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IMPACT OF OIL SPILLAGE FROM WORLD WAR II TANKER SINKINGS

by

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Administrative Statement

The rash of oil tanker mishaps in or near U.S. waters during December 1976 and January 1977 gives this report special significance. Research findings allow us to draw three main conclusions.

First, the amount of oil spilled during the first six months of 1942 within 50 miles of the U.S. Atlantic coast was 484,200 metric tons. This is approximately 145 million gallons of petroleum products, the equivilent of the cargo of 20 Argo Merchants, almost one per week for six months.

Second, the only clean up efforts were the burning of oil incidental to the torpedoing, and the cosmetic actions to clean the swimming beaches for tourists. Otherwise, the ocean and coastal environments had to absorb the full impact of the spilled oil.

Third, findings indicate that the ecology of the coastal regions survived this wartime devastation, though there is no definite evidence that long-term or permanent damage did not occur.

Finally, the areas pinpointed in this study suggest opportunities for follow-up investigations assessing the current physical conditions and long-term impacts of oil spills on the coastal ecology.

Dean A. Horn
Director

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ABSTRACT

The overall effects of spilled oil are studied through available data on tankers sunk along the East Coast of the United States during World War II. The baseline data of ships sunk, cargo, locations and data on sinkings was established through an extensive literature and archives search. Cape Hatteras, North Carolina and its surrounding area was chosen as the primary site of the investigation on the basis of the volume of spilled oil. A computer model was developed to estimate the trajectory of oil released from each ship. In addition, the Asbury Park area of New Jersey was investigated on the merit of substantial documentation of spills in that area. Interviews were conducted in both areas to obtain first hand information on visible effects of the oil. Newspapers and records of marine activities were analyzed to determine environmental and other oil related effects for the selected regions. Results indicated that effects of the oil spills, as observed by residents of the areas under investigation, were negligible. In both cases, regional wildlife and economy survived with minimal difficulty.

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INTRODUCTION

The success of the German U-boat assault of the coastal shipping lane off the Eastern Seaboard of the United States resulted in a plethora of ship sinkings early in World War II. Of those vessels lost, a multitude carried petroleum products in various states of refinement from Aruba and Curacao of the Netherlands Antilles and major refineries of Texas. These cargoes, destined for Great Britain or cities of the northern seaboard, were spilled into the ocean, forming slicks, some of which were reported to be nearly 100 square miles in surface area. How many of these slicks were to be carried to shore inundating vast reaches of the coast with oil and sludge? In most cases, clean-up efforts would have been minimal or nonexistent, leaving nature to absorb the full impact.

It appeared that a careful analysis of the oil spills resulting from these sinkings (i.e., the type of oil spilled, whether crude or refined, the location of the spills, and the points of primary impact) followed by both a historical and current evaluation of the environmental impacts might provide valuable insights relative to the development of potential Outer Continental Shelf oil resources and the establishment of deepwater ports and terminals in the coastal zone. To date, decisions on these matters have been guided by the results of probabilistic computer models that predict trajectories of hypothetical oil spills released at various sites along the East Coast (48). Documentation of oil spills from World War II

and their corresponding movement would give further indication of a site's suitability from an ecological viewpoint as well as exposing possible long term effects hitherto relatively unknown.

HISTORICAL BACKGROUND

Soon after Hitler's declaration of war on the United States on December 11, 1941, the German Command ordered the commencement of a submarine offensive in the Western Atlantic. The prime directive - disrupt the flow of munitions and petroleum to US ports. The Germans drove for the jugular of the American mainland, the coastal shipping lane which skirts the Eastern coastline running from the Saint Lawrence River south to Key West, Florida. Tankers heavily laden with petroleum products from Curacao and Aruba in the Netherlands Antilles as well as Corpus Christi, Houston, and Port Arthur, Texas, would intercept the shipping lane at Key West, Florida. With courses plotted for New York, Boston, and Halifax, the ships would make their way hugging the shore during the daylight hours in an attempt to evade the U-boats waiting in deep water. The lack of escort ships and futility of night air patrols left merchant ships completely defenseless and easy prey for the Nazi wolf pack.

The initial success of the German submarine offensive was devastating. In the last two weeks of January alone, 13 vessels were sunk totaling 95,000 gross tons, of which 70 percent was tanker tonnage (27). Shipping was so plentiful that torpedoes were saved in favor of heavily laden freighters or tankers. In all, 100 merchant ships were sunk during the first six months of 1942 totaling 587,951 gross tons (64). It was not until July, 1942 that an efficient convoy system and a substantially larger

Air Corps reduced the effectiveness of German submarine forces in American coastal waters. Protection of merchant ships utilizing this North-South shipping lane became so proficient as to necessitate a shift of Nazi U-boat operations to assaults on transatlantic convoys.

The exact number of U-boats operating off the East Coast of the US was uncertain. It is known that one month after Germany's declaration of hostilities with the United States, the initial strike force comprised of six submarines was under way for the Western Atlantic commanded by Germany's finest submarine captains. This force was augmented at a later date and according to US Admiralty estimates, the total submarine force in the Western Atlantic had risen to 40 by June 1972. However, the actual hunting force was probably no more than 12 since each submarine was limited by a 42 day cruise capability. That is, since the refueling depots of Brest, Lorient, Saint Nazaire, La Pallice, and Bordeax, France were all two weeks away from the United States, each U-boat could hunt for two weeks before returning to France. The loss of time on patrol was alleviated to some extent by the assignment of a few tanker-submarines known as "milch cows" to American waters. These tankers were cabable of refueling submarines at sea and restocking ship stores. The tankers were similarly refueled by commercial tankers that regularly sailed from the Canary Islands.

A realization of the tremendous losses incurred as a result of the German submarine offensive is gained by the following

example cited by Morrison (27) in a passage taken from a Training Manual prepared at the Naval Air Station at Quonset Point, Rhode Island. If a submarine sunk two 6,000-ton cargo ships and one 3,000-ton tanker, the average cargo lost would be: 42 tanks, 8 six-inch Howitzers, 88 twenty-five pound guns, 40 two-pound guns, 24 armored cars, 60 Bren carriers, 5210 tons of ammunition, 600 rifles, 428 tons of tank supplies, 2000 tons of stores and 1000 tanks of gasoline. If these same three ships had made port safely, it would have taken three thousand successful bombing sorties to destroy the same amount of equipment.

From this present investigation of the German submarine campaign of 1942, it becomes apparent that the massacre of the merchant ships of the East Coast of the United States spilled thousands of tons of petroleum products into the ocean. The goal of this research has been to determine the fate and observable consequences of this oil.

SITE SELECTION

The initial phase of this study involved the selection of the site on the East Coast of the United States that received the greatest inundation with oil due to ship sinkings during World War II. The data base on which this study operated was obtained by culling information found in six references (see refs. 19, 23, 25, 49, 58, 65). Typically, information contained in these references included nationality and type of ship, gross and net tonnage, cargo, date and location of sinking. A ship was selected as an element of the data base subject to three tests. First, the vessel must have been classed as one that was rigged for carrying bulk petroleum products. The decision to accept only tankers was based on the negligible quantity of petroleum carried on other ships in comparison to that carried by tankers. Second, since preliminary examination of the sources indicated that the sinkings of tankers during 1942 greatly exceeded those from other years, only those vessels sunk during 1942 were given further consideration. Lastly, all ships sunk in excess of fifty miles from the coastline were excluded from this study. This arbitrary cut-off was motivated by the compounding of uncertainty in the movement of oil released far offshore. Further, the severity of ecological impact that follows the beaching of oil depends on the amount of weathering the oil has undergone. This is primarily due to the rapid evaporation of the more toxic aromatic components of oil. For this

reason, oil that comes ashore within one to two days after its release can be expected to cause a high degree of initial mortality and may require years for complete recovery (57).

A complete listing of data is shown in Tables 1 and 2. Table 1 is a citation index that displays the sources that contained information about a particular ship. An 'x' indicates that the reference contained a citation and an 'o' the converse. Table 2 contains the quantitative data. Columns four and five of Table 2 give the latitude and longitude, respectively, of the wreck on the bottom of the ocean (58). Columns six and seven cite the position of the attack on the ship as recorded in naval records (65). It should be noted that in column eight, the notation of "unknown - full" indicates that no specific cargo could be determined but trade routes and other information indicated that the ship was laden at the time of sinking. All ships listed in these tables were plotted on nautical charts (Figures 1 and 2) to illustrate the coastwise distribution of attacks on the tankers considered in this study. The dashed line shown in these figures is the fifty mile cut-off previously discussed. These charts show that the area between thirty-four and thirty-six degrees of north latitude was one of intense activity by German submarines. This comes as little surprise since the Outer Banks and shoals in this area forced ships out into deep water where submarines could strike and retreat to the safety of the depths if necessary.

TABLE 1 VESSEL DATA AND CITATIONS

ID	NAME OF VESSEL	FLAG	NET TONNAGE	GROSS TONNAGE	REF. #1	REF. #2	REF. #3	REF. #4	REF. #5	REF. #6
7	NORNESS	PA	6007	9577	X	0	X	0	X	0
2	COIMBRA	BR	3976	6768	X	0	X	X	X	X
63	R. P. RESOR	US	4620	7451	X	0	X	X	X	X
44	PERSEPHONE	PA	5055	8426	X	0	X	X	X	X
75	GULFTRADE	US	4223	6776	X	0	X	X	X	X
5	VARANGER	NO	5505	9305	X	0	X	0	X	X
64	INDIA ARROW	US	5176	8327	X	0	X	X	X	X
65	W. L. STEED	US	3799	6182	X	0	X	X	X	X
66	CHINA ARROW	US	5228	8403	X	0	X	0	X	X
58	FRANCIS E. POWELL	US	4325	7096	X	0	X	X	X	X
86	TIGER	US	3708	5992	X	0	X	0	X	X
87	BYRON D. BENSON	US	4932	7953	X	X	X	X	X	0
8	OLYMPIC	US	3352	5335	X	X	X	X	X	0
59	ALLAN JACKSON	US	4038	6635	X	X	0	X	X	0
31	SAN DELFINO	BR	4800	8072	X	X	X	X	X	X
32	BRITISH SPLENDOUR	BR	4172	7138	X	X	X	X	X	X

TABLE 1 (continued)

ID	NAME OF VESSEL	FLAG	NET TONNAGE	GROSS TONNAGE	REF. #1	REF. #2	REF. #3	REF. #4	REF. #5	REF. #6
37	LANCING	NO	4561	7866	X	X	X	0	X	X
73	AUSTRALIA	US	7221	11628	X	X	X	X	X	X
98	WM. ROCKEFELLER	US	8790	14054	X	X	X	X	X	0
1	EMPIRE GEM	BR	4743	8139	X	X	X	X	X	X
150	F. W. ABRAMS	US	6894	9310	0	X	X	0	X	X
69	DIXIE ARROW	US	4960	8046	X	X	X	X	X	X
77	E. M. CLARK	US	6020	9647	X	X	X	X	X	0
72	ARIO	US	4271	6952	X	X	X	X	X	0
90	TAMAULIPAS	US	4267	6943	X	X	X	X	X	X
88	ATLAS	US	4368	7058	X	X	X	X	X	X
71	W. E. HUTTON	US	4359	7076	X	X	X	X	X	X
76	PAPOOSE	US	3636	5939	X	X	X	0	X	X
70	NAECO	US	3238	5373	X	X	X	X	X	X
151	CASSIMER	US	3105	5030	0	X	X	0	X	X
74	JOHN D. GILL	US	7217	11641	X	X	X	X	X	X
152	ESSO NASHVILLE	US	4697	7943	0	0	X	X	X	X

TABLE 1 (continued)

ID	NAME OF VESSEL	FLAG	NET TONNAGE	GROSS TONNAGE	REF. #1	REF. #2	REF. #3	REF. #4	REF. #5	REF. #6
89	GULF AMERICA	US	4805	8081	X	0	X	X	X	X
220	LUBRAFOL	BE	3988	7138	X	0	X	X	X	X
250	PAN MASSACHUSETTS	US	6025	8202	X	0	X	X	X	0
251	CITIES SERVICE EMPIRE	US	5020	8103	X	0	X	X	X	0
257	HALSEY	US	4389	7088	X	0	X	0	X	X
253	W. D. ANDERSON	US	6552	10277	X	0	X	X	X	0
252	REPUBLIC	US	3237	5287	X	0	X	X	X	X
255	CARRABULE	US	3105	5030	X	0	X	0	X	0
216	POTRERO DEL LLANO	ME	2418	4000	X	0	0	X	X	0
288	J. A. MOFFET	US	6137	9788	X	0	X	X	X	0

REMARKS:

REFERENCE #1 - Official records from the Naval Archives
REFERENCE #2 - "Graveyard of the Atlantic" by David Stick
REFERENCE #3 - "A Guide to Sunken Ships in American Waters" by Adrian Lonsdale and H. Kaplan
REFERENCE #4 - "Dictionary of Disasters at Sea During the Age of Steam" by Charles Hocking
REFERENCE #5 - "Lloyds Register of Ships 1940 - 1941"
REFERENCE #6 - "Wreck List" by the U.S. Hydrographic Office

TABLE 2 WRECK LOCATIONS AND CARGO

ID	NAME OF VESSEL	DATE	N. LAT.#1 (DEG MIN)	W. LNG.#1 (DEG MIN)	N. LAT.#2 (DEG MIN)	W. LNG.#2 (DEG MIN)	CARGO	QUANTITY (BARRELS)
7	NORNESS	1-14	40-26.0	70-50.0	40-28	70-50	UNKNOWN - FULL	
2	COIMBRA	1-15	40-22.0	72-20.0	40-25	72-21	UNKNOWN - FULL	
63	R. P. RESOR	2-26	39-47.8	73-25.8	40-06	73-56	FUEL OIL	78729
44	PERSEPHONE	5-25	39-46.4	74-02.0	39-44	73-53	CRUDE OIL	104431
75	GULFTRADE	3-10	39-43.9	73-50.0	39-50	73-52	FUEL OIL-3 BUNKER 'C'-2	81223
5	VARANGER	1-25	39-00.5	74-05.0	38-58	74-06	UNKNOWN - FULL	
64	INDIA ARROW	2-04	38-33.5	73-50.1	38-48	72-43	DIESEL OIL	88369
65	W. L. STEED	2-02	38-25.0	75-00.0	38-25	73-00	CRUDE OIL	63936
66	CHINA ARROW	2-05	37-59.6	75-11.5	37-55	74-56	FUEL OIL	81773
58	FRANCIS E. POWELL	1-27	37-27.8	75-16.7	38-05	74-53	FURNACE OIL AND GASOLINE	81024
86	TIGER	4-01	36-46.1	75-46.1	36-50	75-18	NAVY #1 FUEL	64321
87	BYRON D. BENSON	5-04	36-08.9	75-14.7	36-08	75-32	CRUDE OIL	91500
8	OLYMPIC	1-22	36-01.0	75-30.0	36-01	75-30	UNKNOWN - FULL	
59	ALLAN JACKSON	1-18			35-57	74-20	CRUDE OIL	72870
31	SAN DELFINO	4-09			35-35	75-06	AVIATION FUEL	96250
32	BRITISH SPLENDOUR	4-06	35-09.3	75-18.3	35-07	75-19	GASOLINE	87500

TABLE 2 (continued)

