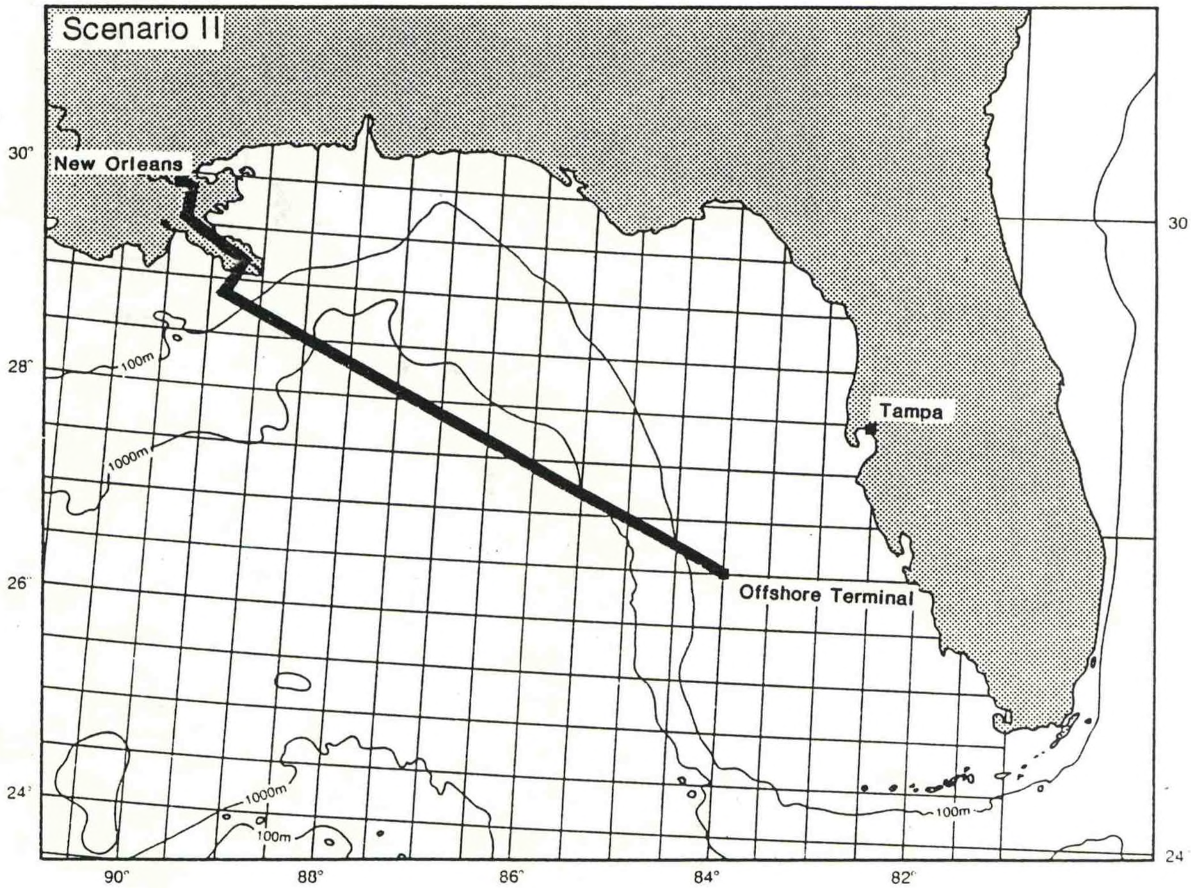

Analysis of Oil Discharges from Proposed Tankering Operations in Eastern Gulf of Mexico

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Prepared for Minerals Management Service
Gulf of Mexico OCS Region
Metairie, Louisiana
by

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SAB's Mission

The Strategic Assessment Branch is one of four branches of the Ocean Assessments Division, Office of Oceanography and Marine Services, National Oceanic and Atmospheric Administration. The mission of SAB is to conduct comprehensive interdisciplinary assessments of multiple ocean resource uses for the Nation and its major coastal and oceanic regions to determine marine resource development strategies which will result in maximum benefit to the Nation with minimum environmental damage or conflicts among uses. To accomplish this goal, SAB evaluates existing and projected ocean resource demands in terms of levels of use, resource availability, pollution discharges, potential environmental impacts and use conflicts, and maintains comprehensive national inventories of coastal and ocean resources and their existing and proposed uses. SAB develops strategic assessment methods and maintains an operational capability with which to evaluate the environmental and economic effects of national policies and management strategies affecting coastal and ocean resources.

Introduction

This report presents the results of an analysis to estimate oil discharges from tank ships that would result from two scenarios for tankering oil produced in the Charlotte Harbor lease area to refineries along the central Gulf of Mexico coast. The study was conducted by the Strategic Assessment Branch, Ocean Assessments Division, Office of Oceanography and Marine Services, National Ocean Service, National Oceanic and Atmospheric Administration, for the Minerals Management Service (MMS), Gulf of Mexico OCS Region, Metairie, Louisiana. It is one of a number of studies initiated by MMS to assess the potential environmental impacts of leasing offshore lands in the eastern Gulf of Mexico for hydrocarbon exploration and development activities. MMS is required to prepare environmental impact statements prior to offering federal outer continental shelf lands for leasing by industry. The Ocean Assessment Division's Strategic Assessment Branch (SAB) was asked to undertake this analysis because of the comprehensive tank ship simulation and oil pollutant transport modelling capabilities it has developed for the Gulf of Mexico, as well as other regions of the Nation's Exclusive Economic Zone.

Two general types of oil discharge that occur due to ship operations were analyzed: "operational discharges," which are routine and intentional discharges during normal operating procedures; and accidental spills. The latter can be divided into two categories: (1) those involving relatively small amounts of oil and resulting, for example, from equipment malfunction onboard a vessel (operational spills), and (2) those resulting from a major accident involving a vessel casualty, for example, a grounding, collision, ramming, fire, or explosion (casualty spills).

While casualty spills, especially the grounding or sinking of tankers, typically capture the attention of the general public and policymakers, operational discharges, allowed under regulations of the International Maritime Organization, account for the major share of oil discharges from marine transportation sources. Over 2.5 million gallons of oil were estimated to have been discharged from vessels during normal ship operations in the Gulf of Mexico during 1979. In comparison, casualty spills in the open waters of the Gulf of Mexico for 1979 and 1980 averaged 170,000 gallons per year.

Operational discharges of oil from ships primarily are the result of bilge water pumping, and tank cleaning and ballasting. The second type of operation is by far the most important, accounting for about 70 percent of operational discharges of oil from ships.

Once the oil (oil emulsion) is discharged onto the surface of the ocean, many factors affect it. Almost immediately, weathering processes begin to act on the oil, and surface winds and currents begin moving it over the ocean surface. Eventually, the oil is spread into very thin layers until surface forces begin to fragment the spreading film into patches, which in turn are fragmented further and weathered.

Surface winds and currents are the most important factors determining the direction and rate at which the oil eventually moves. The physical, chemical, and biological reactions which weather or modify oil as it spreads take place over time scales ranging from a few hours up to months or years. The rate at which these processes weather a given discharge of oil primarily depends on the amount and distribution of various hydrocarbons in the oil and on meteorological conditions. Consequently, the spatial and temporal patterns of surface oil in the Gulf of Mexico due to operational discharges, and the potential for adverse effects on living and non-living resources, vary from season to season and from year to year based on natural factors as well as transportation patterns and operating practices.

The Scenarios

Discussion between MMS and SAB narrowed the study to two scenarios that would reflect the major alternatives for transporting crude oil from the Charlotte Harbor lease area to refineries along the Central Gulf coast. MMS specified that approximately 980 million barrels of crude oil would be produced in the offshore area during a 40 year time period. It could also be assumed that for both scenarios annual production and transportation would average about 24.5 million barrels per year. The scenarios selected are shown in Figure 1 and were specified as follows:

Scenario I: Approximately 67,000 barrels of crude oil would be pumped per day from the Charlotte Harbor lease area to facilities in the port of Tampa; tank ships would then transport the oil from Tampa to refineries near the port of New Orleans.

Scenario II: Approximately 67,000 barrels of crude oil per day would be loaded directly onto tank ships at an offshore terminal located 120 miles southwest of Tampa; the tank ships would then transport the oil to refineries near the port of New Orleans.

Given the changing technology in the tank ship industry and the inherent uncertainty associated with analyzing events over a 40 year time period, "best" and "worst" cases were specified for each scenario. The best case assumes that from the initiation of tankering all tank ships would be new and include the latest pollution control technology currently available. For Scenario II, it is also assumed that loading takes place at an integrated floating production, storage, and loading facility. The worst case assumes that for the first twenty years of operation existing U.S. flag tank ships would be used with new tank ships incorporating the latest pollution control technology used only for the remaining twenty years. For Scenario II, it was also assumed that loading would take place at a single anchor leg mooring facility. The details of each scenario were specified by SAB and its contractor, Engineering Computer Optecnomics (ECO), Annapolis, Maryland. For a more detailed discussion of the technology assumptions made in each scenario, see ECO, 1983.

