New Jersey Department of Energy

W.P.

ENGINEERING COMPUTER OPTECNOMICS, INC.

ECO

1036 Cape St. Claire Center
Annapolis, Maryland 21401
Telephone (301) 757-3245

Systems Analysts for Engineers, Economists and Environmental Scientists

ECO

ENGINEERING COMPUTER OPTECNOMICS, INC.

ANALYSIS OF EXISTING AND POTENTIAL NAVIGATIONAL HAZARDS IN DELAWARE BAY

PREPARED FOR:

CAPE MAY COUNTY PLANNING BOARD
CAPE MAY, NEW JERSEY

"This acknowledges the financial assistance provided by the Coastal Zone Management Act of 1972, as amended, with funds administered by the National Oceanic and Atmospheric Administration, Office of Coastal Zone Management. This study was prepared under the supervision of the New Jersey Coastal Energy Impact Program of the New Jersey Department of Energy. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of N.O.A.A. or of the N.J.D.O.E."

JANUARY 21, 1981

1036 Cape St. Claire Center, Annapolis, Md. 21401 Tel: (301) 757-3245

EXECUTIVE SUMMARY

This Study has been prepared for the Cape May Planning Board under a grant from the Coastal Energy Impact Program of the New Jersey Department of Energy. Its stated objective is to identify existing and potential hazards to shipping and to determine the adequacy of existing aids to navigation and navigational procedures in Lower Delaware Bay and to make recommendations for improvements where warranted.

The Study examines historical vessel accident data and from them conducts the following tasks:

- identification of hazards and/or hazard scenarios;
- identification and analysis of potential corrective measures for those hazards and/or hazard scenarios;
- projection of future trends of acccidents with and without the presence of those potential corrective measures over the 1981 to 2000 period;
- analysis of the annualized costs of those potential corrective measures versus the annualized costs of projected impacts; and,

on the basis of those tasks makes recommendations for the improvement of the existing aid to navigation system in the Lower Delaware.

The Study shows that shipping accidents (collisions, groundings, and rammings) have exhibited an increasing trend with respect to frequency of occurrence over the 1972 to 1978 period. Therefore, holding all things equal (including level of traffic) over the next twenty years will likely result in increased accidents and with that, the potential for a large oil spill becomes a more

credible risk. It also shows, however, that with certain proposed corrective measures, the risk of impacts can be substantially reduced at modest costs. Moreover, given the potential cost of future accidents, the cost of those corrective measures are deemed to be highly cost beneficial to Society.

It is important to understand as is frequently emphasized throughout the text that these conclusions are predicated solely on the basis of the costs to Society which emanate through the occurrence of accidents. They do not include the societal benefits which may be accrued from these corrective measures in terms of the enhancement of the facilitation of commerce. Obviously, such inclusion would further justify their need and provision.

The Study concludes that the provision of the following features within the existing aid to navigation system in the Lower Delaware Bay should be implemented:

- an improved arrangement of buoys within the precautionary area between the traffic separation lanes and the pilot station including a swept frequency RACON on junction buoy "DBJ";
- an upgraded weather forecasting facility;
- a designated/increased spacing concept for the Big Stone Beach Anchorage;
- a second swept frequency RACON on the fixed structure at Brandywine Shoal Light; and,
- a portable electronic position fixing system including a single fixed structure at the entrance to the dredged channel for means of system initialization.

This combined implementation package exhibits a savings cost ratio of approximately ten over the next twenty years or a potential average annualized savings of $1,977,250 in direct accident costs and impacts versus an average annualized cost of $196,609 to procure, install and operate the necessary equipment proposed herein.

Lastly, copies of a draft version of this Study were circulated to various U.S. Coast Guard aid to navigation, engineering, and marine safety offices as well as the Delaware Bay Pilots. Copies of their written comments (where received) are included within this Study as Appendix B. Their comments have been either integrated within the final text where appropriate or specifically responded to in Section VII.

TABLE OF CONTENTS

LIST OF FIGURES

ECO

LIST OF TABLES

I. INTRODUCTION

The Delaware Valley is a major oil refining and petrochemical processing center for the Northeast United States. With an increased reliance on foreign crude oil in recent years, the volume of crude oil being brought into Delaware Bay has increased from 850,000 barrels per day in 1972 to just over one million barrels per day in 1978. While the actual number of ships has not increased, the additional volume of crude oil has been handled through the employment of larger ships. In 1972, the average deadweight of a crude oil carrier in the Delaware was approximately 34,000 long tons; today that figure exceeds 60,000 long tons. Thus, even under the assumption that the occurrence of oil spill events remains constant with increased ship size, the potential for a large volume oil spill becomes greater with increased ship size given the occurrence of an oil spill event.

The importance and fragility of the ecology of Delaware Bay and the adverse impact that a large oil spill will have on that ecological system as well as the tourist industry and economy of the contiguous shore areas of New Jersey and Delaware are well documented [1,2,3] 1/. Accordingly, it is critical that the movement of ships, and oil tankers in particular, within Delaware Bay be as safe as is reasonably possible.

The objective of this Study is to identify existing and potential hazards to those ship movements and to determine the adequacy of existing aids to navigation and navigational procedures in Delaware Bay and to make recommendations for improvements where warranted.

1/ Numbers in brackets designate references listed in Section VIII

The Study Area is the Lower Delaware Bay area from the Ship John Shoal Lighthouse to the mouth of the Bay and the coastal zone from Cape Henlopen to Cape May Point eastward to the limits of the contiguous zone as defined on National Ocean Survey Chart 12214. (See Figures 1 and 2.)

Within that area, this Study examines historical vessel accident data and from them identifies hazards to navigation. It then analyzes potential corrective measures for those hazards and projects future trends of accidents with and without the presence of those potential corrective measures to gauge the extent of their effectiveness over the 1981 to 2000 period. Finally, the Study compares the annualized costs of those potential corrective measures against the annualized costs of impacts over that same 20 year period and makes recommendations with respect to those findings.

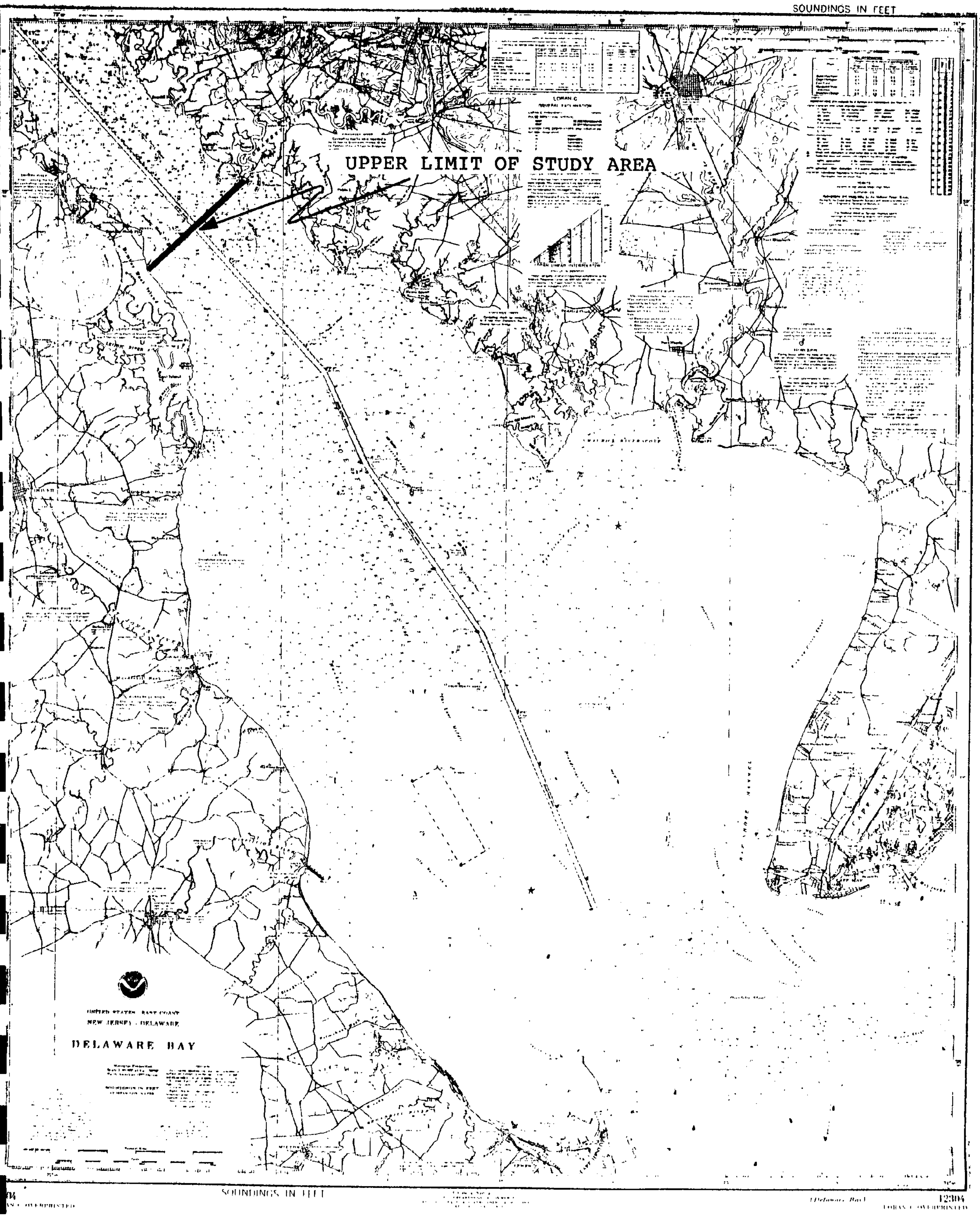


FIGURE 1: DELAWARE BAY (NOS CHART 12304)

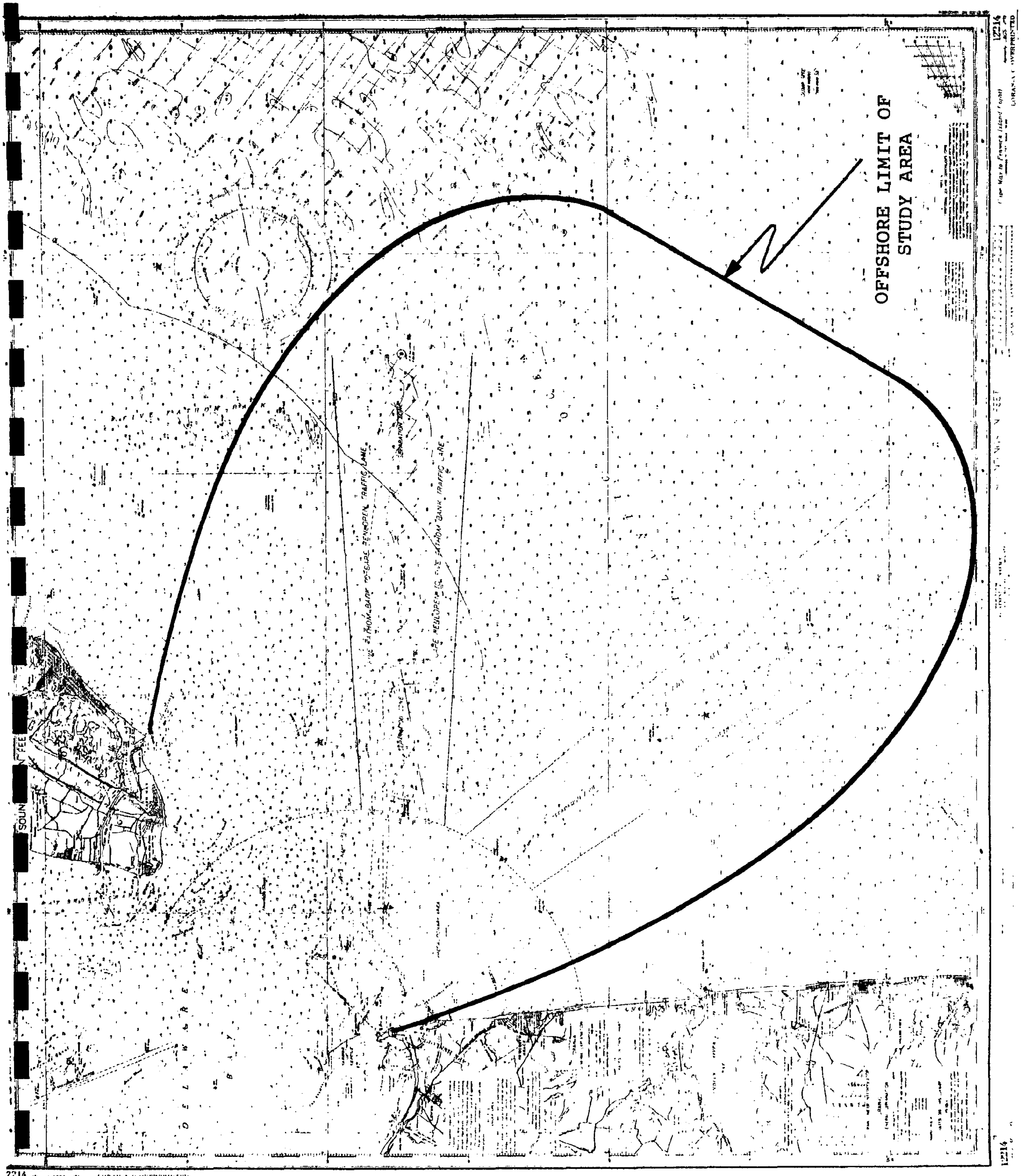


FIGURE 2: CAPE MAY TO FENWICK ISLAND LIGHT

(NOS CHART 12214)

II. HISTORICAL ACCIDENTS

In accordance with the basic objectives and terms of this Study, the United States Coast Guard Commercial Vessel Casualty (CVC) computer data file for all available fiscal years (FY), 1972 to 1978 inclusive, was interrogated for those collision (vessel-to-vessel impacts), grounding, and ramming (vessel-to-nonvessel impacts such as impacts with aids to navigation) accidents which involved any tank ship, cargo ship, and barge with a Gross Registered Tonnage (GRT) of 1,000 tons or greater that occurred in the Lower Delaware Bay. Insofar as the geographic location codes on that data tape are concerned, that three digit code prior to 1976 could only specify location to "Delaware Bay" which includes all navigable waters from the entrance to Delaware Bay (and the contiguous offshore waters thereto) to and including Camden and Philadelphia. Beginning in 1976 and all years thereafter, that code was changed such that the following geographic areas within Delaware Bay could be specified:

- Cape May Point Light;
- Camden, New Jersey;
- Philadelphia, Pennsylvania;
- Chester, Pennsylvania;
- Wilmington, Delaware;
- Reedy Point, C and D Canal East Entrance Light; and,
- Cape Henlopen, Harbor of Refuge Light.

Thus, for FY 1972 to FY 1975 all accidents for the Delaware Bay involving all vessel types with a Gross Registered Tonnage of 1,000 tons and greater were identified; for FY 1976 to FY 1978, all accidents involving all vessel types with a Gross Registered

Tonnage of 1,000 tons and greater for Cape May Point Light, Philadelphia, Cape Henlopen, Harbor of Refuge Light, and the generalized location code for Delaware Bay were likewise identified.

The Philadelphia code was specified because those entries represent half of the entire file for Delaware Bay and frequently, accidents that occur somewhere in the Delaware Bay are miscoded as Philadelphia. Thus, to insure that all accidents which occurred in the Study Area were identified, the computer code Philadelphia was specified for the initial interrogration of the total file.

This interrogation resulted in the identification of four hundred and sixty (460) accident cases, which were reviewed in order to positively establish geographic location, accident type, and vessel type.

Out of those 460 cases, thirty-three (33) of them did <u>not</u> involve a tank ship, a cargo ship, or a barge. These included as examples, tugboats operating without a barge, recreational craft, fishing vessels, etc. An additional one hundred and twenty-eight (128) cases were <u>not</u> collisions, groundings, and rammings; i.e., material failures, explosions, fires, etc., and therefore are not germane to the issue of the adequacy of aids to navigation.

Of the remaining two hundred and ninety-five (295) cases, each of those narrative case files was then read individually to establish the exact location of the accident. (For FY 1972 to 1976, those narrative files are on microfilm tape and were read on a microfilm reader. For FY 1977 and 1978, those narrative files were individually read directly from the hard copy files at U.S. Coast Guard Headquarters in Washington, D.C.)

From those 295 cases, only thirty seven (37) of them were found to have occurred in the Study Area; the remaining 258 cases were found to be either miscoded or located upriver of the Study Area. They were subsequently discarded from any further consideration herein. Of those remaining 37 collision, grounding, and ramming accidents involving tank ships, cargo ships, or barges of 1,000 GRT and greater, 30 were adjudged to be due to inadequate navigational aids, navigational procedures, or weather. The other seven events included various forms of mechanical failure, improper seamanship, or involved recreational craft and were thus discounted from any further analysis.

Finally, to accommodate the analysis procedure which is done on a calendar year basis as opposed to a fiscal year basis (which in the case of FY 1978 terminated on September 30, 1978), the files of the Marine Safety Office in Philadelphia were further investigated to extract any pertinent data for the last quarter of calendar year 1978; i.e., October, November, and December. That investigation revealed two additional cases.

Those 32 accident cases form the basis of all analyses conducted hereafter. A computer file of those cases was generated and the printout of that file is given in Appendix A. Each case includes the following information:

- vessel type;
- vessel registry;
- whether the vessel was inbound, outbound, or in an anchorage;
- time of day;
- month and year;
- gross registered tonnage;

- cargo condition;
- amount of cargo;
- cargo type;
- mean draft of the vessel;
- accident type;
- type of other vessel involved;
- location;
- visibility;
- weather condition;
- wind speed and direction;
- sea height and direction;
- pilotage; and,
- a condensed narrative.

Appendix A also contains the detailed documentation for that file.

Table 1 gives the distribution of the 30 tanker and cargo ship accident events by year and by accident type. (The remaining two events involved barges.)

Figures 3 and 4 show the locations of the total 32 events. (Including the two barge accidents.)

Figure 5 gives the distribution by year of cargo vessel and tanker accidents; i.e., collisions, groundings, and rammings collectively. Figures 6 and 7 give similar annual distributions but subdivided into groundings and collisions respectively. (Inasmuch as there was only one ramming event, collisions and rammings have been combined and are hereinafter referred to as simply collisions.)