ID	NAME OF VESSEL	DATE	N. LAT.#1 (DEG MIN)	W. LNG.#1 (DEG MIN)	N. LAT.#2 (DEG MIN)	W. LNG.#2 (DEG MIN)	CARGO	QUANTITY (BARRELS)
37	LANCING	4-07	35-08.7	75-35.5	35-08	75-22	FUEL OIL AND GASOLINE	60000
73	AUSTRALIA	3-17	35-07.3	75-22.1	35-43	75-22	UNKNOWN - FULL	
98	WM. ROCKEFELLER	6-28	35-07.0	75-07.0	35-07	75-07	FUEL OIL	136697
1	EMPIRE GEM	1-24	35-01.4	75-29.8	35-06	74-58	UNKNOWN - FULL	
150	F. W. ABRAMS	6-10	34-59.5	75-48.5	34-59	75-48	FUEL OIL	101500
69	DIXIE ARROW	3-26	34-53.5	75-44.7	34-55	75-02	CRUDE OIL	88136
77	E. M. CLARK	3-18	34-49.5	75-33.0	34-50	75-35	DIESEL OIL	198725
72	ARIO	3-15	34-37.8	76-19.8	34-37	76-20	IN BALLAST	
90	TAMAULIPAS	4-10	34-31.5	76-01.8	34-25	76-00	HEATING OIL	77782
88	ATLAS	4-09	34-31.0	76-14.1	34-27	76-16	GASOLINE	87000
71	W. E. HUTTON	3-19	34-30.1	76-54.3	34-25	76-50	FUEL OIL	64000
76	PAPOOSE	3-18	34-09.1	76-40.5	34-17	76-39	IN BALLAST	
70	NAECO	3-23	34-02.9	76-34.4	33-59	76-40	KEROSENE AND HEATING OIL	72000
151	CASSIMER	2-26	33-54.1	77-49.0	33-54	77-49	UNKNOWN - FULL	
74	JOHN D. GILL	3-12	33-50.5	77-27.5	33-55	77-39	CRUDE OIL	141981
152	ESSO NASHVILLE	3-23	33-45.5	77-13.3	33-55	77-22	FUEL OIL	106718

TABLE 2 (continued)

ID	NAME OF VESSEL	DATE	N. LAT.#1 (DEG MIN)	W. LNG.#1 (DEG MIN)	N. LAT.#2 (DEG MIN)	W. LNG.#2 (DEG MIN)	CARGO	QUANTITY (BARRELS)
89	GULF AMERICA	4-11	30-16.6	81-13.7	30-10	81-15	FURNACE OIL	101505
220	LUBRAFOL	5-09	29-14.0	80-10.0	26-26	80-00	#2 FUEL OIL	67000
250	PAN MASSACHUSETTS	2-19	28-27.0	80-08.0	28-27	80-08	UNKNOWN - FULL	
251	CITIES SERVICE EMPIRE	2-22	28-23.5	80-02.5	28-25	80-02	CRUDE OIL	95000
257	HALSEY	5-06	27-23.0	80-08.0	27-20	80-03	NAPTHE AND FUEL OIL	78000
253	W. D. ANDERSON	2-22	27-09.0	79-56.0	27-09	79-56	CRUDE OIL	133360
252	REPUBLIC	2-22	27-00.6	80-02.6	27-05	80-15	UNKNOWN - FULL	
255	CARRABULE	5-26	26-10.0	80-00.0	26-18	89-21	LIQUID ASPHALT	
216	POTRERO DEL LLANO	5-12			25-33	79-56	DIESEL OIL	30000
288	J. A. MOFFETT	7-08	24-47.0	80-42.0	24-47	80-42	IN BALLAST	

REMARKS:

Source of LAT #1 and LNG #1 is "Wreck Information List"
Source of LAT #2 and LNG #2 is a computer listing from the Naval Archives.

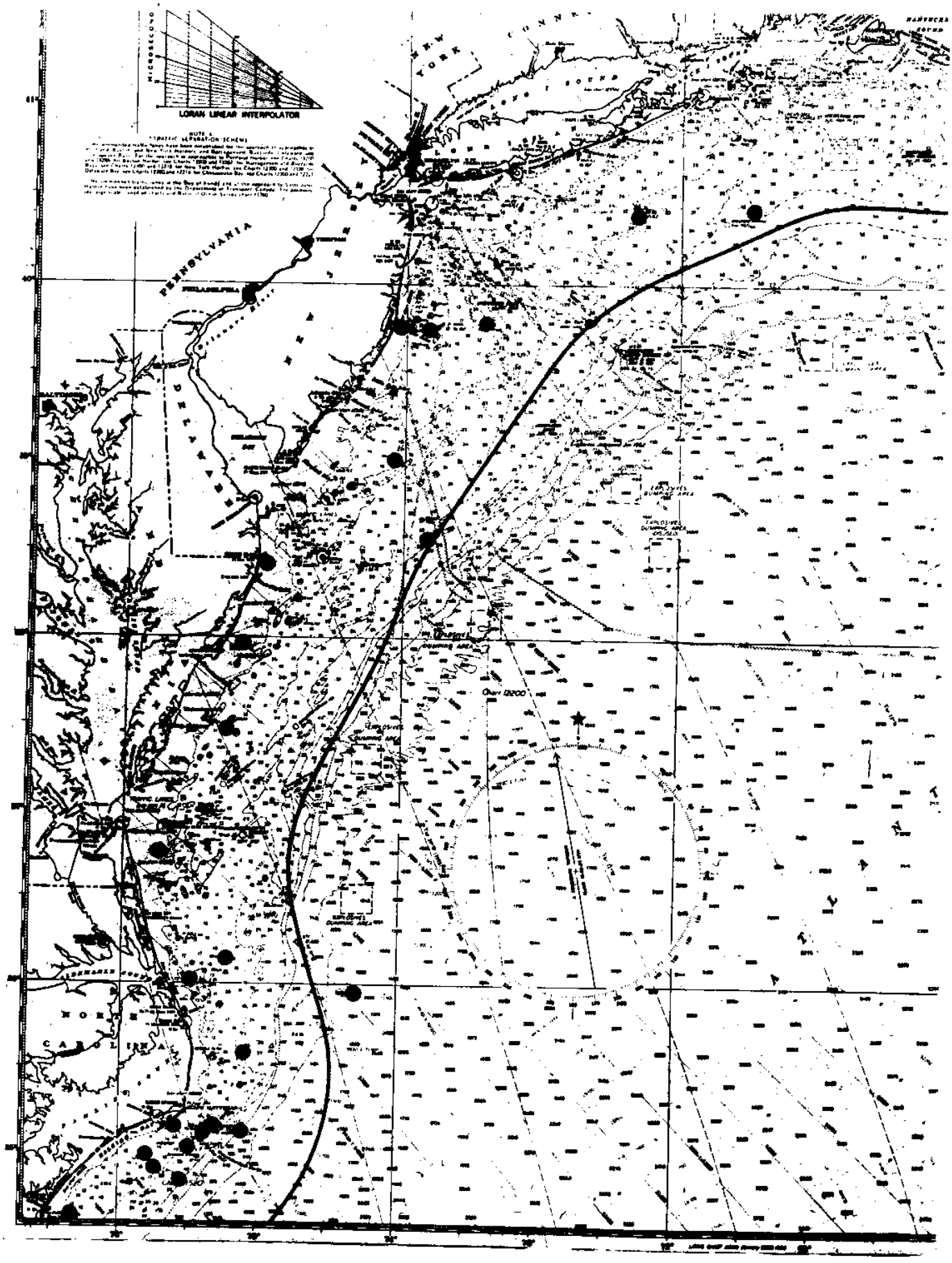


Fig. 1. Tankers sunk during 1942 between Block Island and Cape Hatteras.

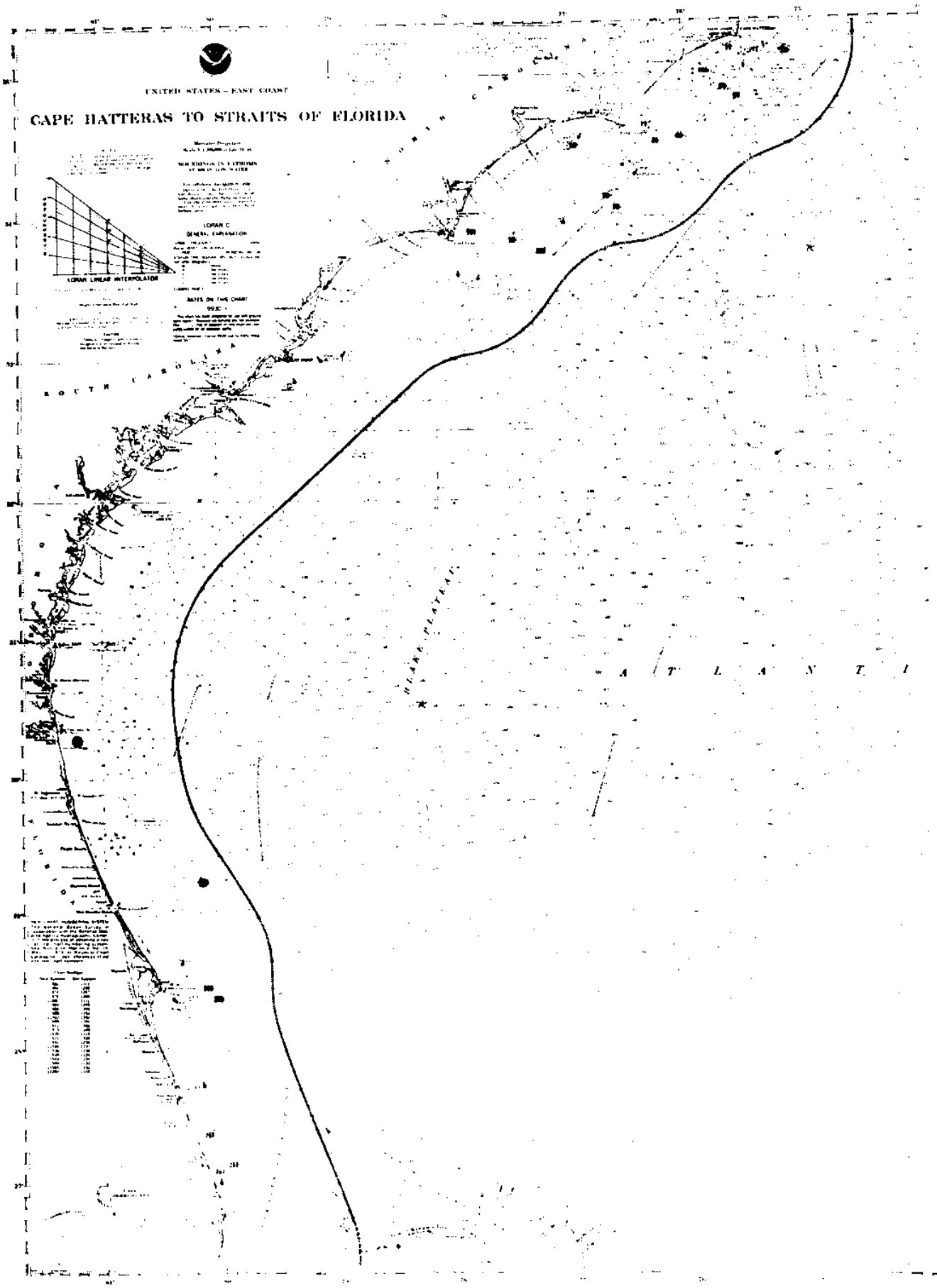


Fig. 2. Tankers sunk during 1942 between Cape Hatteras and the Straights of Florida

To permit a more reliable selection of the primary site for investigation, a quantitative analysis of the tanker sinkings was undertaken. With acquisition of data completed, it was possible to choose a site based on the accumulation of oil in a given sector and the time interval between spills. To accomplish this it was necessary to have comprehensive data on each of the ships cargo. Unfortunately, such information was not available for all ships. As shown in Table 2, however, information on an "in-ballast or laden" basis was available for all forty-three tankers. Explicit cargo volumes were available for all but eleven ships. An approximation of the spill volumes was obtained by assuming that all ships were filled to capacity. That is, if the specific cargo was not known, but the ship was known to be laden (previously described as the "unknown - full" condition in Table 2), the cargo was assumed to be equal in weight to the net tonnage. The results are shown in Figure 3. This figure shows the quantity of oil spilled in metric tons for each degree of north latitude as a function of the months of the year 1942. Note that the numbers in parentheses are the metric tons of oil calculated on an "assumed full" basis. Hence, the total tonnage of oil spilled in a given month between two parallels of latitude is the sum of the assumed cargo weight and the known cargo weight (no parentheses). These results indicate that the area around the thirty-fifth degree of north latitude was the site of the largest weight of spilled oil. At this point, the question arose as to the role that the time interval

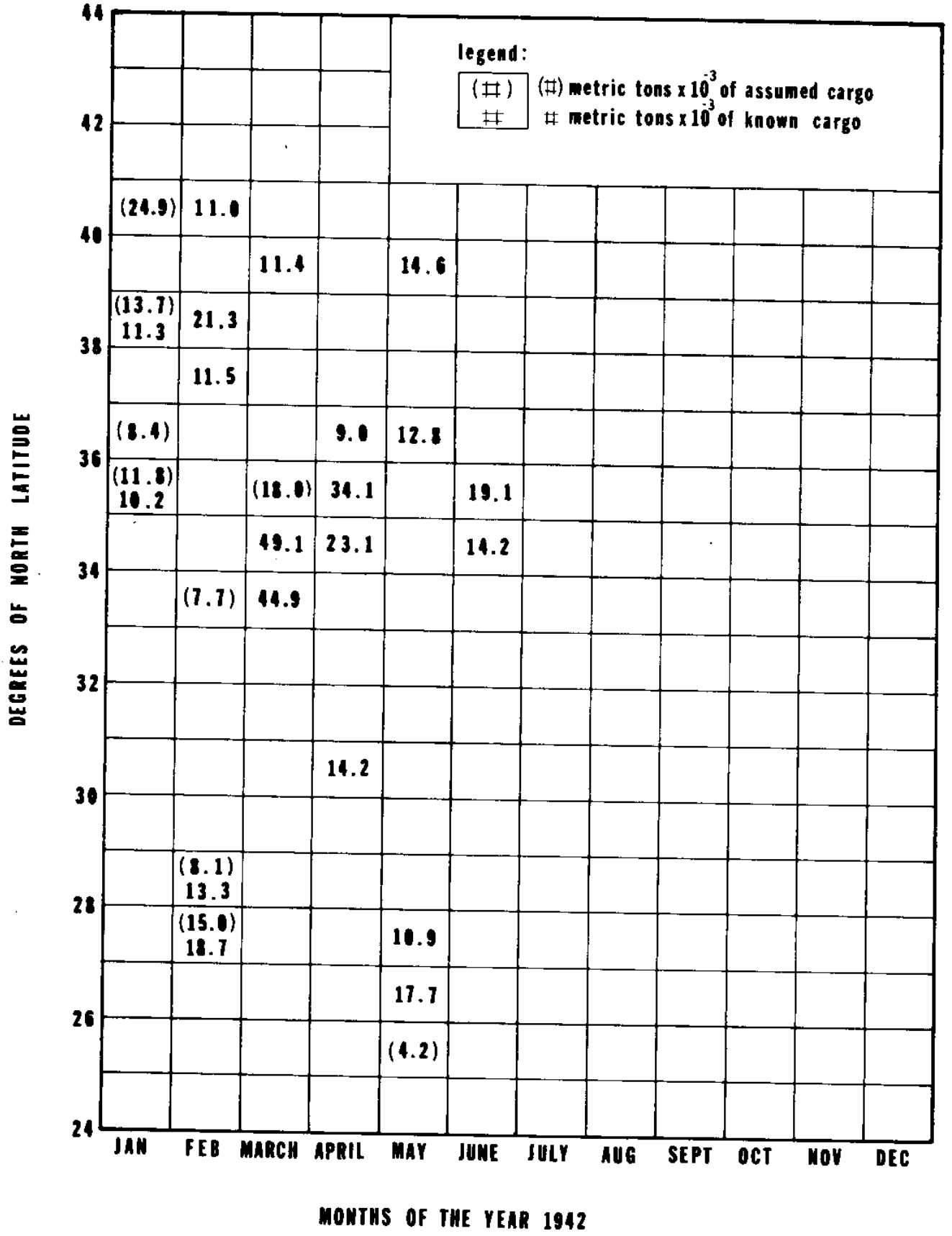


Fig. 3. Tonnage of oil released by latitude and month.

between spills plays in determining the impact on the environment. It is not clear whether a rapid succession of small spills would have caused more damage than several large spills over a period of months. To further complicate the choice was the variety of petroleum products spilled, since the cargo of these tankers varied from crude oil to gasoline. Fortunately, the issue was skirted by observing that the time interval between spills varied from a few days to a month in the area previously cited as containing the largest volume of oil.