Figure 1. Alternative Transportation Routes

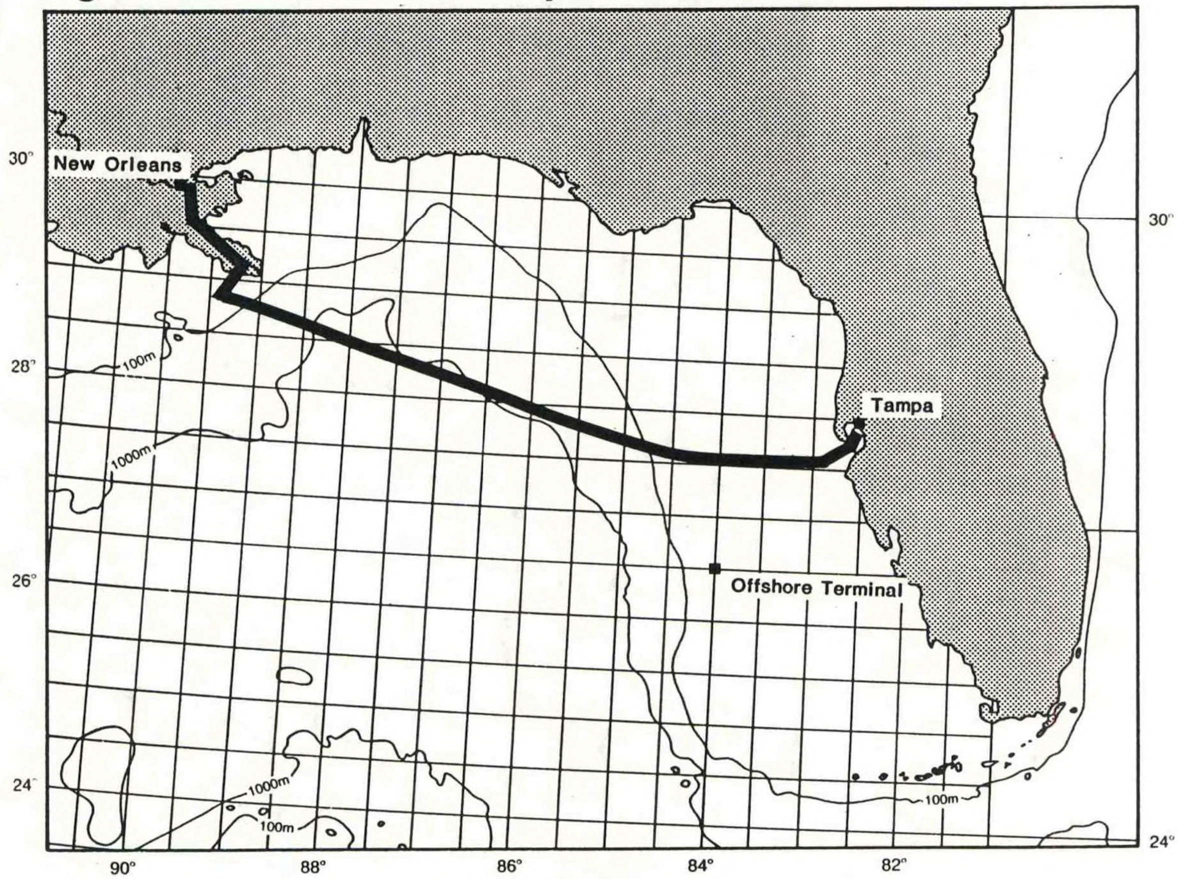

Fig. 1a. Scenario I

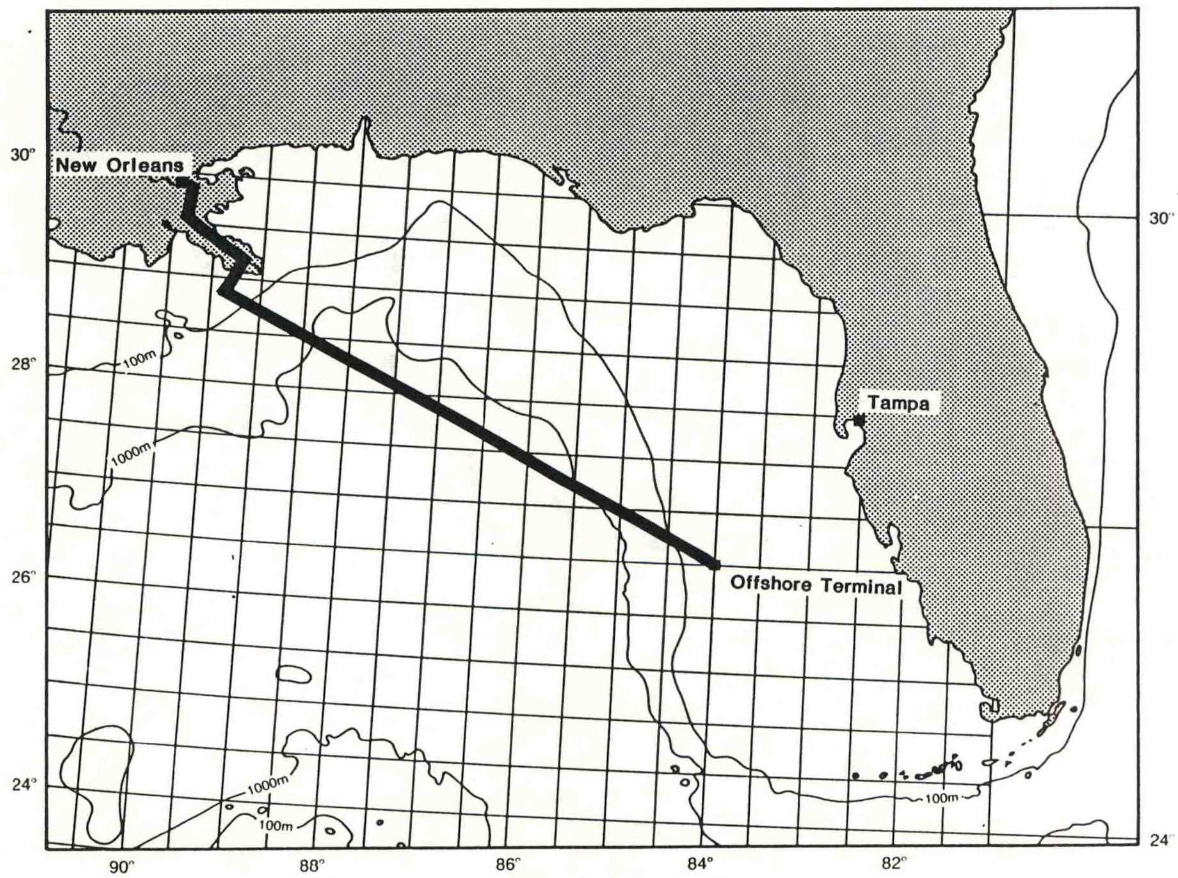

Fig. 1b. Scenario II

Method of Analysis

The analysis was separated into four phases. Phase 1 was application of SAB's tank ship simulation model to estimate the spatial and temporal patterns of: the quantity of operational discharges of oil; the number of operational spills; and the number of tank ship casualties that would occur under each scenario. Phase 2 was to translate the spatial and temporal pattern of oil discharges estimated for each scenario into related patterns in time and space of dispersed and weathered oil, using NOAA's strategic oil pollutant transport model. Phase 3 consisted of comparing these patterns with those estimated to result from all other shipping operations (background) in the Gulf of Mexico, as estimated in 1979 (Ehler and Basta, 1983). Phase 4 was to identify, to the extent possible, the potential risks to living marine resources in areas where the concentrations of surface oil predicted to occur would be relatively high as compared to background conditions. As shown below, the very small surface oil concentrations estimated to result under either scenario did not warrant undertaking Phase 4.

Tank Ship Simulation Model

NOAA's tank ship simulation model was developed primarily to estimate operational discharges of oil from tank ships transiting the Nation's Exclusive Economic Zone (EEZ). It has also been configured to estimate the number and location of operational spills and casualties that may be expected given a distribution of tank ship movements. Five steps were required to apply the model to the Gulf of Mexico.

Step 1: Identification of ports. Starting with the major ports of the Gulf of Mexico, ports were selected on the basis of volume of vessel traffic, until 80 to 90 percent of the total traffic in the Gulf of Mexico was accounted for in the base year (1979). Six types of vessel traffic are included in the Gulf component of the model: tank ships, tank barges, dry cargo ships, tugboats, fishing vessels, and offshore crew and supply vessels.

Step 2: Development of origin and destination data. For each port, two data sets were developed for each category of ship for each month in 1979: (1) the number of ships in each category entering and leaving the port, and (2) the origins and destinations of those ships. For tankships, two additional data sets were developed: (1) the load condition of each tankship -- was it carrying crude or product; and its ballast condition, and (2) the size (deadweight tons) of the ship in one of five size groupings.

No single source provided all of the requisite information for a given port. Information from various sources had to be combined and synthesized to develop the data for U.S. ports. Interviews with experienced local port authorities, the U.S. Army Corps of Engineers, and the U.S. Department of Commerce also were used. The U.S. State Department, the Commission Nacional Coordinadora de Puertos, and interviews with petroleum industry representatives provided data on Mexican ports.

Step 3: Identification of shipping routes. Vessel origin and destination data derived for each port were used to identify the combinations of major ports between which shipping routes had to be mapped. The routes were defined using a variety of sources and plotted on navigational charts. Each shipping route was defined as a sequence of 30-minute by 30-minute grid cells. Thus, as the movement of the ship was simulated along an appropriate shipping route, the oil it discharged could be assigned to specific grid cells.

