP.PORT.SHP.FILE2,UNIT=3330-1,
//     VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,LRECL=38)
//NEWPRT DD DSN=CN5054.PS1.NEWPRT,
//   VOL=SER=PUBL03,DISP=(SHR,KEEP),UNIT=3330-1,
//   DCB=(RECFM=FB,LRECL=200,BLKSIZE=5000)
//ERRMSG DD SYSOUT=A,DCB=(BLKSIZE=2640,LRECL=132,
//   RECFM=FB)
//PRTHASH DD DSN=CN5054.PS1.PPTHSH,VOL=SER=PUBL03,
//   DISP=SHR,UNIT=3330-1
//TRAV DD DSN=CN5054.PS1.TRAVTME.WINTER,VOL=SER=PUBL03,
//       UNIT=3330-1,DISP=(OLD,KEEP)
//DOTINP01 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY01,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP02 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY02,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP03 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY03,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP04 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY04,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP05 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY05,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP06 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY06,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP07 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY07,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP08 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY08,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP09 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY09,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP10 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY10,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP11 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY11,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP12 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY12,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//DOTINP13 DD VOL=SER=PSI001,UNIT=3330,DSN=CN5054.PS1.COPY13,
//   DCB=(RECFM=FB,LRECL=84,BLKSIZE=3108),DISP=SHR
//PROTO01 DD DSN=CN5054.PS1.PROTO01,UNIT=3330-1,
//         DISP=(NEW,KEEP),DCB=(RECFM=FB,LRECL=80,
//         BLKSIZE=3520),VOL=SER=PUBL03,SPACE=(TRK,(10,5))
//PROTO05 DD DSN=CN5054.PS1.PROTO05,UNIT=3330-1,
//         DISP=(NEW,KEEP),DCB=(RECFM=FB,LRECL=80,
//         BLKSIZE=3520),VOL=SER=PUBL03,SPACE=(TRK,(10,5))
//PROTO09 DD DSN=CN5054.PS1.PROTO09,UNIT=3330-1,
//         DISP=(NEW,KEEP),DCB=(RECFM=FB,LRECL=80,
//         BLKSIZE=3520),VOL=SER=PUBL03,SPACE=(TRK,(10,5))
//PRO#TEM DD VOL=SER=PUBL03,UNIT=3330-1,
//         DSN=CN5054.PS1.PRO.TEMP,DISP=(OLD,KEEP),
//         DCB=(RECFM=FB,LRECL=80,BLKSIZE=3120)
```

An execution time parameter is passed to Gamma on the PARM card. Code is as follows:

```
A    →   Fall; sets WK#OF#RPRT=53
                        Fudge=365
B    →   Summer; sets WK#OF#RPRT=40
                        Fudge=286
C    →   Spring; sets WK#OF#RPRT=27
                        Fudge=195
D    →   Winter; sets WK#OF#RPRT=14
                        Fudge=104
E    →   Test case;WK#OF#RPRT=53
                        RTEST=1
```

K. PROGRAM: EPSILON

REFERENCE PARAMETERS (SOURCE PROGRAM)

DSNAME = CN5054.PS1.EPSILON

VOL = SER = PUBL03

UNIT = 3330-1

DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

FUNCTION: EPSILON reads a monthly Proto-Routing Table and from it generates a SHP.DAYS Table. The Proto-Routing Table is indexed by ship type, egress port, and entrance port. EPSILON examines each element of the Proto-Routing Table. If for each ship type, t, the (t,A,B)-th element of the table is zero, then no action is taken. If for some t the (t,A,B)-th element is non-zero, then the (A,B)-th element of the Routing Table is examined.

i. If the (A,B)-th element is a blank followed by an integer, n then the route from A to B is a canonical route and the contents of the (t,A,B)-th position in the Proto-Routing Table are added to the (t,n)-th element of the SHP.DAYS Table where n is the (A,B)-th element of the Siglum Table. This is done for each t where the (t,A,B)-th elements of the Proto-Routing Table is non-zero.

ii. If the (A,B)-th element of the Routing Table is N followed by a zero then A=B and the contents of the (t,A,B)-th element of the Proto-Routing Table are moved into the (t,A)-th element of the RESIDUAL TABLE for random distribution in the vicinity of port A.

iii. If the (A,B)-th element of the Routing Table is a P followed by an integer, M, then the RECURSIVE INDEX LIST is started. P indicates that the voyage from A to B is a compound route. That is, the route is not direct. M is the canonical port number of the end of the first segment of the route. The (A,M)-th element of the Siglum Table stored in the RECURSIVE INDEX LIST. Then the (M,B)-th element of the Routing Table is examined. If it is a canonical route number, that is blank followed by an integer, then the (M,B)-th element of the Siglum Table is stored in the RECURSIVE INDEX LIST, and the list is terminated. If the (M,B)-th element of the Routing Table is a B followed by an integer K, then the MULTIPLE ROUTING TABLE is used to determine which of the two pointers is correct. If the (M,B)-th element of the ROUTING TABLE is a P followed by an integer J, then this step is repeated with the (M,J)-th element of the Siglum Table being added to the RECURSIVE INDEX LIST, and the recursion continues until the list is terminated. When termination occurs, then the RECURSIVE INDEX LIST is used to extract distances from the PORT DISTANCE TABLE. The extracted distances are used to proportion the ship days among the various component routes. That is one assumes the number of days spent going from point A to point M is that same fraction of the total days spent going from A to B as the distance from A to M is to the total distance from A to B.

