PREFACE

This report is one of a series of studies conducted by the United States Coast Guard in support of the Presidential initiative of March 1977, concerning the ability of the United States to respond to the threat of larger oil spills in U.S. waters. The study was directed by the U.S. Coast Guard Office of Research and Development and Office of Marine Environment and Systems. The authors wish to acknowledge with thanks the expert and indispensible assistance rendered by these Offices throughout the project, and in particular that of Cdr. J.T. Leigh/GDOE, Cdr. J.L. Valenti/GWEP, Lt. R.V. Harding/GDSA and Lt. G.D. Marsh/GDOE. They are also indebted to numerous Coast Guard personnel, both at headquarters and in the field organizations, who enthusiastically provided data, advice and information.

The report is in two volumes. The first volume presents the main analysis, while the second contains the technical Appendixes.

The Department of Transportation's report to the President on the entire study effort is entitled "A Plan for Implementing Presidential Initiatives Concerning Oil Pollution Response," and may be ordered through the National Technical Information Service, Springfield, Virginia, 22161, as Report No. AD-A067163. A supplemental report is also available with the NTIS number, AD-A067076.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

Section Page

TABLE OF CONTENTS (CONT'D)

LIST OF ILLUSTRATIONS (CONT'D)

LIST OF ILLUSTRATIONS (CONT'D)

LIST OF ILLUSTRATIONS (CONT'D)

LIST OF TABLES (CONT'D)

LIST OF TABLES (CONT'D)

1. INTRODUCTION

The Oil Pollution Response System study was undertaken by the U.S. Coast Guard in response to a White House policy statement communicated to the Congress on March 18, 1977. The President was moved to make this statement after a number of tanker accidents along the coasts of the United States, including the SANSINENA and the ARGO MERCHANT incidents in December of 1976.

In these and lesser pollution incidents, the Coast Guard may be required to assume responsibility for removing or arranging for the removal of any oil discharged into the navigable waters of the United States. The authority to exercise this responsibility is vested by Congress in the President[1] and delegated by him to the Coast Guard[2].

The Public Law which establishes the Executive authority in this area is the amended Federal Water Pollution Control Act of 1972. In Section 311 of the Act (86 STAT 863), Congress has declared that "it is the policy of the United States that there should be no discharge of oil or hazardous substances into or upon the navigable waters of the United States..." Whenever such discharges do, nevertheless, occur in the coastal regions, whether intentionally or accidentally, the responsible officer of the Coast Guard (the On-Scene Coordinator) has the authority to act if he determines that such action is necessary to limit and/or remove the discharge. In carrying out his responsibilities the OSC is assisted by the response mechanism set up by the National Contingency Plan, which includes the National Strike Force.[3]

---

[1] Public Law 92-500, The Federal Water Pollution Control Act Amendments of 1972

[2] Executive Order No. 11735, August 3, 1973.

[3] Federal Register, Vol. 40, No.28, Part II, Feb. 10, 1975.

a. An equipment siting study;

b. A study of the response problems associated with a massive spill.

It has been pointed out in numerous places and on numerous occasions that more and larger oil spills are an inevitable consequence of the transport and transfer of ever increasing volumes of oil, and oil products. Preventive measures and prudent procedures can limit but not eliminate accidental spills, which are most often small and of minor consequence but occasionally massive, with major impact on the environment and on nearby communities.

It has also been pointed out that in many respects oil spills resemble fires. Both are potentially disastrous events that may happen anywhere and at any time, although it may be possible through careful study to identify the circumstances that increase the risk. Furthermore, the response organizations must maintain themselves in a continuous state of readiness and must always be prepared to act on an emergency basis. In the event, their first duty is to prevent the loss of life; following that, to limit the environmental impact.

When no lives are at stake, the principal concerns become to stop the leak and contain the damage (put out the fire and prevent its further spread). To perform this function efficiently and effectively requires specialized equipment and trained personnel. These are the resources that must be provided by the Coast Guard when large spills occur in open waters where private efforts may be of no avail. The amount and disposition of these resources is the subject of this study.

1.2 PROBLEM DESCRIPTION

Executive Order 11735 requires the Coast Guard to coordinate and direct pollution control efforts at the scene of an actual or potential oil spill on coastal waters of the United States. In most instances, especially in protected waters, this effort is limited to overseeing the actions of the party responsible for the spill or of his representatives. If the predesignated On-Scene

In order to arrive at reasonable answers to these and other questions, certain guidelines and assumptions have been agreed to and are presented in the next section of this Report.

1.3 ASSUMPTIONS AND GUIDELINES FOR THE OIL POLLUTION RESPONSE SYSTEMS STUDY

a. The regions of interest in the equipment siting study are the coasts, harbors, and adjacent waters of the contiguous United States, plus Puerto Rico, the Great Lakes, and oceanic waters out to 50 miles* from shore. In this context, the adjacent waters are defined to include rivers, bays and estuaries from the coast up to the agreed upon boundary that separates the area of responsibility of the Coast Guard from that of the Environmental Protection Agency.

b. The incidents to be studied are those involving actual and potential spills of 50,000 gallons or more of oil or oil products. Data will also be collected for spill magnitudes between 10,000 and 50,000 gallons.

c. For the purposes of this study, a response requirement for major spills, up to 100,000 tons (28×10^6 gallons) in magnitude, is to be able to make an adequate response within six hours.

d. An adequate six-hour response to a spill of 50,000 gallons or more is assumed to include the following features:

1. The On-Scene Coordinator has arrived at the response center.
2. The OSC has assessed the situation and has established an initial operating plan.
3. Lines of communication have been established.
4. The OSC has established control of the equipment he estimates will be needed.
5. Coast Guard response personnel have been briefed and dispatched in accordance with OSC orders.
6. Coast Guard response equipment requested by the OSC has arrived at the designated debarkation point.

---

*Recent law extends some of the U.S. Coast Guard's responsibilities to 200 miles from shore.

3. An effective response is beyond the present state-of-the-art whenever wave heights exceed five feet (sea state 4, or greater).

1.4 THE SCOPE OF THIS REPORT

This final report presents the results of work completed on the two principal tasks of this project: the Equipment Siting Study and the Massive Spill Study. An equipment status study was the subject of a separate working paper issued in April 1978. Applicable portions of that study are included in Section 6 of this report.