Operating personnel in oil companies, cargo shipping companies, and offshore supply and fishing vessel operations were the most important source of information. These individuals were able to provide detailed information on the routes which ships actually take between ports.

Step 4: Allocation of vessels to shipping routes. Each vessel in each port in each month of 1979 then was assigned to a shipping route based on the origin and destination data.

Step 5: Estimation of discharges. Given knowledge of shipboard activities which result in operational discharges and information on the types of ships of interest, operational spill and casualty rate estimates were made based on some simple assumptions. For a more complete explanation of the Gulf of Mexico component of NOAA's tank ship simulation model see Ehler and Basta, 1983.

To implement the simulation for the proposed tankering operations, a detailed specification of vessels and their pollution control technology was required. Based on the oil production and transport rates specified by MMS, it was assumed that a 50,000 deadweight ton (DWT) vessel was the most realistic tank ship for the proposed type of operation. New vessels specified for the best case for each scenario were assumed to have the following pollution control features: segregated ballast, double hull and bottom, crude oil washing system, inert gas system, and load on top. The shipping routes shown in Figure 1 and origin and destination data based on the 50,000 DWT vessel size were added to shipping routes specified in the model. Table 1 summarizes the specifications for each scenario and the analyses conducted. For a more detailed explanation of this application of NOAA's tank ship simulation model, see ECO, 1983.

Strategic Oil Pollutant Transport Model

NOAA's strategic oil pollutant model approaches the oil pollutant transport problem quite differently than most oil spill trajectory models that have been developed (Stolzenback, K. et al., 1977). Rather than focusing on predicting the transport and weathering of oil discharged at a given location due to a particular event, the strategic model analyzes the cummulative effects of numerous sources discharging at many locations over some specified period, such as a month, season, year, or even longer.

Table 1. Specifications of Tankering Scenarios

SPECIFICATIONS	SCENARIO 1		SCENARIO 2	
	Best Case	Worst Case	Best Case	Worst Case
Loading Site				
Tampa Harbor	●	●		
Integrated Floating Production, Storage, and Loading Facility			●	
Single Anchor Leg Mooring System				●
Receiving Site				
New Orleans (Port)	●	●	●	●
Tankship Size (DWT)				
50,000	●	●	●	●
Tankship Pollution Technology				
Segregated Ballast	●	☆	●	☆
Double Hull	●	☆	●	☆
Double Bottom	●	☆	●	☆
Crude Oil Washing System	●	☆	●	☆
Inert Gas System	●	☆	●	☆
Load on Top	●	☆	●	☆
Time Horizon				
Long-Range (40 years)	●	●	●	●
Discharge Analysis				
Spatial Patterns of Operational Discharges of Oil	●	●	●	●
Spatial Patterns of Operational and Casualty Spills of Oil	●	●	●	●
Ambient Quality Analysis				
Spatial and Temporal Patterns of Surface Oil Concentrations		●		●

Abbreviations: DWT, Dead Weight Tons.

☆ For worst case scenarios, pollution control technology is assumed in place only for second half of study period.

The operational problem is to translate a spatial and temporal pattern of oil discharges over a large coastal and ocean area into a related pattern in time and space of dispersed and weathered oil. Although some of the "traditional" oil trajectory models and modelling approaches conceivably could be applied to this problem, running them for a great many sites within a study area, none can be applied inexpensively and efficiently in this context. They were not designed for this type of analysis.

The strategic oil pollutant transport model was developed to address this need. It is not a substitute for detailed oil spill trajectory models. In fact, it is intended to complement them by identifying relatively important source/receptor relationships between living marine resources and sources and locations of marine oil pollution. In this manner, it can indicate where applications of the more detailed and expensive trajectory models might be of particular benefit.

Given the approximately 600 grid cells into which the area has been divided for analysis, the modeling approach was to develop a "transport matrix" for each month, based on wind statistics, such as mean surface winds, and surface currents, that would quantify the transport of surface oil from each grid cell to each of its eight adjoining cells. To develop these matrices, a time-step for the simulation was selected so that transport from any given cell would not go beyond the boundaries of its eight adjoining cells during a single time-step in any given month.

The actual simulation procedure is relatively simple. Given assumptions about weathering rates, and after computing the amount of oil discharged into each cell in each time-step in each month (based on the monthly discharge estimates), the monthly transport matrices are multiplied by the corresponding matrices of oil discharges per cell per time-step per month. The amount of oil estimated to be in each cell after a given time-step is then entered into the next time-step, along with any additional "new oil" discharged during the next time-step.

Setting up the model in this manner provides maximum flexibility, not only in terms of efficiency but also for testing alternative data sets on surface currents and winds and assumptions regarding weathering rates. It also makes it relatively easy to analyze alternative development scenarios which would alter oil discharge patterns. For a more detailed description see Grose, Everdale, and Katz, 1983.

In this analysis, the model was run for each scenario for each case for an entire year. The pollutant discharge patterns input into the model were generated as described above. The surface concentrations estimated are interpreted as the concentrations that can be expected during any given year over the 40-year time period for each scenario.

Results and Conclusions

Analysis results are displayed in Figures 2 through 8.

Figure 2: Shows the total volume of operational discharges of oil from tank ships for each scenario for each case over the 40 year period. Discharges are aggregated by 30'x30' minute grid cells, based on the transportation routes shown in Figure 1. Although there is no significant difference in the total volume of oil discharged in each case between scenarios, the pattern of discharges varies. A significantly larger volume of oil is discharged under the worse case assumptions in each scenario.

Figure 3: Shows the number of operational spills estimated to occur at tank ship terminals during the 40 year period. There is a significant reduction in the number of operational spills located at the offshore terminal in Scenario II (best and worse cases). This can partially be explained by the advanced technology associated with an offshore terminal.

Figure 4: Shows the estimated number of tank ship casualties during the 40 year period. This figure illustrates the improved safety that would result using offshore terminal facilities (Scenario II) as opposed to facilities in Tampa (Scenario I). Less traffic, greater depth, and more room to manuever are some advantages that an offshore terminal offers. While casualties would occur less frequently than operational spills (Figure 3), the volume discharged per event would be much greater.

Figure 5: Shows the estimated surface oil concentrations from operational discharges in Scenario I (worst case). The difference in seasonal distributions illustrate the influence of surface winds and currents at different times of year. Concentrations generally move south in the winter and north in the summer. However the concentrations estimated are very low, e.g., the highest are between .005 and .010 gallons per square mile.

Figure 6: Shows the estimated surface oil concentrations from operational discharges in Scenario II (worst case). The patterns are similar to those seen in Figure 5. The major difference is a southerly shift of oil due to the direct shipping route from the Charlotte Harbor leasing area to New Orleans.

Figure 7: Shows the estimated "background" concentrations estimated from all shipping movements in 1979. These concentrations are far greater than the concentrations estimated for each scenario.

Figure 8: Shows the combined surface concentrations of oil resulting from adding operational discharges from Scenario I (worst case) to "background" conditions. Adding Scenario I to the background concentrations (Figure 7) makes no noticeable change to the pattern or value of surface oil concentrations in either season

Results indicate that operational discharges of oil from tankering operations for the scenarios specified would add little oil to the eastern Gulf of Mexico, especially with respect to existing operational discharges from vessels in the region. The contribution would be so small that discharges would rapidly reach undectable concentration levels. Overall, the tankering requirements to meet the oil transportation needs specified by MMS are minimal. The entire operation could be carried out by 1 or 2 medium size tank ships (50,000 DWT) making a total of about 70 trips per year.

The real threat to the marine environment is the potential for a major casualty event, e.g., grounding, collision, or fire within a port. Given current statistics, a casualty event would probably occur at least once or twice over the 40 year period, but whether or not this would result is a large release of oil cannot be determined. When large releases occur, the casualty often results in loss of the vessel. In addition, about two small spills per year would probably occur within each port due to normal operations. Whether or not the marine environment would be significantly affected by this rate of oil input could only be determined by a more detailed, port-specific analysis.

Using an offshore terminal located in the lease area (Scenario II) would clearly reduce the potential risks of casualty events, as well as the number operational spills that would occur. Discharges at the offshore terminal would also disperse relatively quickly, as compared to the dispersion of discharges within the Port of Tampa.

References

ECO. 1983. Marine transportation alternative scenarios for the Gulf of Mexico. Annapolis: Engineering Computer Optecnomics.

Ehler, C.N. and D.J. Basta. 1983. NOAA's strategic assessment programme in the Gulf of Mexico. Marine Pollution Bulletin, Vol. 14, No. 9, pp 325-334.

Grose, P., F. Everdale, and L. Katz. 1983. Predicting the surface transport of oil pollution in the Gulf of Mexico. Marine Pollution Bulletin, Vol. 14, No. 10, pp 372-377.

Stolzenbach, K. et al. 1977. A review and evaluation of basic techniques for predicting the behavior of surface oil slicks. Report No. MITSG 77-8. Cambridge: Massachusetts Institute of Technology Sea Grant Program.