iv. If the (A,B)-th element of the ROUTING TABLE is a B followed by an integer L, then the various ship types influence the choice of routes. One examines the L-th row of the MULTIPLE ROUTING TABLE if t=3, i.e., ship type is large tanker, the first entry of row L indicates the next canonical port for the route. If t<3 then the second entry of the L-th row indicates the next canonical port.

After processing the entire PROTO-ROUTING TABLE, the program writes out the SHP.DAYS TABLE, zeroes it, and proceeds to the table for the next month.

INPUT DATA SETS

Filename = FT33F001
DSNAME = CN5054.PS1.RTNGTBL.NEW
CONTENTS: Routing Table

Filename = FT34F001
DSNAME = CN5054.PS1.SGLMTBL
CONTENTS: Siglum Table

Filename = FT36F001
DSNAME = CN5054.PS1.PRTDIST.FALL (SUMMER,SPRING,WINTER)
CONTENTS: Port Distance Table

Filename = FT08F001
DSNAME = CN5054.PS1.PROTO48,35,22,09
CONTENTS: First Proto-Routing Table of the Season

Filename = FT09F001
DSNAME = CN5054.PS1.PROTO44,31,18,05
CONTENTS: Second Proto-Routing Table of the Season

Filename = FT10F001
DSNAME = CN5054.PSI.PROTO40,27,14,01
CONTENTS = Third Proto-Routing Table of the Season

OUTPUT DATA SETS

Filename = FT20F001
DSNAME = SHP.DAYS48,35,22,09
CONTENTS: Ship Days Table for the first month of the season

Filename = FT21FC01
DSNAME = SHP.DAYS44,31,18,05
CONTENTS: Ship Days Table for the second month of the season

Filename = FT22F001
DSNAME = SHP.DAYS40,27,14,01
CONTENTS: Ship Days Table for the third month of the season

MAJOR VARIABLES

RTA(69,69)	Alphabetic information from the Routing Table
RTN(69,69)	Numeric information from the Routing Table
PRT(3,69,69)	Proto-Routing Table
MRT(69,69)	Multiple Routing Table
PDT(500)	Port Distance Table
SIG(69,69)	Siglum Table
RESID(3,69)	Residual Table for random distribution in the vicinity of ports
RESINL(20)	The RECURSIVE INDEX LIST, to temporarily hold Siglum values for compound routes.
SDT(3,500)	SHP.DAYS Table indexed by ship type and Siglum

PROGRAM STRUCTURE	FUNCTION
29/42	Reads in the Routing Table, the Multiple Routing Tables, the Siglum Table, the Port Distance Table for the appropriate season.
43/44	Reads in the Proto-Routing Table for each month of the season.
46/92	Performs the function of EPSILON.
49/51	Checks if Proto-Routing Table is zero for these two ports.
53/91	Performs the correct calculation based on the alphabetic value of the Routing Table.
57/58	Routing Table has a blank in the alphabetic position.
60/61	Routing Table has an N in the alphabetic position.

63/65	Routing Table has B in the alphabetic position.
66	Routing Table has a P in the alphabetic position
67/83	Accumulates Siglum in the RECURSIVE INDEX LIST for cases P and B.
87/90	Calculates Ship Days Table for cases P and B.
93/95	Writes the Ship Days Table and the Residual Table onto the disk pack.
96/102	Zeros the SHIP.DAYS and Residual Tables for the next month.
103/105	Increments counters for controlling the number of months processed and the logical devices for I/O.
106	Tests on the number of months processed.

SYSTEM OPERATIONS

The JCL is located in the data sets JCL.EPSILON. Below is a copy of the JCL.

```
// EXEC FTG1CG
//FORT.SYSIN DD DSN=CN5054.PS1.EPSILON,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(SHR,KEEP)
//GO.FT33F001 DD DSN=CN5054.PS1.RTNGTBL.NEW,
//    UNIT=3330-1,VOL=SER=PUBL03,DISP=(SHR,KEEP)
//GO.FT34F001 DD DSN=CN5054.PS1.SGLMTBL,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(SHR,KEEP)
//GO.FT36F001 DD DSN=CN5054.PS1.PRTDIST.FALL,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(SHR,KEEP)
//GO.FT08F001 DD DSN=CN5054.PS1.PROTO$,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,
//    LRECL=80,BLKSIZE=3520)
//GO.FT09F001 DD DSN=CN5054.PS1.PROTO$,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,
//    LRECL=80,BLKSIZE=3520)
//GO.FT10F001 DD DSN=CN5054.PS1.PROTO$,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,
//    LRECL=80,BLKSIZE=3520)
//GO.FT20F001 DD DSN=CN5054.PS1.SHP.DAYS48,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,LRECL=72,
//    BLKSIZE=3120),SPACE=(TRK,(10,5))
//GO.FT21F001 DD DSN=CN5054.PS1.SHP.DAYS44,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,LRECL=72,
//    BLKSIZE=3120),SPACE=(TRK,(10,5))
//GO.FT22F001 DD DSN=CN5054.PS1.SHP.DAYS40,UNIT=3330-1,
//    VOL=SER=PUBL03,DISP=(OLD,KEEP),DCB=(RECFM=FB,LRECL=72,
//    BLKSIZE=3120),SPACE=(TRK,(10,5))
```

L. PROGRAM: THETA1

REFERENCE PARAMETERS - SOURCE PROGRAM

DSNAME = CN5054.PS2.SPLINE2

VOL = SER = PUBL03

Unit = 3330

DCB = (RECFM = FB, BLKSIZE = 3120,LRECL = 80)

REFERENCE PARAMETERS - JCL

DSNAME = CN5054.PS2.SPLINE.JCL

VOL = SER = PUBL03

Unit = 3330

WYLBUR Edit Format

FUNCTION: Generates a set of X values to be used in Theta for the distribution. It takes a set of data points and determines the Type I' Cubic Spline in which it interpolates. Then it uses two iterations of Newton's method to determine intermediate values between any two successive sextile points. Thus producing a set of 13 X values. This is done for each season.