TABLE 1

LOWER DELAWARE ACCIDENT DATA BY ACCIDENT TYPE AND YEAR FOR TANKERS AND CARGO SHIPS

	TANKER COLLISIONS AND RAMMINGS	TANKER GROUNDINGS	CARGO SHIP COLLISIONS AND RAMMINGS	CARGO SHIP GROUNDINGS	TOTALS
1972	3	2	1	0	6
1973	0	2	0	2	4
1974	2	1	0	0	3
1975	0	3	0	0	3
1976	0	4	1	1	6
1977	0	3	0	1	4
1978	0	3	1	0	4
TOTALS	5	18	3	4	30

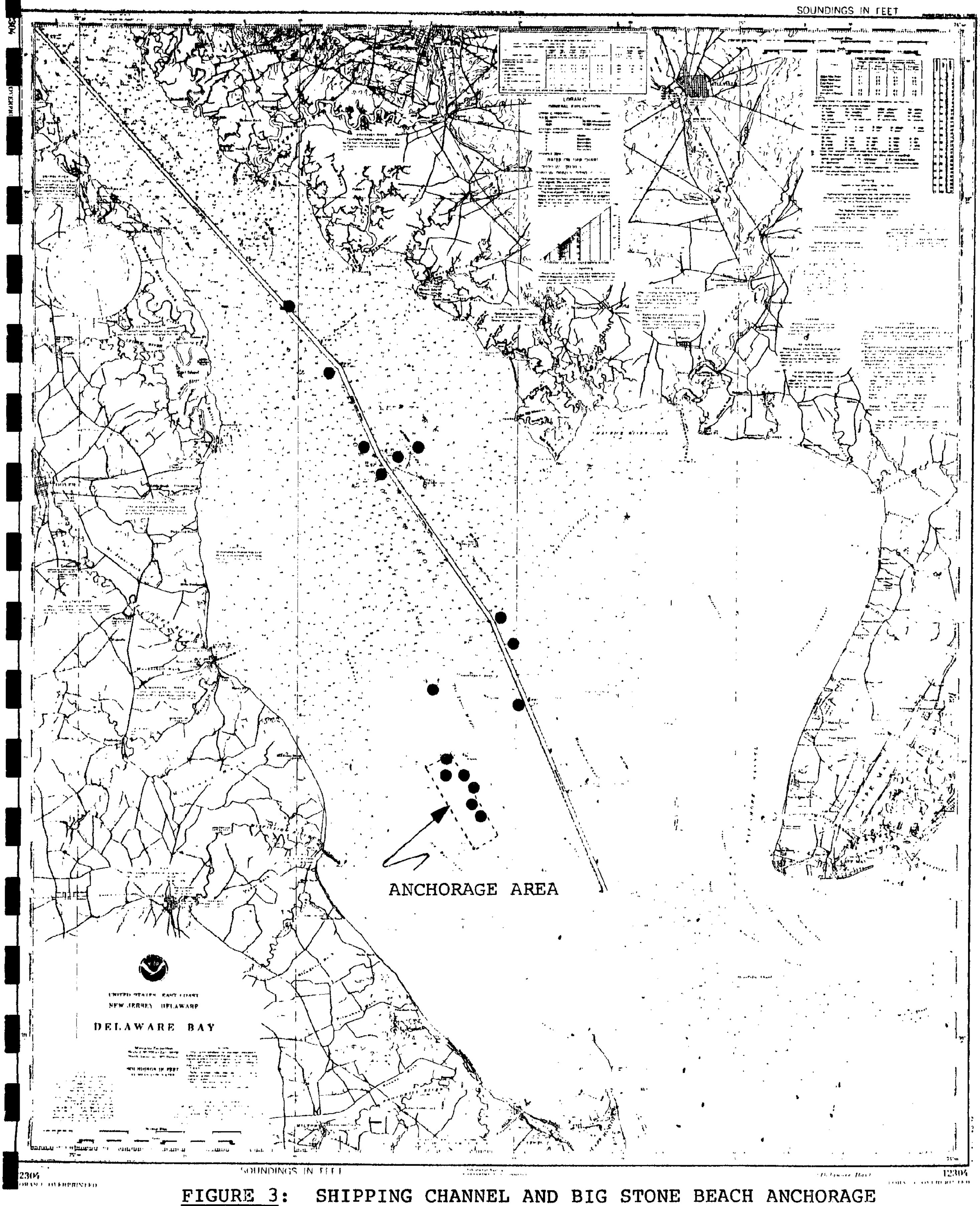


FIGURE 3: SHIPPING CHANNEL AND BIG STONE BEACH ANCHORAGE ACCIDENTS - DELAWARE BAY

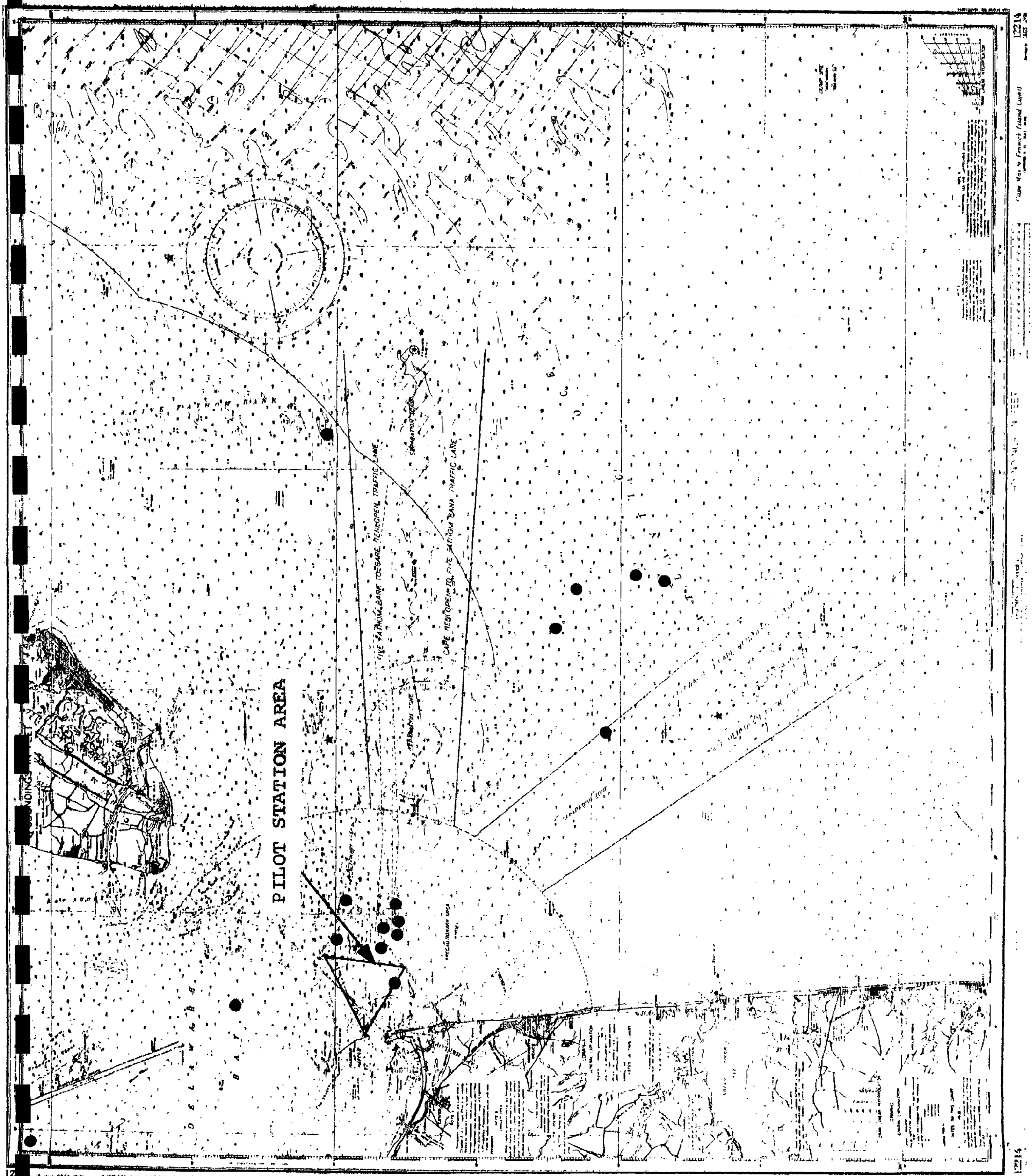
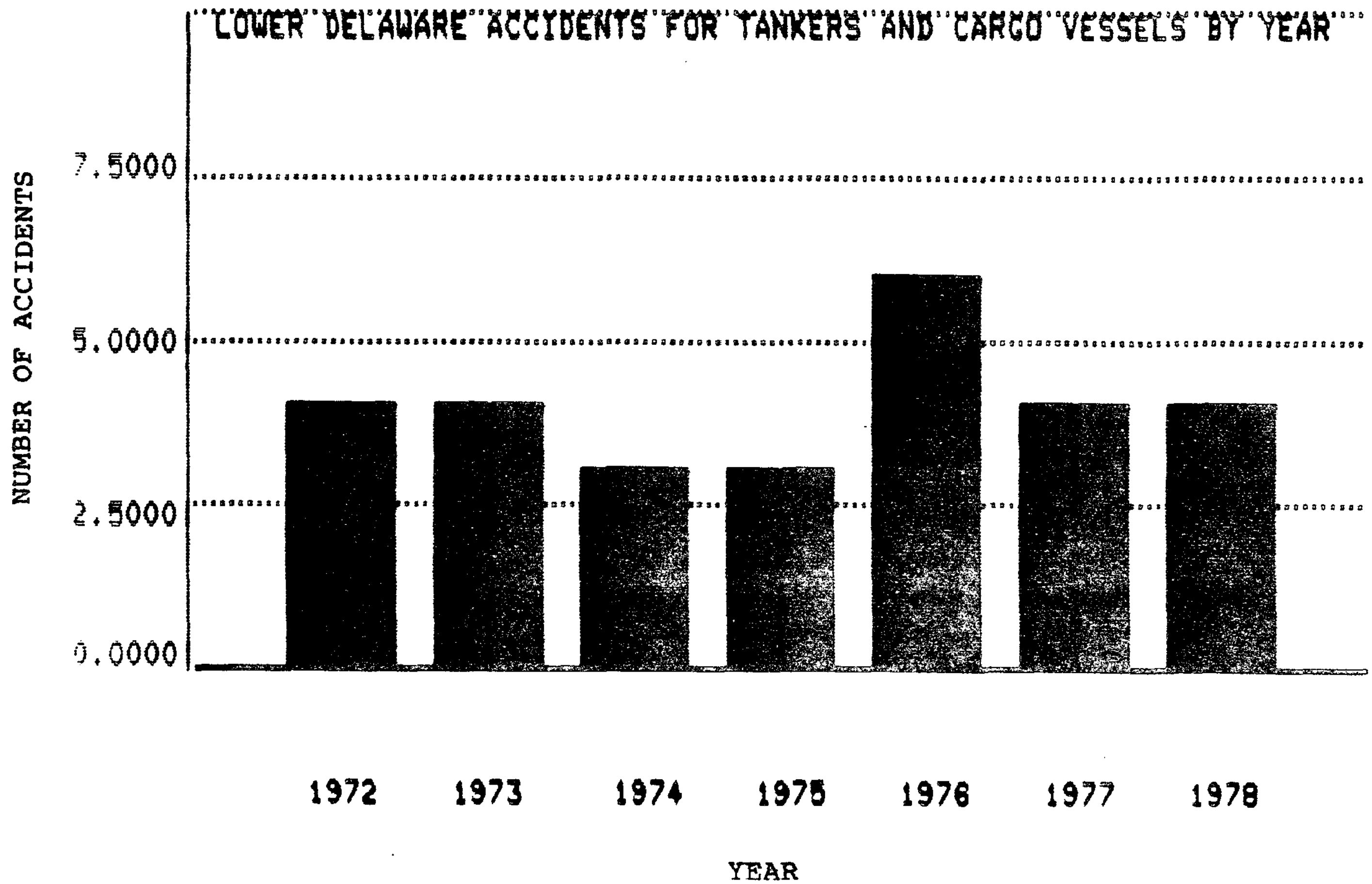
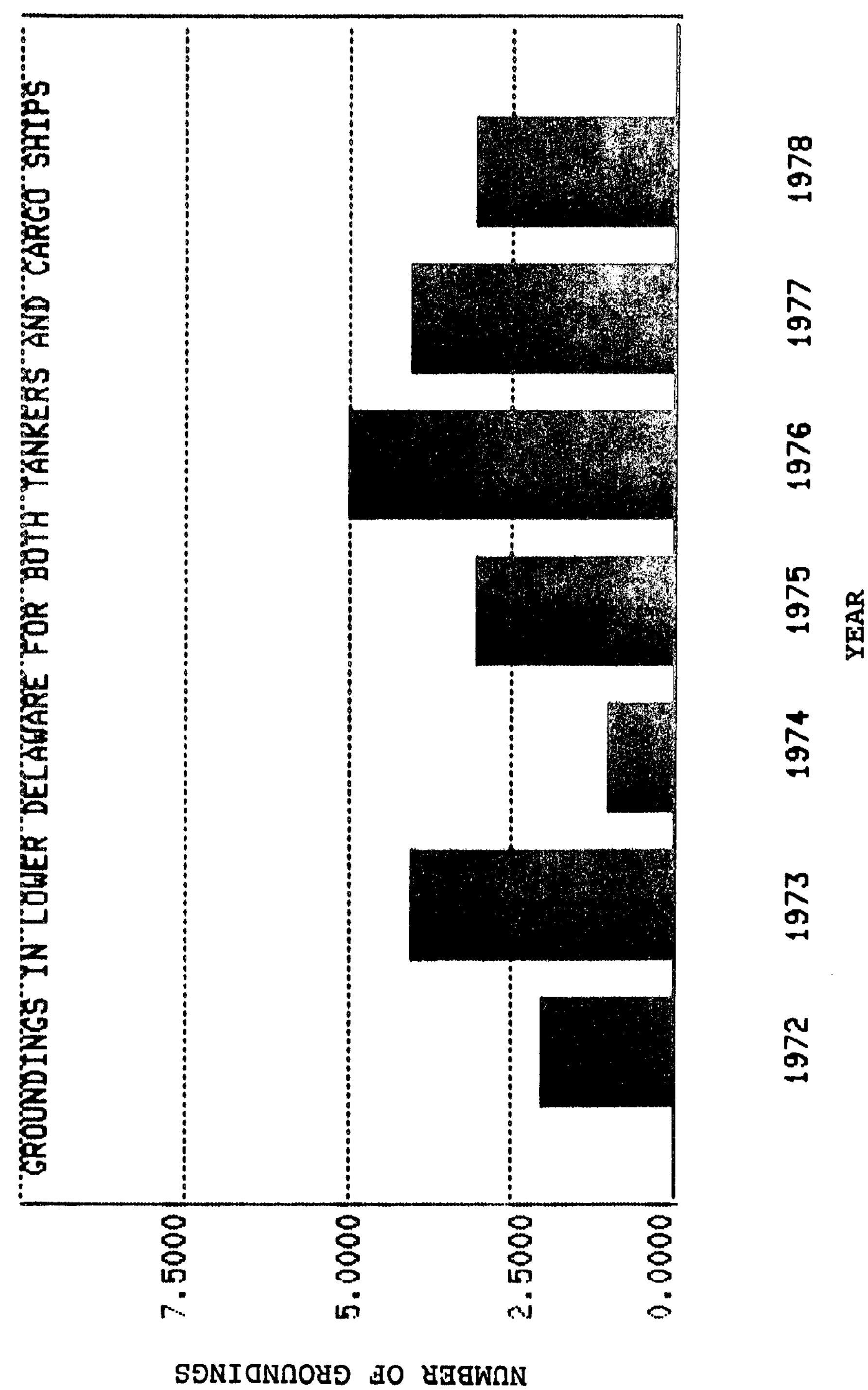


FIGURE 4: PILOT STATION AND ENTRANCE ACCIDENTS - LOWER DELAWARE BAY



LOWER DELAWARE ACCIDENTS FOR TANKERS AND CARGO VESSELS BY YEAR
NUMBER OF ACCIDENTS
7.5000
5.0000
2.5000
0.0000
1972
1973
1974
1975
1976
1977
1978
YEAR

FIGURE 5


GROUNDINGS IN LOWER DELAWARE FOR BOTH TANKERS AND CARGO SHIPS
NUMBER OF GROUNDINGS
0.0000
2.5000
5.0000
7.5000
1972
1973
1974
1975
1976
1977
1978
YEAR

<u>FIGURE 6</u>

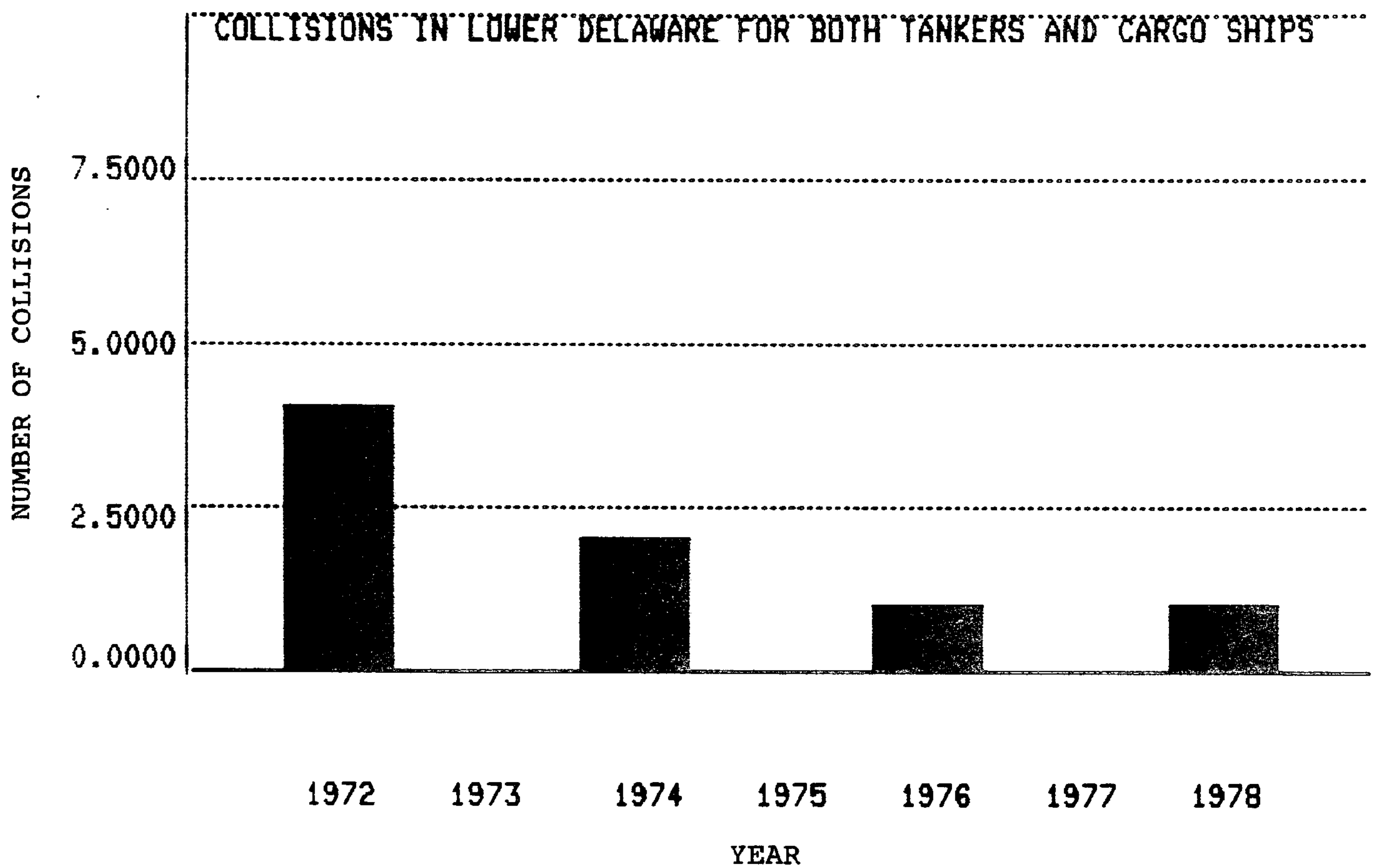

COLLISIONS IN LOWER DELAWARE FOR BOTH TANKERS AND CARGO SHIPS
NUMBER OF COLLISIONS
7.5000
5.0000
2.5000
0.0000
1972
1973
1974
1975
1976
1977
1978
YEAR

FIGURE 7

Figure 8 gives the distribution by month of all accidents in the Lower Delaware for the 1972 to 1978 period. Figure 9 subdivides those accidents into the collision and grounding categories and also gives the distribution of those events by month.