Figure 2. Operational Discharges of Oil from Tank Ships

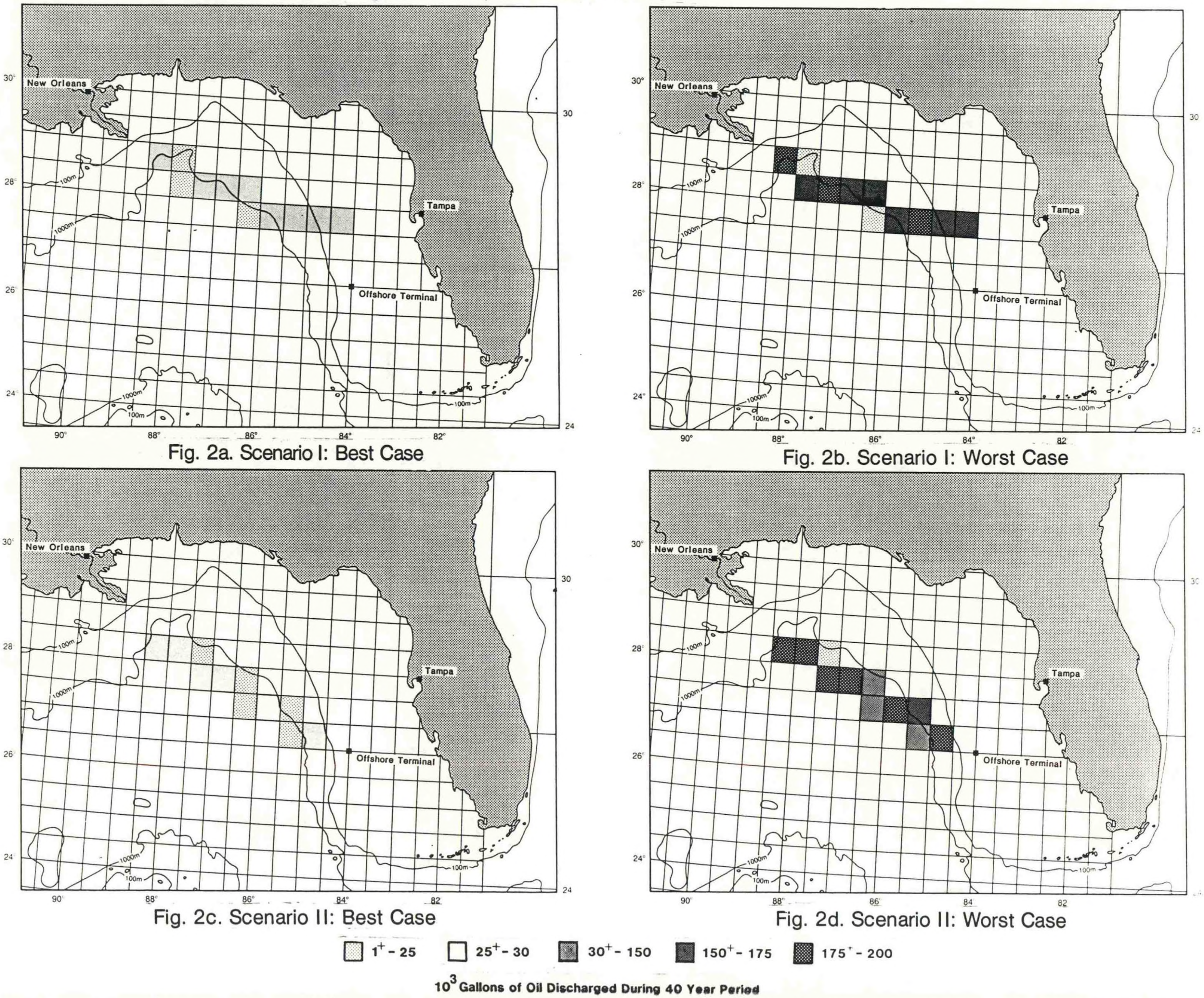

Fig. 2a. Scenario I: Best Case

Fig. 2b. Scenario I: Worst Case

Fig. 2c. Scenario II: Best Case

Fig. 2d. Scenario II: Worst Case

Figure 3. Estimated Number of Operational Spills at Tank Ship Terminals, During 40 Year Period