INPUT FILES:

DSNAME	CONTENTS
CN5054.PS2.SEXTILE.SP	A table of sextile points
CN5054.PS2.SEXTILE.SU	
CN5054.PS2.SEXTILE.FALL	
CN5054.PS2.SEXTILE.WINTER	

OUTPUT FILES

DSNAME	CONTENTS
CN5054.PS2.X13SP	Table containing 13 X values correspond-
CN5054.PS2.X13SU	ing to each route.
CN5054.PS2.X13FALL	
CN5054.PS2.X13WINTER	

MAJOR VARIABLES

M(J)	Coefficients of cubic spline
XTEMP	X value generated after one iteration of the Newton's method
X(13)	The 13 X values, six of which are the original sextile points normalized between [-1,1]

PROGRAM STRUCTURE

LINES	FUNCTION
1/5	Dimensions various vectors and reads in a set of sextile points
5/15	Normalizes the sextile points and checks if they are monotonic.
16/34	Determines the coefficient of the cubic spline from the sextile points, i.e., the mj's.
35/last	Performs two iterations of the Newton method and routes the generated values plus the original ones on a file.

M. <u>PROGRAM</u>: X13 TABLE

REFERENCE PARAMETERS:

DSNAME = CN5054.PS2.X13SU,CN5054.PS2.X13SP
CN5054.PS2.X13FALL,CN5054.PS2.X13WINTER

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB, LRECL = 80,BLKSIZE = 3120)

SOURCE: Generated by THETA1

USAGE: Used by THETA for distribution of shipping data by one degree square.

FORMAT: Matrix 30x13 or 29x13 according to the season. Each group spans two lines 7 entries are on the first line in (7F10.5) and six entries on the subsequent line. For each route there is a corresponding set of 13x values.

FUNCTION: Used by program THETA in the distribution of the density across the route.

N. PROGRAM: SEXTILE TABLE

REFERENCE PARAMETERS:

DSNAME = CN5054.PS2.SEXTILE.SU,
CN5054.PS2.SEXTILE.SP,CN5054.PS2.SEXTILE.FALL,
CN5054.SP2.SEXTILE.WINTER

VOL = SER = PUBL03

UNIT = 3330

DCB = (RECFM = FB, LRECL = 80,BLKSIZE = 3120)

SOURCE: Ocean Routes Envelope Report

USAGE: Used by program THETA1 to build 13 X values for each set of sextile points

FORMAT: SEXTILE table 7x29 matrix or 7x30. Varies according to seasons. Each group spans 1 line with 7 entries in format (7F10.5).

FUNCTION: Used by THETA1 to generate the 13 X values.

O. PROGRAM: THETA

REFERENCE PARAMETERS - SOURCE PROGRAM;

DSNAME = CN5054.PS2.THETAW

VOL = SER = PUBL03

UNIT = 33330

DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)

REFERENCE PARAMETERS - JCL

DSNAME = CN5054.PS2.THETA.JCLW

VOL = SER = PUBL03

UNIT = 33330

DCB = (RECFM = FB, BLKSIZE = 3120, LRECL = 80)

FUNCTION: Takes the Ship-Days - Table, created by Epsilon, applies the growth factor to the ship populations and converts the data from ship-days per route to ships per one degree square. The distributions are done between canonical ports, for the various types of vessels for each month.

INPUT DATA SETS:

DSNAME	CONTENTS
CN5054.PS1.SGLMNDX	Inverse Siglum Table & Siglum Map
CN5054.PS1.ENVINDX	Index Envelope by Route and Index Envelope by Siglum
CN5054.PS2.X13SP	The 13 X values generated by sextilepoints per season
CN5054.PS1.SHP.DAYS	48 Ship days table, per month
CN5054.PS2.POINTR.SP	Pointer to the 13 X values by route, per season
CN5054.PS1.PRTDIST.SPRING	Port Distance Table, one for each season

OUTPUT DATA SETS

DSNAME	CONTENTS
CN5054.MERCH.COUNTS.ARRAY.SPRING	Distribution by 1° square
FALL	
WINTER	
SUMMER	

PROGRAM STRUCTURE

LINES	FUNCTION
1/11	Dimensions various arrays. That is SHIPDS for the ship days table, PRTDST the port distance table, SPLINE the Spline Table, SIGMP2 the Siglum-map, INSIG the Index Envelope by Siglum, IEBR the Index Envelope by Route. The Route Trees are read route at a time and each component is stored in a vector. They consist of LENGTH, the edge length, LAT, the latitude of the vertice, LONG, longitude of the vertice, BPOINT, the backpointer, IDENTS, the identifier of the vertices, WIDTH, the vertex width, EDWITH, the edge width of the segment, DEN, an array that has the 1° square distribution.
11/17	Initializes the distribution matrix DEN to zero.
18/49	Reads in all the input data sets.
50/55	Applies the growth factor to the ship days table
56/62	Begin to process the routes one at a time.
63/67	Checks the line number of the present route by use of a counter called ISTART to that of the Index Envelope by Route.