The Equipment Siting Study has been based primarily on historical data relating to petroleum throughput and concomitant oil spills. As one might expect, the number of spills increases in proportion to the product flow. A more detailed analysis of the statistics of spills greater than 50,000 gallons enables one to calculate expected spill distributions for each of several high-risk areas and to project spill probabilities cautiously into the future. The effects of future deepwater ports, of offshore drilling, and of shifts in the domestic/import oil trade, including transient tankers and lightering, have also been examined.

On the basis of the projected spill potential, it has been possible to produce and evaluate several equipment site configurations which satisfy the six-hour response requirement using land and/or sea transport. The configurations, together with suitable assumptions about the numbers of spills to be expected in specific regions and the availability of all the elements of the Coast Guard baseline response system, provide the grounds for estimating desirable equipment levels at each site in a few selected configurations.

Although spills in excess of 50,000 gallons are not uncommon in U.S. coastal waters, in the four year period, 1974-1977, only one accidental spill of this magnitude occurred in the 3 mile to 50 mile zone - the Argo Merchant in Dec. 1976. This incident is in the class of Massive Spills which is the second subject of this

2. TECHNICAL APPROACH

The overall project objectives may be summarized in the answers to four questions:

a. What probable spills must the U. S. Coast Guard be prepared to combat in the next decade?
b. What types of equipment are needed?
c. How much of it is needed?
d. Where should it be located?

A fifth question may be added, the answer to which follows from the answers to the first four: What personnel, maintenance, communications and logistic support are required.

2.1 OUTLINE OF TASKS

The first question must be answered at least partly before the remaining ones can be attacked. An estimate of the number, location, size, and type of spills to be dealt with is fundamental to assessing what types or quantities of equipment are required, or where it should be placed. Hence, the Geographic Spill Potential Study, described in Section 3, is the starting point in the technical approach. The sequence of investigation, starting with the Geographic Spill Potential Study,is as follows:

Geographic Spill Potential

The projection of spills to be dealt with in the next decade proceeds from a study of historic spills in the recent past. Data have been gathered for the 1974-1977 period on actual and potential spills in the United States. The national and regional spill rates can be related to oil throughput, historically, and projections made of the number of spills as a function of oil traffic. By adding considerations of future deep-water ports, offshore drilling and import/domestic oil trade, these estimates can be improved to cover the 1980-1990 decade.

Site Selection

Site locations will be selected so that (1) as many potential debarkation points as possible lie within the response range of some site, and (2) the average time required to respond to a spill is a practical minimum. Sites will be selected to achieve the first objective by a geometric/geographical approach, and to achieve the second objective by ordering the areas of oil movement by their spill potential (i.e., expected number of spills per year). Several site configurations will be tried and measures of effectiveness applied to compare them. These measures will include (1) the number of potential debarkation points not covered by some site, (2) the number of debarkation points covered by two or more sites, (3) the number of past actual and potential oil spills with debarkation points outside of coverage, (4) the amount of oil movement occurring at ports that are also equipment sites, and (5) the average time to respond to a spill. Based on these measures, one or more site arrangements will be selected.

Equipment Levels

Relative equipment levels at the sites will be determined by considering the expected number of oil spills in the regions covered by the sites, and the expected distribution of spill volumes. Absolute levels of equipment will be related to net effectiveness, using the offloading and recovery rates and capacity derived in the equipment capabilities assessment.

Sheltered Water Coverage

Although open water spills present the most demanding pollution response problems for the Coast Guard, the numerous spills that occur in sheltered waters, or under moderate conditions in open water, are also of concern. Not all such spills are small; many occur in currents that equal or exceed present containment capabilities. The above sequence of tasks provides a basis for selecting equipment site locations, relative and absolute equipment levels, and equipment types, keyed primarily to open water spills in difficult circumstances. These selections will be extended to assure adequate coverage of spills in sheltered waters, from the points of view of site location, equipment type, and equipment quantity.

3. GEOGRAPHIC SPILL POTENTIAL

In this section the geographic spill potential will be developed by examining first the relationship between the historical experience of oil spills and petroleum throughput volumes. Following this, spill threat spectra will be derived based on national and regional (geographic) throughput levels.

3.1 HISTORICAL OIL SPILL DATA BASE

The fundamental assumption in the derivation of probabilities of future oil spill occurrence is that meaningful estimates of spill frequency can be based on past experience. To this end, historical data on oil spills were obtained from reports of and personal contacts with the U.S. Coast Guard (USCG), Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM) of the Department of the Interior (DOI), from non-governmental organizations, and from the open literature. Review of the available information revealed the fact that no one source of historical oil spill data was sufficiently extensive to satisfy the information needs of this effort. It thus became necessary to construct an appropriate data base to include all post-1973 spills of 50,000 gallons or more in and around the United States.* The spill size was selected so as to be consistent with earlier studies (References 3-1 and 3-2), and the time period to allow maximum correlation of multiple sources of information on identifiable spills.**

The resultant data base, designated the Major Oil Spill Information System (MOSIS) consists primarily of information available from the following USCG sources, each of which contains some unique data:

---

*Data was also collected for spills between 10,000 and 50,000 gallons for future consideration.