Thus it was observed that the area around the thirty-fifth degree of north latitude was exposed to large volumes of petroleum products in various states of refinement over a wide range of time intervals. For these reasons, the coastal region bordering the thirty-fifth degree of north latitude was chosen as the primary target of this study. For facility of further discussion, this region will be refered to as the "Cape Hatteras area" as a result of this cape's location in the center of the designated target area.

INVESTIGATION OF PRIMARY SITE

The investigation thus far has revealed that the potential for a major environmental calamity existed in the Cape Hatteras area during the first six months of 1942. It has been shown that large quantities of oil in various states of refinement were spilled in a multitude of locations within a section of ocean approximately 145 miles by 50 miles. It has not been shown, however, that the oil actually came ashore at some later date. For an initial analysis of this matter, a computer model was developed to simulate the movement of oil released from each tanker.

The model was based on the assumption that the movement of the oil released from a tanker could be idealized as the motion of the point corresponding to the center of the slick. That is, all diffusion, evaporation, and spreading phenomenon were neglected to allow computation of the slick's overall trajectory. To determine this trajectory, it was necessary to utilize an expression relating pertinent environmental variables to the transport of oil. A survey of current literature (18) revealed a variety of expressions available for this purpose. This model employed two of the most promising expressions in order to investigate the sensitivity of trajectory calculations to certain variables. The first of these expressions relates the velocity of the slick to the wind and

current by the following expression:

$$\vec{V} = \vec{V}_{current} + 0.03\ \vec{V}_{wind}$$

The expression was obtained by Smith (46) from observation of the gross movement of oil slicks released by the Torrey Canyon. The second relation is a variation of Smith's formulation based on Schwartzberg's (18) assertion that only 56 percent of the current velocity is effective in slick movement:

$$\vec{V} = 0.56\ \vec{V}_{current} + 0.03\ \vec{V}_{wind}$$

Presently, there is a great deal of discussion in the literature as to the validity of these expressions. In view of the correlation of observed and predicted movement found by Smith and the similarity to the type of predictions desired in this model, it was felt that these expressions would provide results consistent with the desired accuracy of this simulation.

The computer model itself was developed around one major loop such that the data for one tanker sinking was examined and the trajectory computations were made until certain limiting criteria were exceeded or the slick washed ashore. At that point, the results were printed, all variables were zeroed, and a spill from another ship was examined. Wind data utilized by this model was obtained from the National

Climatic Center for Cape Hatteras, North Carolina covering the period January 1 through June 30, 1942. The average wind speed for this period was 12 mph with gusts up to 40 mph. The wind tended to be out of the north during January and February and became southwesterly for the remainder of the time. Implicit in the use of this data is the assumption that the recordings made at Cape Hatteras were representative of the entire area covered by the model. The ship locations used in these calculations were shown in Table 2 as "N. LAT. #1" and "W. LNG. #1". These positions were obtained from the U.S. Hydrographic Wreck List (58) and correspond to the ship's position on the bottom of the ocean. These positions were selected for their inherent accuracy. After all wind and ship data was placed in storage, the primary loop was entered and the initial coordinates of the ship were computed relative to a coordinate system with its origin located at Cape Lookout, North Carolina. The positive coordinate axis extended North and East, thus allowing all coordinates to be positive. This coordinate system was subdivided into a coarse grid, shown in Figure 4, of 7 elements varying from 122 miles to 79 miles wide. The sole purpose of this grid was to allow analytic description of the coastline and current distribution within each element, thus ensuring a large degree of flexibility in the specification of current patterns and coastal geography. At this point, a test for critical locations was made. This

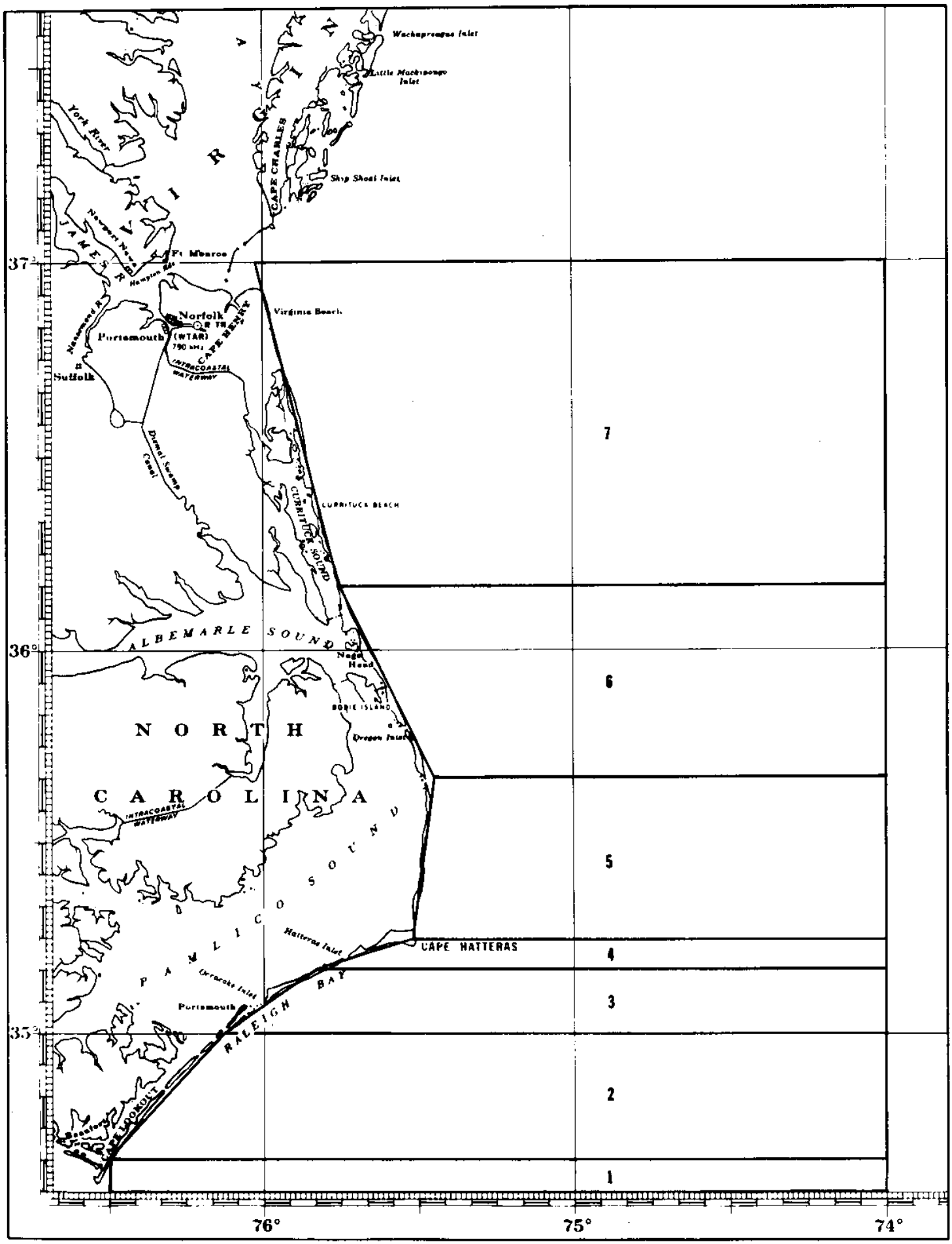


Fig. 4. Grid utilized in the simulation of slick movement in the Cape Hatteras area.

test consisted of two questions: First, was the oil slick outside of the grid; and second, did the oil come ashore. An affirmative response to either question resulted in output of the appropriate condition and the selection of a new ship. The next step in the program was the selection of a set of equations defining the current velocity utilizing the previously defined grid. The currents utilized in this model, shown in Figure 5, were obtained from general flow characteristics shown on current tables (55) and nautical charts of the area. Information obtained from these sources was expressed in simple analytical expressions relating geographic location to current speed and direction. It is recognized that these assumed current patterns are at best crude approximations, but the variable nature of these currents preclude their accurate description. The forty-five degree angle line shown is the approximate inner boundary of the Gulf Stream and serves to define three flow patterns. East of the boundary, the velocity distribution is linear and streamlines are parallel to the boundary. The same situation holds for the area south of Cape Hatteras and west of the Gulf Stream. North of these two regimes, the flow is constant and streamlines parallel a line bearing 158 degrees true. The slick's coordinates were then fed into the equation for the current velocity, thus obtaining the current speed at the location of the oil. Wind velocity for the specific date and hour was retrieved from a 2896 element matrix and plugged into the appropriate slick

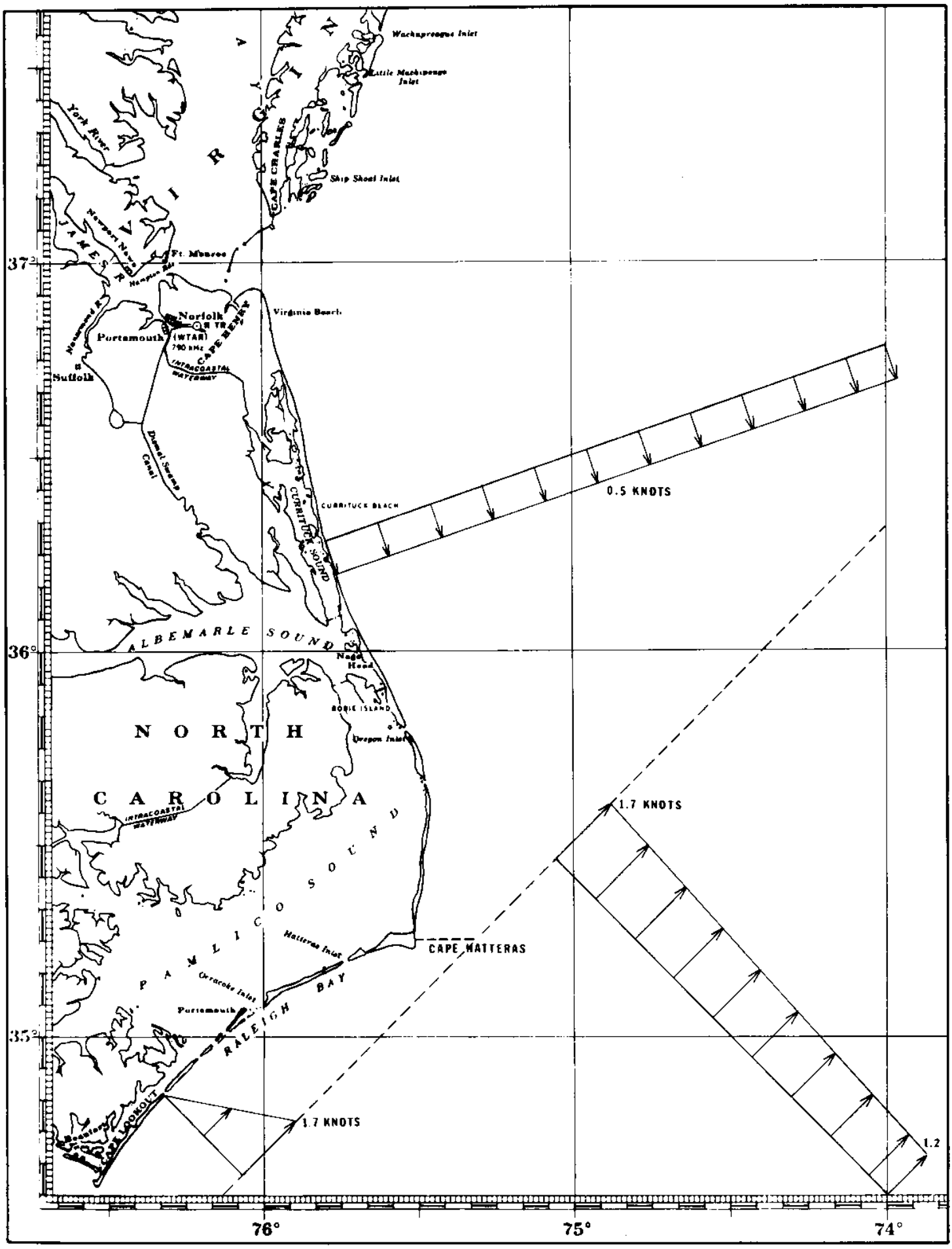


Fig. 5. Assumed currents in the computer simulation.

velocity equation. The total drift in a three hour time interval was calculated by multiplying the slick velocity by three. The selection of the three hour increment was based on a rough inspection of wind data which indicated that the magnitude and direction of the wind remained essentially constant over that period. New coordinates were then obtained by adding the components of the drift vector to the old coordinates. Output was in a table showing time, coordinates, distance to shore, distance and angle of the incremental drift. Graphic output was also utilized in the form of a Gerber flatbed incremental plotter. The plotting routine was written in such a form that slick trajectories were plotted on nautical charts for simplicity and clarity. The final step of the program was a test designed to monitor the total elapsed time of drift. A limit of 168 hours was imposed after which time a new cycle was started with another spill.

The results of the computer simulation indicated that out of 14 spills, 3 slicks moved into shore under current and wind action within one or two days while all others drifted out to sea. Of the three ships responsible for those slicks, ship #72 was in-ballast, ship #37 carried 60,000 barrels of fuel oil and gasoline, and ship #150 carried 101,500 barrels of fuel oil. Figures 6 and 7 show each ship's initial position and the corresponding path of the slick as calculated by Smith's and Schwartzberg's drift equations respectively. Comparison of the two figures illustrates the erratic drift patterns produced by

the reduced dependence on current velocity theorized by Schwartzberg. In general, Schwartzberg's model tends to produce drifting with lower gross slick velocity and greater dependence on highly variable wind velocity. This point is illustrated by slicks #86 and #87, which exhibit an average decrease of 42 percent in the overall transport velocity, as well as the irregularity of trajectory previously discussed. It is important to observe that although significant differences exist between the two trajectories, the areas where oil washed ashore remained the same. Note also, that the point identifying ship #37 does not actually touch shore according to Figure 7. It must be remembered, however, that each point represents the center of the slick which will be offshore when the slick first washes up. Although these results are highly dependent upon the current distribution chosen, the profile chosen yields the best presentaly available approximation to the oil slick's trajectory.

To check these results, a trip was made to Cape Hatteras to interview local inhabitants of that area during the war. A general impression received from these interviews was that oil was present in small quantities north of Cape Hatteras. The oil was usually described as "splotchy". Among the individuals interviewed was a member of the life boat station crew at Oregon Inlet, located approximately 30 miles north of Cape Hatteras, and, as such, made regular patrols along the coastline by boat and car as far north as Virginia Beach, Virginia (41).