68/87	Checks to make sure that a route does not exceed 41 lines. It then proceeds to read in the designated number of line of the route.
88/91	Sets Flag2 to False if the route crosses the date line.
92/99	Accesses the appropriate set of 13 X values for the given route.

100/108	Looks at the first number of the Siglum Map for the given route. This indicates the number of Siglia assigned to that route. It checks to make sure that it is not zero and if it is it processes the next route.
109/110	It refers to the Index Envelope by Siglum for the given Siglia. This tells us the line numbers in the Route Trees for the two canonical ports.
111/119	Next it computes the density, i.e., the number of ship days per month. Also it determines the distance for the given Siglia.
120/145	Next it determines the peak or the common branch in the trees by doing a comparison on the identifiers.
146/155	Calls the subroutine to actually distribute the number of ships across the segment of the route.
156/164	Writes out the 180x360 matrix on a data set.
165	The subroutine that distributes the number of ship days across the route.
166/171	Dimensions and declares various variables.
172/183	Checks if this route crosses the date lines and sets a flag. If it does another flag is set up to determine which segment actually crosses the date line.
184/408	Processes the first segment according to the various cases. If the vertex widths of the 2 vertices are zero, one set of calculations are performed. If one vertex is zero and one is non-zero, one will be sent to another part of the program for various calculations. Still another set of equations are used when both vertices have a non-zero vertex width. All of these equations can be obtained from Chapter 4.

P. DATA FILES

1. TABLE: Routing Table (Alpha) (Final Version)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.RTNGTBL.NEW
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB,LRECL=72,BLKSIZE=3096)

SOURCE: Generated by Program Alpha from the Original Routing Table and the Mediterranean additions, with later corrections made simultaneously to the original.

USAGE: Used by program Betal to generate the Siglum Table.

FORMAT: 1. 69x69 matrix entered in 69 groups of 69 elements. Each group spans 3 lines with 24 elements each on lines 1 and 2, and 21 elements on line 3. Each entry contains:

(a) A 1-letter code; specifying meanings of the following number:

P	Canonical Port
Blank	Canonical Route
B	Multiple Routing Table Index
N	Null Entry

(b) A 2-digit number, with meaning as specified by (a).

2. Multiple Routing Table 15x2 matrix, entered in 15 lines of 2 entries each. Each entry contains a 2-digit code, denoting a canonical port.

FUNCTION: Let α, β denote two canonical ports with $1 \leq \alpha, \beta \leq 69$. Then the (α,β) element of the Routing Table determines the route from port α to port β by specifying either an intermediate port (denoted by P), a canonical route linking α to β (denoted by a blank), a multiple routing table to be checked (denoted by a B), or identity of ports α and β

(denoted by an N). If a multiple routing table is specified, let γ be the numerical code given. Then the (γ,1) and (γ,2) entries in the multiple routing table gives the intermediate port for each of the two options, supertanker and non-supertanker.

CORRECTION PROCEDURE:

Either enter changes simultaneously in the final version, original version, and Mediterranean supplement of Routing Table, or enter changes in the original version and Mediterranean supplement, then rerun program ALPHA. After any changes, the following programs must be rerun: GAMMA1. After changes affecting ports linked by direct routes, the following programs must be rerun: BETA1, BETA, BETA2, GAMMA2. If these modifications cause the number of Sigla to exceed 506, programs BETA and BETA2 will need to be modified internally as well.

2. TABLE: Routing Table (Alpha) (Original Version)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.RTNGTBL.ORG
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB,LRECL=60,BLKSIZE=3120)

SOURCE: Entered from the Ocean Routes Envelopes Report, with corrections (attached).

USAGE: Used by program Alpha to build the final version of the Routing Table.

FORMAT: 1. Routing Table 50x50 matrix, entered in 50 groups of 50 entries each. Each group spans 3 lines with 20 entries each on lines 1 and 2 and 10 entries on line 3. Otherwise, like Routing Table (final version).

2. Multiple Routing Table 4x2 matrix, arranged as in the Routing Table (final version).

FUNCTION: As in the Routing Table (final version), except that the Mediterranean canonical ports are excluded.

CORRECTION STATUS PROCEDURE:

See Routing Table (final version).

3. TABLE: Routing Table (Alpha) (Mediterranean Additions)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.RTNGTBL.ADD
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB,LRECL=72,BLKSIZE=3096)

SOURCE: Entered from the Ocean Routes Envelopes report, with corrections (attached).

USAGE: Used by program Alpha to build the Routing Table (final version).

FORMAT: 1. Routing table 24x24 matrix, entered in 24 lines of 24 entries each.

FUNCTION: It is like the Routing Table (final version), but it includes only Mediterranean canonical ports. Indexing of the port numbers differs from that of final version, and is related to it by the Mediterranean port/route renumbering table.

CORRECTION STATUS PROCEDURE:

See Routing Table (final version).

4. TABLE: Mediterranean Port/Route Renumbering Table

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.WYLIB (PORTNO)
VOL = SER = WYLIB 1
Wylbur Edit Format

SOURCE: Generated by program Alpha while building the final Routing Table.

USAGE:

port numbers assigned to the Mediterranean's additional ports and routes.

FORMAT: Lists of new canonical port, route number and the corresponding Mediterranean additional port numbers and routes, as used in the ORE report.

5. TABLE: Route Trees (Original Form)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.ENVELOPE

VOL = SER = PUBL03

UNIT = 33[illegible]

DCB = (RECFM=FB,LRECL=80,BLKSIZE=3120)

Sequenced in columns 73 through 80.