**1974 is the first year for which both PIRS and NRC data are available.

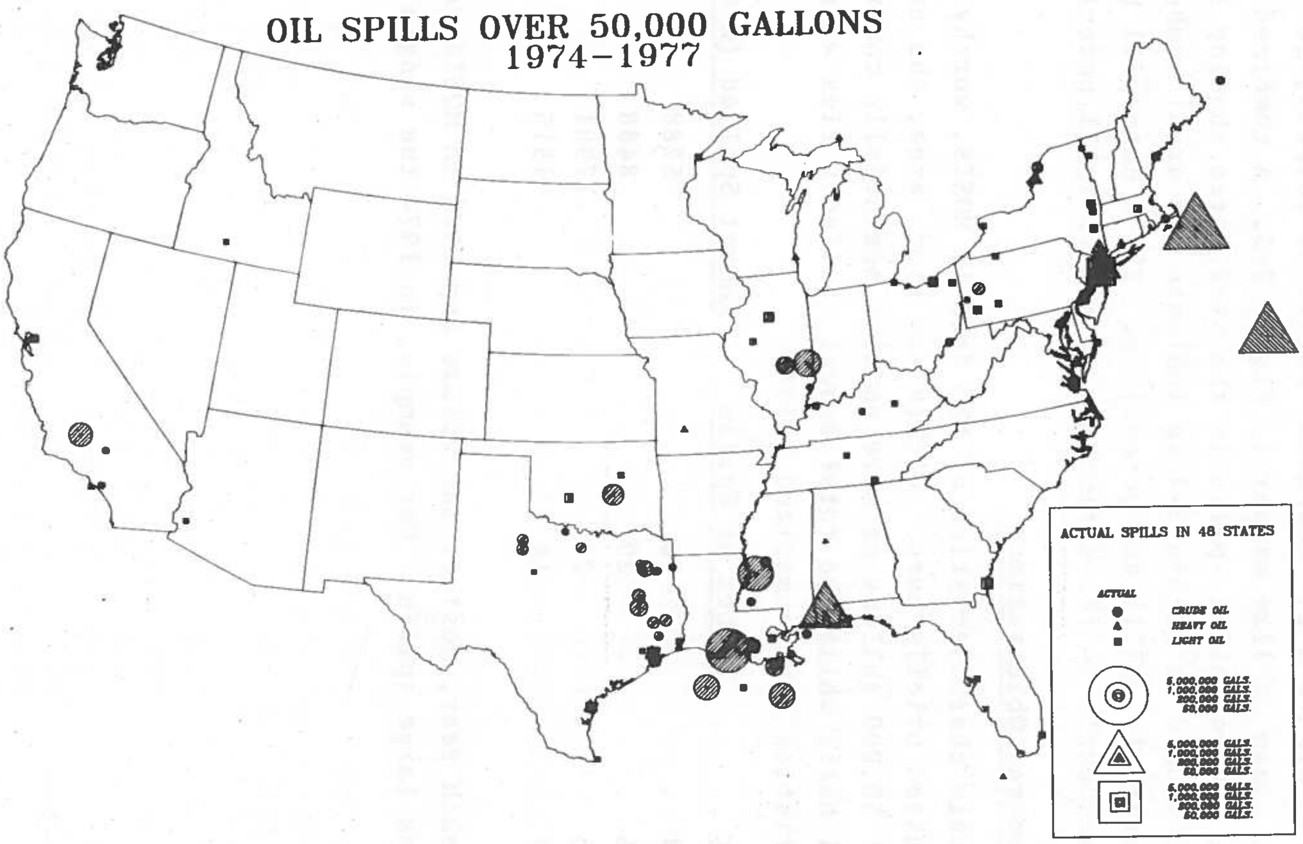


FIGURE 3-1. ACTUAL SPILLS IN 48 UNITED STATES, 1974-1977

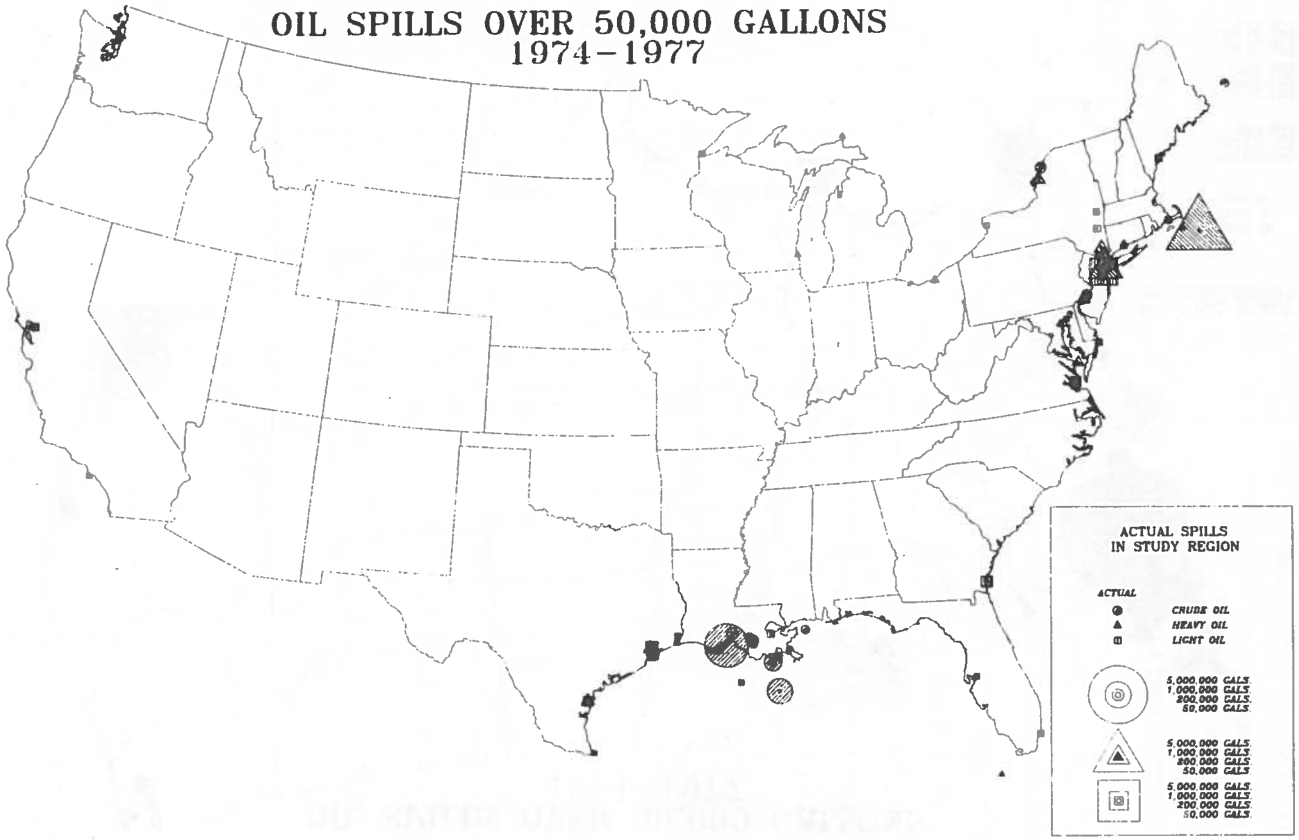


FIGURE 3-2. ACTUAL SPILLS IN STUDY AREA, 1974-1977

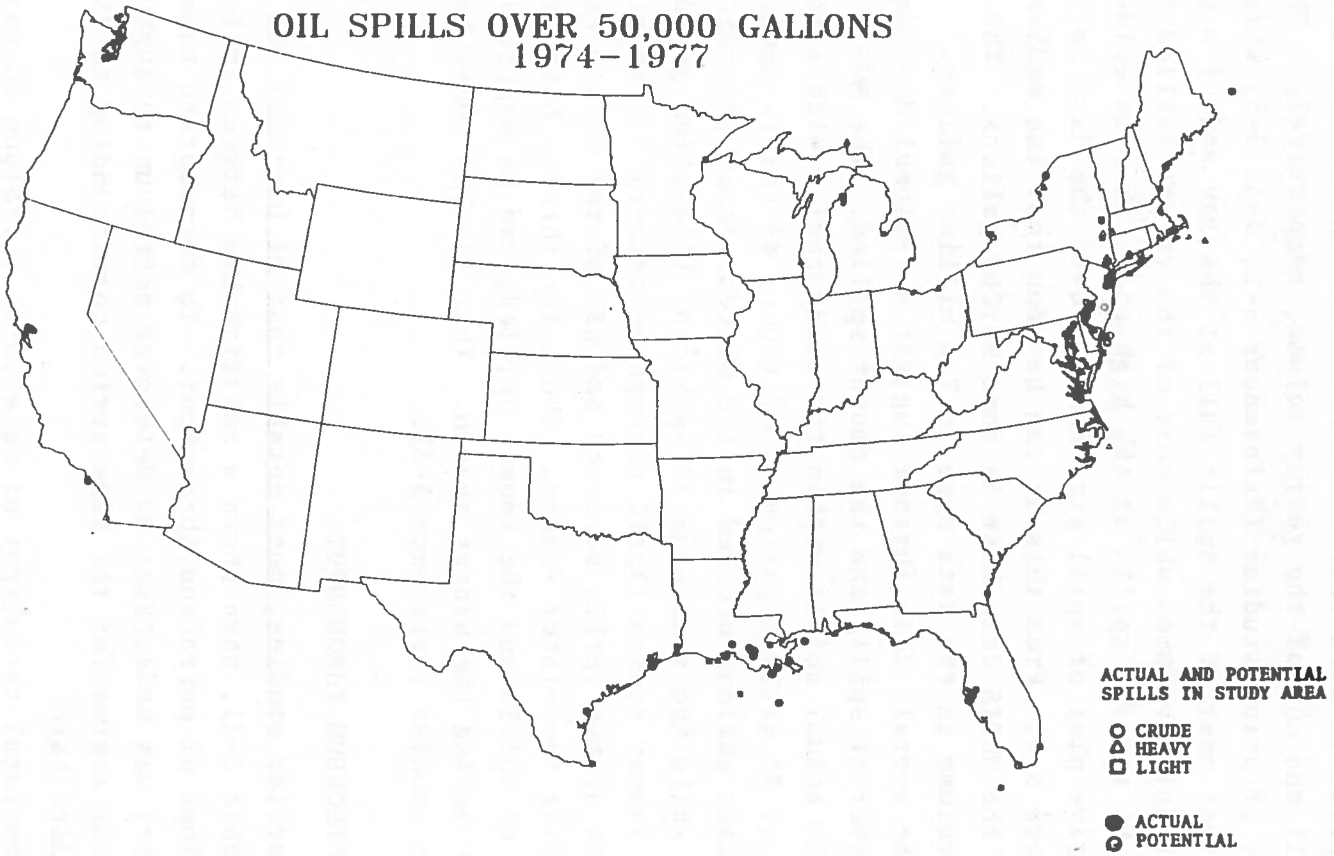


FIGURE 3-4 DISTRIBUTION OF ACTUAL AND POTENTIAL SPILLS IN THE STUDY AREA

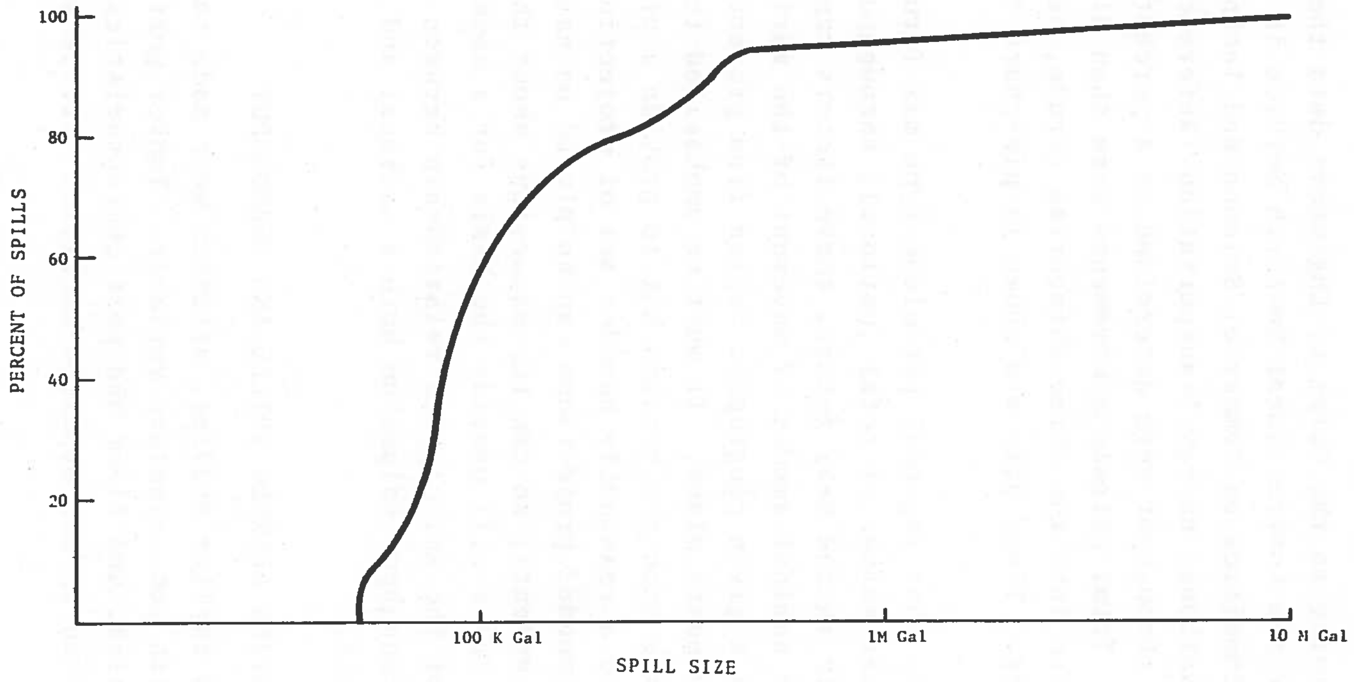


FIGURE 3-5. CUMULATIVE OF SPILL SIZE DENSITY FOR SPILLS $\geq$ 50,000 GAL

TABLE 3-1. PETROLEUM THROUGHPUT IN THOUSANDS OF SHORT TONS

Year	Domestic Coastal*	Local**	Import	Total
1974	182838	61473	328725	573036
1975	184397	55375	332473	572245
1976	190416	58565	414542	663523
1977 (Estimated)	195000	60000	520000	775000

---

*Includes traffic between Great Lakes ports and seacost ports.