Figures 10, 11, 12, and 13 present various combinations of groundings and collisions for tankers and cargo ships by visibility. As can be seen from Figure 12, aproximately one-sixth of the total tanker accidents and approximately one-fifth of the tanker groundings occurred in visibility less than one mile where the average value for the visibility was approximately 0.3 mile. For cargo ship groundings that visibility value is also approximately one quarter of a mile and represents 25 percent of the cargo ship groundings. From Table 2, however, it can be seen that visibility occurrences of one quarter of a mile or less occur only 13 percent of the time (that is, the mean number of days per year during which at least some part of the 24 hour period, the visibility was measured at one quarter of a mile or less.) This strongly suggests a relationship between visibility and accident occurrence, in the Lower Delaware; i.e., a disproportionate number of accidents occur in low visibility than do in good visibility given the occurrence of low visibility versus good visibility and presuming that traffic flow remains constant over different visibility conditions. However, it is known that when poor visibility arises, traffic flow is lessened which then says that this skew in accident occurrence in periods of low visibility is even more intensified.

For each of those 32 cases, it was either determined directly from the CVC files or by the employment of standard empirical models for cost estimating, the cost (in dollars) of those accidents. Those values are given in Table 3. As can be seen from that Table, the total cost is categorized into the following four major headings:

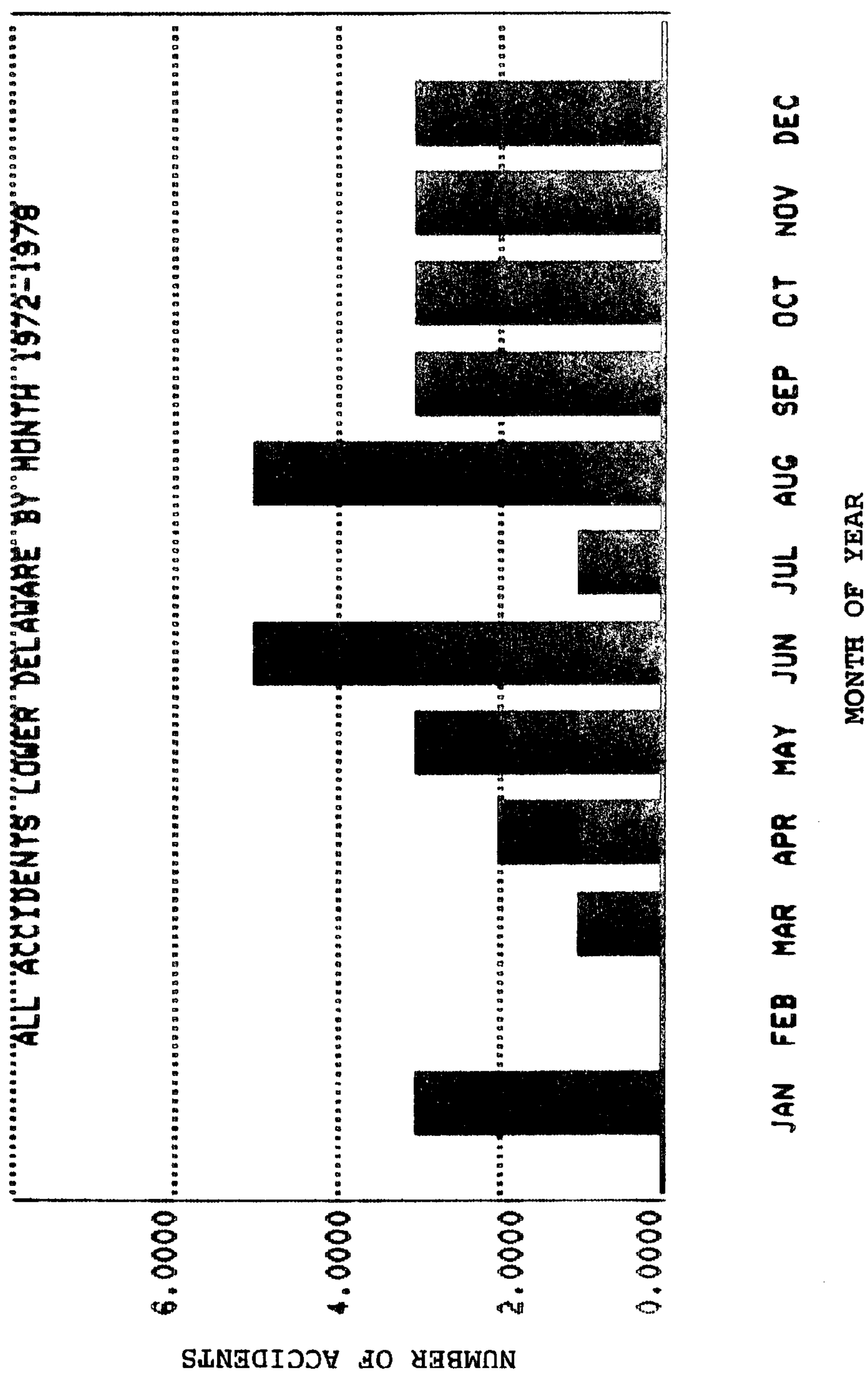

ALL ACCIDENTS LOWER DELAWARE BY MONTH 1972-1978
6.0000
4.0000
2.0000
0.0000
NUMBER OF ACCIDENTS
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH OF YEAR

FIGURE 8

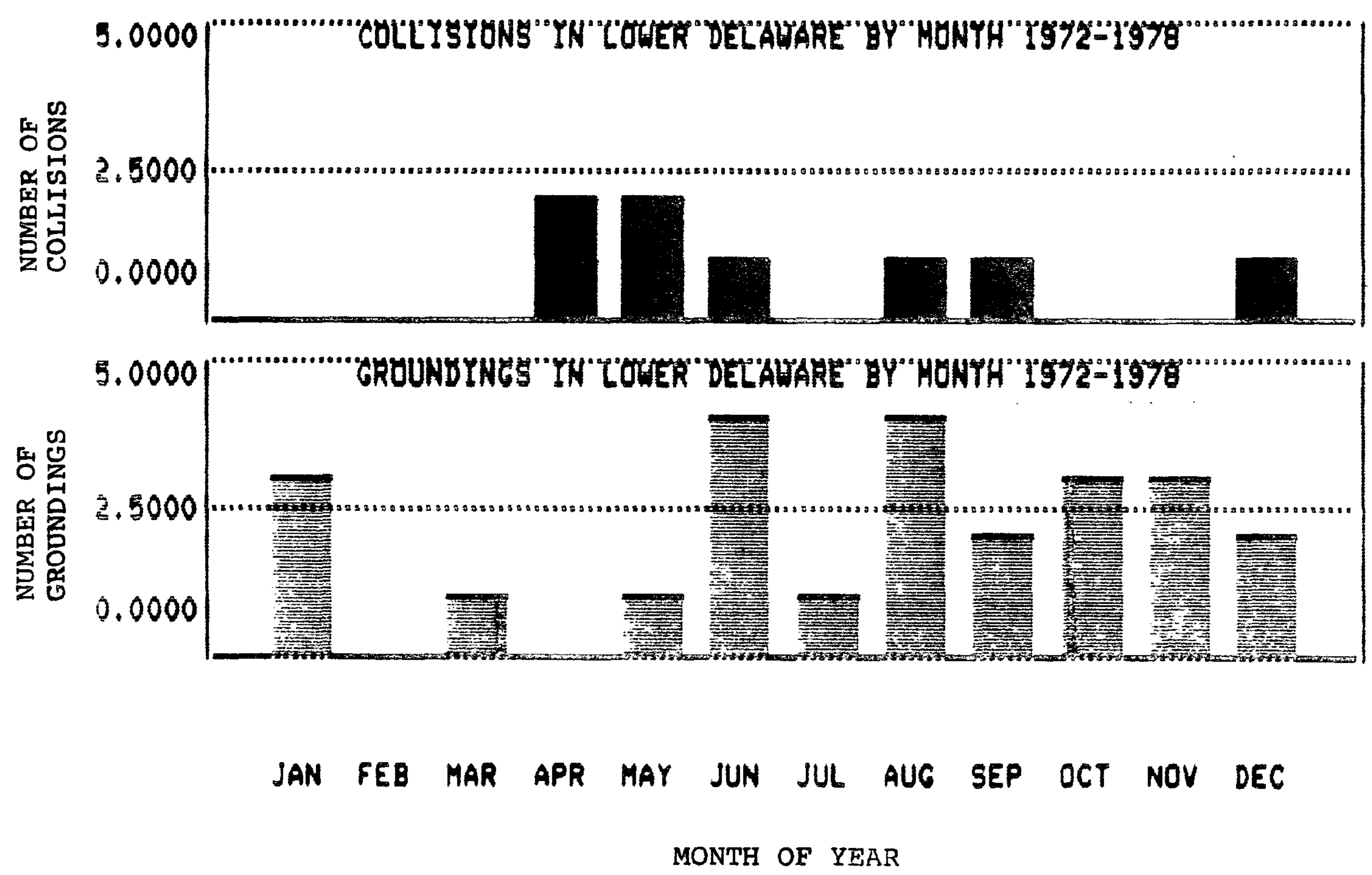

COLLISIONS IN LOWER DELAWARE BY MONTH 1972-1978
GROUNDINGS IN LOWER DELAWARE BY MONTH 1972-1978
NUMBER OF COLLISIONS
NUMBER OF GROUNDINGS
5.0000
2.5000
0.0000
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH OF YEAR

FIGURE 9

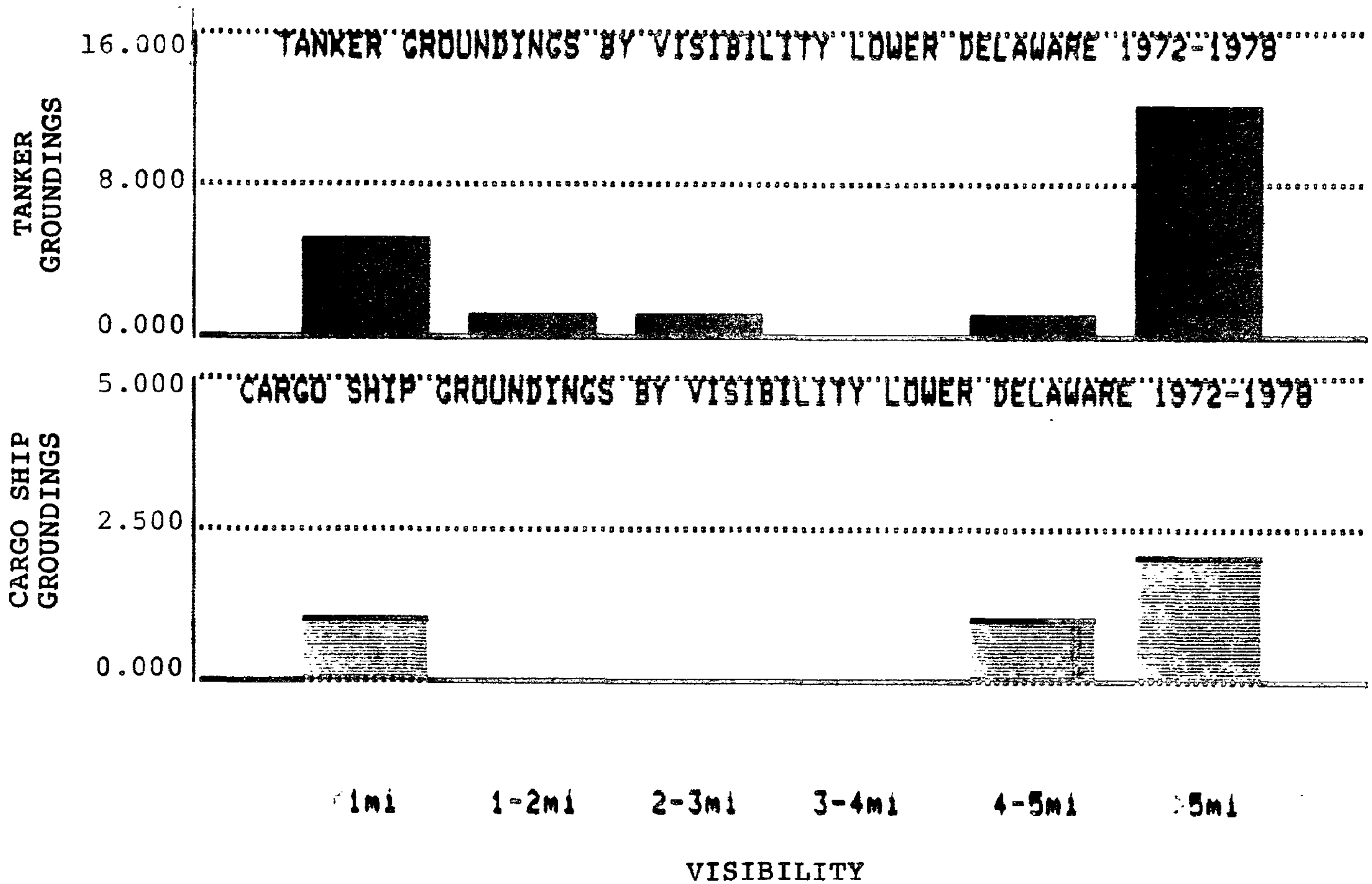

TANKER GROUNDINGS BY VISIBILITY LOWER DELAWARE 1972-1978
TANKER GROUNDINGS
16.000
8.000
0.000
CARGO SHIP GROUNDINGS BY VISIBILITY LOWER DELAWARE 1972-1978
CARGO SHIP GROUNDINGS
5.000
2.500
0.000
<1mi
1-2mi
2-3mi
3-4mi
4-5mi
>5mi
VISIBILITY

FIGURE 10

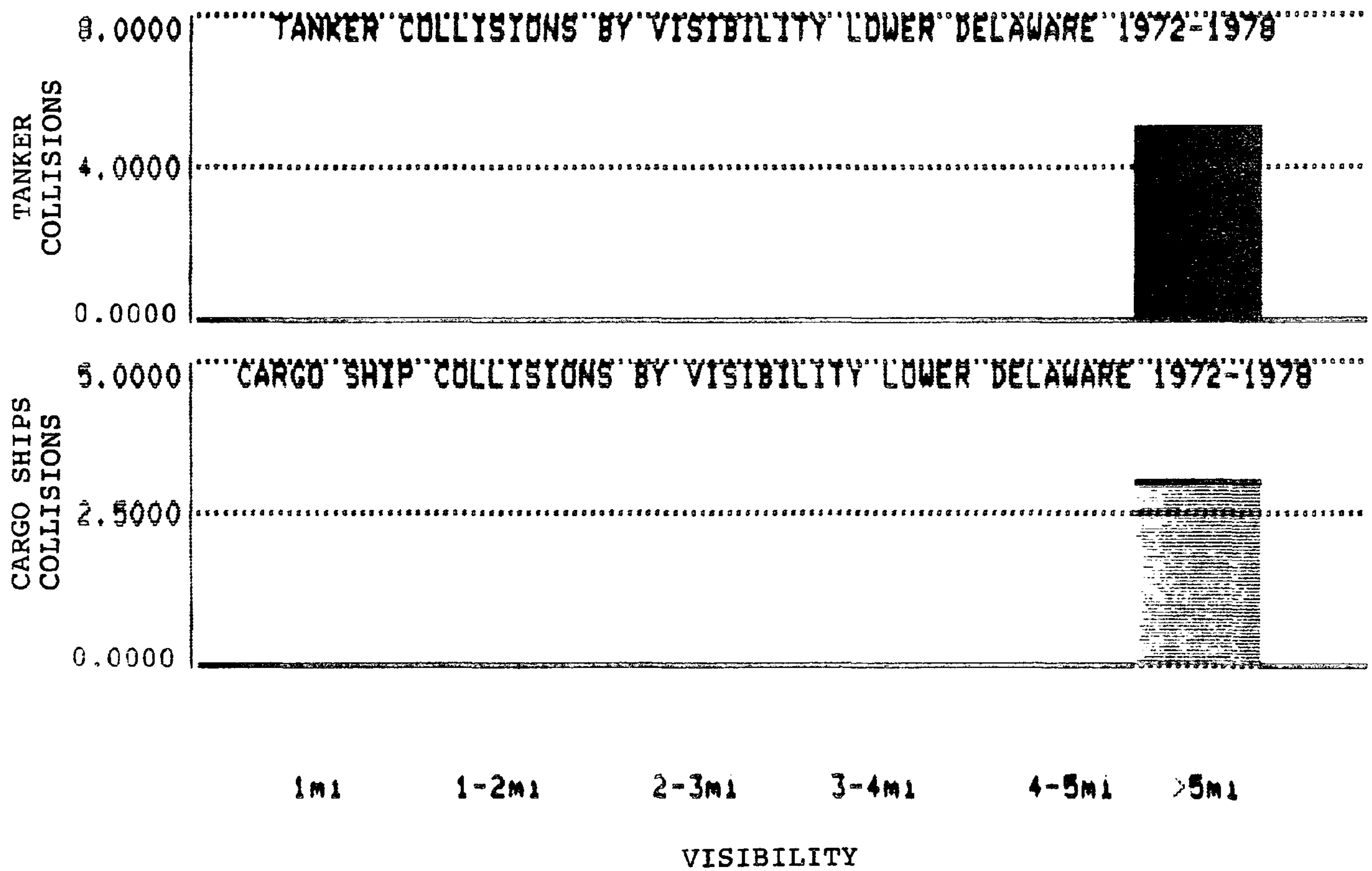

TANKER COLLISIONS BY VISIBILITY LOWER DELAWARE 1972-1978
TANKER COLLISIONS
8.0000
4.0000
0.0000
CARGO SHIP COLLISIONS BY VISIBILITY LOWER DELAWARE 1972-1978
CARGO SHIPS COLLISIONS
5.0000
2.5000
0.0000
1mi
1-2mi
2-3mi
3-4mi
4-5mi
>5mi
VISIBILITY