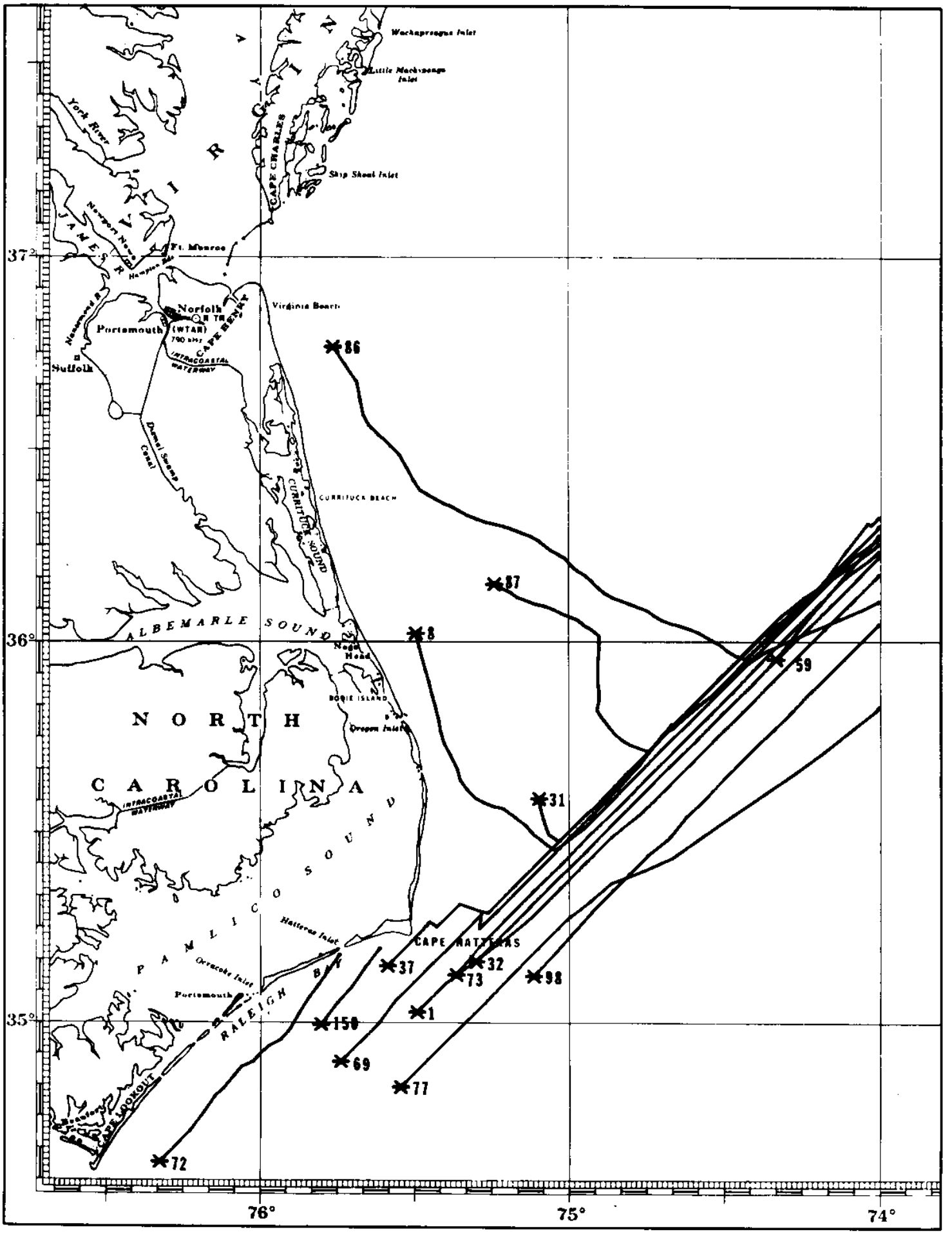


Fig. 6. Slick trajectories based on Smith's drift model.

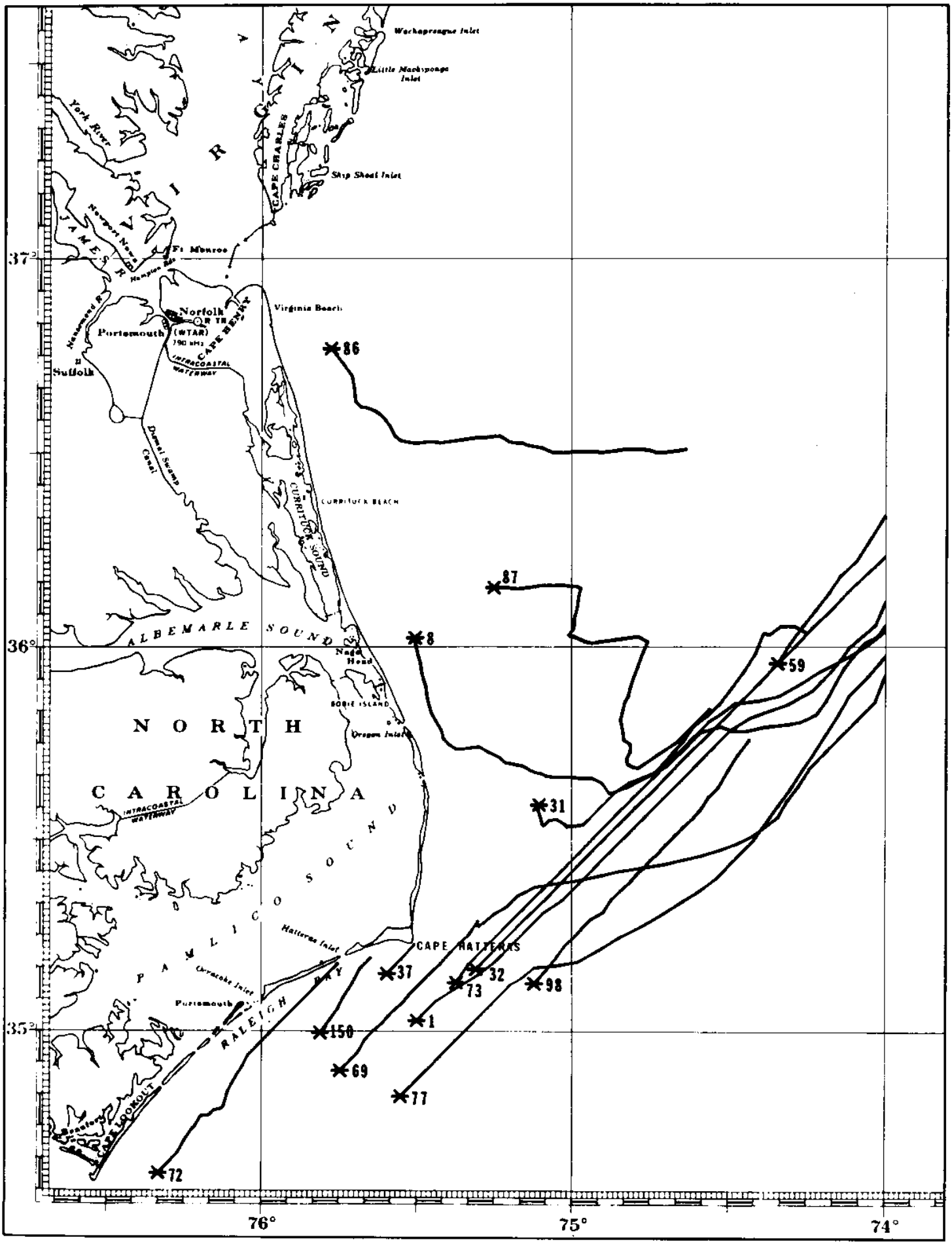


Fig. 7. Slick trajectories based on Schwartzberg's drift model.

He recalled seeing oil on the water and stated that they made an effort to steer around it in their boat. No order of magnitude could be associated with the size of these slicks, however. In any case, it was concluded that the oil ashore in this area was minor. This is not the case in the area south of Cape Hatteras. The general impression was that a sizable quantity of oil came ashore, particularly on the island of Ocracoke. One eyewitness stated that there was so much sticky oil that it was difficult to walk on the beach. The information received from these interviews is supportive of the results of the computer simulation.

Further evidence substantiating the computer simulation was found in the "War Diary of the Eastern Sea Frontier" (see Appendix 1, report #61) in the form of a report stating that two bodies, originally from the British merchant ship "Bedfordshire", sunk on May 12, 1942 at 34°N - 76°W, had washed ashore at Ocracoke Inlet, 60 miles to the north, on May 16. This indicates that the two bodies followed a trajectory similar to that predicted for slick #72. Although this evidence is far from being conclusive, it does instill greater confidence in the current patterns chosen for the simulation.

Further documentation of the slick trajectories was attempted by examining the records of the Fifth Naval District, which provided records of oil slick sightings in the area from Halifax to Jacksonville, Florida. These records specified time and location of the sightings and, in many cases, provided an

estimation of slick size and source. A complete list of sightings is presented in Appendix 1. All sightings within the range of the computer model's grid were plotted, as shown in Figure 8, in an attempt to correlate slick sightings with known tanker sinkings. Unfortunately, it was not possible to produce meaningful correlations since there was no absolute link between a slick and its possible source. For example, feasible sources for slick #31 were tankers #72, #73 and #77 since all of these vessels were sunk reasonably close in time and position to the sighted slick. These, however, were not the only possibilities. Since no information on the magnitude of the slick was given, the sinking of a submarine or cargo vessel could not be ruled out as a possible origin. To further complicate the matter was the possibility that a slick was emitted as a result of depth charging previously sunken vessels. Although the data presented in Figure 8 is not amenable to correlation of sighted slicks and known tanker sinkings, it does give some insight into the number of slicks that were adrift during the first six months of 1942 in the area covered by the simulation grid.

Before concluding the discussion of the behavior of slicks and the quantity of oil washed ashore, the matter of the reduction of slick size by burning must be addressed. It is evident from interviews and deck logs of destroyers patrolling in the Atlantic (62) that tremendous fires engulfed many tankers after they were torpedoed and continued burning for

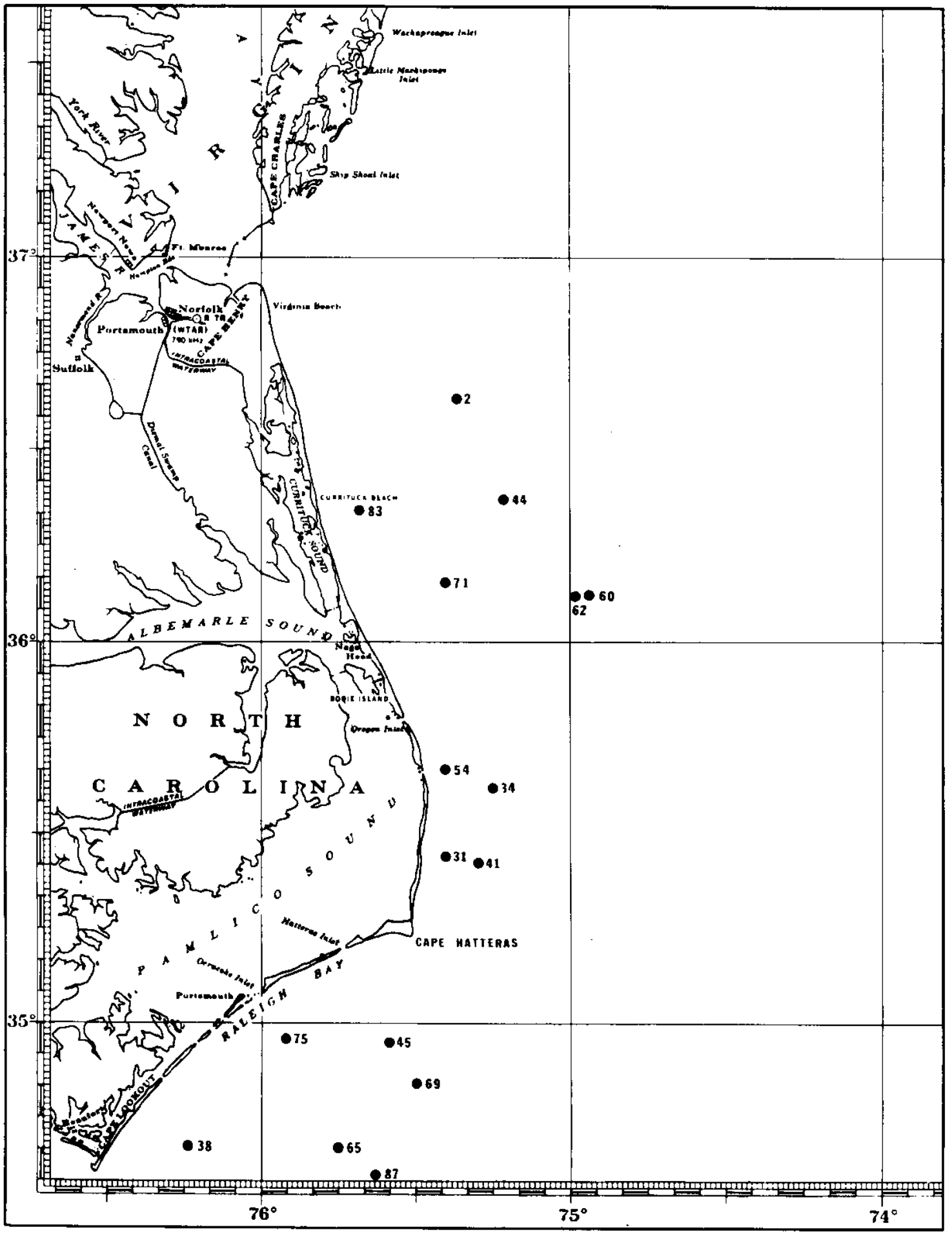


Fig. 8. Miscellaneous slick sightings.

hours, some even for days. It is very likely that these fires greatly reduced the quantity of spilled oil. In fact, on several occasions patrol planes sighted burning slicks far from the sight of any wreckage (see Appendix 1, report #38). No meaningful estimates of volume reduction could be made. It is possible, however, to determine from survivor interviews, presented in Appendix 2, if extraordinary burning took place. In those cases, the maximum slick volume based on the tanker cargo volume could be annotated as possibly containing significant error. Examination of the survivor reports indicated that no unusual burning took place on the two tankers whose cargo was predicted to have washed ashore south of Cape Hatteras. As a result, it was reasonable to assert that a total volume of oil washed ashore on or near Ocracoke Island which was on the order of 160,000 barrels of fuel oil and gasoline.

At this point, it has been ascertained that the area south of Cape Hatteras, North Carolina was the site of a significant inundation with oil. Further, results from the computer simulation of drifting oil suggests that a portion of the oil washed ashore in that area was spilled from the tankers "F.W. Abrams" sunk on June 10, 1942, and "Lancing", sunk on April 7, 1942. Other oil slicks striking shore may have originated from tankers south of the zone covered by the computer model as well as sources not directly related to tanker sinkings. With this in mind, it is now reasonable to inquire as to the fate of local fisheries and wildlife.

In an attempt to quantitatively determine the impact of the previously discussed spills on the fish populations in the Cape Hatteras region, data on commercial fisheries was obtained from the University of North Carolina Sea Grant Report No. UNC-SG-75-12, Synopsis of Marine Fisheries. This publication presents a complete tabulation of all existing data on the commercial fisheries of North Carolina. The statistics presented were of the nature that measures of success in fishing, such as the number of fish caught per boat-device-county-year, could have been calculated. However, calculations of this type would have been useless for the following reasons: First, data for the years 1940-1945 was unavailable, resulting in the loss of any short term effects; second, even if this data did exist, the results might have been indistinguishable from the large natural variations in population typical of fish caught commercially. Further, the fish caught in the Cape Hatteras area generally reside in either deep water or the Pamlico Sound. The species of finfish found in deep water, although generally unaffected by direct contact with oil, might suffer losses as a result of high mortality of some organism vital to the survival of its food chain. Under these circumstances, however, highly mobile finfish would be most likely to migrate to another more favorable area. On the other hand, crabs and clams, as well as fish living in the Pamlico Sound, are generally less mobile and would have been forced to endure depleted food supplies. This is a moot point, however, since reports

indicate that the Sound remained free from oil. It is also interesting to note that newspapers of the period from Cape Hatteras (12) indicate that local fishing was as good as ever. This may have been true since a large amount of fishing was done in the Pamlico Sound and this was free from oil as previously discussed. If, however, this were not the case, reports of poor fishing might have been commercial suicide for the small towns of the area which depend so heavily on the influx of tourists for pleasure fishing.