**Includes traffic within a single channel of a port and traffic between the several channels of a port. Includes such traffic within Great Lakes ports.

FIGURE 3-7. CRUDE OIL MOVEMENT BY WATER 1974 (FROM REFERENCE 3-6)

in these attempts due primarily to incomplete or inconsistent data or to a determination that the candidate exposure variable was an inappropriate measure. Based on the degree of correlation between the number of spills and petroleum throughput found in other studies (e.g., References 3-1 and 3-2), linear regressions were performed to determine what, if any, degree of correlation exists between the two using the data of Sections 3.1 and 3.2. Regressions were carried out for both the overall study region and for selected geographic areas (regional level) where data permitted for both actual and potential spills.

3.3.1 Actual Spill Data

3.3.1.1 Overall Study Area - The spill and petroleum throughput data for actual spills within the overall study region are summarized below:

Year	Actual Spills	Throughput(MT)
1974	20	573.0
1975	20	572.2
1976	22	663.5
1977 (E)	18	775.0

where MT represent millions of short tons. The least squares fit to the cumulative of these data is:

$$n = 2.057 + 0.0314V$$

where n is the number of spills and V the throughout volume in MT. Figure 3-9 shows this relationship graphically. This relationship has a correlation coefficient of 0.9965 and a standard error estimate of 2.337. The nominal spill rate over this data period is thus 0.0314 spills per million tons of pertroleum throughput. The maximum and minimum rates are 0.0349 (+11%) in 1975 and 0.0232 (-26%) in 1977.

3.3.1.2 Regional Level - Reference to the areal number density plot of Figure 3-4 indicates that there are few geographic regions that have historically experienced a large enough number of major spills to be examined as separate entities. In fact, only four such regions can be tentatively identified: Greater New York with 12 spills, Delaware Bay with 7, the Louisiana Coast with 19, and the Northern Coast of Texas with 8. No other region had more than 3 major spills in the four years of record.

From the considerations of Section 3.2, the regions noted above represent, nominally, 21.5, 4.7, 10.5 and 15.2 percent, respectively, of the total annual waterborne petroleum throughput volume. Least square fits to the regional spill and throughput data are as follows:

Greater New York: $n = -0.171 + 0.0212V$

Delaware Bay: $n = 0.0627V$

Louisiana Coast: $n = 0.852 + 0.0682V$

North Texas Coast: $n = 0.818 + 0.0193V$

where once again n is the number of spills and V is the throughput volume in millions of short tons. The associated correlation coefficients and standard errors of estimate are as follows:

	Correlation Coef.	Standard Error
Greater New York	0.991	0.567
Delaware Bay	0.978	0.575
Louisiana Coast	0.995	0.631
North Texas Coast	0.976	0.596

As with the overall study region, these regional relationships indicate a very high degree of correlation between spill rate and throughput volume. These relationships are shown graphically in Figure 3-10, along with that of the nationwide average for comparison. From these plots it is evident that there can be considerable variation in spill rate from region to region. However, for regions other than those identified here, there is little choice but to apply the nationwide average.

3.3.2 Potential Spill Data

3.3.2.1 MOSIS File Data - The attempt to correlate potential spills in the MOSIS file with petroleum throughput did not meet with the same success reported above. This should be apparent from the annual potential spill data summarized below for the overall study area and the selected geographic regions.

Year	Overall	New York	Delaware Bay	Louisiana Coast	North Texas
1974	25	10	4	0	0
1975	28	6	7	0	0
1976	14	0	1	0	0
1977	9	0	1	1	0

Although some degree of correlation can be inferred for the overall study region, there is no meaningful degree of correlation in the sub-regions. The reasons for this are related to many questions as to the definition of potential spills and/or the manner in which they have been reported in the past. Due to this lack of correlation, these potential spill data were not further considered in this study.

3.3.2.2 USCG Casualty File Data - The lack of success met in the attempt to use the potential spill data available to the MOSIS file led to consideration of the use of those incidents reported in the USCG Casualty file which could be potential sources of oil spills. The data available for such consideration spanned the time period from FY1972 to FY1975. During this period over 20,000 tanker and barge casualties were reported. Vessels of greater than 10000 GT were involved in some 2180 or 11% of these incidents which were distributed by cause as summarized in Table 3-2. Identification of incidents where there is a potential of a spill $\geq$50,000 gallons is not possible, directly from the casualty file. The format used in the computerized casualty data management file was developed to facilitate the use of these casualty data by permitting the rapid sort on and/or retreival of selected data such as that shown in Table 3-2. The number of data elements required to characterize an incident for casualty evaluation purposes precludes the inclusion of sufficient ancillary data for spill potential assessment. The requisite data for this purpose can be had only through review of the narrative reports on file for each incident. Because of the number of incidents to be evaluated and the uncertainty of a useful end-product, a detailed evaluation of the casualty file for spill potential was not undertaken during this study, and no potential spill data were used in subsequent analyses.

3.4 SPILL THREAT ANALYSIS

The methodology employed here to estimate probabilities of oil spill occurrence was taken from Devanney and Stewart (Reference 3-2). The application of this methodology requires the acceptance of three basic assumptions: the fundamental assumption that meaningful estimates of future spill incidents can be based on past experience, plus the two further specific assumptions (1) that spills occur independently of each other (i.e., as a Poisson process) and (2) that the number of spills is proportional to the volume of petroleum throughput. The data of the preceding sections are quite supportive of these assumptions.

The referenced methodology is developed from the assumption that spill experience is a Poisson process. If, within this process, the intensity, λ, is known, the probability density of the number of spills can be determined from the expression:

$$p(n|\lambda,t) = \frac{e^{-\lambda t}(\lambda t)^n}{n!}$$

where t is the amount of exposure contemplated and λ is the mean spill rate in spills per unit exposure.