FIGURE 11

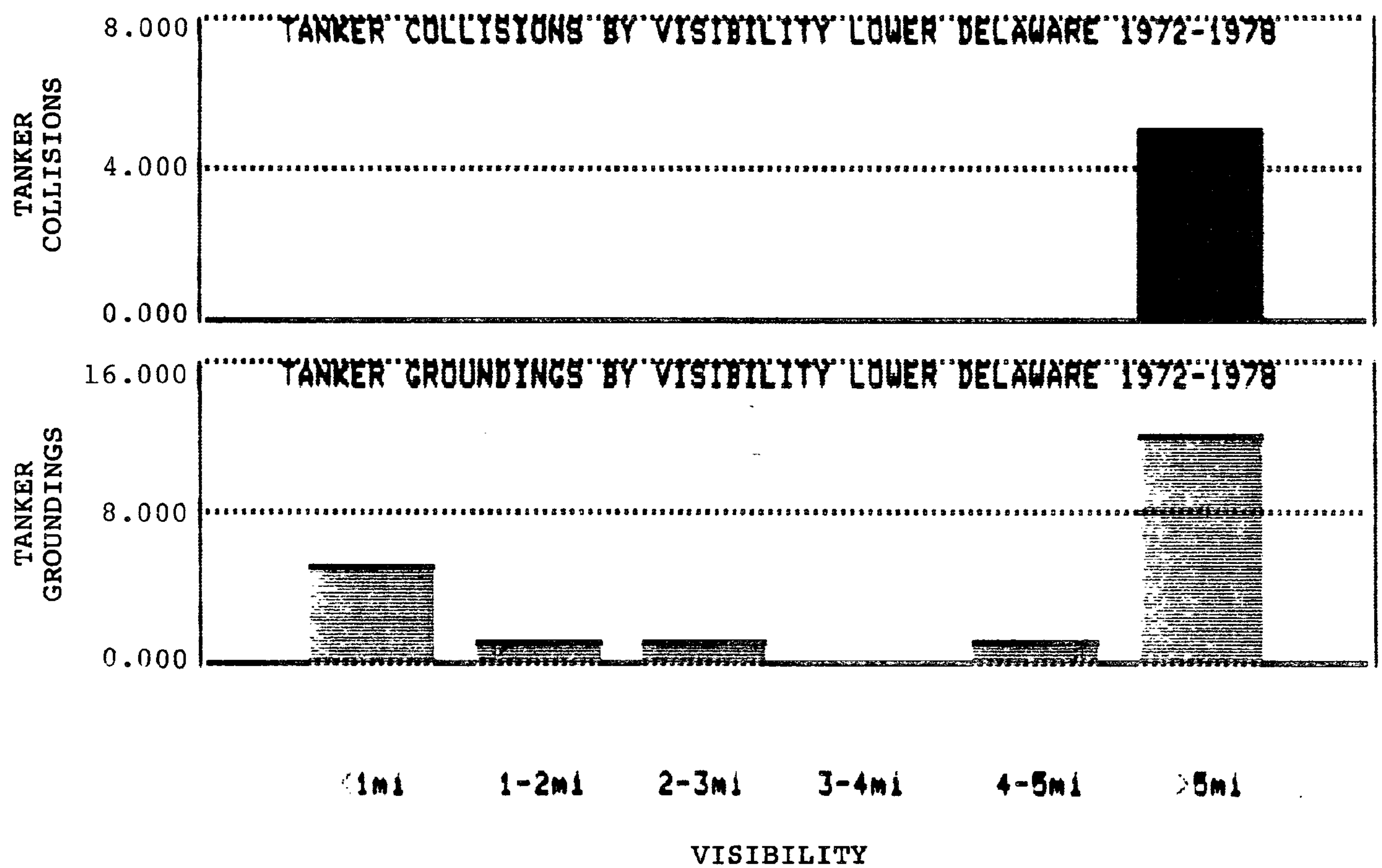

TANKER COLLISIONS BY VISIBILITY LOWER DELAWARE 1972-1978
TANKER COLLISIONS
8.000
4.000
0.000
TANKER GROUNDINGS BY VISIBILITY LOWER DELAWARE 1972-1978
TANKER GROUNDINGS
16.000
8.000
0.000
<1mi
1-2mi
2-3mi
3-4mi
4-5mi
>5mi
VISIBILITY

FIGURE 12

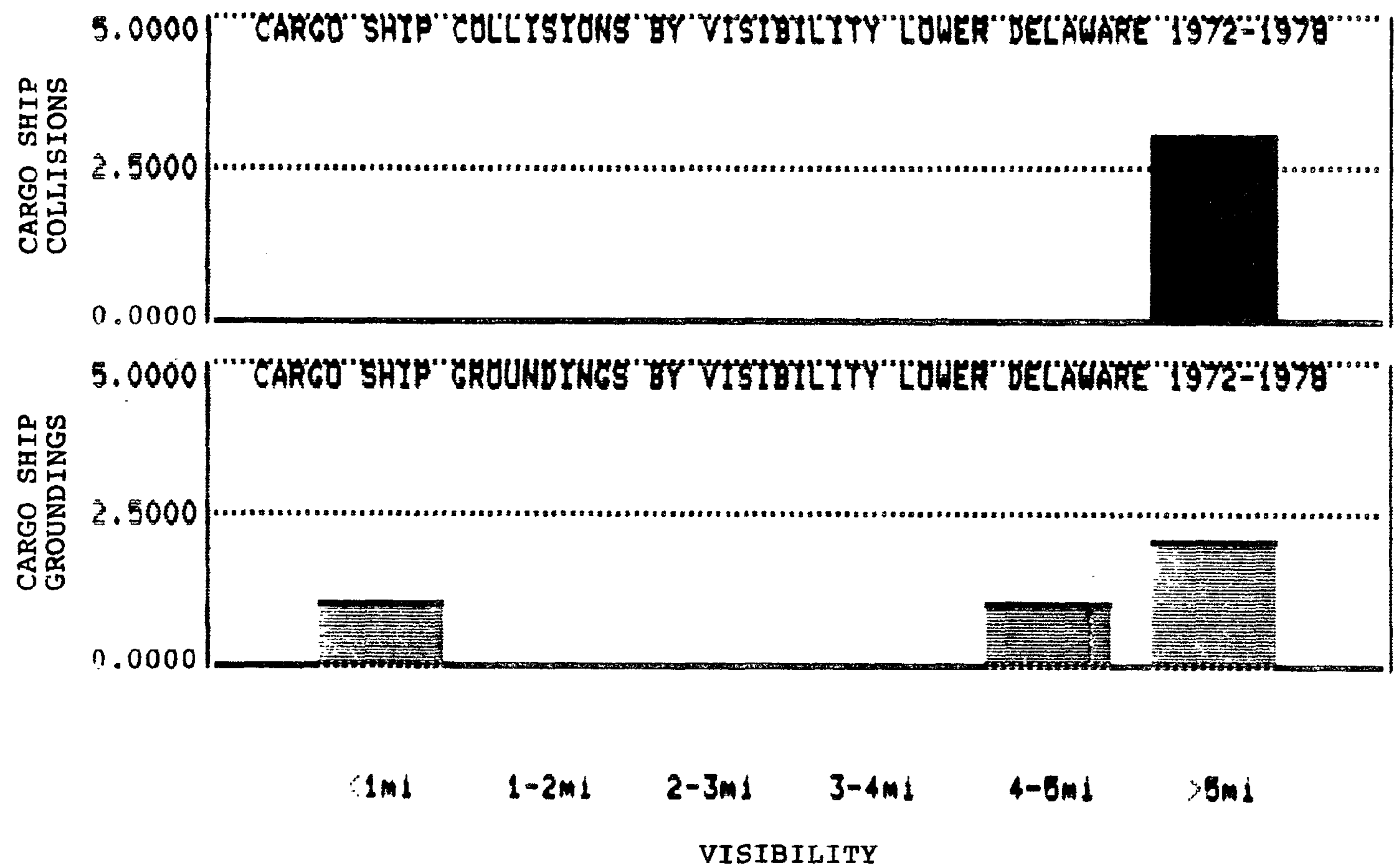

CARGO SHIP COLLISIONS BY VISIBILITY LOWER DELAWARE 1972-1978
CARGO SHIP COLLISIONS
5.0000
2.5000
0.0000
CARGO SHIP GROUNDINGS BY VISIBILITY LOWER DELAWARE 1972-1978
CARGO SHIP GROUNDINGS
5.0000
2.5000
0.0000
<1mi
1-2mi
2-3mi
3-4mi
4-5mi
>5mi
VISIBILITY

FIGURE 13

TABLE 2

MEAN NUMBER OF DAYS VISIBILITY
RECORDED AT 1/4 MILES OR LESS

MONTH	MEAN NUMBER OF DAYS*	PERCENT OF MONTH/YEAR
JANUARY	4	12.9/1.09
FEBRUARY	3	10.7/0.82
MARCH	4	12.9/1.09
APRIL	4	13.3/1.09
MAY	5	16.1/1.37
JUNE	5	16.7/1.37
JULY	4	12.9/1.09
AUGUST	4	12.9/1.09
SEPTEMBER	4	13.3/1.09
OCTOBER	5	16.1/1.37
NOVEMBER	3	10.0/0.82
DECEMBER	3	9.7/0.82
TOTAL	48	- /13.11

*BASED ON 21 YEARS OF OBSERVATIONS THROUGH 1979, ATLANTIC CITY NEW JERSEY LOCAL CLIMATOLOGICAL DATA, NATIONAL CLIMATIC CENTER, ASHEVILLE, NORTH CAROLINA, (MOST PROXIMATE WEATHER STATION TO STUDY AREA).

TABLE 3

ACCIDENT COST DATA

CASE NUMBER	REPORTED DAMAGE	DERIVED DAMAGE	TUGS/ PILOTAGE	LIGHTERING/ DEMURRAGE	POLLUTION	TOTAL
20902	0	$5,000	0	0	0	$5,000
20571	0	0	0	$5,000	0	$5,000
20783	0	0	0	0	0	0
20905	$220,000	0	0	0	0	$220,000
21206	0	0	0	$26,000	0	$26,000
21755	$100,000	0	0	0	0	$100,000
21778	$3,800	0	0	0	0	$3,800
32738	0	0	0	0	0	0
32901	0	0	$5,000	0	0	$5,000
40110	0	0	0	0	0	0
41248	$207,000	0	0	0	0	$207,000
42500	0	0	0	$99,500	0	$99,500
42814	0	$420,000	0	0	0	$420,000
50601	$20,000	0	0	0	0	$20,000
51305	0	0	0	0	0	0
52337	0	0	0	$1,000	0	$1,000

TABLE 3 (CONT'D)

60554	$10,000	0	$8,000	$64,500	0	$82,500
61142	0	0	$13,000	0	0	$13,000
62877	0	0	0	$2,000	0	$2,000
63777	0	0	0	$6,000	0	$6,000
63792	0	$10,000	$12,000	$60,000	$18,000	$100,000
63795	0	$1,000	0	0	0	$1,000
64217	0	0	0	$15,000	0	$15,000
70657	0	0	0	0	0	0
71045	0	0	0	0	0	0
72865	0	0	$12,000	$38,000	0	$50,000
80271	0	0	0	$70,000	0	$70,000
81775	0	0	0	$50,000	0	$50,000
82747	0	0	0	0	0	0
83696	$150,000	0	0	0	0	$150,000
TOTALS	$710,000	$436,000	$50,000	$437,000	$18,000	$1,651,800
PERCENT TOTAL	(0.430)	(0.264)	(0.030)	(0.265)	(0.011)	(100.00)
	$1,146,800					
	(0.694)					

- damage costs;
- tug/pilotage costs;
- lightering and/or demurrage costs; and,
- pollution costs.

The damage costs are further subdivided into reported dollar amounts and those costs which were estimated based upon the reported extents of damage to the vessel(s) and/or other physical property.

As can be seem from Table 3, 43 percent of the total cost is actual reported damages. Derived costs represent 26.4 percent of the total while the tugs/pilotage, lightering and/or demurrage, and pollution costs represent 3, 26.5, and 1.1 percent of the $1,651,800 total respectively. The subtotal for damage costs (both reported and derived) is $1,146,800 and accounts for 69.4 percent of the total costs for the seven year period.

Table 4 gives the number of tanker and cargo ship port calls (a port call is the inbound and outbound transit of a port by a ship) as measured at the entrance to Delaware Bay by the Philadelphia Maritime Exchange.

Accident and casualty events for ships are conventionally measured in terms of a rate parameter or event per port call (which is termed as an exposure) to account for any variance in that exposure. Figure 14 gives the annual distribution of that rate parameter for all accidents or casualties in the Lower Delaware Bay as a function of the number of port calls and is subdivided into the tanker and cargo ship categories. Figures 15 and 16 present those data by collision and grounding accident events for tankers and cargo ships respectively.

TABLE 4

TANKER AND CARGO SHIP PORT CALLS
BY YEAR FOR LOWER DELAWARE*

	TANKERS	CARGO SHIPS**	TOTAL
1972	2,052	2,505	4,557
1973	2,115	1,880	3,995
1974	2,015	1,607	3,622
1975	1,747	1,727	3,474
1976	1,818	1,666	3,484
1977	1,871	1,462	3,333
1978	1,789	1,432	3,221
1979	1,662	1,284	2,946

*SOURCE: PHILADELPHIA MARITIME EXCHANGE

**BOTH BREAK BULK AND CONTAINER SHIPS

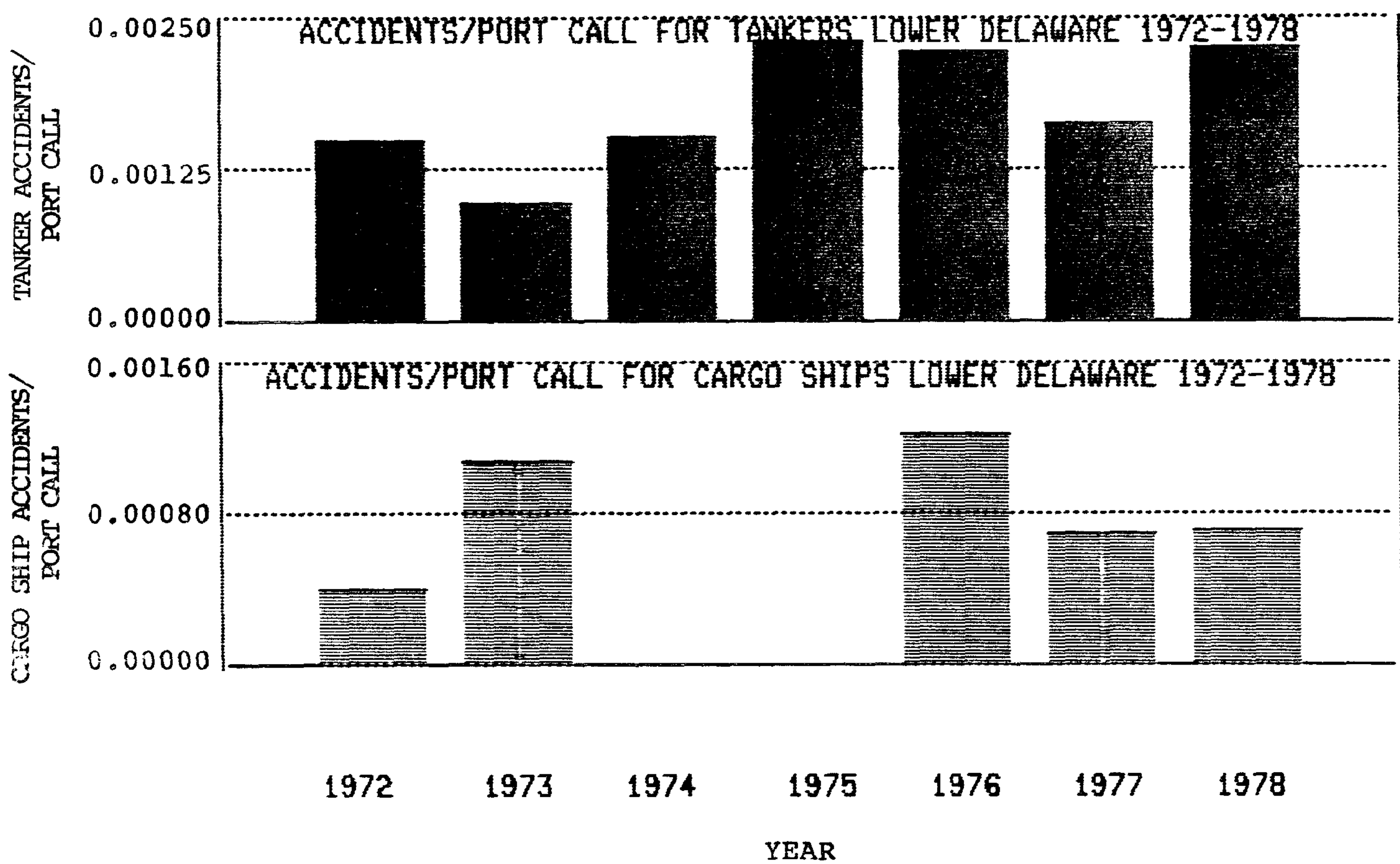

ACCIDENTS/PORT CALL FOR TANKERS LOWER DELAWARE 1972-1978
TANKER ACCIDENTS/ PORT CALL
0.00250
0.00125
0.00000
ACCIDENTS/PORT CALL FOR CARGO SHIPS LOWER DELAWARE 1972-1978
CARGO SHIP ACCIDENTS/ PORT CALL
0.00160
0.00080
0.00000
1972
1973
1974
1975
1976
1977
1978
YEAR