Further investigation of environmental damage was undertaken by a search of wildlife statistics. Although statistics of this nature would have been free from many of the problems encountered in fisheries data, records were unavailable for coastal regions. It was, however, discovered that it was not uncommon to see "a few" oiled birds on the beaches. The number and species were not known but the general impression was that these incidents were minor. This coincides with the idea that a great number of birds residing in the inland area of the Sound used the Sound as a primary source of food and were, therefore, relatively unaffected by the oil. On the other hand, there are species of birds that live on the ocean side of the outer banks and these birds, which are typically diving birds, would have been the most greatly effected. As before, newspapers reported that duck hunting was better than ever. Again, these reports should be viewed skeptically since statements to the contrary could have seriously effected the area's economy.

In all, general appearances and local impressions lead to a "qualified conclusion" that the impact from oil washed ashore in the Cape Hatteras area was minor. This conclusion is "qualified" in the sense that there is no solid proof of this assertion in the form of statistical records and controlled population surveys. It may be concluded, however, that the geography of this area tends to protect those areas that would be highly susceptible to ecological disaster. That is, the Outer Banks tend to barricade the inland water so necessary for the survival of the local wildlife residing in a multitude of national wildlife reserves presently established there. Another important factor in the protection of this area is the swift Gulf Stream that tends to carry oil slicks out to sea where they would dissipate and consequently present little threat to coastal wildlife.

SELECTION AND INVESTIGATION OF AN AUXILIARY SITE

In the preceding sections, the documentation of tanker sinkings in the Cape Hatteras, North Carolina area during 1942 was presented and the corresponding impact on the ecosystem was discussed. A computer model was formulated to approximate the gross trajectories of individual oil slicks under the influence of current and wind action. This model, together with evidence obtained through individual interviews, permitted the designation of areas of the North Carolina coastline most likely to have been affected by petroleum products spilled by sinking tankers. It was through these techniques that conclusions were drawn concerning the impact on the local wildlife and fisheries without benefit of photographs or other concrete evidence. There was no doubt that evidence of this nature could have yielded further insight into the extent of damage incurred by the environment. It was for this reason that further research on an alternative geographical area was deemed necessary.

The task of site selection was begun with a re-evaluation of all potential study sites previously excluded from consideration on the basis of spill volume. In this case, the region studied was chosen not only for the potential of extensive damage to the environment, but more importantly, for the likelihood of locating comprehensive documentation of the spills and impact-related material.

Figures 1 and 2 were used to designate areas where one or more sinkings had occured close to shore, thereby ensuring a high probability of the oil washing ashore. These findings were tempered with the supposition that an inundation of beaches with oil in a highly populated area was more likely to have been recorded. The areas meeting these requirements were Asbury Park, New Jersey; Norfolk, Virginia; and Jacksonville, Florida. To determine which of these areas had the greatest documentation of spills in their regions and the ensuing damage, if any, newspapers from each of the towns were examined. The premise was that if a spill were considered important enough to receive thorough coverage, there was a reasonable chance of locating photographs and witnesses with first hand knowledge of the event in question. Through this technique, it was found that the Asbury Park-Belmar area of New Jersey was the most promising area, since a number of newspapers indicated that the coastal beaches of New Jersey had been fouled by oil in the summer of 1942 and documentation appeared comprehensive. It was also known that the coastal resort cities were heavily dependent upon the condition of their beaches, therefore, any cessation of tourist traffic as a result of poor beach conditions was sure to cause a furor that would be long remembered. Furthermore, this area was heavily populated by wintering waterfowl and, therefore, possessed a high potential for substantial impact.

The area of concentration now targeted, the investigation proceeded with an analysis of all tankers sunk in the aforementioned region. As previously reported, three tankers were sunk off the New Jersey coast during 1942, as shown in Figure 9: the "R.P. Resor", the "Gulftrade", and the "Persephone".

The first of these, the "R.P. Resor", was torpedoed on February 26, 1942 while transporting approximately 79,000 barrels of fuel oil. The attack took place approximately 9 miles southeast of Belmar, New Jersey (see Figure 9). Newspaper reports and recent interviews indicated that the response of the resort municipalities was immediate. Many of the townspeople who had access to boats attempted to aid the Coast Guard in rescue operations. The New York Journal American (29) reported that "there was a scum of oil about three inches thick for a half mile around the tanker". Other reports went on to say that the oil was so thick that it slowed down one of the cabin cruisers and stopped the engine of a twenty-six foot motor-sailboat. It was further indicated that in many places oil that covered the sea was ablaze and that the tanker was on fire from bow to stern as well. It was at this point that a divergence of recollections occured. An article published in the New York Times (33) on February 28, 1942, stated that "three bodies were reported sighted floating in the oil clogged waters of Manasquan Inlet". This was approximately 8 miles west of the site where the "R.P. Resor" was attacked, giving the first indication that some oil had drifted

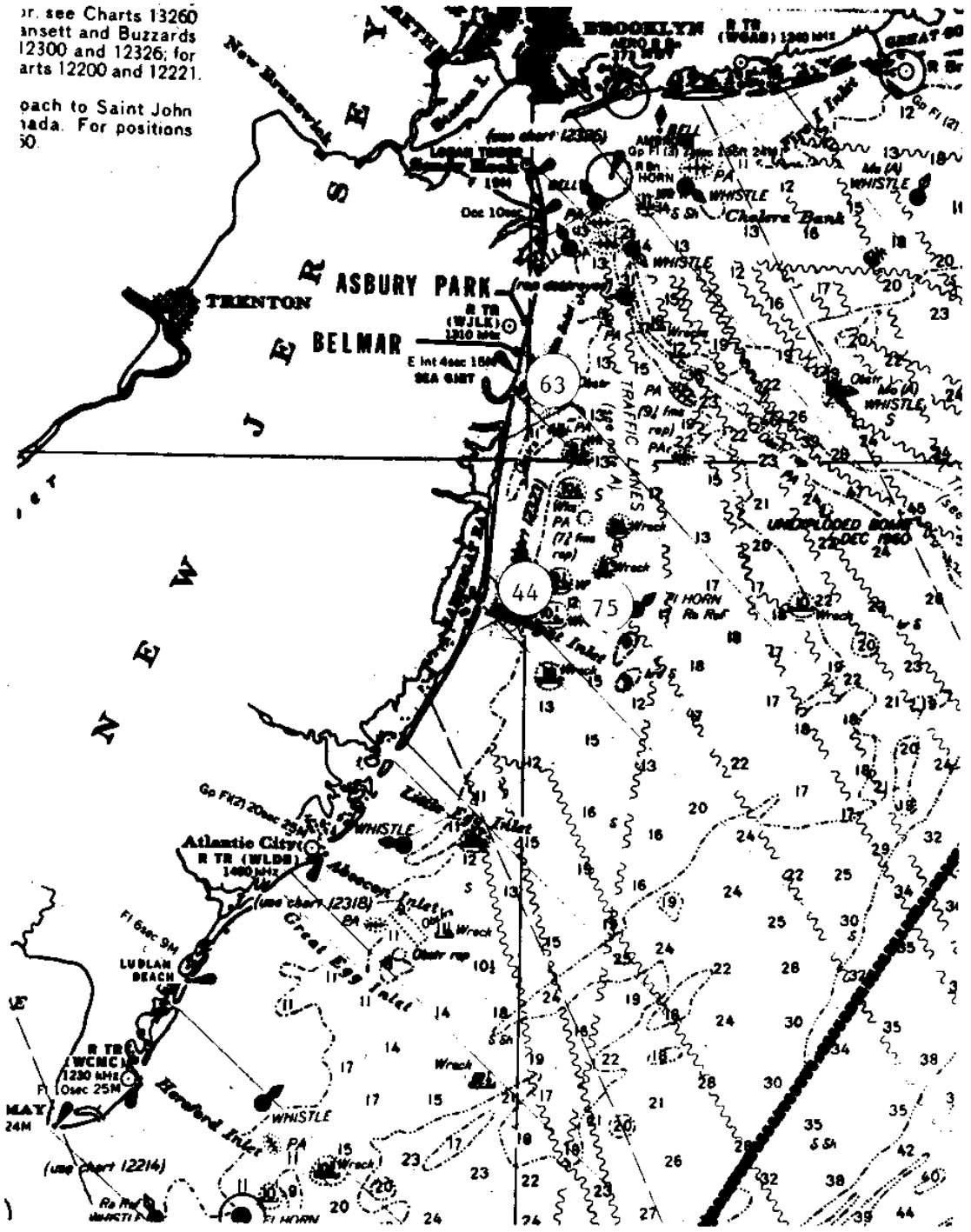


Fig. 9. Wrecks along the New Jersey coastline.

due west to the vicinity of the inlet. Further on in that same article, it was reported that:

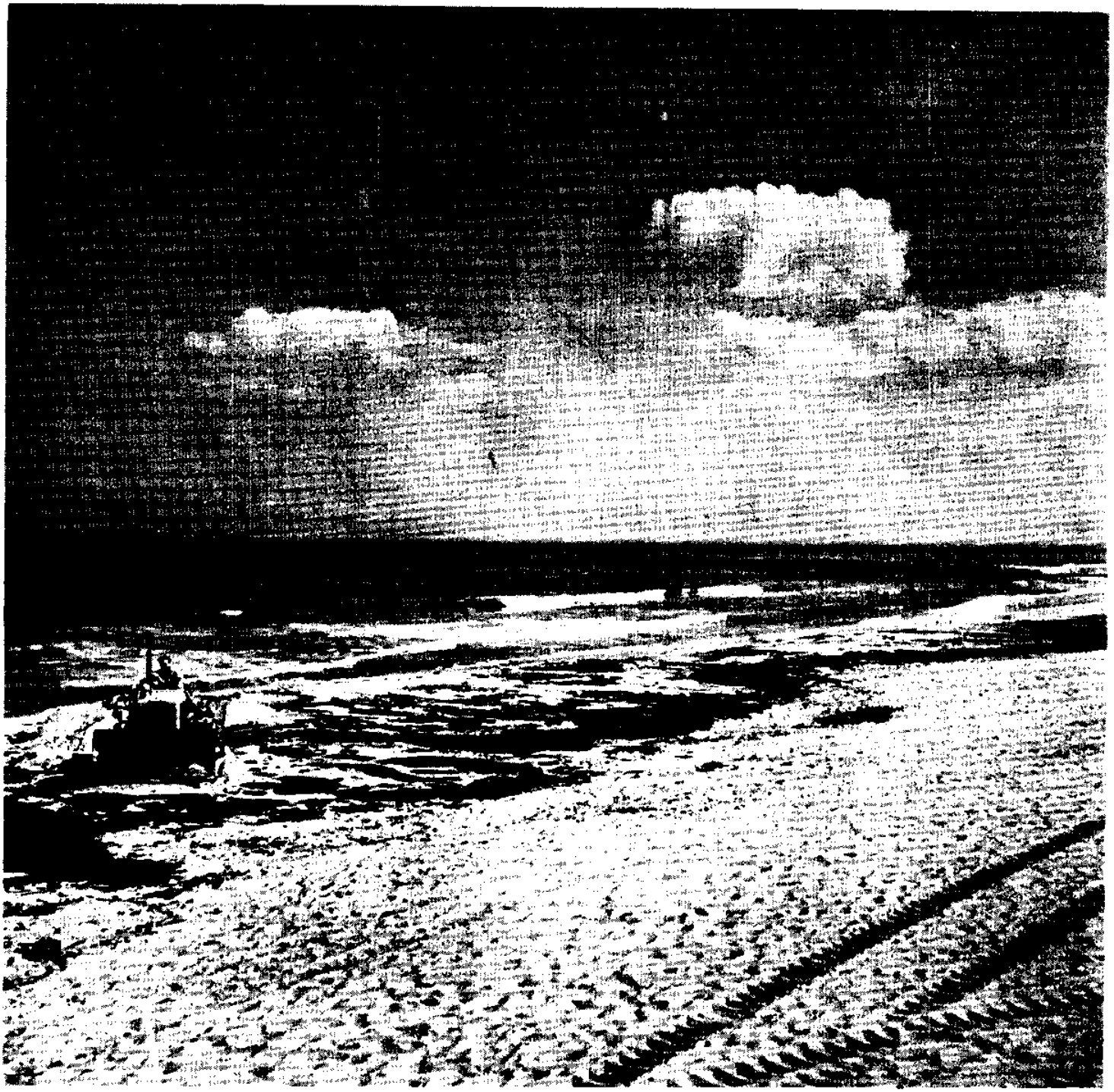
> "Photographers who set out in a chartered boat from Brielle, N.J., yesterday afternoon to photograph the smoldering hulk, which by then had drifted a considerable distance north of the spot where it was attacked, reported seeing three bodies floating in the oil around the ship."

These reports indicate that the spilled oil divided into at least two slicks of unknown magnitude with one moving west, while the other drifted north. No reports, however, have been found that place any of this oil ashore. Newspapers which had copiously reported details of the Resor's sinking made no mention of oil on the beaches in subsequent issues. This lack of follow-up on the part of the news media could be attributed to attempts of resort operators to squelch any publicity that would have been detrimental to the local economy. However, all individuals questioned in this regard, with a few notable exceptions, insisted that no oil came ashore during the winter months. Those few exceptions who stated that oil did come ashore during the winter months, qualified this statement with the remark that this spill was the only incident of oil coming ashore. It will be shown later that there was a signficant inundation of the Asbury Park - Belmar beaches during June 1942 and for this reason it is likely that the sinking of the "R.P. Resor" was confused with the June spill. Thus it seems reasonable to conclude that some of the oil spilled by the attack on the "R.P. Resor" came close to shore but did not wash ashore in notable quantities.

The second of the three tankers sunk in the New Jersey coastal waters was the "Gulftrade". Enroute from Port Arthur, Texas to New York with a cargo of 81,000 barrels of fuel oil and bunker 'c', the vessel was torpedoed amidships and almost immediately split in half approximately three and a half miles east of Barnegat Light (26 miles south of Belmar; see Figure 9). The New York Times (34) reported on June 11, 1942, that residents of Barnegat City and other small seaside communities in the area saw "a sudden pillar of flame" when the vessel was torpedoed. It was further indicated that heavy seas succeeded in rolling over both halves of the vessel, thereby extinguishing the flames. The report went on to say that the bow of the "Gulftrade" drifted to a point about six miles from Barnegat City and at that point ran aground. At no time was the disposition of the ship's cargo ever mentioned in any article. From this it seems that the circumstances were similar to those of the Resor sinking. That is, in both cases spilled oil from tankers may have come close to shore, but it appears that no significant amount actually washed ashore.

The last of the tankers sunk in New Jersey coastal waters was the "Persephone". Although details of the sinking are sketchy, it is known that the attack took place on May 25, 1942 approximately 23 miles south of Belmar while the ship was enroute to New York with 104,000 barrels of crude oil. Survivor debriefing revealed that there was a "spurt of oil and fire" but the ship did not burn.

The sequence of events that followed the sinking of the "Persephone" and the attitudes of the seaside residents are perhaps best indicated by several articles that appeared in the local newspapers. On May 26, 1942, one day after the attack on the "Persephone", the Newark Evening News (36) reported that the New Jersey State Advertising Council had been named as the agency to carry on an advertising campaign to dispel rumors of oil on the New Jersey beaches. Sixteen days later, the Trenton Evening Times (52) reported that representatives of the seaside communities from Sea Bright to Cape May attended a meeting at Belmar and, at that time, agreed to pool their resources to cleanse their beaches of oil from "tankers sunk offshore". There were no longer rumors that needed to be dispelled - oil was on the beaches. Although these articles clearly documented the fact that oil was on the beaches and that the conditions were severe enough to require the combined efforts of seaside municipalities, further evidence was required to quantify the extent of inundation. The lead to this information was found during a conversation with Leon Abbott (1), ex-mayor of Belmar whose term of office was coincident with these sinkings, when he stated that Marie Hansen, a photographer for Life Magazine, had come to Belmar in June to document the extent of the oil spill and its effect on the towns. Through the cooperation of Time-Life Picture Agency, a series of forty-two photographs taken by Marie Hansen were



Photo/Marie Hansen, TIME-LIFE Picture Agency, copyright, Time Inc.