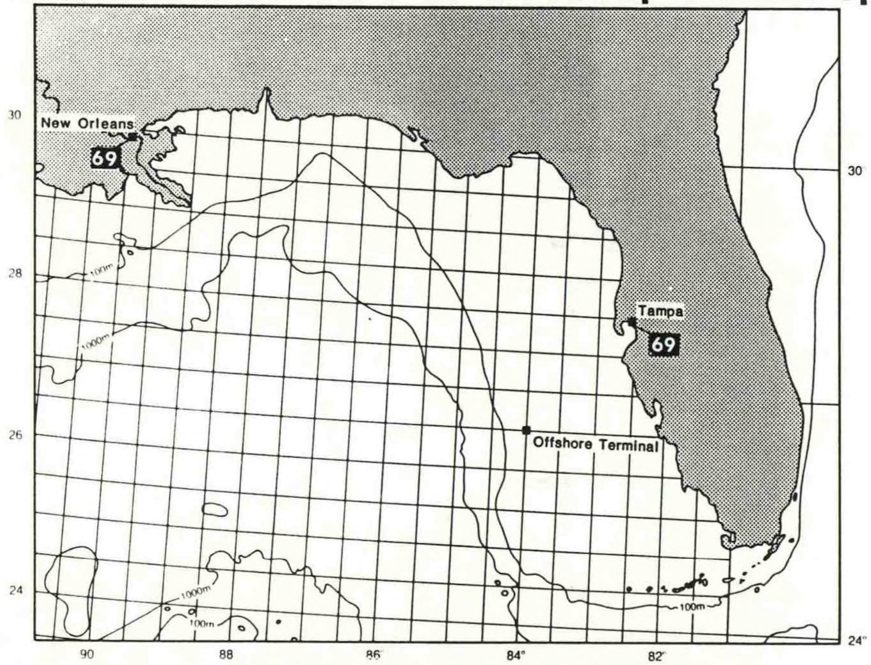

Fig. 3a. Scenario I: Best Case

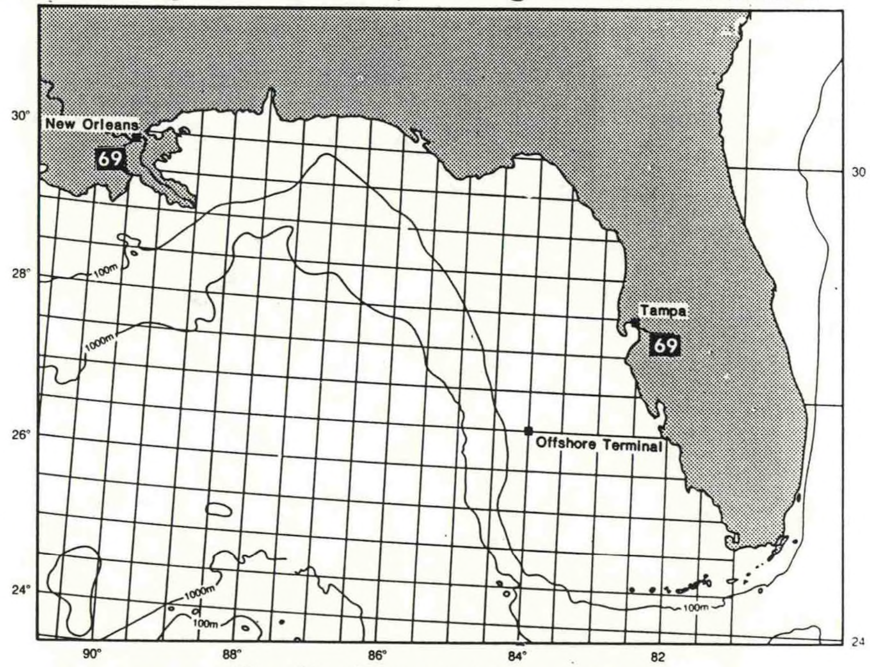

Fig. 3b. Scenario I: Worst Case

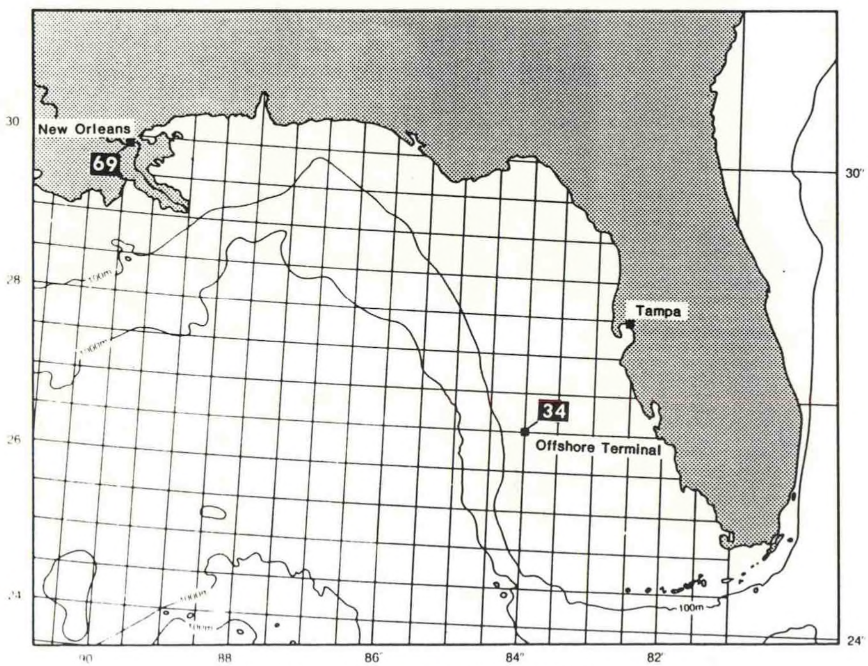

Fig. 3c. Scenario II: Best Case

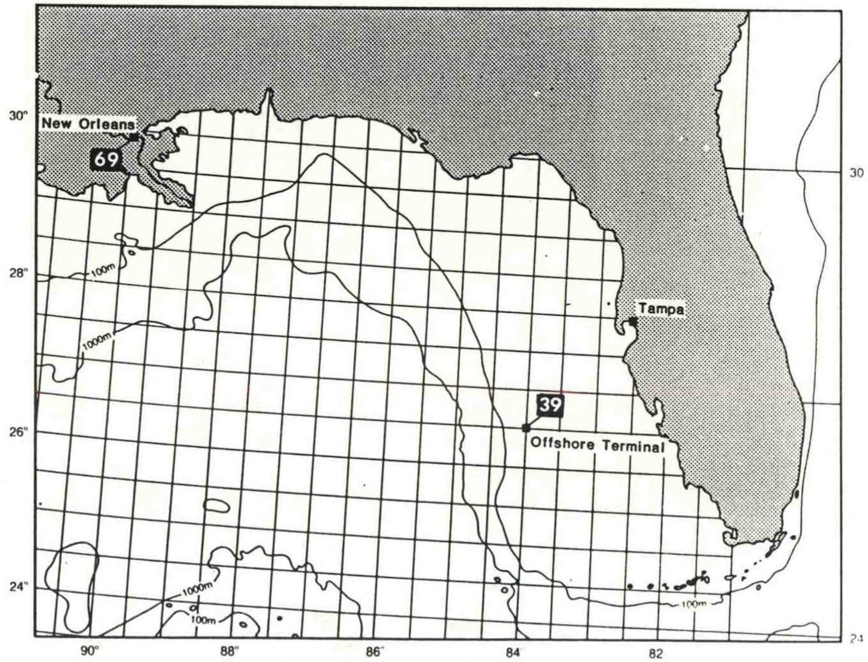

Fig. 3d. Scenario II: Worst Case

Figure 4. Estimated Number of Tank Ship Casualties, During 40 Year Period

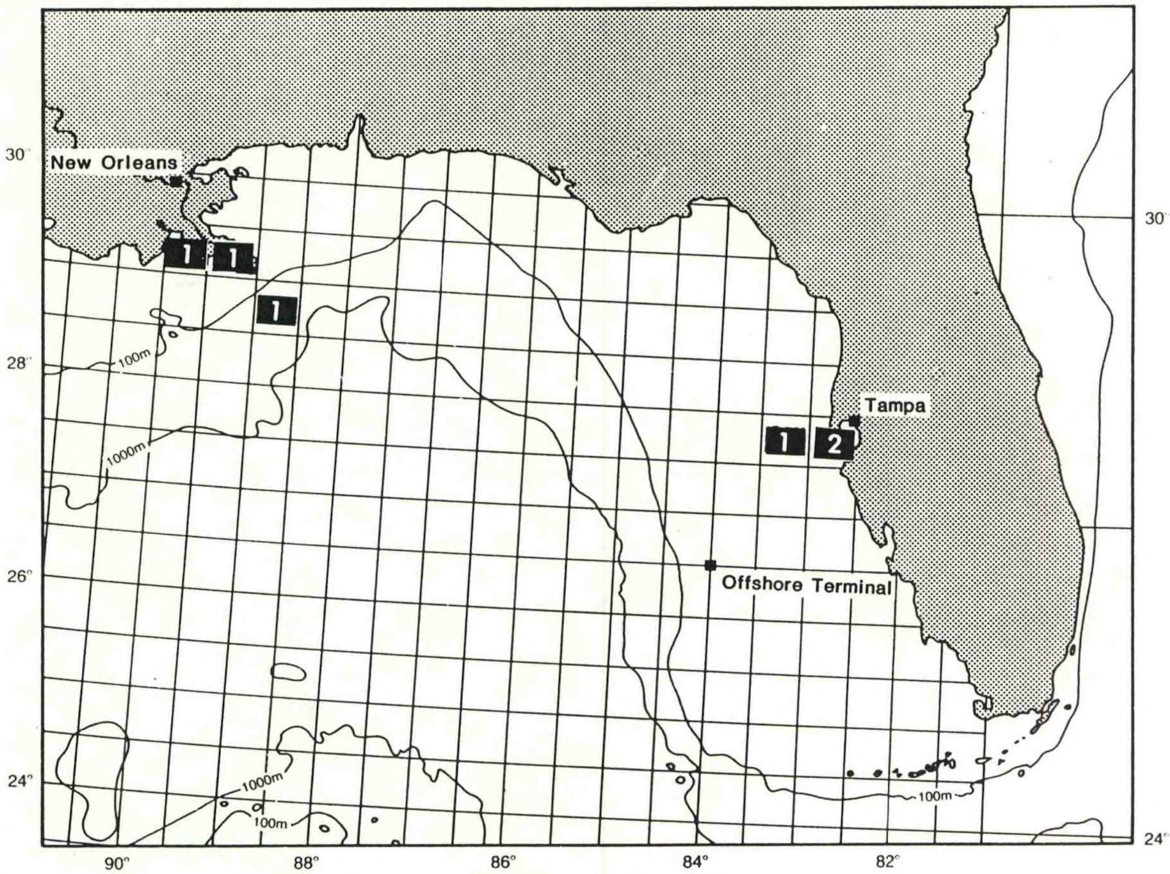

Fig. 4a. Scenario I

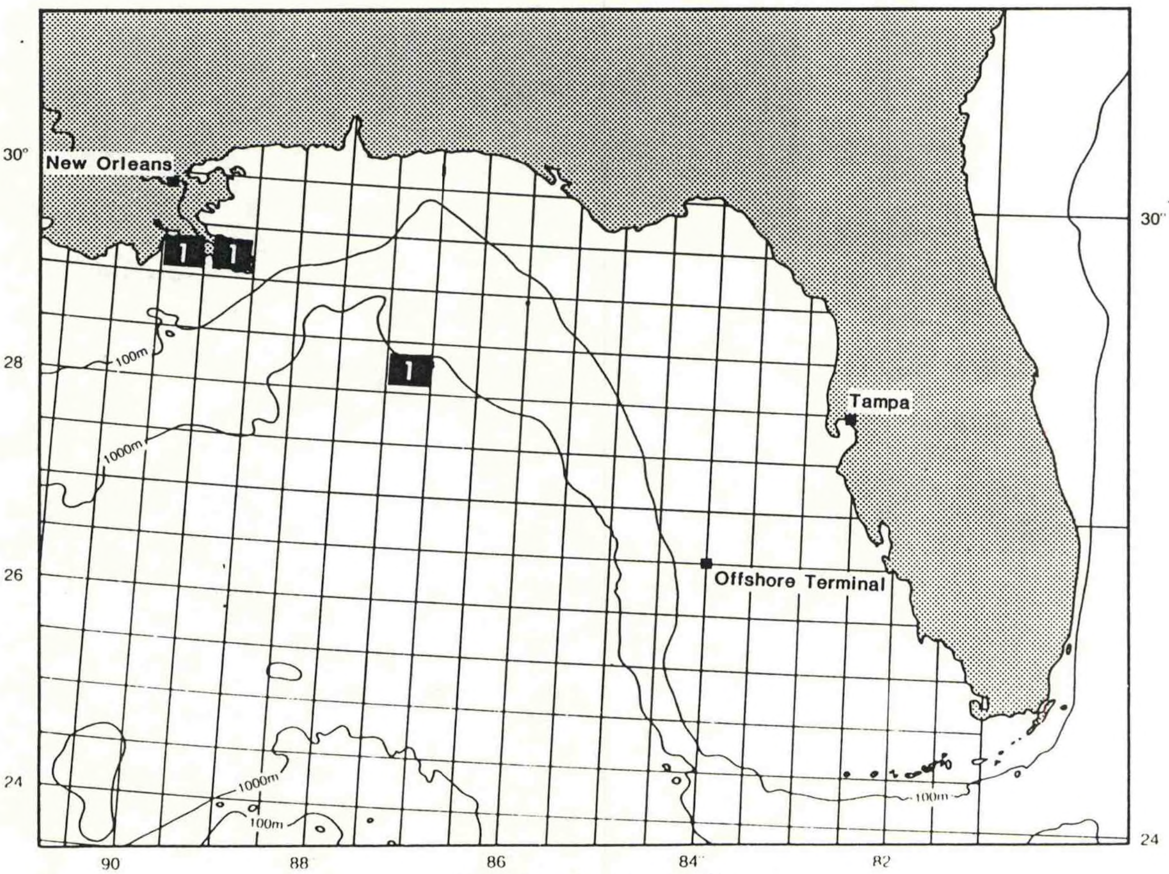

Fig. 4b. Scenario II

Figure 5. Estimated Surface Oil Concentrations: Scenario I (Worst Case)