FIGURE 14

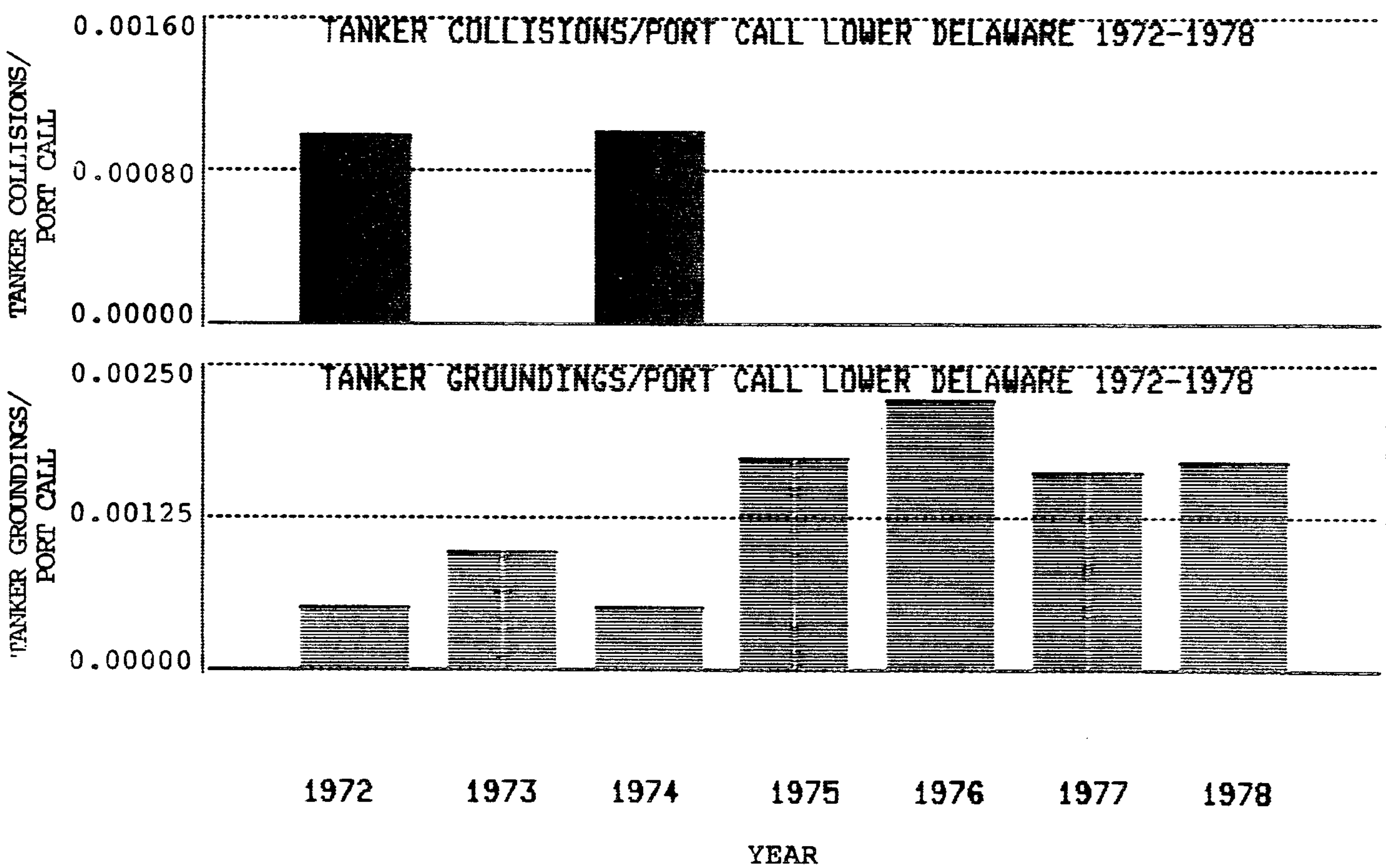

TANKER COLLISIONS/PORT CALL LOWER DELAWARE 1972-1978
TANKER COLLISIONS/
PORT CALL
0.00160
0.00080
0.00000
TANKER GROUNDINGS/PORT CALL LOWER DELAWARE 1972-1978
TANKER GROUNDINGS/
PORT CALL
0.00250
0.00125
0.00000
1972
1973
1974
1975
1976
1977
1978
YEAR

FIGURE 15

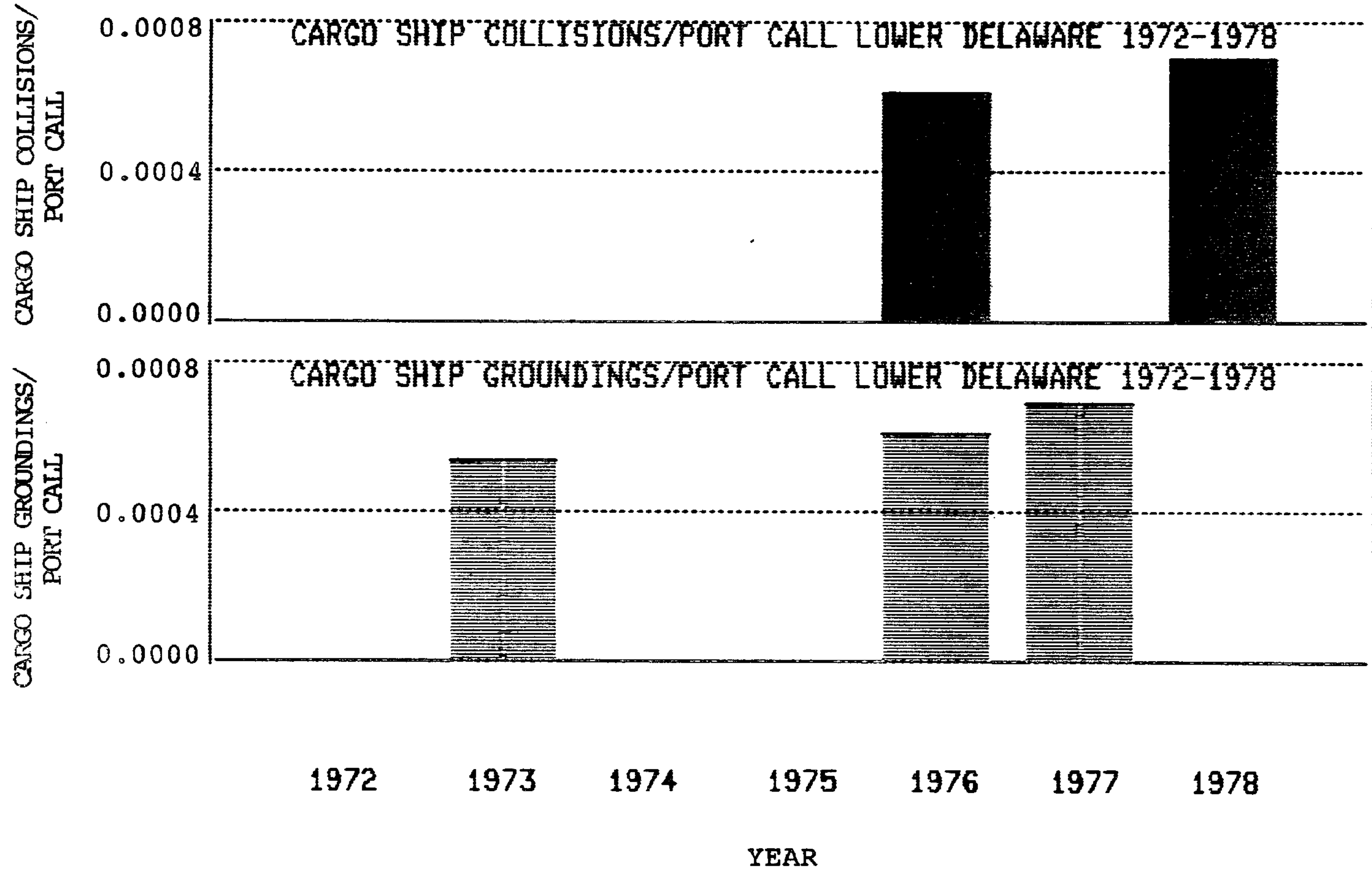

CARGO SHIP COLLISIONS/PORT CALL LOWER DELAWARE 1972-1978
CARGO SHIP COLLISIONS/ PORT CALL
0.0008
0.0004
0.0000
CARGO SHIP GROUNDINGS/PORT CALL LOWER DELAWARE 1972-1978
CARGO SHIP GROUNDINGS/ PORT CALL
0.0008
0.0004
0.0000
1972
1973
1974
1975
1976
1977
1978
YEAR

FIGURE 16

From the historical distribution of data shown on Figures 15 and 16, a trend line analysis was made through the year 2000 in order to make future projections. The lower portions of Figures 17, 18, 19, and 20 are computer generated trend lines for tanker collisions, tanker groundings, cargo ship collisions, and cargo ship groundings respectively for the period 1980 to 2000. The upper portions of those same figures show small vertical lines which are the data inputs taken from Figures 15 and 16 for the 1972 to 1978 sampling period and from which the respective trend lines have been generated.

Each of the four trend lines is a mathematically drawn "best fitting line" through the data points extended through the future period. From those lines, expected values for the frequency of occurrence of the various events may be read for any given year in the future. In turn, expected values for the number of future events may be derived directly from those frequencies; i.e., the frequency of occurrence is the occurrence per port call which when multiplied by the number of port calls gives the expected number of events.

The computer generated imagery of Figures 17 through 20 also gives the slope (m) of the best fit line and the y- intercept (b) such that the equation of any one of those trend lines is of the form, $y = mx+b$. The correlation coefficients or the measure of the goodness of fit of the trend lines to the data are -0.63, 0.76, 0.65, and 0.20 respectively. In terms of the surety that the trend lines are representative of the physical situation obviously presents some problems because of the sample size and variance of the four data sets. Nonetheless, by employing a test statistic which follows a student's t- distribution with n-2 degrees of

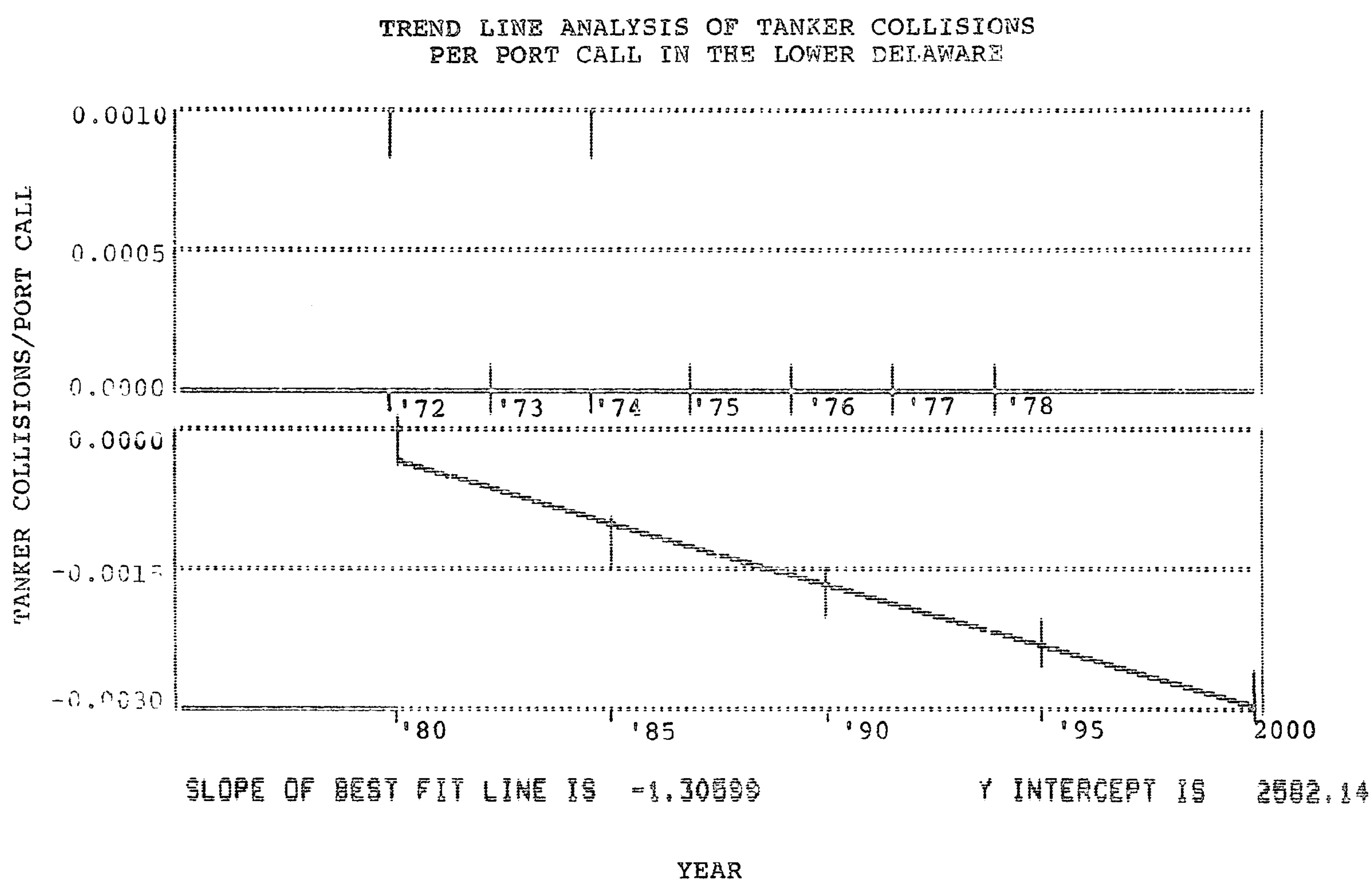
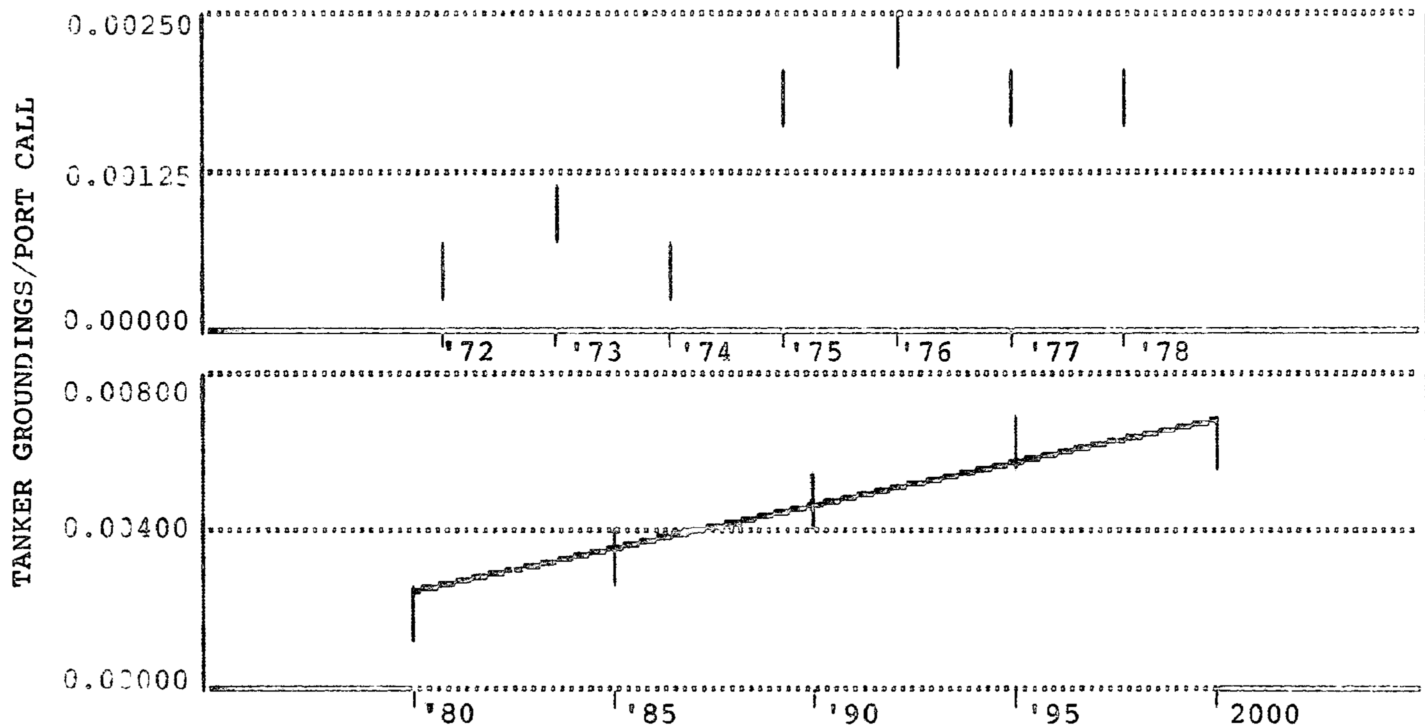

TREND LINE ANALYSIS OF TANKER COLLISIONS
PER PORT CALL IN THE LOWER DELAWARE
0.0010
0.0005
0.0000
0.0000
-0.0015
-0.0030
TANKER COLLISIONS/PORT CALL
'72
'73
'74
'75
'76
'77
'78
'80
'85
'90
'95
2000
SLOPE OF BEST FIT LINE IS -1.30599
Y INTERCEPT IS 2582.14
YEAR