Nominal spill rate as a function of throughput volume was examined in Section 3.3 where a high degree of correlation was noted. However, this correlation does not imply certainty. Thus, for example, past experience of ν spills in τ volume throughput does not necessarily imply that $\lambda = \nu/\tau$. In the limit, of course, the larger ν and τ the more likely it is that λ approaches ν/τ. However, with a limited data base, which is most certainly the

3.4.1 Overall Study Area

The probability density distribution described above was applied to the spill and throughput data of Section 3.3.1 to determine overall spill threat spectra for the study region. This was done in parametric fashion about throughput volume to permit generalized application to most geographic regions of concern. The discrete threat spectra so determined are shown in Figure 3-11 (parts a, b, c, and d), along with an indication of the mean (or expected value) of the distribution as shown in alternative forms in Figures 3-12 and 3-13. The first, Figure 3-12 is a cumulative plot of the information contained in the threat spectra of Figure 3-11, indicating the cumulative probability of n or fewer spills of 50,000 gallons or more as a function of throughput volume. The cumulative is convenient in that the probability that the actual number of spills will fall between any two specified values can be determined by simply subtracting the cumulative associated with the higher value from that associated with the lower. Although smooth curves are shown in Figure 3-12 connecting the high points of the cumulative steps, it must be remembered that, in the real world, spills occur in integral units and these integral points are the only ones that have any physical meaning.

Figure 3-13 is a restatement of the threat wherein the probability that there will be at least n spills of the magnitude considered for the indicated throughput volumes is presented. This format is particularly useful in estimating bounds on spill expectations.

The use of the information in these figures to provide "average" estimates throughout the study area requires only an estimate of the throughput volume experienced by a given area over an arbitrary time period since, by this treatment, prior spill experience becomes an endogenous parameter with throughput volume being the exogenous determining function. The range on parametric throughput has been made sufficiently wide to accommodate almost any regional throughput on an annual basis, at least over the next decade. It can also accommodate many regions over extended periods of time.

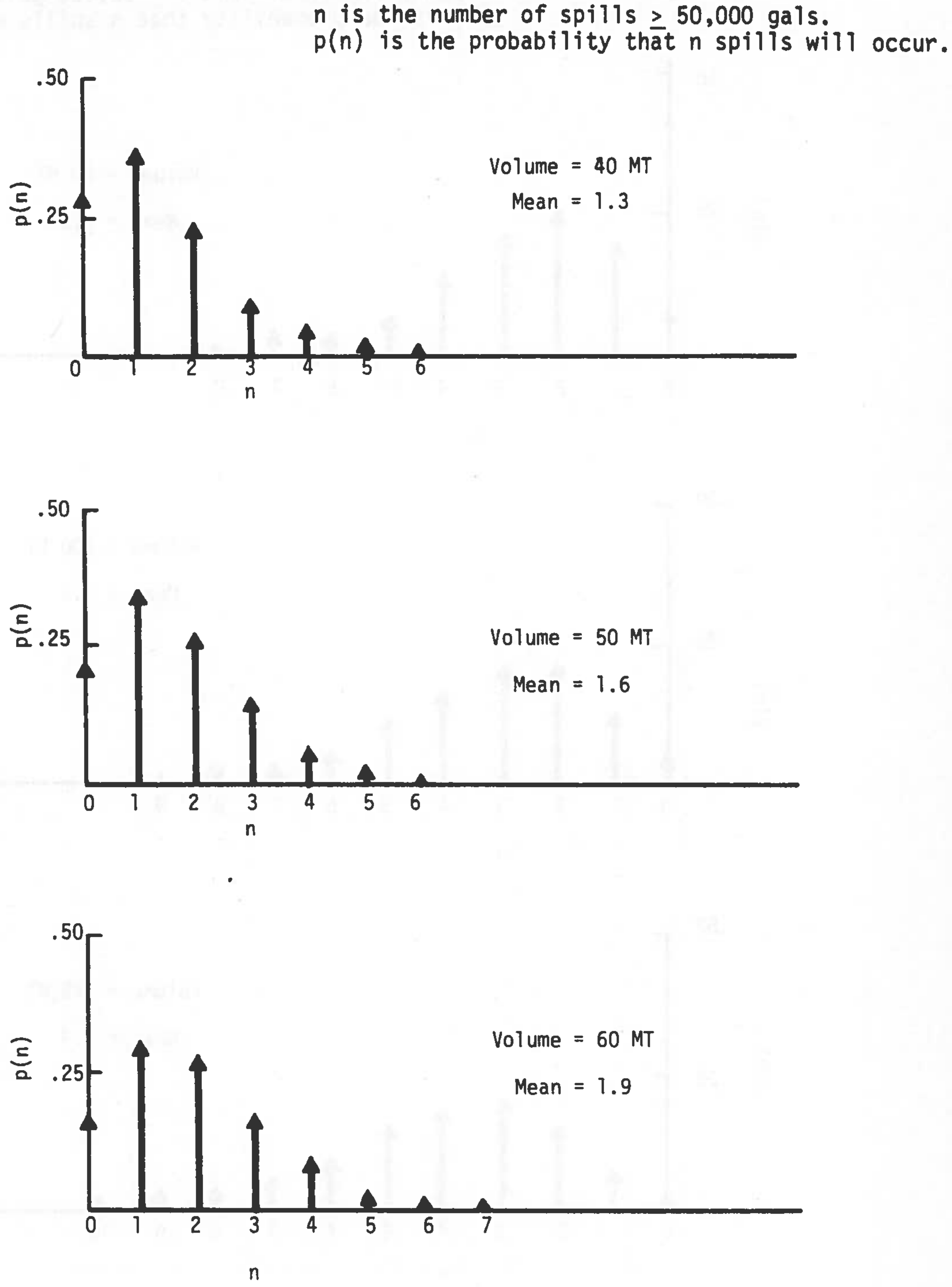
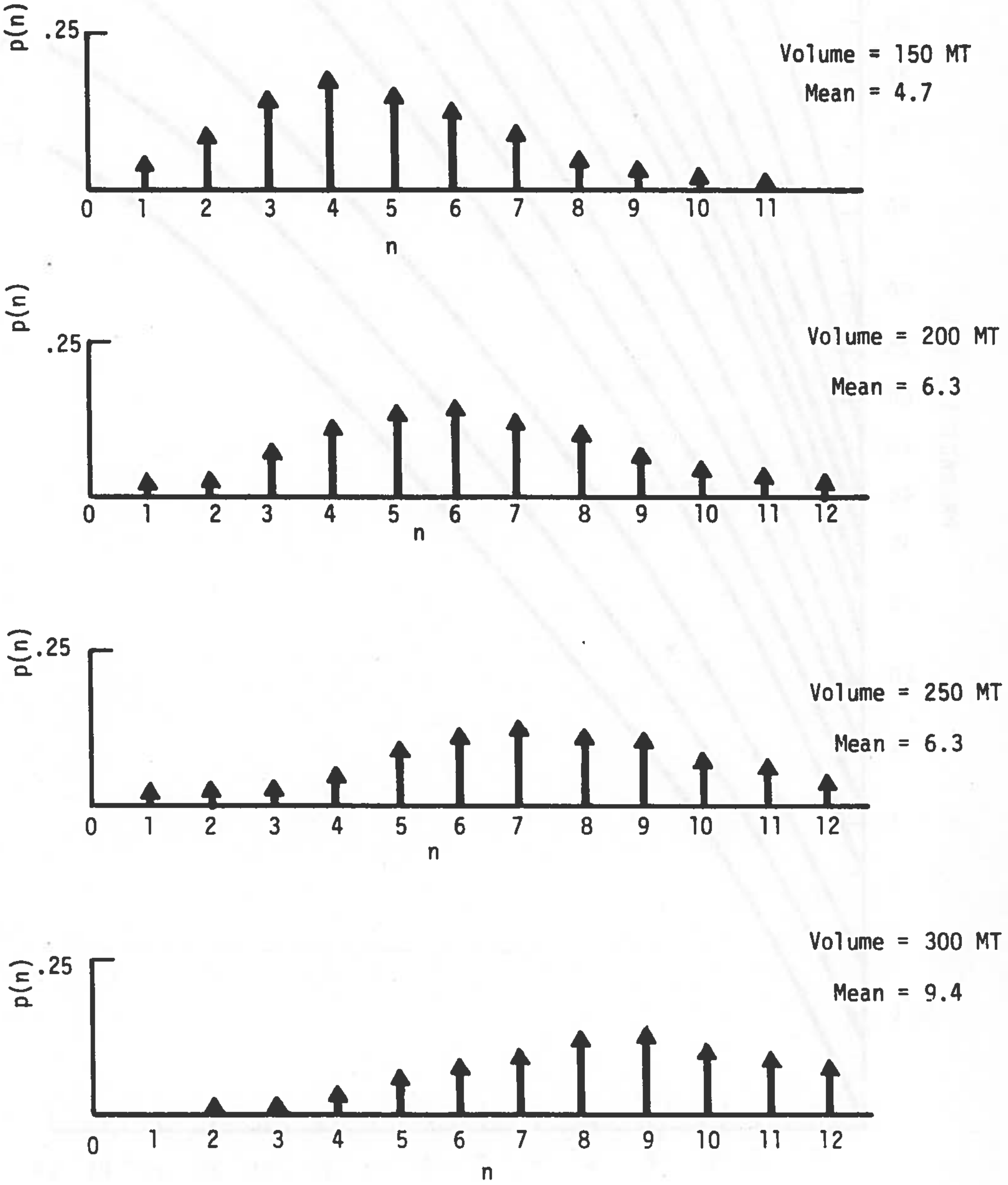