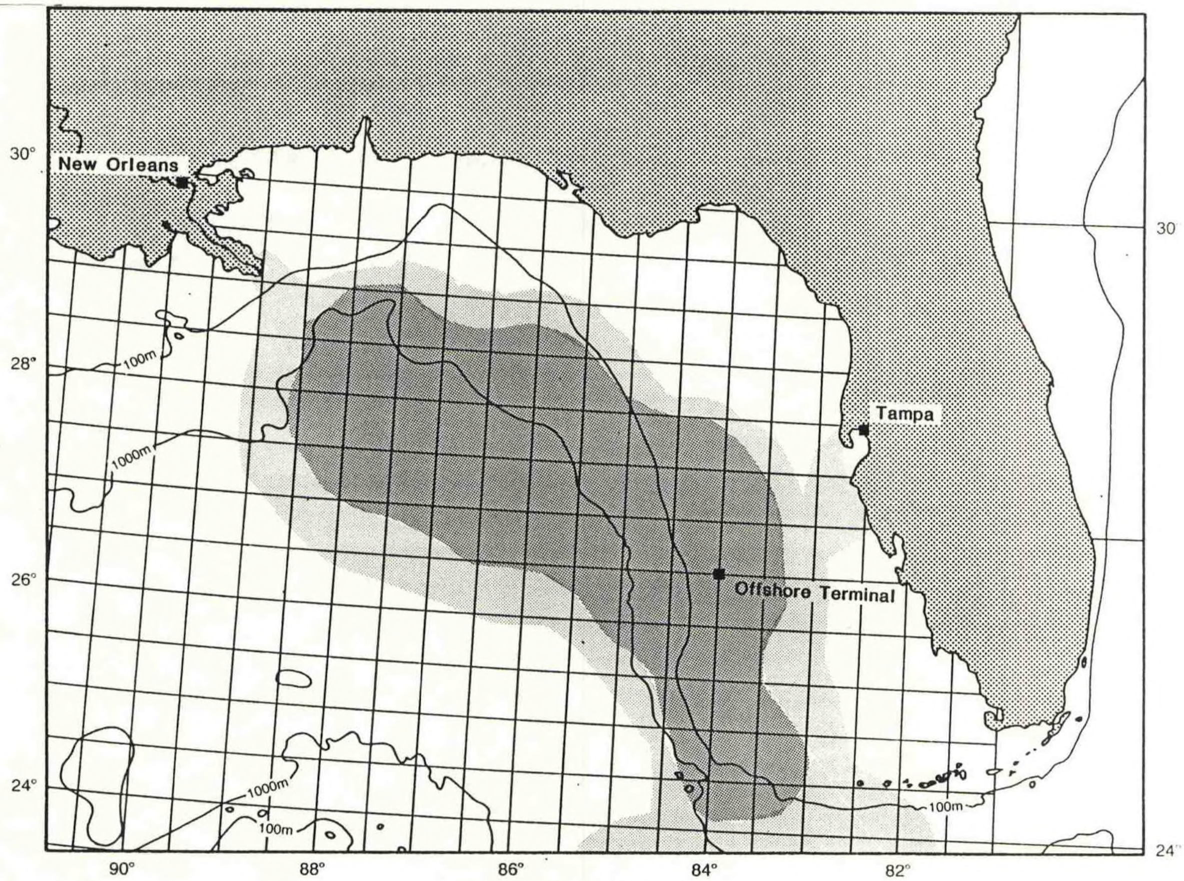

Fig. 5a. January

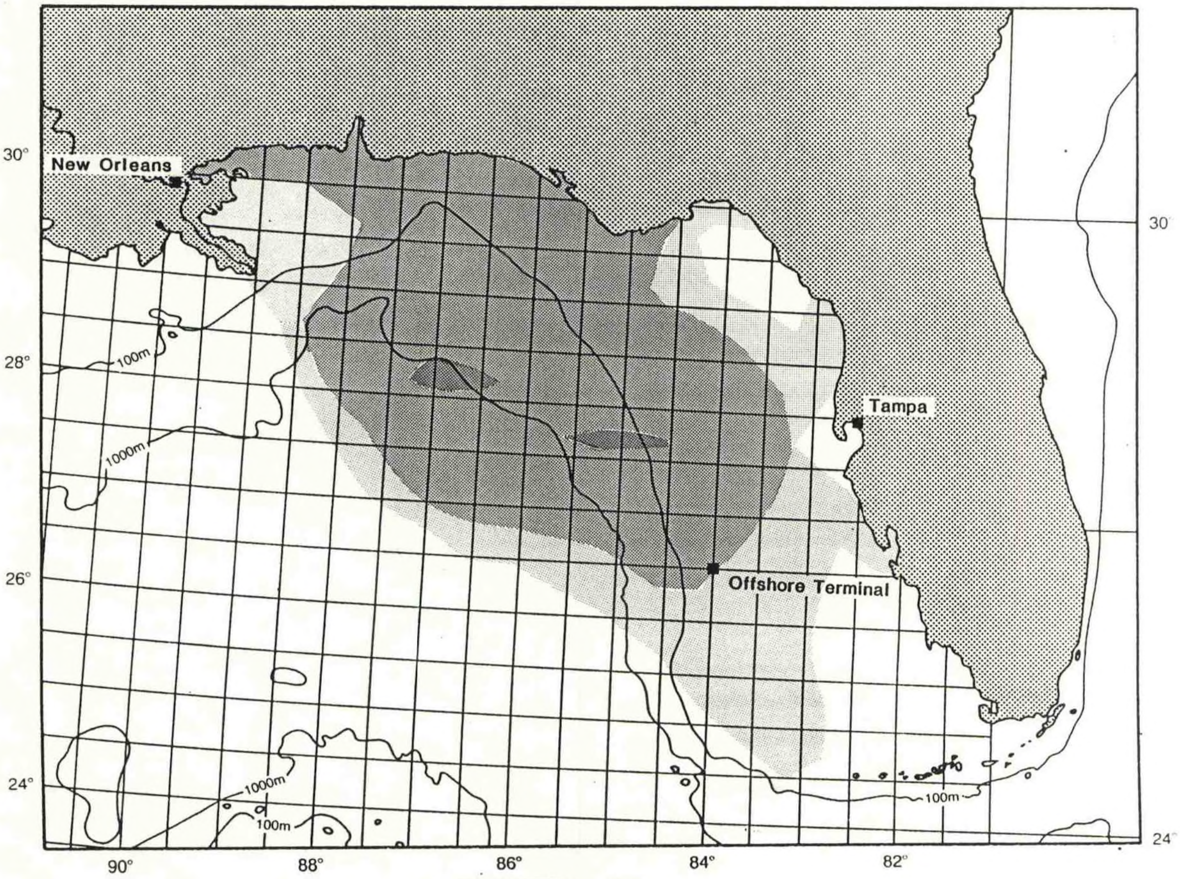

Fig. 5b. July

.05 - .10 | .10 - .50 | .50 - 1.0 | 1.0 - 5.0 | 5.0 - 10.0

10^{-2} Gallons of Oil per Square Mile

Figure 6. Estimated Surface Oil Concentrations: Scenario II (Worst Case)