FIGURE 17

TREND LINE ANALYSIS OF TANKER GROUNDINGS
PER PORT CALL IN THE LOWER DELAWARE

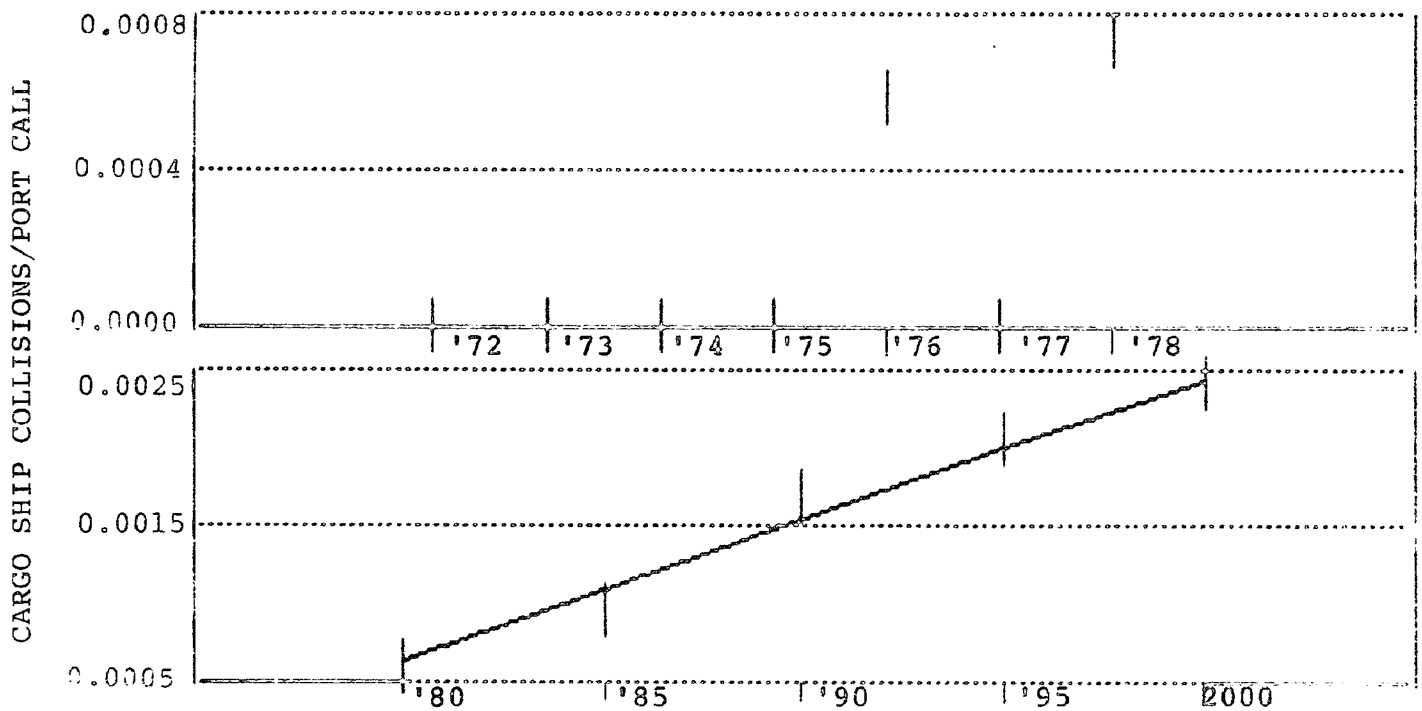


SLOPE OF BEST FIT LINE IS 2.19636 Y INTERCEPT IS -4324.76

YEAR

FIGURE 18

TREND LINE ANALYSIS OF CARGO SHIP COLLISIONS
PER PORT CALL IN THE LOWER DELAWARE

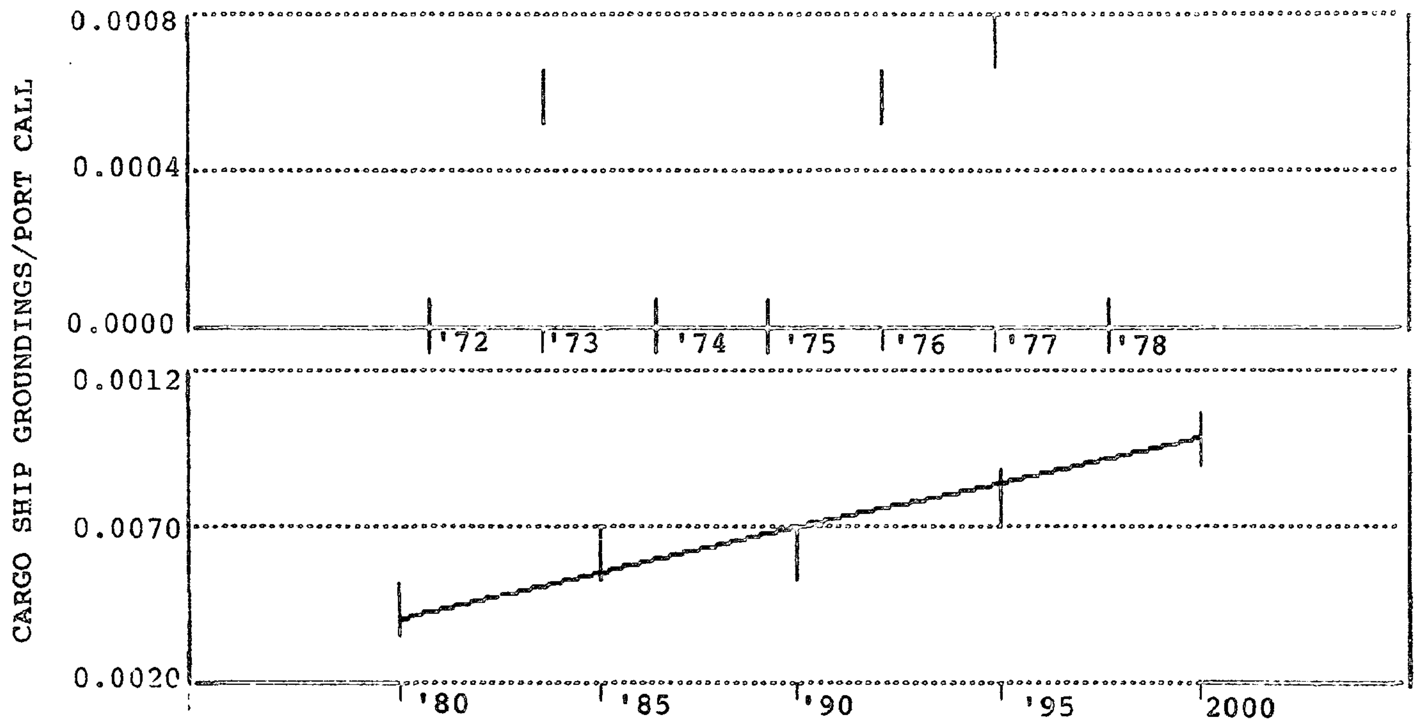


SLOPE OF BEST FIT LINE IS .898372 Y INTERCEPT IS -1772.43

YEAR

FIGURE 19

TREND LINE ANALYSIS OF CARGO SHIP GROUNDINGS
PER PORT CALL IN THE LOWER DELAWARE



SLOPE OF BEST FIT LINE IS .288151 Y INTERCEPT IS -566.532

YEAR

FIGURE 20

freedom, the level of significance for tanker groundings is 0.01 and for tanker collisions approaches 0.2 or one has one in a hundred chances and one in five chances respectively of being in error with regards to the prediction based on the trend line relationship. In the case of the cargo ship accident events, the levels of significance are not nearly as high and really meaningless due to the limited sample size and large variance. However, as will be seen Sections V and VI, these cargo ship data have no significant impact on the overall analysis since future impacts and costs are almostly wholly driven by the tanker events.

From these trend lines, it can be presumed that given the status quo, the rate of tanker groundings, cargo ship collisions, and cargo ship groundings will increase over the next twenty years; tanker collision rates on the other hand may decrease. Therefore, unless the number of port calls decreases proportionally, the expected total number of events will increase.

For the purposes of this analysis, it will be assumed that tanker port calls will level out at approximately 1,700 per year over the next 20 years and likewise, cargo ship port calls will level out at approximately 1,200 per year which are consistent with current traffic levels. To determine more detailed future projections of traffic is beyond the scope of this Study.

III. HAZARD ANALYSIS

In determining hazards from which potential corrective measures may be postulated requires that the historical accident data exhibit some sort of pattern or commonalties surrounding their circumstances. If they do not and are random or unique events then it obviously becomes impractical to treat them independently. Thus, the applicable historical data which were integrated in the previous Section were sorted in various ways to see what, if any, pattern or commonality those data exhibit.

As it turned out, by taking collisions and groundings separately and then subdividing them by vessel type (i.e., tanker, cargo ship, or barge), by movement (i.e., inbound, outbound, or anchored), by cargo condition, and by location (i.e., Big Stone Beach, in the dredged shipping channel at or above channel buoy number "9", or approaching the Pilot Station area), some definitive patterns did emerge. Tables 5 and 6 are those results for collisions and groundings respectively. As can be seen from Table 5 (again recognizing the limited sample size), the collision events by themselves may be said to be unique events; i.e., no real pattern appears. Table 6 for groundings on the other hand, gives three distinct hazard "scenarios" or pattern of accidents: one at the approach to the Pilot Station at the entrance to the Lower Delaware, one at Big Stone Beach Anchorage, and one in the shipping channel above buoy number "9". (See also Figures 3 and 4.) By combining Tables 5 and 6, the Big Stone Beach Anchorage scenario is even further enchanced.

TABLE 5

COLLISION ACCIDENTS ON THE LOWER DELAWARE 1972-1978

- COLLISIONS (8)
  - TANKERS (5)
    - ANCHORING (2)
      - LOADED (2)
        - BIG STONE BEACH (2)
        - PILOT STATION (0)
        - CHANNEL (0)
      - IN BALLAST (0)
    - INBOUND (2)
      - LOADED (2)
        - BIG STONE BEACH (0)
        - PILOT STATION (1)
        - CHANNEL (1)
      - IN BALLAST (0)
    - OUTBOUND (1)
      - LOADED (0)
      - IN BALLAST (1)
        - BIG STONE BEACH (0)
        - PILOT STATION (0)
        - CHANNEL (1)
  - CARGO SHIPS (3)
    - ANCHORING (0)
      - LOADED (0)
      - IN BALLAST (0)
    - INBOUND (2)
      - LOADED (2)
        - BIG STONE BEACH (0)
        - PILOT STATION (2)*
        - CHANNEL (0)
      - IN BALLAST (0)
    - OUTBOUND (1)
      - LOADED (1)
        - BIG STONE BEACH (0)
        - PILOT STATION (0)
        - CHANNEL (1)
      - IN BALLAST (0)

*ONE EVENT WAS RAMMING BUOY

TABLE 6

GROUNDING ACCIDENTS ON THE LOWER DELAWARE 1972-1978

- GROUNDINGS (24)
  - TANK BARGES (2)
    - ANCHORED (0)
    - INBOUND (0)
    - OUTBOUND (2)
      - LOADED (1)
        - BIG STONE BEACH (0)
        - PILOT STATION (0)
        - CHANNEL (1)
      - EMPTY (1)
        - BIG STONE BEACH (0)
        - PILOT STATION (0)
        - CHANNEL (1)**
  - TANKERS (18)
    - ANCHORED (4)
      - LOADED (4)
        - BIG STONE BEACH (4)
        - PILOT STATION (0)
        - CHANNEL (0)
      - IN BALLAST (0)
    - INBOUND (14)
      - LOADED (13)
        - BIG STONE BEACH (0)
        - PILOT STATION (10)
        - CHANNEL (3)***
      - IN BALLAST (1)
        - BIG STONE BEACH (0)
        - PILOT STATION (1)
        - CHANNEL (0)
    - OUTBOUND (0)

TABLE 6 (CONT'D)

- CARGO SHIPS (4)
  - ANCHORED (0)
  - INBOUND (1)
    - LOADED (1)
      - BIG STONE BEACH (0)
      - PILOT STATION (1)
      - CHANNEL (0)
    - IN BALLAST (0)
  - OUTBOUND (3)
    - LOADED (3)
      - BIG STONE BEACH (0)
      - PILOT STATION (0)
      - CHANNEL (3)****
    - IN BALLAST (0)

*IN STRAIGHTAWAY
**OPERATING OUTSIDE CHANNEL
*** IN TURN WITH 1 MEETING SITUATION AND 1 ICE
****ALL 3 IN TURN WITH 2 MEETING SITUATION AND 1 ICE

The descriptions of those resultant hazard scenarios are:

- a loaded tanker approaching the entrance to the Lower Delaware fails to correctly establish/evaluate its position and navigates outside of the desired/required trackline and runs aground (10 cases). This hazard scenario will hereinafter be referred to as the Pilot Station Hazard Scenario;
- a loaded tanker at anchor or in the process of anchoring in the Big Stone Beach Anchorage is either adversely affected by weather conditions or while anchoring loses power and then either collides with an anchored tanker or exceeds the anchorage limits and subsequently grounds (6 cases). This hazard scenario will be referred to as the Big Stone Beach Anchorage Hazard Scenario; and,
- a ship navigating the ship channel above channel buoy "9" fails to correctly establish/evaluate its position and exceeds the channel limits and subsequently grounds (6 cases) and is hereinafter referred to as the Shipping Channel Hazard Scenario.

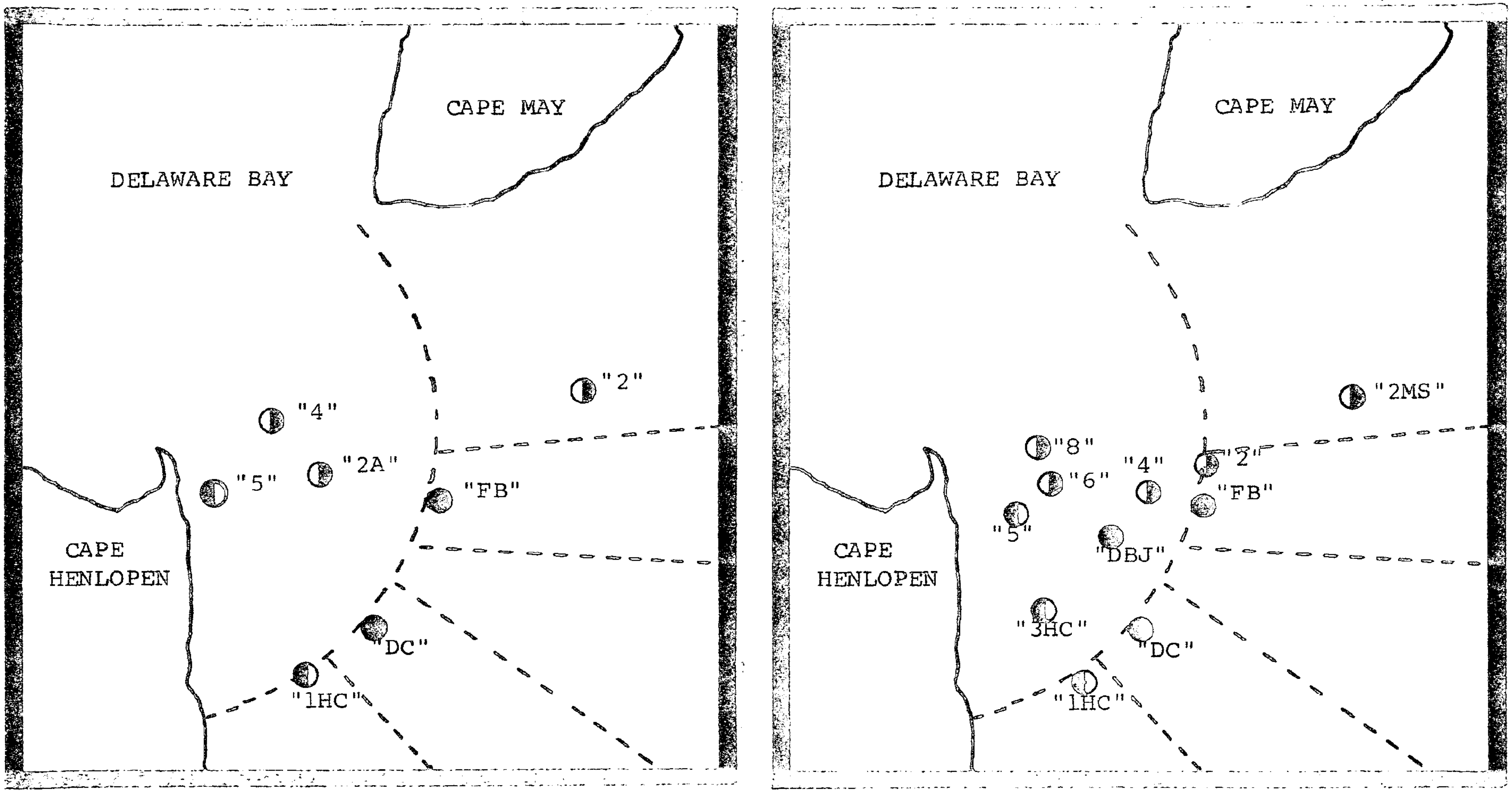
The remaining 8 cases are considered to be more or less unique events. None were particularly severe accidents and are not given any futher analysis in this Study.

IV. POTENTIAL CORRECTIVE MEASURES

For each of the three hazard scenarios identified in the previous Section, there are potential corrective measures to mitigate the occurrence of the respective accident events with varying degrees of effectiveness and attendant costs. This Section enumerates a group of those potential corrective measures and estimates their effect on future accidents in terms of a percentage.

For the scenario concerning the inbound loaded tanker at the entrance to Delaware Bay as it approaches the Pilot Station to take the Pilot onboard, it was clear from the accidents that an improved method of making initial landfall, maintaining position within the traffic separation lanes, making the passage through the precautionary area, and negotiating the passage at the point of confluence in the vicinity of the Pilot Station was necessary. This basic need dictates an improved series of aids to navigation over that system which existed in the 1972 to 1978 period. As it turned out, the Coast Guard in the latter portion of 1978 did in fact make a major change to that system and which is now in place and use. (See Figure 21.) As can be seen on that figure, this constituted moving some existing buoys and adding a number of additional primary buoys.

A time series from 1972 to 1978 was run for the accident events within this hazard scenario and then it was extended through 1980. These 1979 and 1980 data were obtained from the individual case files in the U.S. Coast Guard's Marine Safety Office in Philadelphia. That time series showed that except for two grounding events which occurred in 1979 and 1980 because the tanker was using uncorrected charts (i.e., the navigating officer was unaware of the change to the aid to navigation system), the 1979 to 1980 period exhibited a 61 percent decrease in grounding events from that which was projected to occur given the previous seven year trend.



MAJOR BUOY SYSTEM PRIOR TO OCTOBER, 1978

MAJOR BUOY SYSTEM AFTER OCTOBER, 1978

= JUNCTION OR FAIRWAY BUOYS = GREEN BUOYS = RED BUOYS

(NUMBERS/LETTERS IN PARENTHESES INDICATE BUOY DESIGNATIONS)

FIGURE 21: CHANGE TO MAJOR BUOY SYSTEM AT ENTRANCE TO DELAWARE BAY

Improved electronic aids to navigation were also considered to augment the foregoing, and with the exception of installing some swept frequency radar transponders (RACONS) on one or more of those buoys (for example, on junction buoy "DBJ"), all of those electronic systems require some form of specialized shipboard equipment which ships today are not required to have and which, in general, they do not carry. Although the Coast Guard has the authority under various laws to make unilateral requirements on both foreign and domestic vessel in U.S. ports, this regulatory process and the international implications associated with this type of action is so complex that all such options were discounted from any further consideration. It was therefore made an assumed requirement that all corrective measures postulated herein were limited to those which did not require the ship to have any specialized onboard equipment except that portable equipment which it can be reasonably expected to have the Pilot take on board with him. Obviously, for this first scenario which is prior to the embarkation of the Pilot, even that option is not available.

Accordingly, the only viable option to providing the necessary aids to navigation are those which are external to the ship and which do not require any extraordinary onboard equipment. This basically means visual aids to navigation and those which provide a radar reflection or signal, radio signals for use with a radio direction finder, voice radio signals, and for tankers in U.S. waters, LORAN-C signals. In the case of this hazard scenario, the judgement was made that given the foregoing, only the external visual aids to navigation and RACONS appeared feasible as a potential corrective measure.

In terms of the Big Stone Beach Anchorage hazard scenario, an analysis of the applicable accident events showed the following needs:

- to control the density, spacing, and placement of anchored tankers in order to maximize spacing between tankers and mitigate collision events and to avoid tankers being anchored in too close proximity to the anchorage boundaries and shallow water;
- to provide a better forecasting system of winds in that anchorage zone in order to forewarn mariners as early as possible of changing wind directions and forces;
- to provide a means of onboard monitoring of an anchored tanker's position in that anchorage in order for onboard personnel to ascertain that their anchor is not being "dragged"; and,
- to provide some means of compensating for a tanker losing power while in the process of anchoring and to provide some form of assistance to a tanker whose anchor is being dragged.

In the instance of the first need, it is proposed that an anchorage scheme be provided such that within the 2,000 yard by 6,800 yard existing anchorage limitations, a series of individual anchorages be specifically designated such as conceptually shown on Figure 22 where a tanker would be assigned to and drop its anchor somewhere in close proximity to the center of one of the individually designated anchorage circles. The rationale behind such a scheme is to first, insure that tankers do not anchor too close to the outer boundaries of the overall anchorage limits. Second, this scheme would control the density and spacing of tankers within the anchorage zone and provide ample spacing between them to account for not only the lightering operations but for the eventualities of a tanker dragging its anchor or losing power while

FIGURE 22: PROPOSED BIG STONE BEACH ANCHORAGE (CONCEPTUAL) SPACING, DESIGNATION, AND EXPANSION

underway. In other words, the idea is to provide more distance and thereby time, between the tanker dragging its anchor or the underway tanker losing power and other tankers within the anchorage and thus provide an increased measure of safety.

As previously stated, Figure 22 is conceptual. The final design of such a concept would necessarily include such factors as tanker size, scope of chain, number of tankers using the overall anchorage at one time, etc. (At present levels, the ten anchorages would be sufficient to handle the normal anchorage loading requirements.) Based on some preliminary estimates and as shown on that Figure, with a slight increase in size of the existing anchorage on the southeast corner, ten such individually designated anchorages may be provided with radii of approximately 1,650 feet and given 900-foot tankers with six shots (540 feet) of chain out on scope, minimum separations of 900 to 1,000 yards can be achieved.

In order to accommodate the second need requires a wind direction and force monitoring system in proximity to the anchorage. The problem today is that current weather forecasts are predicated upon weather stations which are both ashore and removed in distance from this locale. Obviously, the wind data taken from these stations and upon which forecasts are made are inappropriate to the anchorage area and in fact, are known to be misleading to the mariner.