FIGURE 3-11(b). OVERALL SPILL THREAT SPECTRA AS A FUNCTION OF THROUGHPUT VOLUME IN MILLIONS OF TONS



n is the number of spills $\geq$ 50,000 gals
p(n) is the probability that n spills will occur.

FIGURE 3-11(d). OVERALL SPILL THREAT SPECTRA AS A FUNCTION OF THROUGHPUT VOLUME IN MILLIONS OF TONS

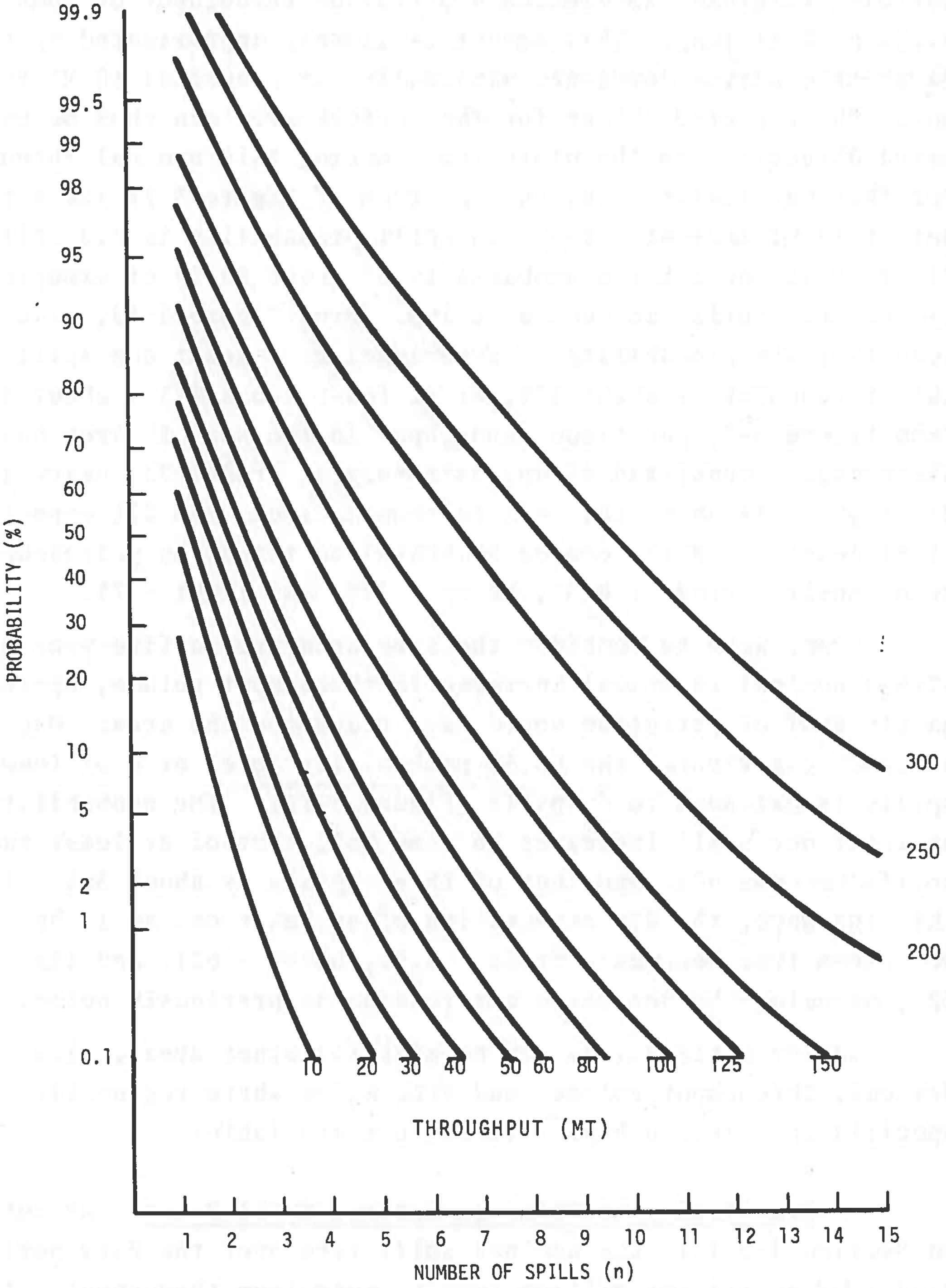


FIGURE 3-13. PROBABILITY OF AT LEAST n (>n) SPILLS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS

nominal were examined to determine the sensitivity of the information contained in Figures 3-12 and 3-13 to such excursions. The results of this analysis are summarized in Figure 3-14 where the upper, lower, and nominal expectancies of n or less spills are plotted as a function of throughput for the 50% and 95% probability levels. These plots indicate that spill expectancies resulting from the extreme observed spill rates are about plus or minus one spill from the nominal over the expected range of individual port throughput experience. Hence, the spill probabilities reported in the preceeding section are not overly sensitive to departures from the nominal spill rate and can be used with some degree of confidence in the future if spill rates fall within the noted extremes.