SOURCE: Entered from the ORE report, with subsequent corrections.

USAGE: Used by program Beta to generate the final form of Route Trees and various indices.

FORMAT: 84 groups containing a variable number of lines, corresponding to each of the 84 canonical routes. Each group is headed by a marker card with an'R' in column 1 and the 2-digit route number in columns 3/4. Each line within the group represents a separate vertex, except when alternate data must be entered for the various seasons. In this case, a group of four lines represents a vertex, with the season code ('P' for spring, 'S' for summer, 'F' for fall, 'W' for winter) punched in column 1. Data fields on each line and formats are as follows:

Columns	
1	Route Header or season marker
2/5	Edge width (F4.2)
6/10	Latitude (2-digit degree, 2-digit minute, 1-letter hemisphere code (N or S)
11/16	Longitude (3-digit degree, 2-digit minute, 1-letter hemisphere code (W or E)
17/20	Vertex width (F4.2)
21	Always blank
22/23	If the vertex is identical with a canonical port, the canonical port number was inserted, otherwise it remained blank

Columns

24	Always Blank	
25/48	Binary identifier	
49	If the vertex is identical with a canonical port, a direction code, as follows:	
	Blank	Entrance and Egress point
	1	Entrance point only
	2	Egress point only

FUNCTION: It provides the basic tree structure, which was obtained from the ORE Report. It is used to create the final form of the Route Trees by program Beta.

CORRECTION STATUS

Errors detected by BETA program corrected. Errors detected by examining output from BETA2 and DELTA1 have been corrected.

CORRECTION PROCEDURE:

Enter corrections, then rerun programs BETA, BETA2 and GAMMA2.

6. TABLE: Route Trees (Final Form)

VERSIONS: 4 (one for each season)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.OUTENV.SPRING, CN5054.PS1
OUTENV.SUMMER, CN5054.PS1.OUTENV.FALL,
CN5054.PS1.OUTENV.WINTER

VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB, LRECL=55, BLKSIZE=3135)

SOURCE: Generated by program Beta from Route Trees (original version)

USAGE: Used by program BETA2 to build the PORT DISTANCE TABLE, and also in Theta to distribute the ships across the routes.

FORMAT: Approximately 800 lines, each containing data for a single vertex as follows:

Columns	
1/24	Vertex Identifier (Binary)
25/30	Vertex Latitude (F6.2) (Decimal Degrees) (Negative - Southern Hemisphere, Positive - Northern Hemisphere)
31/37	Vertex longitude (F7.2) (Decimal Degrees) (Negative - Eastern Hemisphere, Positive - Western Hemisphere)
38/41	Vertex Width (F4.2)
42/47	Edge Length (F6.2) (In Latitudinal Degrees)
42/51	Edge Width (F4.2)
52/55	Back Pointer (I4)

FUNCTION: Determine the Siglum assigned to a given pair of canonical ports from the Siglum Table. Look up this Siglum on the INDEX TO ENVELOPE BY SIGLUM. The two line numbers contained in this table point to the verticies in the ROUTE TREE ENVELOPES corresponding to these ports. From each of these vertices, trace the Route Trees backwards using the back pointer until the first common parent node is encountered. This may be most easily determined by comparing the identifiers. Alternatively, use the INDEX TO ENVELOPE BY ROUTE to locate the root node of the tree structure for any given route. Look up the Siglum Map as well, using the route number. The list of sigla given here for that route may now be used to determine the terminal leaves of the Route Tree by looking them up in the INDEX TO ENVELOPE BY SIGLUM.

CORRECTION STATUS:

As for Route Trees (original version).

CORRECTION PROCEDURE:

Make all changes to the original version of the Route Trees (or to Routing Table), then rerun BETA to update indices as well. The following programs must then be rerun: BETA2, GAMMA2.

7. TABLE: Siglum Table

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.SGLMTBL
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB, BLKSIZE=3096, LRECL=72)

SOURCE: 1. Siglum Table: constructed by program BETA1 from final version of RTNGTBL.
2. Multiple Routing Table: carried from Routing Table, final version.

USAGE: Will be used in EPSILON

FORMAT: 1. Siglum Table: 69x69 matrix, corresponding to each possible pairing of world canonical ports, entered in 69 groups of 69 entries each. Each group spans 4 lines, with 18 entries in each of the first 3 lines and 15 in the last. Each entry consists of:
a. A 1-letter-code, determining meaning of the accompanying number:

P	Canonical Port
Blank	Siglum
B	Multiple Routing Table Index
N	Null entry

b. A 3-digit number, with meaning as specified by (a).
2. Multiple Routing Table: See Routing Table, final version.

FUNCTION: Like the Routing Table, except that route numbers have been replaced by sigla. To every ordered pair of canonical ports linked by a canonical route a different siglum is assigned. This siglum may be used later to retrieve the route trees, and ship table.

CORRECTION STATUS:

As for Routing Table.

CORRECTION PROCEDURE:

Make all corrections to routing table, then rerun BETA1 to update indices as well. The following procedures must also be rerun: BETA, BETA2, GAMMA2.

8. TABLES: Siglum Indices

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.SGLMNDX
VOL = SER = PUBL03
UNIT = 3330,
DCB = (RECFM=FB, LRECL=72, BLKSIZE=3096)

SOURCE: Built by program BETA1 while constructing the Siglum Table.

USAGE: Used by program BETA while constructing route envelope tree indices, and by GAMMA while checking them.