Accordingly, the corrective measure proposed to accommodate this need is the installation of wind monitoring instrumentation to be placed on and powered from Brandywine Shoal Light in conjunction with a transmitter to relay that data (wind speed, wind direction, and maximum wind gust observed) at fixed intervals to the National Weather Service, Philadelphia, who will in turn broadcast that data over the existing marine weather network.

The third need to provide a continuous means for the anchored tankers to monitor their position within the anchorage on a 24 hour, all weather condition, may be met through the provision of a swept frequency RACON again placed on and powered from the Brandywine Shoal Light fixed structure. The swept frequency RACON when triggered by a ship's radar will emit a characteristic signal and be superimposed on the ship's radar as a radial line originating from the RACON's position. This will provide the observer on the ship with an automatic and continuous display of bearing and distance from a fixed object and from which the ship's position may be determined. This is a quick and relatively easy means to monitor position without regard to floating aids which may be off station and without regard to any visual aid to navigation which may be obscured due to visibility, light intensity limitations, or other ships obstructing another ship's view.

The fourth need to provide some additional measure of safety in the event of an underway tanker losing power or to assist an anchored tanker with a dragging anchor, can only be met (at least from the "external-to-the-ship" point of view) by a tugboat. This tugboat would be required on a 24-hour a day basis in the anchorage to assist or standby during movements within the anchorage and to standby for the eventuality of providing assistance to an anchored tanker when and if necessitated. It is estimated for at last conceptual purposes, that such a tugboat would be a twin screw, 4,000 BHP (brake horsepower), diesel driven vessel with principal dimensions (length, beam, and draft) of 103 feet, 33 feet, and 17 feet.

The combined effectiveness of the designated anchorage scheme, the improved weather forecasting system, and RACON installation has been adjudged to be 50 percent [4]. The effectiveness of the tugboat is adjudged to be 40 percent in the case of assisting anchored tankers and 20 percent in the case of assisting an under-way tanker which loses power [5].

The shipping channel hazard scenario basically dictates that some reliable means of establishing navigational position under all conditions of weather, and in particular, during periods of low visibility be provided. Two options appear to be available. One is to provide an electronic means to ascertain the ship's position relative to the centerline of the channel in a continuous fashion [6]. Such a system (which again does not require any special onboard equipment) is one which operates through a small portable instrument carried onboard by the Pilot and continuously provides an output to the operator of distance left or right of trackline along any one reach of the channel and distance to the next turn. The portable device is a programmed instrument which operates off LORAN-C signals and can continually track the ship relative to either side of and along the channel centerline. It does, however, require initialization of position as an input. To accommodate this initialization, it is proposed to replace existing channel buoy "9" with a fixed structure. The reason for the fixed structure is to obviate the need for floating aids which are subject to position inaccuracies, are limited in height and power sources for lights, and to limitations in positive radar identification under conditions of limited visibility. Such a system (which is similar to systems in Rotterdam and Hamburg) is estimated to have an effectiveness of 40 percent in reducing grounding accidents [7,8].

The construction and installation of two additional fixed structures in place of existing channel buoys "19" and "32" (see NOS chart 12304) would provide fixed aids to navigation impervious to weather, including ice damage, and moreover, give the mariner the means to more readily and accurately establish his position. They would further be more conducive to having larger power sources (i.e., diesel generators) upon which higher intensity lights and additional RACONs could be installed. The increased effectiveness of these fixed structures is estimated to be 25 percent [9].

V. FUTURE PROJECTIONS

For each of the three hazard scenarios, a regression analysis was conducted for the rate parameter or accident rate and trend line projections were made to the year 2000. By multiplying those rates by the average annual traffic levels previously stated (i.e., 1,700 for tankers and 1,200 for cargo ships), the expected number of future accidents events were determined with no change to the system. Then, those trend lines and subsequent expected number of accident events were recalculated but under the various combinations of potential corrective measures and their expected effectiveness on accidents.

For the hazard scenario of a loaded tanker grounding at the entrance to the Delaware or the approach to the Pilot Station, the trend line shows a sharp increase in accident rate; from approximately 1.80×10^{-3} groundings per port call in 1981 to nearly 5.0×10^{-3} grounding per port call in 2000. (See Figure 18.) It may be speculated that this increase is probably due to some combination of increased tanker size; limited maneuvering space and underkeel clearance in an area of high traffic density and convergence; and, a situation which places a relatively difficult-to-maneuver tanker in restricted waters and requires it to slow down and create a lee for the pilot boat thus further placing the tanker in a more vulnerable position with respect to all of the following:

- its own controllability (which decreases with decreased speed);
- its orientation to the channel and other traffic; and,
- its exposure to external forces such as current and wind.

Moreover, this occurs at the previously mentioned point of highest traffic density and convergence in the Lower Delaware.

Assuming that the average annual number of port calls per year is 1,700, the expected number of groundings in 1981 is nearly three and in 2000, that expected value is approximately eight. The average value for the rate parameter is about 3.3×10^{-3} groundings per port call and the average number of groundings per year will be just under six. These of course assumes no change in the trend exhibited during the 1972 to 1978 period.

With the upgraded aid to navigation system installed in the latter portion of 1978 as previously described, the expected number of events will be approximately one in 1981 and three in 2000 or an approximate 60 percent decrease based on the adjudged effectiveness of that system. Obviously, the upward trend remains since the 1972 to 1978 data exhibit that upward trend for whatever reason. However, the rate at which it increases is lessened. Nonetheless, it is important to understand as previously mentioned that there are factors causing the upward trend, possibly increased tanker size to name one, which are beyond the scope of this analysis, but which could change that trend. For example, if the increased tanker size were one of the controlling factors in causing that upward trend and if tanker size leveled off at some point in the future, then it could be said that the accident rate would level off accordingly and appropriate adjustments made to any future projections. Aside from the point of the limitations of this Study, it is strongly suspected that there are a multiplicity of interactive factors which have caused the trend and to truly understand them and compensate for them in a future projection sense is a formidable undertaking.

In any case, given that historical trend and assuming that it will continue without some change to the overall system, the upgraded aid to navigation system is projected to prevent 70 out of a possible 114 grounding events in the future.

In the case of the Big Stone Beach Anchorage hazard scenario, the attendant accident rate is expected to range from approximately 0.7×10^{-3} accidents per port call in 1981 to 1.75×10^{-3} accidents per port call in 2000 with an average value of about 1.25×10^{-3} accidents per port call. Under the assumptions used herein, this translates to just over two accidents per year on the average over the next 20 years or a total of 41 accidents.

With the installation/imposition of the swept frequency RACON on Brandywine Shoal Light, the improved weather forecasting service, and increased anchorage spacing, 14 of those 41 projected accidents are not expected to occur. Likewise with the employment of a full time tugboat in the anchorage for use by either anchored or underway tankers, an additional 16 tanker accidents within the Big Stone Beach Anchorage are projected to not occur.

The cargo ship and tanker grounding hazard scenario with the dredged channel, unlike the previous two scenarios, exhibits a slight negative or downward trend in accident rate. For 1981, the expected value is approximately 0.23×10^{-3} groundings per port call in 1981 and for 2000 that value is 0.2×10^{-3} groundings per port call. This gives an average expected value of groundings of just in excess of one grounding every other year or an expected total of 13 grounding events in the 20 year period, 6 of which would be tanker groundings.

With the installation of the electronic aid to navigation system, five of those future groundings are expected to be eliminated (two of which would be tanker incidents). If the fixed structure aids to navigation are employed, one additional cargo ship grounding and one additional tanker grounding would be further eliminated.

To recapitulate, over the next twenty years, considering only the three hazard scenarios analyzed herein, under the assumptions that traffic levels remain more or less constant and the accident trends exhibited over the past eight years continue (i.e., no significant changes are made to the system), it is projected that 161 tanker and 7 cargo ship accidents will occur. The reasons for the disparity in tanker events are that first, approximately 80 percent of the accident data base are tankers. Second, within the specific hazard scenarios considered herein tankers constitute an even greater proportion of the events.

Of those 168 total projected future events, it is expected that given all the proposed corrective measures, 103 of the future tanker events and four of the cargo ship events can be eliminated.

From the oil pollution point of view, the historical data base used for this analysis contained only one pollution event of 20 gallons which was discharged due to some leaking rivets following the accident. Obviously, one event of this magnitude does not provide sufficient data upon which future oil spill projections may be made.

As an alternate method, the tanker accident rate parameter for the Lower Delaware during the 1972 to 1978 period was 1.724×10^{-3} per port call. A worldscale value for collisions, groundings and rammings during the 1969 to 1978 period in similar operating environments was 1.695×10^{-3} per port call. Thus, the Lower Delaware rate parameter is for all intents and purposes identical to the worldscale value for similar situations. Accordingly, it may be assumed that given a tanker accident, the conditional probability of having a large oil spill (with a volume equal to or greater than the contents of one wing cargo tank) from the worldwide data of 6.06×10^{-3} [10] may also be fairly applied to the Lower Delaware.

Given a projected value of 161 tanker accident events over the next 20 years, the rate parameter for a large oil spill in the Lower Delaware is approximately 2.87×10^{-5} per tanker port call. With 1,700 tanker port calls per year over the next 20 years this gives a probability for a large oil spill in the Lower Delaware of 0.623 with no major system change.

If all of the proposed corrective measures proposed herein were implemented that probabilistic value could be reduced to approximately 0.3 or the probability of a large oil spill will be halved to that expected. The incremental values for the probability of a large oil spill in the Lower Delaware are as follows:

- under the present system - 0.623;
- with the provision of the entrance aid-to-navigation system, the improved weather forecasting facility, the increased anchorage spacing, the RACON installation on Brandywine Shoal Light, and the portable electronic aid to navigation system including one fixed structure in the vicinity of existing channel buoy "9" for initialization purposes - 0.365 or a decrease of 0.258;

- with the installation of 2 additional fixed structures - 0.362 or a total decrease of 0.261; and,
- with the employment of a tugboat in the anchorage - 0.296 or a total decrease of 0.327.

VI. COST ANALYSIS

All cost data given herein are given on an annualized basis. Proposed corrective measures, all of which require some form of capital investment and annual operating costs, have the capital investment (in September, 1980, dollars) taken over 20 years at a 14 percent value of money. The average annual cost is therefore the sum of the annualized investment cost and the annual operating cost [11]. The summaries of those average annual costs are as follows:

- the six additional entrance buoys have a total capital cost (buoy structure, sinker, aid to navigation package including power source) of $25,000 each and an annual service cost of $5,000 each [12]. This translates to a total investment of $150,000 and a total annual operating cost of $30,000. In terms of the average annual cost, this is $52,650.
- the upgraded weather forecasting system for the Lower Delaware will require an initial investment of $150,000 and is expected to have an annual operating cost of $20,000 [13]. The average annual cost is therefore, $42,650.
- the cost to create an enlarged spacing arrangement within the Big Stone Beach Anchorage is assumed to be strictly a front end administrative cost with no annual operating costs. That administrative cost would be one to design and propose the new anchorage regulations, receive public comments, and implement the final regulations. That cost has been estimated at $120,000 [14] and in terms of an annualized cost that value is $18,120.
- the capital cost to install a swept frequency RACON on Brandywine Shoal Light is $12,000 and the annual operating cost associated with that RACON is estimated to be $2,000 [12]. This gives an average annual cost of $3,812.

- the portable electronic aid to navigation system in conjunction with a new fixed structure in the vicinity of existing channel buoy "9" to be used as an initializer for the navigation system will have an initial cost of $180,000 (based on 15 portable units) for the electronic package [15] and $147,000 for the fixed structure including the navigation equipment [16,17]. This gives an annual investment of $49,377 which when added to the annual operating costs of $10,000 for the electronic package and $20,000 for the fixed structure creates a total average annual cost of $79,377.
- the installation of two additional fixed structures including the navigation equipment would require a capital outlay of $294,000 [16,17]. The annualized cost of that investment is $44,394 which when added to an annual operating cost of $40,000 for those two structures yields an average annual cost of $84,394.
- Lastly, the provision and employment of a 4,000 BHP tugboat at the anchorage would require a capital investment of $6,000,000 for the tugboat [18] or an annual investment of $906,000. With an average annual operating cost of $1,800,000 (fuel, crew, insurance maintenance, and overhead costs), this gives a total average annual cost of $2,706,000 for the tugboat.

The cost of accidents are derived directly from the data enumerated on Table 4 of Section II. For each historical accident event within each of the three hazard scenarios, the total accident cost (reported or derived damage, tugs/pilotage, lightering/demurrage, and pollution costs) was extracted from those data and then the average total cost per accident event within that scenario was calculated.

In the case of the approach to the Pilot Station hazard scenario the average ship related accident cost is $37,600 per incident.

For the Big Stone Beach Anchorage hazard scenario there are two values. The first is for those events not involving a power failure on the tanker and that average value for ship related costs is $55,000 per incident. The second value which relates to the situation where a tanker in the process of anchoring loses its main propulsion plant and subsequently collides with another vessel or runs aground is $210,000 per incident.

Those cargo ship and tanker grounding accidents which occurred in the vicinity of the main shipping channel above channel buoy "9" and constitute the channel hazard scenario, had an average value of ship related costs of $2,000 per incident.

The event of an oil tanker accident leading to a large outflow of oil would incur at least the following costs:

- cleanup and/or removal costs;
- damage to real or personal property;
- damage to natural resources;
- loss of earnings resulting from injury to real or personal property or natural resources, without regard to ownership; and,
- loss of use of real and personal property or natural resources.

The total dollar amount of these costs will, of course, vary according to a number of factors including:

- location of the spill;
- weather at the time of the spill;
- time of the year; and,
- numerous other factors including availability and deployment of cleanup equipment.

It is a considerable task, and one not within the scope of this Study, to develop the impact of all spill scenarios that could be foreseen and their interrelating factors. Rather, this Study considers two different spill scenarios which correspond to the hazard scenarios contained herein and develop representative resultant damage costs.

The two spill scenarios are projected to occur at the Big Stone Beach Anchorage and in the area just outside the entrance to the Delaware Bay.

A major spill at the Big Stone Beach Anchorage location could affect the following areas and activities:

- the spawning and growing areas of fin and shellfish;
- the abundant wetlands and natural vistas surrounding the Lower Bay;
- commercial fishing;
- recreational fishing and boating;
- birds and waterfowl; and,
- resort and tourist activities.

Some of the above factors lend themselves to quantification while others require a much higher degree of qualified judgement. For instance, the commercial fishing industry in Cape May County alone was estimated in 1976 at $14,600,00 [19]. Adjusting for inflation this value would nowadays approach 22 million dollars and a major spill would perhaps effect an entire season. Fortunately, recent studies [20] have developed a "bench mark" with which one can put a quantifiable judgement on the effect of a spill. This Study projects that a spillage of oil would cost one dollar and seventy cents ($1.70) per gallon for cleanup and removal and fifty dollars ($50.00) per gallon for direct and indirect damages to others.

The cost of a 1,500,000 gallon spill (approximately the contents of a single wing cargo tank of an 80,000 deadweight ton (DWT) tanker) in this particular area would then be:

- $2,500,000 for cleanup costs;
- $75,000,000 for other damages; which gives,
- a total cost for the spill of $77,500,000.

A spill at the entrance to the Delaware Bay in the summer months would affect the following areas:

- commercial fishing;
- recreational fishing and boating;
- coastal wetlands and barrier island growth; and,
- have a major effect on the resort and tourist activities of the area.

The resort economy of the area can be estimated by adjusting the results of a previous study done by the Cape May County Planning Board [1] for inflation. This would result in an expected resort economy of approximately $370,000,000 per year. An oil spill of the magnitude considered in this Study would have a major effect on this economy if it landed on the beaches of the area. The IXTOC I spill in the Gulf of Mexico was said to have devastated the tourist economy because of lack of ability to utilize the water resources which attracted the tourists. If it is assumed that the oil spill will have a significant impact on the economy for the first month of the spill, in effect bringing the economy to a standstill, and would have an effect on the rest of the resort season equal to the loss of the first month, then one can estimate that the loss to the tourist economy would be in the neighborhood of $125,000,000. Coupled with the previously derived losses of $77,500,000 for cleanup and other damages that would occur without the major effect on tourist/resort economy the total cost would be $202,500,000.

The average cost of either of the two spills is $140,000,000.

For the purposes of this cost analysis, the proposed corrective measures of the six additional entrance buoys, the upgraded weather forecasting system, the enlarged anchorage spacing, the RACON on Brandywine Shoal Light, and the portable electronic navigation system including the single fixed structure are taken as a single total package. The reason for this integration is that on initial review of the associated annualized costs, those values were seen to be relatively small; thus, in the interest of avoiding a repetitive series of step functions for each of these corrective measures individually, they are taken together collectively.

For the remaining corrective measures of the two additional fixed structures along the channel and the tugboat at the anchorage (which each represent relatively significant cost investments,) these two corrective measures are treated separately for cost analysis purposes.

If the average annual costs of the six additional entrance buoys, the upgraded weather forecasting system, the enlarged anchorage spacing at the Big Stone Beach Anchorage, the installation of the RACON on Brandywine Shoal Light, and the portable electronic navigation system including the single fixed structure for initializing purposes are, as previously stated, taken collectively, that value is $196,609. As indicated in a previous Section this collective arrangement is projected to reduce 86 tanker accident events and 3 cargo ship accidents events. From the costs of historical accidents given in Table 4 of Section II and the average value per incident derived therefrom, the total direct ship cost savings (damage, tugboats/pilotage, demurrage/lightering, etc.) are $3,425,000 over the 20 year period or $171,250 per year on an average basis.

With an average potential oil spill cost of $140,000,000 and a reduction in the probability of that oil spill in 20 years from 0.623 to 0.365 with the imposition of this collective arrangement of corrective measures, the expected value for savings in oil spills is $36,120,000 or $1,806,000 per year on an average annual basis. Thus, the total expected savings is $1,977,250 per year versus an average annual cost of $196,609 or a savings-cost ratio of approximately ten. In fact, the savings in ship related costs alone of $171,250 per year nearly equals the average annual cost of the proposed corrective measure package of $196,609; i.e., not even considering the large oil spill issue.

The average annual cost for the two additional fixed structures is $84,394. Over the 20 year period this will result in the prevention of one tanker and one cargo ship grounding accounting for approximately $4,000 in ship related costs. It will also reduce the probability of a large oil spill within the 20 year period from 0.365 to 0.362 which gives a further expected oil spill savings of $420,000 or $21,000 per year. The total expected savings are thus $21,200 per year measured against an average annual cost of $84,394. This gives a savings-cost ratio of 0.25.

The employment of a tugboat at the anchorage has an average annual cost of $2,706,000 associated with it. Given that this tugboat is expected to eliminate 16 tanker accidents over the 20 year period with a total ship related cost value of $3,360,000 or an average annual cost of $168,000 per year. The tugboats will reduce the probability of the large oil spill event in 20 years from 0.362 to 0.296 which translates to an expected savings value of $9,240,000 or $462,000 per year. The total expected savings is $630,000 per year and when compared against the average annual cost for the tugboats of $2,706,000, the savings-cost ratio is 0.23.

If all three corrective measure combinations are taken together, the total average annual cost is $2,987,003 and the expected annual savings are $2,628,450.