Fig. 11. Belmar, New Jersey beach, June 1942.

Photo/Marie Hansen, TIME-LIFE Picture Agency, copyright Time Inc.

found, two of which are shown in Figures 10 and 11. These photographs corroborate the severity of inundation implied in the articles previously discussed by revealing wide expanses of beach literally covered with what was reported to be crude oil.

Although it has been implied, up to this point, that the source of the oil shown in Figures 10 and 11 was the "Persephone", this fact has not been verified. Contributing to the veracity of this assertion was the knowledge that the attack on the "Persephone" was the only incident within a reasonable time of the articles reporting oil on the beaches. However, James Logan (24), who at that time was Chief Engineer of the State Highway Department and coordinator of the oil removal, stated that the majority of oil involved in this spill washed ashore at Belmar, approximately thirty miles north of the attack on the "Persephone". At first, this appeared to be counterintuitive since it is a well established fact that the flow of geostrophic currents off the New Jersey shore are in a southerly direction. However, Lt. Cmdr. Lissauer (22) of the Coast Guard Research and Development Center in Groton, Connecticut, said that his work on the development of a computer model to simulate the drift of oil in New Jersey coastal waters indicated that a drift in a northerly direction is feasible but would be dependent upon the predominant wind strength and direction. Thus, it is evident that the sinking

of the "Persephone" could have been the source of oil. Alternatively, the only other possible source of large volume would be large sunken tankers opened by depth charging. Observations by patrol planes and blimps indicate that a single large slick was sighted on May 27, 1942 at 39°-47'N; 72°-47'W, approximately 49 miles from the attack on the Persephone two days earlier. No speculation was made as to the source of that slick, but the possibility does exist that it originated with the "Persephone". If this were the case, then either the Belmar beaches were not oiled by the "Persephone's" cargo or the spilled oil split into at least two large sections and drifted in diametrically opposed directions. On the other hand, if the sighted slick originated from some other source then either slick or perhaps even both slicks were responsible for the oil on Belmar beaches.

The reaction of the seaside communities was immediate. As previously discussed, representatives from Sea Bright to Cape May met at Belmar on June 11 to decide what measures were to be taken. It was at this meeting that James Logan was appointed coordinator of oil removal. Municipal representatives pledged to place at least fifty trucks and two hundred men at his disposal. Work was begun on Monday, June 15. The New York Times (35) reported that workers had improvised various methods of cleansing the oil stained beaches which ranged from washing the oil back into the ocean with fire hoses to burning the oil deposits and burying the slag-like deposits in the sand. One

Fig. 12. Burying of oiled sand, Belmar, New Jersey, June 1942.

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report indicated that reclaimation of the oil was considered, but it was decided that the process would have been too long and costly. It was decided that the oiled sand would be buried in its "unburned" condition after tests proved that the oil was too impregnated with salt water and sand to burn. Mr. Logan (24) stated in a recent interview that the burying method involved gathering the layer of oiled sand into large piles with heavy machinery and subsequently carting the deposits to large holes, approximately 500 ft by 320 ft by 10 ft deep, that had been dug by a crane rigged with a large scoop as shown in Figure 12. Once the holes had been filled to within five feet of the surface, they were then covered with clean sand. Mr. Logan further stated that he was concerned about the oil being uncovered in a storm, but to his knowledge, those fears were never realized. However, Thomas Tye (54), editor of the Asbury Park Press, recalled that the buried oil did resurface for the next few summers as a result of storms and drifted with long-shore currents. If this was the case, it was probably not a significant problem since no other reports of this nature were found. Reports concerning the duration of the initial cleanup vary, depending on the source, from a couple of days to a couple of months. However, it was estimated that major swimming beaches were clean in a few weeks while a complete cleanup required most of the summer.

With documentation of the New Jersey oil spills complete, the investigation was then focused on the task of assessing the extent of impact on coastal wildlife and fisheries. As stated in the previous section, an assessment of damage based on commercial fishery statistics of the period would have been of little value. Alternatively, qualitative data was obtained from interviews with individuals who possessed first hand knowledge of the conditions on the Belmar beaches. Every interview without exception revealed that there had been no visibile sign of fish mortality. Further, none of those interviewed had any recollection of an adverse affect on New Jersey commercial fisheries. A discussion of this matter with Charles R. Dodd (16), a retired charter boat captain who had operated in the New Jersey waters for most of his life, indicated that he knew of no effect on local fish. In fact, he recalled that fishing during the war was excellent. In support of that assertion was the fact that all of Marie Hansen's photographs showed a notable absence of dead fish. Although the evidence presented here is meager, it does indicate the attitude of Belmar residents concerning the effects of the oil. That is, the presence of oil on New Jersey beaches caused great apprehension about the possible loss of tourist trade, but generated very little concern for the plight of birds and fishes.

It is a well established fact that one of the greatest consequences of oil spills is bird mortality. To examine this

aspect, Richard Kane (21), an ornothologist for the New Jersey Audubon Society, was contacted in an effort to determine what data would be necessary to form conclusions on the oil's impact on bird populations. It was indicated in that interview that the required information would consist of a body count of dead birds and a profile of the bird population returning to the spill site the following year. With this material, estimates could be made of adult bird mortality. Unfortunately, data of this nature was unavailable since activities of the Audubon Society were suspended during the war. However, it was possible to predict which species would have been residing in the New Jersey area at that time and what damage might have occured. It was indicated by Mr. Kane that spills which occured during the winter were by far the most dangerous since a large number of ducks, grebes and loons lived on the ocean off the New Jersey coast during those months. Further, the potential damage from the sheer number of birds is enhanced by the increase in likelihood of death resulting from the loss of insulation that occurs when a bird is coated with oil. Mr. Kane further indicated that the ingestion of oil would not have been a high source of mortality. Thus if a bird could have withstood the loss of insulation and did not become exhausted trying to free itself from the oil, its chance of survival would have been good. However, a bird's chances during the winter months are at best poor as a result of the near freezing temperature of the water. In

addition, it is a well established fact that wintering birds return to the same area each year. Thus, it appears very likely that birds would have stayed in their chosen wintering grounds even if they had become fouled with oil. Spills that occur during the summer present a somewhat different picture. This is due to the fact that the bird population during the summer is considerably smaller than in the winter. Furthermore, once in contact with oil, a bird would probably not have been subject to conditions as severe as those encountered in winter. For example, Mr. Kane indicated that birds would not necessarily die from loss of insulation if they became fouled with oil of grade six or less in warm weather. Rather, molting of its feathers might have ensued. As previously mentioned quantification of the impact on birds that resided in New Jersey coastal waters was impossible, but as before, general recollections proved to be of some benefit in categorizing the overall effect. Since there was no evidence of the winter spills reaching shore, thereby presenting some visible indication of the damage to waterfowl, it can not be concluded that the mortality was low or that high mortality was hidden as a result of the effected birds being carried out to sea with the drifting oil. On the other hand, the spill that occured in June afforded people first hand observations of the effects visible on shore. It was reported by many of the individuals interviewed that they had seen some oiled birds on the beach and they recalled seeing some groups of people attempting to

clean birds washed ashore. As previously noted, there were no pictures of dead birds in the entire set of forty-two photographs taken for Life Magazine. It is reasonable to assume that had there been a noteworthy number of dead birds on the beach at that time, photographs would have been taken. Again, the lack of pertinent data prohibits the formation of meaningful conclusions concerning the magnitude of the impact, but it is known at this time that no species was exterminated as a result of those spills.

CONCLUSIONS

1. The eastern seaboard of the United States was an area of intense enemy submarine activity during the first six months of 1942. Records indicate that approximately 484,200 metric tons of petroleum products were spilled into American coastal waters. Of this quantity, nearly one-quarter was concentrated in the waters surrounding Cape Hatteras, North Carolina.

2. Computer simulation of gross oil slick movement in the Cape Hatteras vicinity using Smith's and Schwartzberg's drift models proved to be highly dependent on assumed ocean current distributions. Current distributions were assumed and the resulting trajectories agreed well with the limited documented observations available.

3. The Cape Hatteras computer model, supported by on-site interviews, revealed that three out of fourteen slicks originating from torpedoed tankers washed ashore on or near Ocracoke Island, North Carolina. The total volume released from these sources was estimated to be a maximum of 161,500 barrels of fuel oil and gasoline.

4. The lack of statistical data on fisheries and wildlife populations for the duration of the war precluded any

definitive statements concerning the short-term impact on the Cape Hatteras area resulting from the inundation with oil. However, quantitative estimates obtained through interviews indicated that the observable effects on fish and waterfowl were minimal.

5. Waterfowl habitating the inland area of the Pamlico Sound appeared to have suffered little consequences from the oil washed ashore since the primary link in the food chain, Pamlico Sound, was free from oil. This was not the case for oceanic diving birds, however, since reports indicated that there was some mortality.

6. Evidence indicated that the Outer Banks of North Carolina act as a natural barrier to drifting oil and as such protects inland waters so vital to local fisheries and wildlife.

7. Investigation of a secondary site was undertaken in an attempt to document spills and their ensuing effects with a higher degree of certainty. Through this effort, it was determined that approximately 264,000 barrels of petroleum products in various states of refinement were spilled into the New Jersey coastal waters during the first six months of 1942.

8. The actual extent of impact on fish and waterfowl in the effected region was indeterminate as a result of insufficient statistical data. However, interviews and photographs indicated that effects of the oil on fish and waterfowl were minimal as seen on or near shore.

9. It would be desirable to draw from these results the conclusion that nature would recover its losses in all cases given the required amount of time. Although this may be true, the results of this study will not prove this assertion. It can, however, be said that in two cases, regional wildlife and economy survived with minimal difficulty. Cities in the effected regions still prosper and wildlife populations bear no traces of diminished numbers let alone exterminated species as a result of these incidents.

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APPENDIX 1

EASTERN SEA FRONTIER

ENEMY ACTION AND DISTRESS DIARY

1942

1. January 28, Time 0935

   Oil slick 1.5 miles wide, 20 miles long seen by plane 23 miles bearing 186°T from Montauk (NY). Wind from N.NE; end of slick about 40 miles from Montauk.

2. January 30, Time 1254

   55th Army Observation group plane reported an oil slick 5 miles long at 36-38N; 75-22W.

3. Time 0000

   Naval aeroplane from Quonset reported large oil slick and bow of ship protruding above water at 40-37N; 70-45W.

4. February 10, Time 1340

   Moving oil slick bombed, possible submarine, 20 miles east of Atlantic City, bearing 120°T.

5. Time 1542

   Blimp K-5 dropped four bombs on oil slick 13 miles east of Atlantic City.

6. February 11, Time 0900

   Oil slick reported by Navy plane from Floyd Bennett 197°T. 64 miles from Ambrosea Track 330.

7. Time 1020

   At 38N; 74-35W, oil slick seen by 112 Observation Squadron plane (from Dover, Delaware) 3 miles long running NE to SW.

8. Time 1209

   17 miles 120°T from Atlantic City, planes dropped bombs on suspicious slick. Claimed slick moving 335 zig-zag, speed two.

9. Time 1310

   Tripped dropped 3 large and 3 small depth charges in vicinity of oil slick 39-04N; 74-10W on good sound contact.

10. February 11, Time 1422

Reference 1020 above: Oil slick increasing in length. Position 38-01N; 74-35W.

11. March 1, Time 1440

Dallas attacked sub after good contact at 38-03N; 74-12W. First contact at noon. Made 15 attacks and dropped 46 depth charges. Contact did not move after 1500. Heavy oil slick and some debris. Calypso sent to assist.

12. Time 1549

An oil slick and wreckage noted by 59th Group at 74-43N; 39-10W.

13. Time 1615

Stringham, while escorting Delta, made contact with what was thought to be submarine 120°T and 3.5 miles off Permaceti Cove. K-4 assisted in the attack; later reported oil slick and air bubbles coming to surface and believed had a submarine on the bottom. Buoy left at spot. 57 depth charges dropped. Antietam and PC507 also at scene of attack.

14. March 2, Time 1130

The bomber command sighted an oil slick .25 miles wide, 10 miles long at 38-45N; 74-15W.

15. March 4, Time 1352

Army plane sighted patches of oil and floating timber covering an area two to five miles in diameter 39-55N; 73-35W.

16. Time 1635

Army plane sighted a heavy oil slick 50 feet in diameter 39-27N; 73-30W.

17. Time 1825

Army plane sighted oil slick, overturned life boat and overturned life raft 38-15N; 74-22W.

18. March 6, Time 0832

Herbert (DD) made sound contact 2 miles W of X-Ray-Mike (Cape Henry). Several attacks netted oil slick and wreckage including aircraft tires of American origin. Target probably motor vessel wreckage. Roper assisted in the action.

19. March 8, Time 1300

At 39-30N; 73-30W, Army pilot saw life raft painted black, probably from large boat, had barrel and box with several small articles in it. Directly north of the raft, perhaps 0.25 miles, saw oil trail 500 yards long, 300 yards wide. No boats or suspicious activity in area.

20. Time 1440

119th Army Observation Squadron plane reports oil slick 20 feet in diameter with two broken rafts nearby at 40-07N; 72-51W.

21. March 10, Time 0925

An unidentified tanker was reported sinking at 39-05N; 74-00W. Later, lifeboats were reported being lowered. At 1100 an oil slick was reported on the surface at this position but no ship.

22. Time 1352

The 59th Observation Group reported a submerged ship at 39-52N; 73-50W. Air bubbles and oil slick were noted. A life raft and possible survivors were seen nearby.

23. March 11, Time 1138

Large oil slick containing much flotsam sighted by Army plane 40-30N; 73-45W.

24. Time 1200

Army plane (DB-7) sighted large oil slick with much debris 39-35N; 73-45W.

25. March 14, Time 0010

S. S. EMPIRE ANTELOPE, enroute New York, passed through a very heavy oil slick at 40-30N; 71-40W.

26. March 15, Time 0807

Large oil slick with bodies in it, some apparently alive, at 39-02N; 74-30W.

27. March 16, Time 0940

K-3 reported on station (39-02N; 74-30W) many oil slicks in sight. Searching. At 1056 K-3 reports 1 patrol boat and several planes at scene, fishing boats 1 mile NE of position. But no success. At 1605 K-3 reports Hereford Inlet C. G.

Station picked up one body, which appeared to have been in water some time and, later, a second body in similar condition. At 1735 K-3 reports several bodies in oil slick off C. G. Station 116.

28. March 19, Time 1650

From 104 Observation Squad: four dark oil spots at 39-18N; 74-16W (ten miles E of Atlantic City). Two observation planes maintaining constant surveillance.

29. March 25, Time 1400

Pan-American plane reports oil slick seen at 1100, March 25 at 37-53N; 70-33W. We have no record of sinkings in this vicinity.

30. March 26, Time 1420

Pan-American plane sighted an oil slick at 38-38N; 74-00W. 44 miles NE of this position, bow of ship was sighted above water. No activity on board.

31. March 27, Time 1623

Plane sighted fresh oil slick at 35-26N; 75-24W (about 10 miles off coast just north of Cape Hatteras) and dropped one depth charge. Also pilot noted a suspicious vessel with an opening in the stern at 35-29N; 75-18W. This information came from Elizabeth City to E.D.C.

32. March 31, Time 1830

Civil Air Patrol sighted very large oil slick at 37-55N; 74-57W (1000 yards from Winter Quarter Shoals). Airplane (bomber) wheel and other debris floating in middle of slick. No life rafts seen.