FORMAT: 1. Inverse Siglum Table: Headed by word 'INV#SGLM#TBL', followed by a list of number pairs, with 12 pairs per line and 2 spaces between pairs. Each pair corresponds to a successive siglum, and contains two 2-digit numbers specifying the pair of canonical ports (origin and destination, in order) associated to that siglum. (WARNING: The current version of BETA expects up to 506 entries in the INV#SGLM#TBL, corresponding to a maximum of 506 sigla. If this limit is exceeded, BETA must be modified. If less than 506 sigla exist, INV#SGLM#TBL may need to be padded with blank lines to simulate this number.)

2. Siglum Map: Headed by word 'SGLM#MAP'. Contains 85 canonical routes, each requiring three lines. Each group contains a header entry plus 45 entries (15 per line) in I4 format beginning in Column 3. The header entry is in I2 format and begins in Column 1 of the first line of each group. The header entry specifies the number of port pairs linked by that canonical route (or equivalently, the number of sigla assigned to each route).

These sigla themselves follow as a list in the regular entries, with excess entry positions set to 0.

FUNCTION: Let x be a given siglum number. Then the x-th entry in the Inverse Siglum Table gives the port pair associated with that siglum. (If this port pair were looked up in the Siglum Table, the corresponding entry there would be x). Let y be a canonical route number. Then the y-th group of entries in the Siglum Map gives all sigla corresponding to that route.

CORRECTION STATUS:

As for Routing Table.

CORRECTION PROCEDURE:

Make all changes to Routing Table, then rerun BETA1, to update Siglum Table as well. Following programs must then also be rerun: BETA, BETA2, GAMMA1.

9. **TABLE:** Envelope

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.ENVINDX
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB, LRECL=72, BLKSIZE=3096)

SOURCE: Built by program BETA from Route Envelope Trees and Siglum Indices.

USAGE: Used by program BETA2 when building Port Distance Table, and by GAMMA and THETA whenever referencing Route Trees Table. Also for debugging Route Trees and Routing Table.

FORMAT: 1. Index to Envelope by Route headed by word 'INDX#ENVLP#BY#ROUTE', followed by 84 numbers in (I4,2X) format with 12 numbers per line, forming 7 lines.

2. Index to Envelope by Siglum immediately follows index to envelope by route. Headed by word 'INDX# ENVLP#BY#SGLM' followed by one pair of numbers for each siglum in (I4, I4, 4X) format with 6 pairs per line. (There are currently 501 sigla, hence 501 such pairs).

FUNCTION: See Route Trees (final version). A '0' anywhere except at the end of the Index to Envelope by Siglum indicates that a leaf was missing or not correctly identified as a canonical port in the tree structures (original version), or that an incorrect route was specified in the routing table. (A 0 at the end occurs if the number of sigla < 506).

CORRECTION STATUS:

As for Route Trees and Routing Table.

CORRECTION PROCEDURE:

Make all changes in original version of tree structure or in routing table. Then rerun BETA1 (for changes in routing table) and BETA (always). Before re-running BETA, pad the siglum index with blank lines, if necessary to simulate 506 sigla. Following programs must then also be rerun: BETA2, GAMMA2.

10. **TABLE:** Port Distance Table

VERSIONS: 4 (one for each season)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.PRTDIST.SPRING
VOL = SER = PUBL03
UNIT = 3330
DCB = (LRECL=72, BLKSIZE=3096, RECFM=FB)

SOURCE: Generated by BETA 2 program from route trees (final version, copy appropriate to given season) and Index to Envelope by Siglum.

USAGE: Used by GAMMA2 to construct estimated travel time table, and also in Epsilon to build the Ship Days Table.

FORMAT: One pair of numbers in (1X,I4,1X,F6.2) format for each siglum (currently approximately 500 in all), with 6 pairs in a line. The first number in each pair is the number of the siglum to which the pair corresponds, the second, the distance (in units of latitudinal degrees) between the pair of canonical ports corresponding to that siglum.

CORRECTION STATUS:

As for Routing Table .

CORRECTION PROCEDURE:

Make all changes in Routing Table or Route Trees then re-run BETA1, BETA, and BETA2. Program GAMMA2 must then also be rerun to construct new Estimated Travel Time Table.

FUNCTION: Determine siglum corresponding to port pair linked by direct route, look up in Port Distance Table to determine distance between them. Unreasonable distances indicate poor routings by Routing Table or route trees.

11. TABLE: Estimated Travel Time Table

VERSIONS: 4 (one for each season)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.TRAVTME.SPRING
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB, BLKSIZE=3096, LRECL=72)

SOURCE: Built by Program GAMMA2 from Siglum Table and Port Distance Table.

USAGE: To be used by GAMMA when needed to reconstruct arrival/departure dates.

FORMAT: 69x69 matrix each entry corresponding to every possible corresponding port pair, whether linked by direct route or not. These entries are arranged in 69 groups of 69 entries each, with each group spanning 4 lines with 18 entries each in lines 1-3 and 15 entries in line 4. (The Siglum Table is laid out similarly). Each entry is in I4 format and gives either (if positive) the expected travel time in integral days between the two ports or else (if negative) an index to the Multiple Travel Time Table. This is followed immediately by the Multiple Travel Time Table, consisting of pairs of numbers in (I4, I4) format, one pair per line, giving the estimated travel times for each of the 2 type classes (super-tanker, non-super-tanker).