VII. CONCLUSIONS AND RECOMMENDATIONS

The analysis conducted herein has shown that the Lower Delaware Bay has three major hazard scenarios which relate to the adequacy of existing aids to navigation and navigational procedures. It has also shown that given the historical trends exhibited during the 1972 to 1978 period, projections of future accident trends are expected to be of an increasing nature. As often stated in this Study, those future projections are predicated on the assumption that no major change is or will be made to that which existed in the 1972 to 1978 period.

It also should be emphasized that any recommendations made herein are solely based upon the mitigation of accident events and not on the facilitation of commerce which is beyond the scope of this Study. It should be apparent that if the facilitation of commerce were addressed such as the accommodation of traffic on a 24 hour a day, 365 day per year basis, many additional benefits could be accrued from various aids to navigation and/or navigational procedures which may be either discounted or not even considered herein and might prove to be cost beneficial to Society from the commerce point of view.

Given the foregoing understanding, it is therefore concluded and recommended that the upgraded aid-to-navigation system at the entrance to the Lower Delaware Bay, the upgraded weather forecasting facility, the designated/increasing spacing concept for the Big Stone Beach Anchorage, the installation of a swept frequency RACON on Brandywine Shoal Light, and the portable electronic aid-to-navigation system including the single fixed structure for system initialization exhibits a highly favorable savings cost ratio (approximately ten) and therefore is recommended for ultimate design, acquisition, installation, and implementation.

This combined package is expected to eliminate 89 out of a possible 168 future cargo ship and tanker accidents over the next 20 years; or, put in terms of tankers alone, it is projected that it will eliminate 86 future tanker accidents out of a possible future subtotal of 161 tanker accident events. In addition, from the potential large oil spill point of view, it has been projected over the next 20 years that the probability of such an occurrence in the Lower Delaware is 0.623. With the provision of this combined package, that probability is expected to be reduced to 0.365.

Although the additional two fixed structures are expected to reduce one additional tanker and one additional cargo ship grounding over the next twenty years and reduce the probability of a large oil spill to 0.362, the annualized costs of this corrective measure does not exhibit an acceptable savings-cost ratio and is therefore not recommended. Again, however, it must be emphasized that this judgement is solely based upon accidents alone and not the facilitation of commerce issue which probably, if included, would justify the inclusion of these structures.

The provision and utilization of a tugboat in the anchorage area which is projected to eliminate an additional 16 tanker accidents over the next 20 years and reduce the probability of a large oil spill to 0.296, is also concluded to be unacceptable from the savings-cost ratio point of view. Although, the potential savings are high on an absolute basis, the annualized costs for acquiring and operating that tugboat appear to be prohibitive.

It is important to recognize that despite the fact that accident data in the Study Area does not indicate a significant likelihood of collisions in the future, the potential for such an event nonetheless remains.

This is especially true at the entrance to the Bay which is an area of intense traffic confluence and through which all traffic entering to or departing from Delaware Bay must transit. This is even further compounded due to the fact that this is the same area in which most traffic must slow down and maneuver to either embark or disembark pilots thereby placing themselves in an even more vulnerable position with respect to other traffic. Moreover, it must be recalled that the terms of reference for this Study have limited the data base to only those events in which the adequacy of the existing aid to navigation system was deemed to be a causal factor. It does not include, for example, collision events which occurred due to other causes such as machinery failure, improper detection of other vessel's intentions, etc.

In any case, the point is that this situation is real and thereby the potential for a collision is real. While from an analytic point of view this cannot be demonstrated within this Study, it is strongly suspected that the provision of some means for the mariner to quickly adjudge his position within that area under all conditions of visibility would be beneficial towards the future mitigation of collision events. One suggestion is the installation of a swept frequency RACON on junction buoy "DBJ". The cost of such an installation is minimal and if incorporated within the total package proposed herein, would have a negligible effect upon the total annualized costs. On the other hand, it probably will have a discernable impact upon collision events in this area in the future and therefore, the savings cost ratio.

Another point which bears special emphasis is the adequacy of aids to navigation within the dredged channel under conditions of limited visibility and the reasoning behind the inclusion of the portable electronic aid to navigation system. Under the existing situation, vessels do not usually enter the channel at all when the visibility becomes restrictive. Thus, the only vessels that do make the transits under these conditions are those committed to the channel and after which that commitment is made does the visibility decrease to that otherwise restrictive level. As stated in Section II, approximately one-fifth of the total accidents considered herein occurred when the visibility was less than one quarter of a mile yet visibility of one quarter of a mile occurs on only thirteen percent of the days of the year. This skew is is even more intensified when one realizes two additional facts. First, the measure of visibility occurrence is by days during which at least some portion thereof the visibility was recorded at one quarter of a mile or less as opposed to the entire twenty-four hour cycle; and second, the notion that traffic levels are decreased during these limited visibility conditions. In other words, given equal traffic exposure, if visibility was not related to accident occurrence, one would expect the percentage of accidents in limited visibility to be approximately equal to the occurrence of that limited visibility; i.e., visibility occurrence and accident occurrence are independent of one another. Obviously, they are not and accident occurrence is dependent upon visibility such that as the visibility decreases, the occurrence of accidents increases. Moreover, since traffic exposure is not equal and in fact decreases with decreased visibility, the accident rate or accident per port call increases at an even more pronounced rate.

If a contingency table could be compiled consisting of accidents and safe passages at various levels of visibility, one would be able to quantitatively establish dependency by employing a CHI-SQUARE test and then measure the degree of that relationship through regression analysis. Unfortunately, those safe passage data are not available. Nonetheless, statistical inference strongly suggests that this relationship is present. Accordingly, the recommendation for the installation of an improved all weather navigation system or more specifically, the portable electronic navigation system, has been made to alleviate this situation. Such a system can then accommodate the channel transits under conditions of limited visibility whether they occur by choice or by chance due to changing meteorologic conditions once a vessel is committed to the channel, at a reduced level of risk.

Based upon all of the foregoing, it is recommended that the aid to navigation package proposed herein be implemented as soon as is reasonally practical in the interest of marine safety, the protection of the marine environment, and the overall mitigation of risk to the Lower Delaware including the various economies derived therefrom.

VIII. REFERENCES

1. "The Resort Economy of Cape May County, N.J. - 1974 Update," The Cape May County Planning Board, August, 1975.

2. "Energy, Oil, and the State of Delaware," Delaware Bay Oil Transport Committee, January, 1973.

3. "A Study of New Use Demands on the Coastal Zone and Offshore Areas of New Jersey and Delaware," A Report to the Office of Technology Assessment, United States Congress, the BDM Corporation, December, 1975.

4. R.O. Goss, "Costs and Benefits of Navigational Aids in Approaches," Department of Trade and Industry, U.K., 1971, London.

5. R.W. Black, "Analysis of Tug Effectiveness in Preventing Collision and Grounding of Tanker Vessels in Confined Waters," Symposium on Marine Resources Development in the Middle Atlantic States, Chesapeake and Hampton Roads Section of the Society of Naval Architects and Marine Engineers, October, 1976, Williamsburg, Virginia.

6. J.P. Hooft, P.J. Paymans, V.F. Keith, and J.D. Porricelli, "Horizontal Dimensioning of Shipping Channels," Spring Meeting/STAR Symposium of the Society of Naval Architects and Marine Engineers, April, 1978, New London, Connecticut.

7. N. Schimmel, "Traffic Regulation in Europoort and its Approaches," Conference on Marine Traffic Engineering, Royal Institute of Institute of Navigation and Royal Institution of Naval Architects, May, 1972, Teddington, England.

8. W.M. Benkert and R.C. Hill, "U.S. Coast Guard Vessel Traffic Systems - A Status Report," Radio Technical Commission for Marine Services, Assembly Meeting, April, 1972, New Orleans, Louisiana.

9. "Offshore Vessel Traffic Management (OVTM) Study," U.S. Department of Transportation, Research and Special Programs Administration, Study Prepared for the United States Coast Guard, Office of Marine Environment and Systems, August, 1978, Washington, D.C.

10. "ECOTANK," A Proprietary Worldwide Tanker Accident Data Base, 1969 to 1978, ECO, Inc., Annapolis, Maryland.

11. H. Benford, "Fundamentals of Ship Design Economics," Department of Naval Architecture and Marine Engineering, College of Engineering University of Michigan, April, 1970, Ann Arbor, Michigan.

12. Personal Communication, U.S. Coast Guard, Office of Navigation, October, 1980, Washington, D.C.

13. Personal Communication, National Oceanic and Atmospheric Administration, National Weather Service, Eastern Region, October, 1980, New York.

14. Personal Communication, U.S. Coast Guard, October, 1980, Washington, D.C.

15. Personal Communication, U.S. Coast Guard, Office of Research and Development, October, 1980, Washington, D.C.

16. Personal Communication, U.S. Coast Guard, Third Coast Guard District, Engineering Division, October, 1980, New York, New York.

17. J.F. Bradley, "Aids to Navigation on the Delaware Bay and River, An Evaluation," April, 1979.

18. Private communication with U.S. East Coast Shipyard, Cost Estimating Department, October, 1980.

19. S. Kemmerle and A. Meredith, "Cape May County Commercial Fishing Industry: Economic and Marketing Considerations," June, 1977.

20. T. Miller et al, "Description of the Pollution Loss Potential of the Components of the Petroleum Industry," Unpublished Report to the U.S. Department of Commerce, July, 1980. Washington, D.C.

APPENDIX A

ACCIDENT FILE COMPUTER PRINTOUT AND DOCUMENTATION

DATA FILE PRINTOUT

```
20902TAMO2355087219046BA        20COLGCSTR010S3506    YF USCGC IN WX TURNED NOT DETECTED
20571TAMI0819107218347L031291F035GRD CTUR.3F009       YF GAVE WAY TO OUTBOUND EBB TIDE SET DOWN
20783TAMI1512117160877BA        23GRD PSTA05PC10070507N  GAVE WAY TO OUTBOUND WIND SET DOWN
20905TLIA    127131825L052482C041COLTABSB07           Y  WIND AND CURRENT WHILE ANCHORING
21206TAMI1042037337784L075031C042GRD PSTA.5RA25130614N  RADAR NOT OPERATING OFF COURSE
21755TLII2135047229699L050448C040COL CSTR00F0         U
21778CAMI2023057207972L003067CA19RAMBPSTA05CL1010     N  APPROACHED PILOT STATION FLOOD TIDE SET DOWN
32738CAMO1046067308673          24GRD CTUR.1F00612    Y  GAVE WAY TO INBOUND
32901CAMO1317067314640L024110CA35GRD CTUR.3F0         YF GAVE WAY TO INBOUND
40110TLIA0138067361668L090000C048GRD ABSB02DC16       YS ENGINE FAILURE WHILE ANCHORING
41248TLII0138097418954L027545F035COLBPSTA10PC15       Y
42500TFAI1155057429140L048350C041GRD PSTA.5F0         N
42814TLIA0545067433419L063777C041COLTABSB15           Y  LOST BOILER WHILE ANCHORING COLLIDED WITH TANKER
50601BAMO1630087502187BA        16GRD ABSB15CL        N  NAV CHANNEL TO BSB  ANC NO POSITION
51305TAMI0500107523460L039632BC37GRD PSTA10CL1510     N  ALTERED COURSE FOR CROSSING VESSELS NEAR SHOALS
52337TAMI2120117626281L048712C039GRD CTUR15CL1212     N  ON CHANNEL EXTREMITY LOWER THAN NORMAL TIDE
60554TAMI0020107523460L039279GA36GRD PSTA10DC22030603N  APPROACH PILOT STAT MADE TURN WRONG BUOY
61142TLII1537127572132L099999C054GRD PSTA99CL05       N  CHANGE COURSE TO AVOID VES PICK UP PILOT INCOR CHT DEF
62877CAMI0420067611757          27GRD PSTA050C05090609N  MISTOOK TEMP A/N FOR INOP BUOY WX INT W/ELECNAVSYS
63777TAMI0400087628460L046016H040GRD PSTA01F00708     N  UNABLE TO ASCERTAIN POSITION
63792TLII    077637958L040000C041GRD PSTA15CL10       N  GYRO INOPER 20 GAL POLLUTION OCCURRED
63795CGRO0228057612347LO     CA06COLGCSTR10CL         YS HI IN BOW LOST SITE OF VES TURN CONTRARY TO AGREE
64217TLIA2200087647133L090459C050GRD ABSB.1RA06  12   N  DRAGGED ANCHOR HIGH SEAS
70657TAMI0505017717055L027613C034GRD CTUR15  351400   YS AIDS OFF STATION ICE  CAME TOO FAR RIGHT
71045CGRO0600017719162L028880CA36GRD CTUR15           YS MISJUDGED TURN  A/N OFF STATION ICE
72865TSWI0435097751501L096930C048GRD PSTA030C04       N  AWAITING PILOT TIDE SET DOWN
80271TLIA2250117763234L099999C055GRD ABSB15PC40       YS SHIFT ANCHOR HIGH WINDS SET DOWN
81775TLIA    057869177L099999C054GRD ABSB15  70  10   N  DRAGGED ANCHOR  HEAVY SEAS WIND
82747BAMO1510017804179L006447C020GRD CSTR00F025  04   N  UNABLE TO ASCERTAIN POSITION
83693CBRI    047810846L001594CA21COLCPSTA10           N  JUST DROPPED OFF PILOT COLLIDED WITH APPROACH VESSEL
89998TGRI0707087844031L049210C037GRD      .1F0010200  N  GYRO INOPER USING OLD CHART  NO LOCAL CHART
89999TLII0800127834886L053719C039GRD      15CL40101010N  MISJUDGED POSITION EQUIPMENT OK .25 N EAST OF CHNL
```

KEY TO ENCODING DATA

COLUMN NUMBERS	CODE AND EXPLANATIONS	
1 TO 5	CASE NUMBER	
6	VESSEL TYPE	
	T	TANKER
	B	BARGE OR TUG/BARGE
	C	CARGO OR CONTAINERSHIP
	O	OTHER
7 TO 8	REGISTRY	
	AM	AMERICAN
	PA	PANAMANIAN
	GR	GREEK
	BR	BRITISH
	LI	LIBERIAN
	SW	SWEDISH
9	HEADING	
	I	INBOUND
	O	OUTBOUND
	A	ANCHORING OR AT ANCHOR
10 TO 13	TIME OF ACCIDENT	
14 TO 17	MONTH AND YEAR OF ACCIDENT	
18 TO 22	GROSS REGISTERED TONNAGE	
23 TO 24	CARGO CONDITION AT TIME OF ACCIDENT	
	LO	LOADED
	BA	IN BALLAST
25 TO 29	TONS OF CARGO ON BOARD (IF LOADED)	
30 TO 31	TYPE OF PRODUCT	
	CO	CRUDE OIL
	HO	HEATING OIL
	FO	FUEL OIL
	GA	GASOLINE
	BC	BUNKER C
	CA	CARGO OTHER THAN HYDROCARBON OR LIQUID BULK
32 TO 33	MEAN DRAFT	
34 TO 36	ACCIDENT TYPE	
	COL	COLLISION
	GRD	GROUNDING
	RAM	RAMMING
37	IF COLLISION TYPE OF OTHER VESSEL INVOLVED	
	T	TANKER

Columns	Field / Code	Description
	C	CARGO OR CONTAINER VESSEL
	G	GOVERNMENT VESSEL
	O	OTHER
38 TO 41	LOCATION OF ACCIDENT	
	CTUR	IN CHANNEL (TURNING)
	CSTR	IN CHANNEL (STRAIGHT PATH)
	PSTA	PILOT STATION
	ABSB	ANCHORAGE AT BIG STONE BEACH
42 TO 43	VISIBILITY AT TIME OF ACCIDENT IN MILES	
44 TO 45	WEATHER CONDITIONS AT TIME OF ACCIDENT	
	FO	FOG
	OC	OVERCAST
	RA	RAIN
	OS	OVERCAST WITH SQUALLS
	PC	PARTLY CLOUDY
	CL	CLEAR
46 TO 47	WIND SPEED IN KNOTS	
48 TO 49	WIND DIRECTION	
	00	N
	01	NNE
	02	NE
	03	ENE
	04	E
	05	ESE
	06	SE
	07	SSE
	08	S
	09	SSW
	10	SW
	11	WSW
	12	W
	13	WNW
	14	NW
	15	NNW
50 TO 51	HEIGHT OF SEAS	
52 TO 53	DIRECTION OF SEAS	
	SAME AS ABOVE	
54	PILOT ON BOARD	
	Y	YES
	N	NO
	U	UNKNOWN
55	LICENSE OF PILOT	
	F	FEDERAL
	S	STATE
56 TO 65	NAME OF PILOT	
66 TO 120	CONDENSATION OF NARRATIVE	

APPENDIX B

WRITTEN COMMENTS RECEIVED ON
DRAFT REPORT

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS:
U.S. COAST GUARD G-NSR/14
WASHINGTON, DC 20593
PHONE: 202 426-0980

16500
DEC 16 1980

Mr. J. D. Porricelli
Managing Principal
Engineering Computer Optecnomics, Inc.
1036 Cape St. Clair Center
Annapolis, MD 21401

Dear Mr. Porricelli:

Herewith I am returning a copy of your report concerning navigation hazards in the lower Delaware Bay. My comments are written in the margins. Despite the fact that the accident history in the area does not reveal significant likelihood of collisions in the "precautionary area" at the entrance to Delaware Bay, I do believe that the probability for a collision there within ten years, for instance, indeed may be quite significant merely because that precautionary area is a "mixing bowl" through which all traffic in and out of Delaware Bay must travel. Elaboration on this point would seem appropriate for your report.

Additionally, you might expand somewhat on meeting situations in Delaware Bay, particularly in poor visibility. Pilots will not enter the dredged channel in poor visibility, but are the aids adequate for vessels without rate-of-turn indicators considering the few times during the year in which poor visibility besets vessels already committed to the channel? Again, accident statistics may not be a sufficient basis for judgment on the adequacy of the aids.

I enjoyed reading your report and hope my comments are helpful.

J. T. MONTONYE
Captain, U. S. Coast Guard
Asst Chief, Short Range Aids
to Navigation Division

Enclosure

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

Commander (e)
Third CG District
Governors Island
New York, NY 10004
(212) 668-7076

PSN 90003

DEC 3 1980

J.D. Porricelli
Engineering Computer Optecnomics, Inc.
1036 Cape St. Claire Center
Annapolis, MD. 21401

Dear Mr. Porricelli:

Thank-you for your draft copy of the "Analyses of Existing and Potential Navigational Hazards in Delaware Bay" being prepared in the Cape May County Planning Board. We have read through the draft and have no comments or changes to propose. The overall cost figures provided in your report are consistent with our preliminary estimates for construction of new fixed aids to navigation structures. We do note that the new fixed aids may require commerical power. If they do we presume that the commerical power life cycle cost would be less than the cost you have used in your report.

We have noted that your study is limited to measuring cost versus savings solely on the bases of marine accidents and not on any other factors. Again thank-you for the opportunity to review your draft report.

Sincerely yours,

B. L. SOLOMON
Captain, U.S. Coast Guard
Chief, Engineering Division
By direction of the Commander
Third Coast Guard District