33. Time 2045

Plane from 112th Observation Squadron, Dover, sighted oil slick, wreckage and a life preserver labeled "Pacific" at 37-38N; 74-50W (due east of Winter Quarter Shoals). The CQM's departure schedule lists a tanker Pacific Sun that may have departed Chester, PA for Texas.

34. April 3, Time 1670

Mobile flight unit bombed oil slick at 35-37N; 75-15W (close into Wimble Shoals). No results observed. Continuing observation. Report from Air Support Liaison.

35. April 3, Time 1005

Plane dropped bomb on oil slick 5 miles 60°T from Five Fathoms Bank. Asked for surface assistance.

36. April 9, Time 1055

45th Bomber reports large oil slick about 12 miles in diameter surrounded by small patches of oil. Position 39-50N; 73-30W at 0805. (No sinkings near this position recently, 20 miles NE of Barnegat).

37. April 11, Time 1300

C. G. pilot reports fresh oil slick on fire on water at 35-26N; 75-11W (about 12 miles SE of Wimble Shoals). No wreckage or survivors in vicinity. Earlier at 0642, Army B-17 had seen same burning slick. No recent attack has been identified with this incident.

38. Time 1630

C. G. pilot sighted bow of steamer sticking out of water in 34-41N; 75-53W. This vessel is new to pilots who fly this area regularly. Pilot also reported oil slick on fire in 34-40N; 76-14W. Is believed to be location of tanker reported afire and sunk yesterday in connection with floating mine. (Note - TAMAULITAS was torpedoed April 10 at 0029 at 34-25N; 76W).

39. April 13, Time 0808

C. G. plane reports derelict bottom up, apparently afloat, and adrift, and constituting menace to navigation in 34-48N; 75-51W (about 30 miles SSW from Cape Hatteras). Also reports sunken ship with both masts projecting above water, reasonably fresh oil slick and some debris but no boats in 35-24N; 75-21W. At 0925 SSS Allo from S.S. CRISTOBAL (U.S. transport 10,021 tons) northbound in 34-49N; 75-47W, about 5 miles inshore from position of reported derelict above.

40. April 15, Time 0330

NOB Bermuda reports an empty lifeboat and oil slick at 33-50N; 71-10W. Another oil slick at 34-30N; 72W. These positions E of Cape Fear, about half-way to Bermuda. NOB Bermuda says, "Questionable whether these slicks relate to EMPIRE PEREGRINE."

41. April 16, Time 0700

Two O-46 Air Support planes dropped 4-100 lb. demolition bombs on an oil slick at 35-25N; 75-18W.

42. April 17, Time 1600

Airplane pilot reports sighting 3 black fishing boats at 1320, 90°T, 25 miles from Isles of Shoals. Fishing boats arranged in triangle with large oil slick in center. "Appeared to be fueling submarine. Submarine not sighted." Boats similar to those reported by this pilot on April 15. AARON WARD proceeding to scene to search until 0800 April 18.

43. April 22, Time 1320

Army plane saw blimp in about 39-31N; 73-45W (about 10 miles from position in 1320 above) circling oil slick, with large bubbles rising from it. Blimp had dropped 2 smoke flares. Plane dropped 3 depth charges (1 over 100 feet, 1 over 50 feet, 1 in middle). Another Army plane arrived, dropped 3 more. At 1550 Blimp X-3 reported that a patrol boat had a contact in 39-40N; 73-55W. Com 4 reported at 2025 that Brigantine Life Saving Station heard a very loud explosion offshore at 1945. PC boats investigating.

44. April 24, Time 1005

Army bomber at 0907 saw destroyer drop 4 depth charges in 36-22N; 75-13W. 200 foot oil slick formed. Nothing further heard on this.

45. April 26, Time 1515

ST. LOMAN (anti-sub trawler) reports 2 attacks on moving sub contact distant 19 miles, bearing 188°T from Cape Hatteras Light (34-57N; 75-35W). Large quantities oil and bubbles. At 1640 reports 3rd deliberate attack with depth charge pattern on firm contact at 1612. Spreading oil patch 3 miles long, 200 yards wide. Position buoyed, standing by. Cominch reported sub sighted in 34-55N; 75-45W, at 1515 April 25. (Ships Plot has no wreck charted in this position).

46. Time 1235

Civilian Air Patrol sighted oil slick and heavy boxes floating in 38-22N; 74-57W.

47. Time 1540

Army plane reports wreckage in increasing oil slick; ship's ladders, bedding, furniture, shattered timber, in 39-37N; 73-19W (37 miles of Barnegat Inlet). Lakehurst sending blimp.

48. April 28, Time 1148

Civilian Air Patrol sighted the fishing boat RELIANCE (90-100 feet long from Hampton, Virginia) in an oil slick about 100 feet in diameter at 37-58N; 75-06W (just south of Rahabeth Beach). Three men and a large hose were on deck. The vessel moved when the plane approached and stopped when the plane withdrew.

49. May 1, Time 1545

Army plane sighted oil slick 29-40N; 81W (10 miles SE of St. Augustine). Two PBY's dropped flares. Army plane dropped 2 depth charges, slick changed course twice and considerable black substance appeared. Two more attacks made prior to 2000. Results considered good. One or more ships at scene, perhaps DD's. MAC LEISH patroling in this area.
Later - PC 496 reported "seven attacks made cooperating with Army and Navy planes. No visible results. Standing by till destroyers arrive. Directing MAC LEISH to proceed to scene. New position 29-40N; 80-55W." At 2210 Cominch reports sub sighted 29-28N; 80-50W.

50. Time 1820

Army plane sighted life raft with 2 survivors at 34-30N; 74-25W (255 miles east of Lookout). Raft on fresh oil slick. C.G. proceeding to scene from Hatteras ETA 0800 May 2. Planes will direct.

51. May 2, Time 0740

Army bomber sighted wreckage, oil slick, broken life rafts, one life raft intact, lumber, ropes, ladders in 42-18N; 38-05W. British merchant vessel near scene was signaled and investigated.

52. May 5, Time 0715

One ship, possibly two, were sunk within 2 miles of 27-15N; 80-00W off St. Lucie Inlet, Florida. Survivors of SS AMAZONE (1294 ton Dutch cargo) were landed near St. Lucie Inlet. SS EASTERN SWORD, ESSO GETTYSBURG and a CAP plane saw a "Stanship tanker" afire and "blow up" at 0715-0720 in 27-15N; 80-00W. Both merchantmen saw the sub on the surface. Nothing reported of tanker survivors during the day. The CAP plane also saw 2 miles NE of this position a sunken ship with masts showing, surrounded by barrels, crates, oil, 2 overturned lifeboats, 2 rafts, and considerable other wreckage, possibly the AMAZONE.

53. May 9, Time 2220

NAS Jacksonville reported that a Navy plane sighted bubbles and an oil slick at 1606 in 29-22N; 80-53W.

54. May 11, Time 0812

59th Observation Squadron reported oil and gas slick in 40-41N; 72-39W (7 miles off Westhampton Beach, Long Island).

55. Time 1420

NAS Jacksonville reports long oil slick bleeding continuously from stationary source in 29-23N; 80-50W (12 miles off Daytona Beach, Florida). 2 depth charges dropped; no increase in oil bubbles or debris. (MAC LEISH made attacks about 20 miles NNW of this position on May 2 and May 3).

56. Time 1940

EDC reports on attack on sub made May 8 (see 0851 May 8): Attack made on moving oil slick after obtaining excellent contact in 28-19N; 80-00W (80 miles ESE of Cape Canaveral, Florida). Four attacks made. After third attack observers saw black steel object projected above surface. Much oil and large air bubbles gushed up astern. LEA concludes that "if object was a sub, it was destroyed, but it is very possible that it was a sunken tanker." (There have been several sinkings in this area, the closest tankers sunk being the LESLIE April 13 in 28-21N; 80-19W and the PAN MASSACHUSETTS February 19 in 28-06N; 80-00W.)

57. May 12, Time 1410

Navy Air NY reports oil streaks in 39-46N; 74-04W (just off Barnegat Inlet).

58. May 13, Time 2235

S. S. MANISQUAN (weather ship) reported an oil slick at 1400 in 42-47N; 83-14W, running 270°T (see our 0815 above No. 3, S. S. KITTY'S BROOK).

59. May 15, Time 1229

CG plane from Elizabeth City surprised submarine on surface about 40 miles east of Wimble Shoals. Sub crash dived leaving two men on conning tower. Dropped 2 depth charges ahead of submarine while stern still visible. Wreckage, possibly deck grating, appeared on surface and large oil

slick 100 feet wide and three miles long developed. Submarine resembled Italian type. Original position thought to be 36-07N; 74-57W. CG plane relieved by second plane and ZNP K-4. K-4 position after covering area of oil slick until dark 36-20N; 74-57W. At 1900 Army B-17 sighted orange float with white triangular flag on 10 foot staff at 35-40N; 75-24W, 30 feet from fresh oil slick. Buoy similar to those used by enemy submarines but none of this description used by CG or our forces. No wreck known to be near this position, depth 17 fathoms. May be sub damaged by above attack.

60. May 16, Time 0640

Army plane sighted oil slick in 35-45N; 75-00W. (Our 1229 May 15 reported attack on sub in this area and sighting of buoy). At 1700 plane reported oil slick at 36-07N; 74-57W. At 1940 plane reported sighting "wreck of sub" in 36-09N; 74-54W. Oil slick with oil still coming up. ELLIS (DD) sent to vicinity, but plane at scene of buoy failed to contact her or corvette in vicinity.

61. Time 2030

ComFive reports bodies of one officer and one rating from H.M.S. BEDFORDSHIRE (trawler) found washed ashore at Ocracoke Inlet, North Carolina. Empty lifeboat also found but not definitely identified as from BEDFORDSHIRE. Latter reported as not having been heard from since May 11.

62. May 17, Time 1630

CG plane from Elizabeth City reported oil slick at 1400 in 36-07N; 74-59W. Fresh oil still rising (see our 1229 May 15).

63. Time 1740

Oil slick sighted by plane in 42-11N; 70-33W.

64. May 18, Time 1535

Civilian Air Patrol sighted two submarines in ESF waters; one in 38-30N; 75W near Fenwick Shoals. Navy plane searched and found thick oil slick in this position at 1835. Second CAP sighting at 1630 in 37-33N; 75-30W, off Parramore Banks, course 130°T, moving fast, saw swirl. Investigating Army plane saw a definite solid oil slick, empty raft, two masts floating in 37-30N; 75-30W at 1845.

65. May 21, Time 1200

CG plane from Elizabeth City dropped depth charges on rising oil bubbles at 0830 in 34-40N; 75-45W. "No results. Evidently from sunken wreck." (We have no record of wreck in this position).

66. May 22, Time 0925

PC-463 and LUDLOW searching for survivors of PLOW CITY (our 0935 May 21). LUDLOW saw large oil slick in 38-45N; 69-12W. Last message from vessel was in 38-53N; 69-00W. Coast Guard Hall Boat observed pilot house deck and two empty rafts in 39-00N; 69-18W at 1515. No survivors sighted.

67. Time 1430

CAP plane saw very thick new oil slick 1 mile long, 10 miles south of Lake Worth, Florida, 4 miles offshore. At 1910 a lookout saw 3 CAP planes dropping depth charges in approximately this position, and a CAP plane reported sighting a sub 1 mile off Lantana, Florida, at 1941. Position is about 26-40N; 79-59W.

68. May 24, Time 1620

Pan Am plane reports sighting three life rafts, one damaged life boat, wreckage, and oil slick scattered over area centering at 31N; 68-15W at about 1317 May 23. No survivors noted. We have no record of recent sinkings in that vicinity, nor has NOB Bermuda.

69. May 27, Time 0945

Army plane reported moving oil slick in same vicinity as sighted yesterday (34-50N; 75-30W), moving westward, length 10 miles. At 1110 Army plane reported moving oil slick in 34-08N; 76-08W. (Our 1535 May 26 refers to attack by Army plane on sub in 34-38N; 75-40W).

70. Time 1000

CG plane from Cape May sighted a large oil slick in 39-47N; 72-40W and at 1250 sighted oil streak bubbling to surface in 38-49N; 74-12W.

71. Time 1230

CG plane sighted oil slick rising to surface in 36-09N; 75-24W. (This in vicinity of several attacks on a sub by planes and a blimp on May 15 - our 1229 that date.

Also near attack on BYRON D. BENSON - U.S. tanker which was left afire on April 4 in 36-08N; 75-32W).

72. May 29, Time 1045

Our 2350 May 28 reported a ship afire in 30-37N; 81-20W. This was proved to be in error by a survey made by a Navy plane. Plane, however, did report two masts visible, much oil, but probably old wreckage. (SS ESPARTA torpedoed and sunk on April 9 in 30-46N; 81-11W).

73. Time 1145

Army plane sighted oil slick at 1115, in 39-20N; 74-08W. Dropped 1 depth charge.

74. Time 2130

Army plane sighted oil slick at 1455 in 34-35N; 77-52W. Attacked with 3 depth charges, results negative. Sub chaser dropped 4 depth charges. Bubbles but no oil appeared. Sub chaser remained in position.

75. June 2, Time 1040

K-8 dropped 2 depth charges on MAD contact in 34-55N; 75-55W. Rising oil and air bubbles. At about 1300, CG cutter dropped 5 depth charges on a strong sound contact in 34-57N; 75-55W (10 miles - 140°T from Ocracoke). Large amount of oil and air bubbles appeared. At 1400, dropped 2 more depth charges. Large quantities of oil and air bubbles appeared. (Position is 20 miles from scene of attack by LEGARE on May 30 and is close to position EMPIRE GEM - British tanker, 10,600 tons - was torpedoed January 23).

76. June 15, Time 1235

Hall Boat from Floyd Bennett saw stationary oil slick in 41-01N; 71-33W, 8 miles south of Block Island. Dropped depth charge. Negative results.

77. Time 1605

ComFive reports ALCOA PIONEER saw oil drums, wreckage, and lumber newly in the water plus a large oil slick on June 13 at 1800 Q in 33-16N; 68-49W. No survivors were sighted. LIBERTY GLO, U.S. cargo, sighted same wreckage in identical position on June 14. Both vessels were enroute Norfolk from Trinidad. (PLEASANTVILLE was sunk June 7 in approximately 33-20N; 67-15W - "120 miles west of Bermuda" was position given to plane by ship that picked up 3 boatloads of survivors).

78. June 5, Time 1214

Coast Guard Hall Boat depth charged moving oil slick in 39-50N; 72-57W (55 miles SE of Ambrose). Oil slick continued to move. ARTIC EXPLORER (corvette) and ZIRCON (PY) ordered to scene.

79. June 6, Time 0920

A plane attacked a moving oil slick at 1740 June 2, in 33-29N; 78-11W.

80. June 15, Time 0621

Navy plane dropped two bombs on moving oil track in 39-58N; 72-50W. No result.

81. June 16, Time 1535

Navy plane bombed moving oil slick in 39-46N; 73-25W (45 miles 156°T from Ambrose). Slick continued to move after bombing - oil increased. (See our 0621, June 15 above).

82. June 17, Time 1100

First Bomber Command reported that Lt. Col. Goldenberg and another pilot searched the 34-30N; 77-00W area in Onslow Bay where a DB-7 thought it sank a sub at 0640, June 17. Pilots saw a buoy in the area, which had also been noted by DB-7 pilot, as well as an oil slick and a sunken tanker lying on its side in 50 feet of water.

83. June 18, Time 1430

Navy plane dropped depth charges on oil slick in 36-20N; 75-41W (10 miles offshore, 40 miles south of Cape Henry).

84. June 20, Time 0630-1130

CG plane (PH-3) sighted oil slick in 39-50N; 73-35W (20 miles NE of Barnegat Light).