FUNCTION: Let (x,y) denote a pair of canonical ports. Then the (x,y) entry gives the estimated travel time between these to ports, unless it is negative. In that case, let its absolute value be Z, then the Zth pair in the Multiple Travel Time Table gives the estimated travel time between those two ports for each of the type classes. Unreasonable travel times indicate poor Routing Table or Route Trees. Travel time estimates assume velocity of 12 knots.

CORRECTION STATUS:

As for Routing Table and Route Trees.

CORRECTION PROCEDURE:

Make changes in Routing Table and Route Trees. Then rerun programs BETA, BETA1, BETA2, and GAMMA2.

12. TABLE: Port Table

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.NEWPORT.
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=FB, BLKSIZE=3120, LRECL=80)
Sequenced 73/80
(Old version: DSNAME = CN5054.PS1.PORTTBL.)

SOURCE: Hand corrections to output from the ORE report program, which used DOT port table.

USAGE: Used by GAMMA1 to build Port Hash Table, and by GAMMA to assign ports to proper canonical ports.

FORMAT: The line number of each entry in the Port Table is the port number used by DOT. The first field contains a new port number, which is usually the same but differs in the following cases:

1. Port abbreviation occurs with several spellings - port numbers reset to assign the same port number to all variants.
2. Port name is a generic term (such as East Coast U.S.) - port number is flagged with a negative sign.

The other fields give latitude, longitude of port and assigned canonical port.

CORRECTION STATUS:

Mediterranean canonical port assignments, enter variant spellings and generic names flagged. Errors discovered by DELTA2 are corrected in NEWPORT, with generic names not flagged in PORTTBL.

CORRECTION PROCEDURE:

Enter corrections directly, then rerun GAMMA1.

13. TABLE: Port Hash Table (Machine Readable Form)

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.PRTHASH,
VOL = SER = PUBL03
UNIT = 3330
DCB = (RECFM=F , LRECL=10000)

SOURCE: Built by program GAMMA1 from port table.

USAGE: Used by program GAMMA to determine the port number assigned to each port abbreviation.

FORMAT: Machine readable only. Each bin consists of 10 bytes, as follows:

Byte	Contents
1/6	Port Abbreviation (character)
7/8	Port number (fixed binary (15))
9/10	Overflow pointer (fixed binary (15))

The prime area currently contains 2999 bins, and the overflow area contains 2001 bins.

CORRECTION STATUS:

Does reflect flagging of variant spellings and generic names in the port table.

CORRECTION PROCEDURE:

Make changes (if any) in Port Table, then rerun program GAMMA1.

FUNCTION: Take character string value of the port abbreviation, treat it as a number, then divide it by 2999 (or other prime number, if this is changed), use this as bin index. Compare port abbreviations, if they are the same, then the port number is as given in that bin. Otherwise, use overflow pointer as the new bin index (to overflow area) and repeat this until either port abbreviation is found, or overflow printer = 0, in which case port abbreviation is not in port table.

(CONT)13. TABLE: Port Hash Table (People - readable form).

REFERENCE PARAMETER:

DSNAME = CN5054.PS1.HASHOUT

VOL = SER= PUBL03

UNIT = 3330

DCB = (RECFM = FB, LRECL = 18, BLKSIZE = 1800)

SOURCE: Built by program GAMMA 1 from PORT TABLE.

USAGE = People - readable form of PORT-HASH TABLE - no other function.

FORMAT:

Columns	Field
1/6	Port Abbreviation (Character)
7/8	Blank
9/12	Port Number (I4)
13/14	Blank
15/16	Overflow Index (I4)

First 2999 records belong to prime region, remainder to overflow.

FUNCTION: Same as PORT HASH TABLE (machine-readable form).

CORRECTION STATUS, PROCEDURE: Same as PORT HASH TABLE (machine-readable form).

14. TABLE: Sextile Array

REFERENCE PARAMETERS:

DSNAME = CN5054.PS2.X13FALL,CN5054.PS2.X13W,
CN5054.PS2.X13SP,CN5054.PS2.X13SU

VOL = SER = PUBL 03

DCN = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

SOURCE: A supplementary program entitled Newton which processed the sextile points created by the ORE.

USAGE: Used by program Theta to help produce the Merchant Counts Array

FORMAT: An array which varies in sizes from 29x13 to 31x31 according to seasons. The first group of thirteen elements spans two lines. The first line has 7 entries in F10.5 format and the second line has 6 elements in the same format.

FUNCTION: It takes the Type I' Cubic Splines consisting of seven sextile points from the ORE work. These points are then normalized to the interval [-1,1], and the five intermediate sextile points which were determined by Newtons method will describe the distribution. This data is stored in the Sextile Array and is accessed via the Cubic Spline Pointer Table. The last set of points is the general default spline.

15. TABLE: Cubic Spline Pointer Table

REFERENCE PARAMETERS:

DSNAME = CN5054.PS2.POINTR.SP,CN5054.PS2.POINTR.SUMMER
CN5054.PS2.POINTR.FALL,CN5054.PS2.POINTR.WINTER

VOL = SER = PUBL03

DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3120)

SOURCE: Hand generated according to given route

USAGE: Used by program THETA as one of the inputs to help create the Marchants Count Array

FORMAT: There are 7 lines with 12 numbers on each line in I3,3X format

FUNCTION: This table contains the pointers to the Sextile Array. This table contains 85 entries, one for each route, one per season.