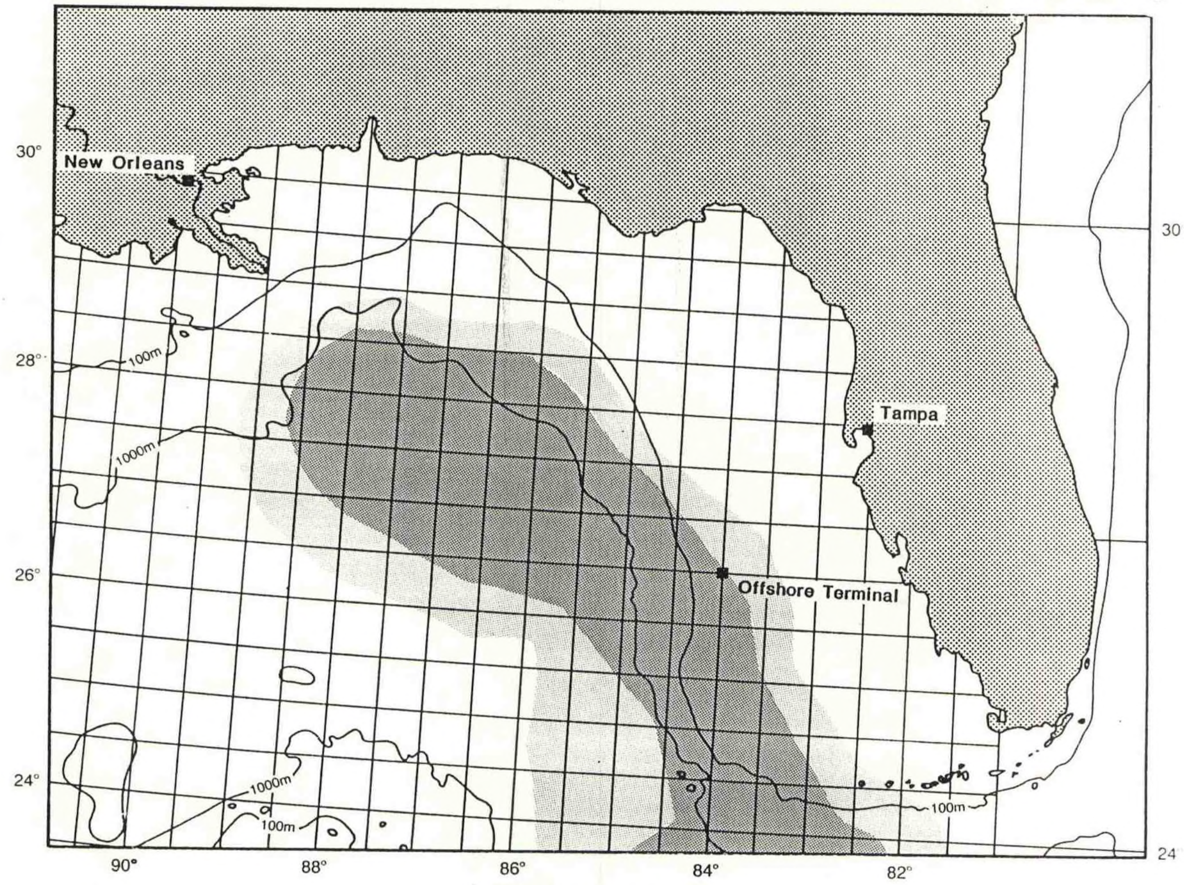

Fig. 6a. January

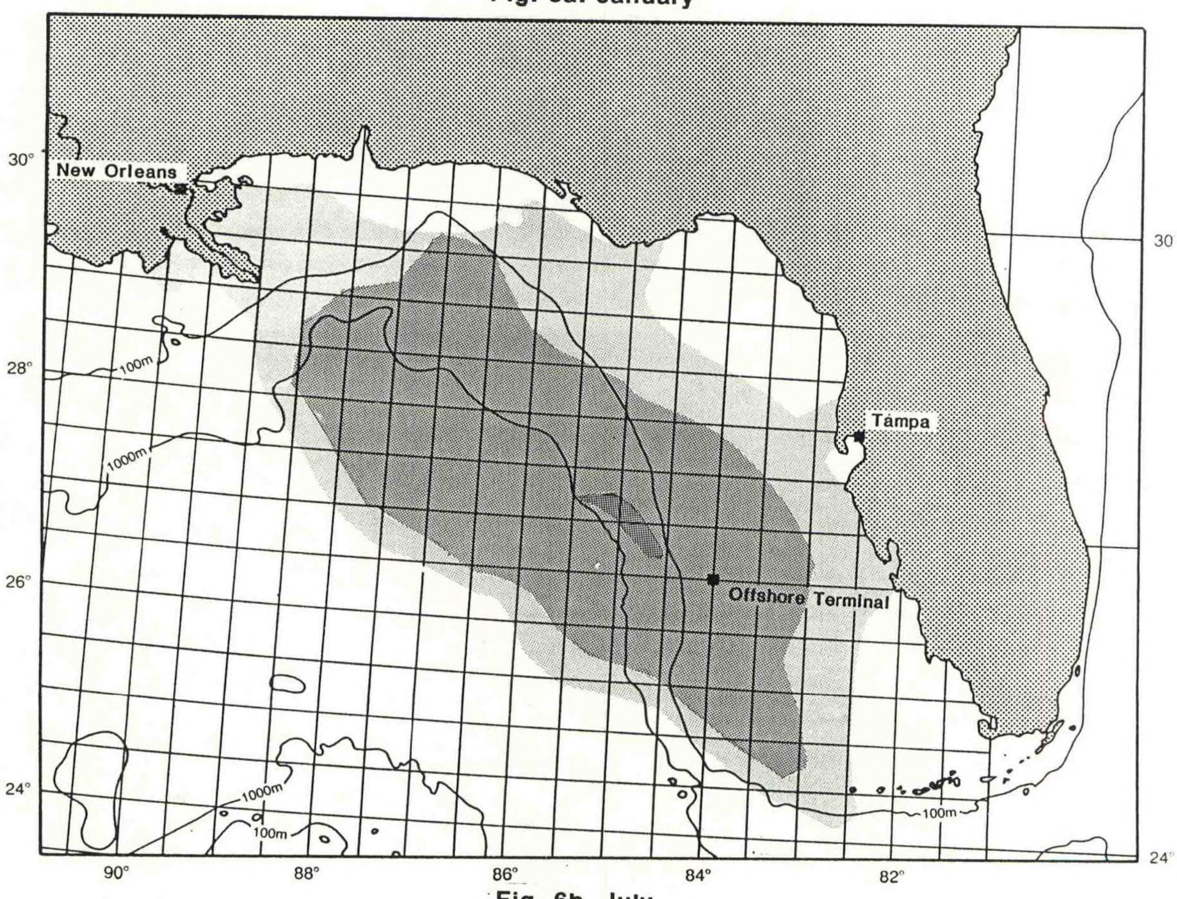

Fig. 6b. July

.05 - .10 | .10 - .50 | .50 - 1.0 | 1.0 - 5.0 | 5.0 - 10.0

10^{-2} Gallons of Oil per Square Mile

Figure 7. Estimated Surface Oil Concentrations: Operational Discharges from all Shipping Movements in 1979