85. Time 0850

Patrol plane dropped depth charge on oil slick in 27-57N; 79-52W (20 miles east of Indian River, Florida). Raised mud. (Ship was almost torpedoed near same location.)

86. Time 1955

Army plane sighted bubbling oil at head of 3-mile long oil slick in about 39-50N; 72-46W (about 66 miles NE of Barnegat Light).

87. June 21, Time 1300

Army plane dropped depth charge on oil slick 1-1/2 miles long in 34-36N; 75-38W. No result.

88. June 26, Time 0903

Navy plane sighted moving oil slick in 29-42N; 79-45W (80 miles east of St. Augustine, Florida). Course 170; speed 2 knots. Plane later reported he was trailing sub at 1125.

89. Time 0930

Navy plane sighted and attacked sub in 29-32N; 79-45W with no result. An experienced pilot from VP-94 Jacksonville later reported sighting an oil slick in this position, but believes it is the same slick he attacked on June 21.

90. June 28, Time 1410

EDC reports a CAP plane sighted an oil slick and a submerged sub in 39-15N; 74-20W, 10 miles SE Atlantic City.

91. June 30, Time 1305

Plane from Observation Squadron 105 at Langley Field sighted a narrow oil slick and a long thin object beneath the surface in 33-50N; 77-40W, dropped 100-pound demolition bombs and a British Trawler attacked with 5 depth charges. Results undetermined. NOTE: JOHN D. GILL was sunk March 3 in 33-55N; 77-39W.

APPENDIX 2

NAME: EMPIRE GEM
DATE: 1-24-42
TIME:

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack:
Speed:
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: moderate
Wind: west
Visibility:
Weather: clear

REMARKS: The ship proceeded for three hours at full speed before she broke in half. The bow was still anchored.

NAME: FRANCIS E. POWELL
DATE: 1-27-42
TIME: 1245

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack:
Speed: 10 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: moderate
Wind: north by northwest at force 3
Visibility: one mile
Weather: overcast

REMARKS:

NAME: INDIA ARROW
DATE: 2-4-42
TIME: 1900

PERTINENT INFORMATION

Destination: New York
Port of Origin: Corpus Christi, Texas
Location of Attack:
Speed: 10 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: small
Wind: northwest breeze
Visibility: excellent
Weather: clear

REMARKS:

NAME: CHINA ARROW
DATE: 2-5-42
TIME: 1115

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack:
Speed: 9 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: slightly choppy
Wind: light
Visibility: good
Weather: overcast

REMARKS: Fire broke out in number 8,9 and 10 tanks just forward of the engine room bulkhead.

NAME: PAN MASSACHUSETTS
DATE: 2-19-42
TIME: 1344

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack: 28-27N; 80-08W
Speed: 12.5-13 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: rough
Wind: force 4
Visibility: 1-2 miles
Weather: misty

REMARKS: Ship broke or buckled amidships with a yellow flame reported.

NAME: REPUBLIC
DATE: 2-21-42
TIME: 2303

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack: 27-05N; 80-15W
Speed: 11 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: heavy ground swell
Wind: northwest at force 4 or 5
Visibility: poor
Weather: overcast

REMARKS: Flames and smoke hit the generator. She sank on the afternoon of 2-23-42.

NAME: CITIES SERVICE EMPIRE
DATE: 2-22-42
TIME: 0525

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack:
Speed: 9.5-10 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: moderate to heavy
Wind: little
Visibility: good
Weather: good

REMARKS: Fire broke out and in a few seconds the ship was ablaze. She broke in half before she sank.

NAME: W. D. ANDERSON
DATE: 2-22-42
TIME: 1900

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack:
Speed: 10-11 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: moderate, few white caps
Wind: northwest
Visibility:
Weather:

REMARKS: Instantly, a flame shot across the ship 20 to 30 feet high. After a little more than two hours, the ship settled to the stack.

NAME: R. P. RESOR
DATE: 2-26-42
TIME: 0025

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack:
Speed: 12 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: west and moderate
Visibility: good
Weather: fine

REMARKS: Ship sank 48 hours after she caught fire.

NAME: S. S. GULFTRADE
DATE: 3-10-42
TIME: 0040

PERTINENT INFORMATION

Destination: New York
Port of Origin: Port Arthur, Texas
Location of Attack:
Speed:
Cargo: Bunker 'C' fuel oil

ATMOSPHERIC CONDITIONS

Sea State: rough
Wind: southwest, force 5
Visibility: good
Weather:

REMARKS: Torpedoes cut the ship in half. Tanks 5, 6 and 7 were open. Oil all over the vessel caught fire. In less than one minute, high seas extinguished the fire.

NAME: S. S. JOHN D. GILL
DATE: 3-12-42
TIME: 2210

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack: 33-55N; 77-34W
Speed: 14.2 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: light, southeast
Visibility: poor, one mile
Weather: hazy

REMARKS: A self-igniting life ring was thrown overboard and ignited the escaping oil. One tank after another exploded after the men were off the ship. All caught on fire.

NAME: ARIO
DATE: 3-15-42
TIME: 0122

PERTINENT INFORMATION

Destination: Corpus Christi, Texas
Port of Origin: New York
Location of Attack:
Speed:
Cargo: water ballast in tanks 2, 5, 7

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: west, force 2
Visibility: excellent
Weather: clear

REMARKS: At 12:30, the ship was on her side and in a sinking condition. Several holes in ship (30 to 40 shells).

NAME: S. S. AUSTRALIA
DATE: 3-16-42
TIME: 1400

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack: 35-07N; 75-22W
Speed: 11 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: southeast, force 3
Visibility: hazy
Weather: favorable

REMARKS: At 1430, the stern settled on the bottom with the bow still floating. The tanks were not broken.

NAME: E. M. CLARK
DATE: 3-18-42
TIME: 0135

PERTINENT INFORMATION

Destination:
Port of Origin:
Location of Attack: 34-05N; 75-35W
Speed: 10 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: moderately rough
Wind: southwest, force 4
Visibility: 3 miles
Weather:

REMARKS: There were two hits by torpedoes so they were forced to abandon ship.

NAME: PAPOOSE
DATE: 3-18-42
TIME: 2230

PERTINENT INFORMATION

Destination: Corpus Christi, Texas
Port of Origin: Providence, Rhode Island
Location of Attack:
Speed: 11.4 knots
Cargo: in ballast

ATMOSPHERIC CONDITIONS

Sea State: moderately rough
Wind: northwest
Visibility: good
Weather:

REMARKS: At 0730 the vessel was still afloat.

NAME: W. E. HUTTON
DATE: 3-18-42
TIME: 2210

PERTINENT INFORMATION

Destination: Marcus Hood, PA
Port of Origin: Smith Bluff, Texas
Location of Attack:
Speed: 10 knots
Cargo: 65,000 bbl of #2 bunker oil

ATMOSPHERIC CONDITIONS

Sea State: choppy
Wind: west, force 4
Visibility: good
Weather: clear

REMARKS: Within a few seconds, a second bomb blew up the decks which buckled and overturned the pilot house. Amidships caught fire. The ship sank at 2245.

NAME: ESSO NASHVILLE
DATE: 3-21-42
TIME: 0015

PERTINENT INFORMATION

Destination: New York
Port of Origin: Port Arthur, Texas
Location of Attack: 33-35N; 77-22W
Speed: 12.4 knots
Cargo:

ATMOSPHERIC CONDITIONS

Sea State: moderately choppy
Wind: south by southeast, force 3
Visibility: poor
Weather: clear

REMARKS:

NAME: NAECO
DATE: 3-23-42
TIME: 0400

PERTINENT INFORMATION

Destination: Sewaren, NJ
Port of Origin: Houston, Texas
Location of Attack: 33-59N; 76-40W
Speed: 10 knots
Cargo: 97,000 bbl of domestic heating oil and kerosene

ATMOSPHERIC CONDITIONS

Sea State: moderately choppy
Wind: southwest, fairly strong
Visibility: good
Weather: clear

REMARKS: All ablaze. Burning oil spurted into the sea. Sunk, 0830.

NAME: DIXIE ARROW
DATE: 3-26-42
TIME: 0858

PERTINENT INFORMATION

Destination: Paulsboro, NJ
Port of Origin: Texas City, Texas
Location of Attack:
Speed: 10.5 knots
Cargo: 96,000 bbl of crude oil

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: force 2
Visibility: excellent
Weather:

REMARKS: Ship broke in two one hour after attack. The fore part was in flames almost at once.

NAME: TIGER
DATE: 4-1-42
TIME: 0017

PERTINENT INFORMATION

Destination: Norfolk, Virginia
Port of Origin: Aruba, Dutch W.I.
Location of Attack: 36-50N; 75-49W
Speed: 5 knots
Cargo: 65,000 bbl of Navy fuel oil

ATMOSPHERIC CONDITIONS

Sea State: choppy
Wind: north, force 2
Visibility:
Weather: clear

REMARKS: Many explosions. Stern began to settle.

NAME: BYRON D. BENSON
DATE: 4-6-42
TIME: 2135

PERTINENT INFORMATION

Destination: Bayonne, NJ
Port of Origin: Port Arthur, Texas
Location of Attack:
Speed:
Cargo: 100,000 bbl of crude oil

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind:
Visibility: hazy, no moon
Weather: good

REMARKS: Torpedo hit number 7 and 8 tanks. Ship burst into flame. Burning oil spurted from the ship and remained ablaze on the water. Sunk 4-7-42.

NAME: BRITISH SPLENDOUR
DATE: 4-6-42
TIME: 2215

PERTINENT INFORMATION

Destination: New York
Port of Origin: Houston, Texas
Location of Attack: 35-07N; 75-19W
Speed: 10 knots
Cargo: 10,000 tons of gasoline

ATMOSPHERIC CONDITIONS

Sea State: smooth
Wind: south by southwest, force 2
Visibility: good
Weather: clear

REMARKS: Sank stern first. Sunk by 4-7-42.

NAME: S. S. LANCING
DATE: 4-7-42
TIME: 0435

PERTINENT INFORMATION

Destination: New York
Port of Origin: Curacao, Dutch W.I.
Location of Attack: 35-08N; 75-22W
Speed: 9 knots
Cargo: 60,000 bbl of fuel oil

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: southeast
Visibility: good
Weather: slightly overcast

REMARKS: Sank by stern 0617.

NAME: S. S. ATLAS
DATE: 4-9-42
TIME: 0350

PERTINENT INFORMATION

Destination: Sewaren, NJ
Port of Origin: Houston, Texas
Location of Attack: 34-27N; 76-16W
Speed: 10 knots
Cargo: 83,000 bbl gasoline

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: light and variable
Visibility: light haze
Weather: partly cloudly

REMARKS: Left ship fully in flame but afloat 0557.
Second torpedoe set cargo on fire.

NAME: SAN DELFINO
DATE: 4-9-42
TIME: 2200

PERTINENT INFORMATION

Destination: New York
Port of Origin: Houston, Texas
Location of Attack: 35-35N; 75-06W
Speed: 11.5-12 knots
Cargo: 11,000 tons of aviation gasoline

ATMOSPHERIC CONDITIONS

Sea State: small
Wind: force 2
Visibility: good
Weather:

REMARKS: Vessel on fire but afloat when left. Small cargo explosion. Ship eventually sunk.

NAME: S. S. TAMAULIPAS
DATE: 4-9-42
TIME: 2320

PERTINENT INFORMATION

Destination: New York
Port of Origin: Tampico, Mexico
Location of Attack: 34-25N; 76-00W
Speed:
Cargo: 10,200 tons gas oil

ATMOSPHERIC CONDITIONS

Sea State: small
Wind: east, force 2
Visibility: fair
Weather: variable

REMARKS: Explosion set ship on fire immediately and broke the ship's back. Last seen with bow and stern in water.

NAME: S. S. GULF AMERICA
DATE: 4-10-42
TIME: 2220

PERTINENT INFORMATION

Destination: New York
Port of Origin: Port Arthur, Texas
Location of Attack: 30-10N; 81-15W
Speed: 14 knots
Cargo: 90,000 bbl of fuel oil

ATMOSPHERIC CONDITIONS

Sea State: smooth
Wind: northwest, force 2
Visibility: good
Weather:

REMARKS: Immediately caught fire. Burning oil on water split and drifted apart in two patches. Sunk 4-16-42.

NAME: S. S. HALSEY
DATE: 5-6-42
TIME: 0455

PERTINENT INFORMATION

Destination: New York
Port of Origin: Corpus Christi, Texas
Location of Attack: 27-14N; 80-03W
Speed: 12 knots
Cargo: 40,000 bbl naptha and 40,000 bbl fuel oil

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: east by southeast, force 3
Visibility: good
Weather: clear

REMARKS: Torpedo cut a 60-foot gash in the hull. Naptha fumes were heavy on the deck. Exploded amidship. Flames were fore and aft. Divided into two parts which drifted apart. One part burned for a half hour and the other for several hours. Lighting of calcium ring set off explosion.

NAME: LUBRAFOL
DATE: 5-9-42
TIME: 0415

PERTINENT INFORMATION

Destination: New York
Port of Origin: Aruba, Dutch W.I.
Location of Attack: 26-25N; 80-00W
Speed: 12.5 knots
Cargo: 67,000 bbl of #2 fuel oil

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: west by northwest, force 2
Visibility: good
Weather: clear

REMARKS: Tank #5 immediately burst into flames when the torpedo exploded. Simultaneously, tank #1 caught fire. Still burning and drifting on 5-11. Sunk 5-12.

NAME: POTRERO DEL LLANO
DATE: 5-15-42
TIME: 2355

PERTINENT INFORMATION

Destination: New York
Port of Origin: Tampico, Mexico
Location of Attack: 25-33N; 79-56W
Speed: 9.5 knots
Cargo: 35,000 bbl of diesel oil

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind:
Visibility: fair
Weather: fair

REMARKS: Explosion demolished bridge. Surrounding area gutted with fire. Crew separated into two groups.

NAME: S. S. PERSEPHONE
DATE: 5-25-42
TIME: 1500

PERTINENT INFORMATION

Destination: New York.
Port of Origin: Aruba, Dutch W.I.
Location of Attack: 74-01N; 39-46W
Speed: 10 knots
Cargo: 80,000 bbl of crude oil

ATMOSPHERIC CONDITIONS

Sea State: calm
Wind: east by northeast, force 2
Visibility: 5-7 miles
Weather: clear

REMARKS: Vessel sank by the stern with the bow settling slowly. Torpedo hit the engine room and tank #8. There was a spurt of fire and oil but the vessel did not catch on fire.

NAME: F. W. ABRAMS
DATE: 6-11-42
TIME: 0640

PERTINENT INFORMATION

Destination: New York
Port of Origin: Aruba, Dutch W.I.
Location of Attack: 34-52N; 75-95W
Speed:
Cargo: 90,000 bbl of fuel oil

ATMOSPHERIC CONDITIONS

Sea State: moderate
Wind: south by southeast, force 3 or 4
Visibility: 1/4 mile
Weather: squally

REMARKS: One torpedo hit and caused one explosion. A second explosion flooded the pump room and buckled the deck. Probably struck mine field. At 1755 same day, the tanker's bow was submerged.

NAME: WM. ROCKEFELLER
DATE: 6-28-42
TIME: 1216

PERTINENT INFORMATION

Destination: New York
Port of Origin: Aruba, Dutch W.I.
Location of Attack: 35-07N; 75-05W
Speed: 9 knots
Cargo: 135,000 bbl of bunker 'C'

ATMOSPHERIC CONDITIONS

Sea State: smooth
Wind: north, light
Visibility: good
Weather: clear

REMARKS: Cargo caught fire from explosion and ship sank 2338 the same day. Drifted 15 miles northeast of position before sinking. Torpedo hit made a 20-foot diameter hole and flooded the pump room. Tank #5 set fire.