16. TABLE: Proto Routing Table

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.PROTO48,CN5054.PS1.PROTO44,
CN5054.PS1.PROTO40,CN5054.PS1.PROTO35,
CN5054.PS1.PROTO31,CN5054.PS1.PROTO27,
CN5054.PS1.PROTO22,CN5054.PS1.PROTO18,
CN5054.PS1.PROTO14,CN5054.PS1.PROTO09,
CN5054.PS1.PROTO05,CN5054.PS1.PROTO01

VOL = SER = PUBL03

DCB = (REFM = FB, LRECL = 80, BLKSIZE = 3520)

SOURCE: Built by program GAMMA while processing the Lloyds data base.

USAGE: Used by program EPSILON to produce the Ships Days Table by month.

FORMAT: There are three 69x69 arrays one for merchants, tankers less than 70,000gt, and tankers greater than 70,000gt. The first line of each array indicates which month is being processed for example WEEK = 35. The second line indicates the shiptype for example, TAU = 1. The 69x69 array signifies the number of canonical ports, of a given shiptype in a given month. The format is as follows: line 1 contains message WEEK = __, line 2 has TAU = __. The 69 groups of 69 entries each spans five lines with 16 entries each in lines 1-4 and 5 entries in line 5. Each entry is in I5 format. Therefore the format is as follows: 4(16I5/),5I5. The code for the ship types and months are as follows:

TAU = 1 signifies that the following table consists of the number of ship days for merchant vessels between pairs of canonical ports

TAU = 2: signifies that the following table consists of the number of ship days for tankers under 70,000 gt. between pairs of canonical ports

TAU = 3: signifies that the following table consists of the number of ship days for tankers over 70,000 gt. between pairs of canonical ports

WEEK = 1 represents the month of January
WEEK = 5 represents the month of February
WEEK = 9 represents the month of March
WEEK = 14 represents the month of April
WEEK = 18 represents the month of May
WEEK = 22 represents the month of June
WEEK = 27 represents the month of July
WEEK = 31 represents the month of August
WEEK = 35 represents the month of September
WEEK = 40 represents the month of October
WEEK = 44 represents the month of November
WEEK = 48 represents the month of December

FUNCTION: Let (x,y) denote a pair of canonical ports. Then the (x,y) entry gives the total number of days that ships have been enroute between ports x and y.

17. TABLE: Ship Days Table

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.SHP.DAYS48,CN5054.PS1.SHP.DAYS44,
CN5054.PS1.SHP.DAYS40,CN5054.PS1.SHP.DAYS35,
CN5054.PS1.SHP.DAYS31,CN5054.PS1.SHP.DAYS27,
CN5054.PS1.SHP.DAYS22,CN5054.PS1.SHP.DAYS18,
CN5054.PS1.SHP.DAYS14,CN5054.PS1.SHP.DAYS09,
CN5054.PS1.SHP.DAYS05,CN5054.PS1.SHP.DAYS01

VOL = SER = PUBL03

DCB = (RECFM = FB, LRECL = 72, BLKSIZE = 3096)

SOURCE: Built by program EPSILON from the Proto Routing Table, Siglum Table and Routing Table.

USAGE: Used by program Theta to produce the Merchants Count Array

FORMAT: The format of the Ship Days Table is similar to that of the Proto-Routing Table. There are again three different ship types; TAU = 1, TAU = 2, TAU = 3. Each class is composed of 501 elements and is listed according to siglia i.e., canonical ports that are linked by a direct route. Following this lies the Residual Table, again for each ship type. Heading the table is the specified TAU. Then the 500 element vector spans 63 lines where the first 62 lines contain eight elements in F9.1 format and line 63 has five entires in the same format. Then there is a header entitled RESIDUAL TABLE. The following 69 entries, corresponding to the canonical ports, which span six lines. The first five lines contain 12 entires in I6 format and the sixth line has nine entries in 16 format.

17. TABLE: Ship Days Table

REFERENCE PARAMETERS:

DSNAME = CN5054.PS1.SHP.DAYS48,CN5054.PS1.SHP.DAYS44,
CN5054.PS1.SHP.DAYS40,CN5054.PS1.SHP.DAYS35,
CN5054.PS1.SHP.DAYS31,CN5054.PS1.SHP.DAYS27,
CN5054.PS1.SHP.DAYS22,CN5054.PS1.SHP.DAYS18,
CN5054.PS1.SHP.DAYS14,CN5054.PS1.SHP.DAYS09,
CN5054.PS1.SHP.DAYS05,CN5054.PS1.SHP.DAYS01

VOL = SER = PUBL03

DCB = (RECFM = FB, LRECL = 72, BLKSIZE = 3096)

SOURCE: Built by program EPSILON from the Proto Routing Table, Siglum Table and Routing Table.

USAGE: Used by program Theta to produce the Merchants Count Array

FORMAT: The format of the Ship Days Table is similar to that of the Proto-Routing Table. There are again three different ship types; TAU = 1, TAU = 2, TAU = 3. Each class is composed of 501 elements and is listed according to siglia i.e., canonical ports that are linked by a direct route. Following this lies the Residual Table, again for each ship type. Heading the table is the specified TAU. Then the 500 element vector spans 63 lines where the first 62 lines contain eight elements in F9.1 format and line 63 has five entires in the same format. Then there is a header entitled RESIDUAL TABLE. The following 69 entries, corresponding to the canonical ports, which span six lines. The first five lines contain 12 entires in I6 format and the sixth line has nine entries in I6 format.

FUNCTION: The 500 element vector represents the total number of ship days for the given siglia. The Residual Table stores the number of ships to be distributed for local traffic and 'non-route' traffic about the canonical ports.

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