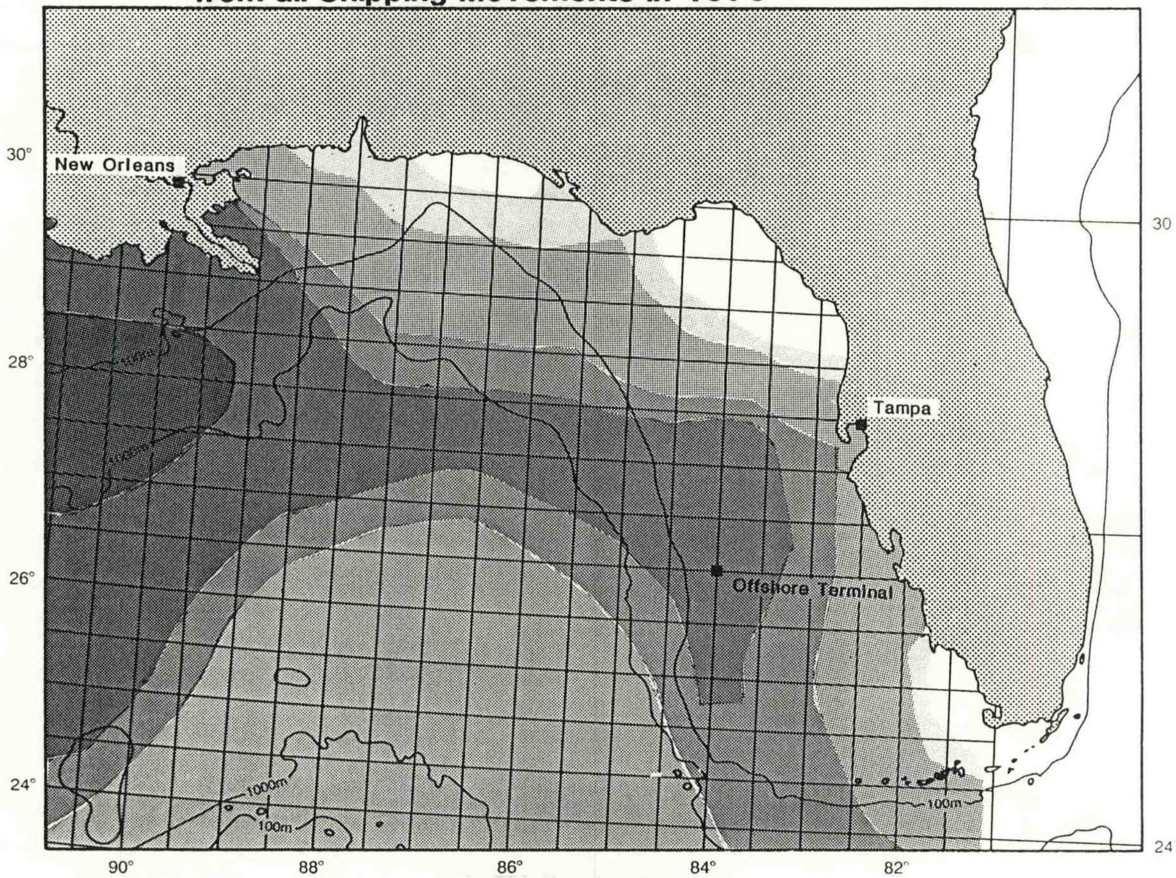

Fig. 7a. January

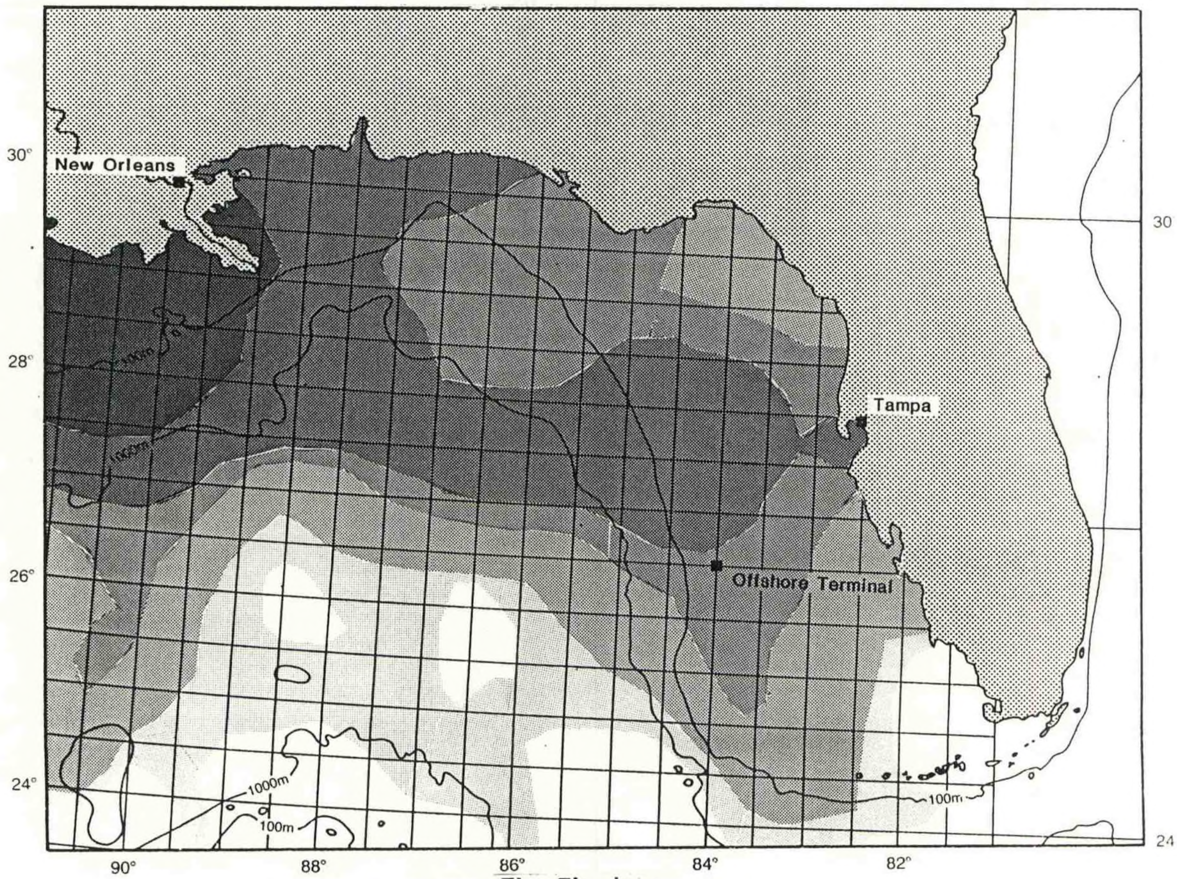

Fig. 7b. July

.05 - .10 | .10 - .50 | .50 - 1.0 | 1.0 - 5.0 | 5.0 - 10.0

10^{-2} Gallons of Oil per Square Mile

Source: Ehler, C.N. ,D.J. Basta, and T.F. LaPointe, 1983: Analyzing the effects of operational discharges of oil from ships in the Gulf of Mexico. Proceedings of the 1983 Oil Spill Conference, San Antonio, Tx, February,1983.

Figure 8. Estimated Surface Oil Concentrations: All Discharges in 1979 plus Scenario I (Worst Case)

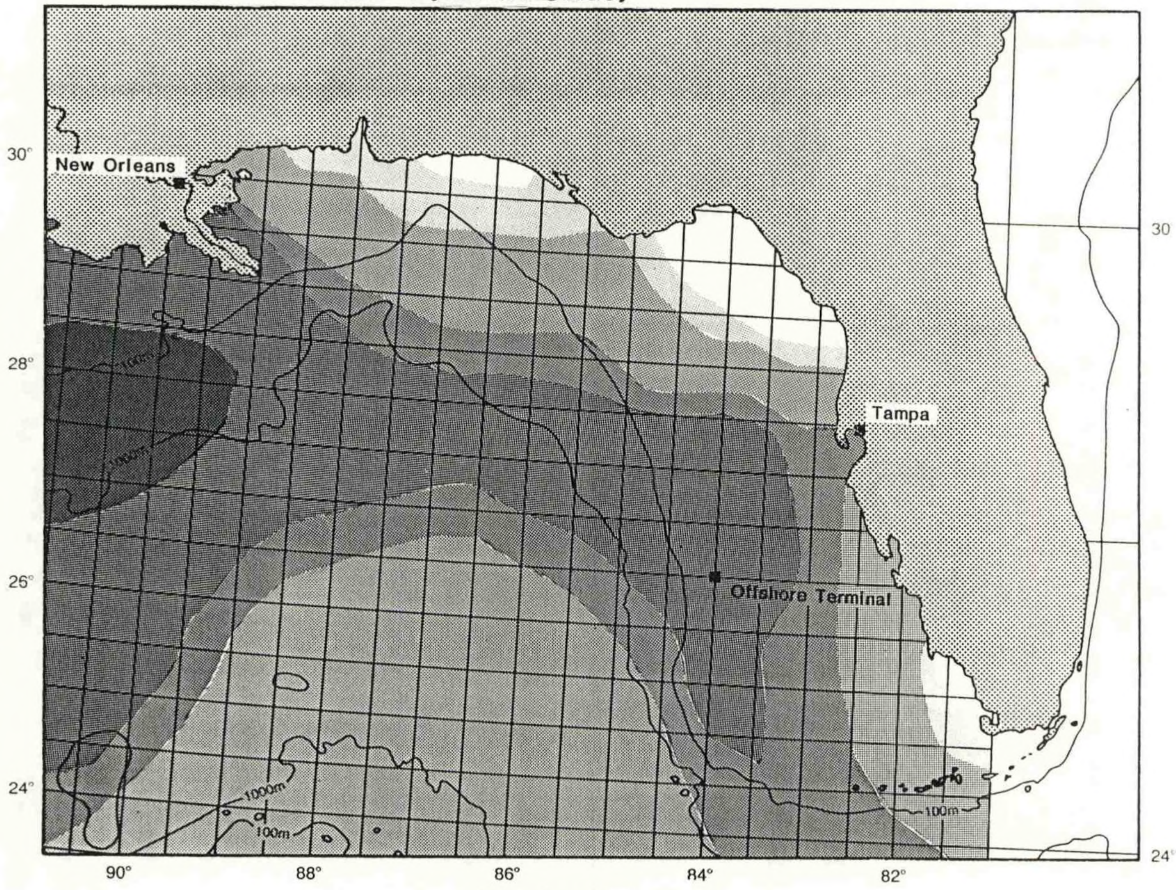

Fig. 8a. January

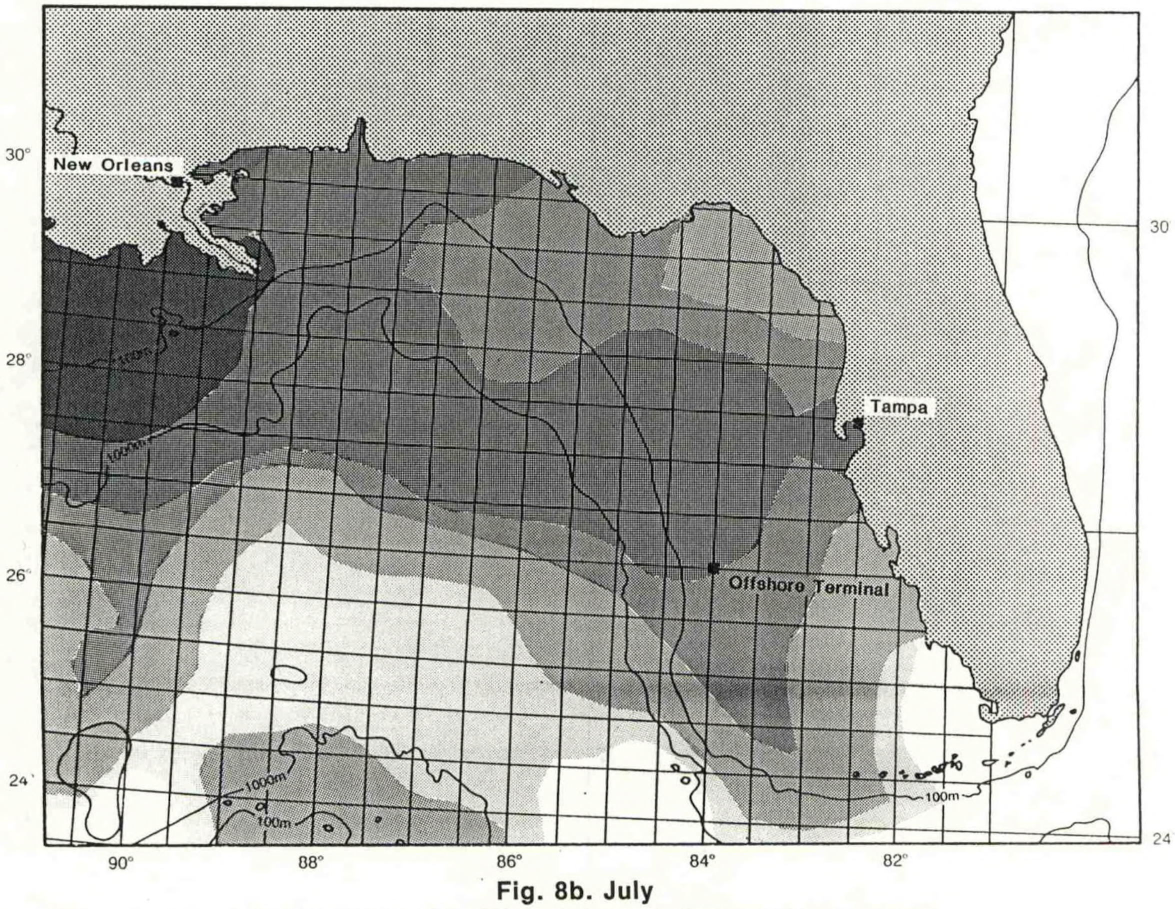

Fig. 8b. July