3.4.2 Regional Level

As noted in Section 3.3.2, there are four geographic regions wherein threat spectra other than the nationwide average can be tentatively identified: Greater New York, Delaware Bay, the Louisiana Coast and the Northern Texas Coast.

The cited regions were individually subjected to the treatment described above for the overall study region. The results for each region are summarized separately in Figures 3-15 through 3-18, where estimates of spill probabilities are shown parametrically for nominal current and future (1980, 1990) throughput volumes. These figures contain the combined information content of Figures 3-12 and 3-13, as previously described.

It is immediately obvious from these charts that, although there is a high degree of spill-throughput correlation in each region, a marked variablity of spill potential can be expected from one geographic region to another. The four regions cited account for 57.6% of the spills in the MOSIS file and 51.9% of the throughput. The spill-throughput relationship in each of the noted

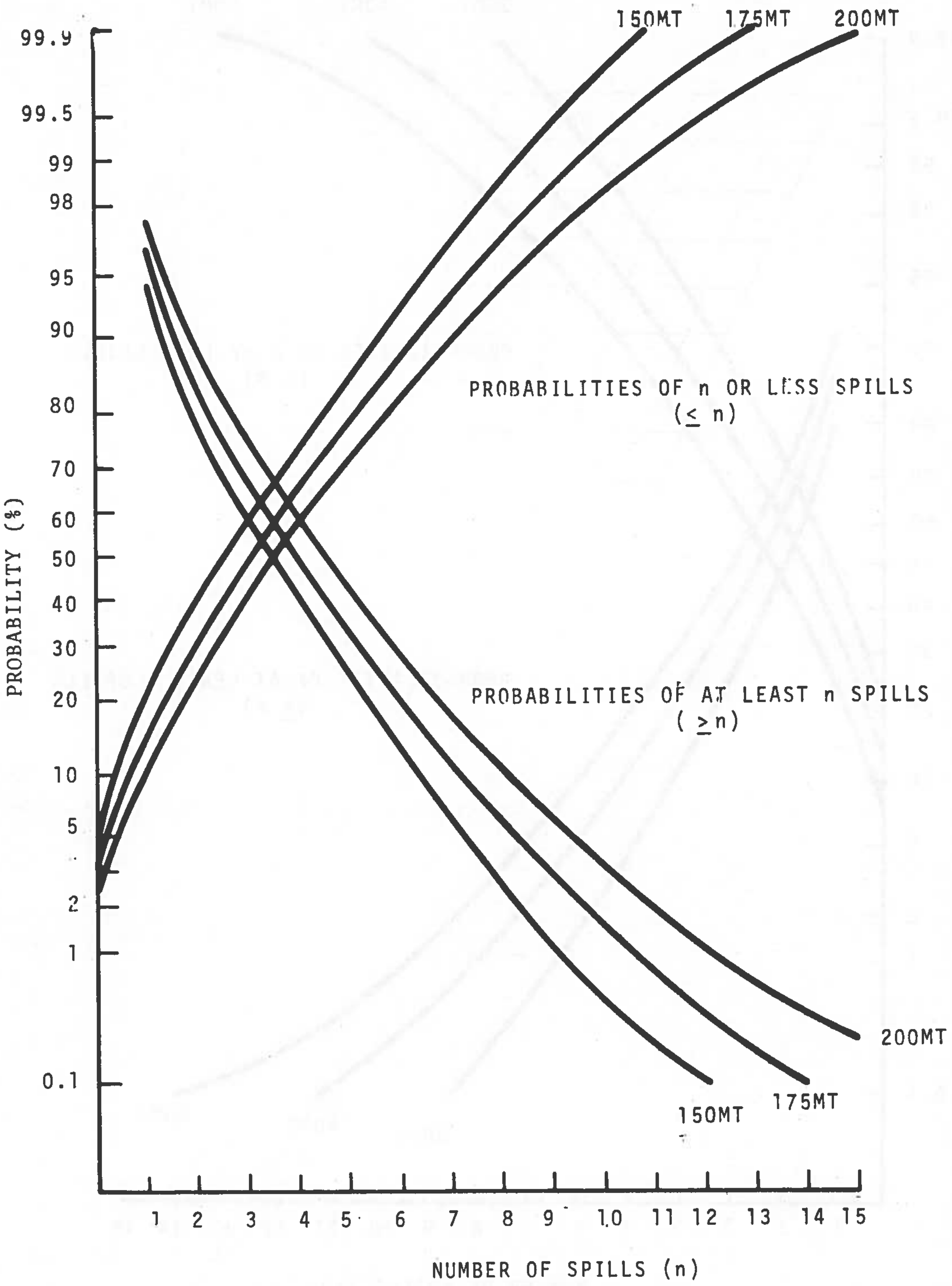


FIGURE 3-15. PROBABILITIES OF SPILLS ≥ 50,000 GALLONS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS --- GREATER NEW YORK REGION

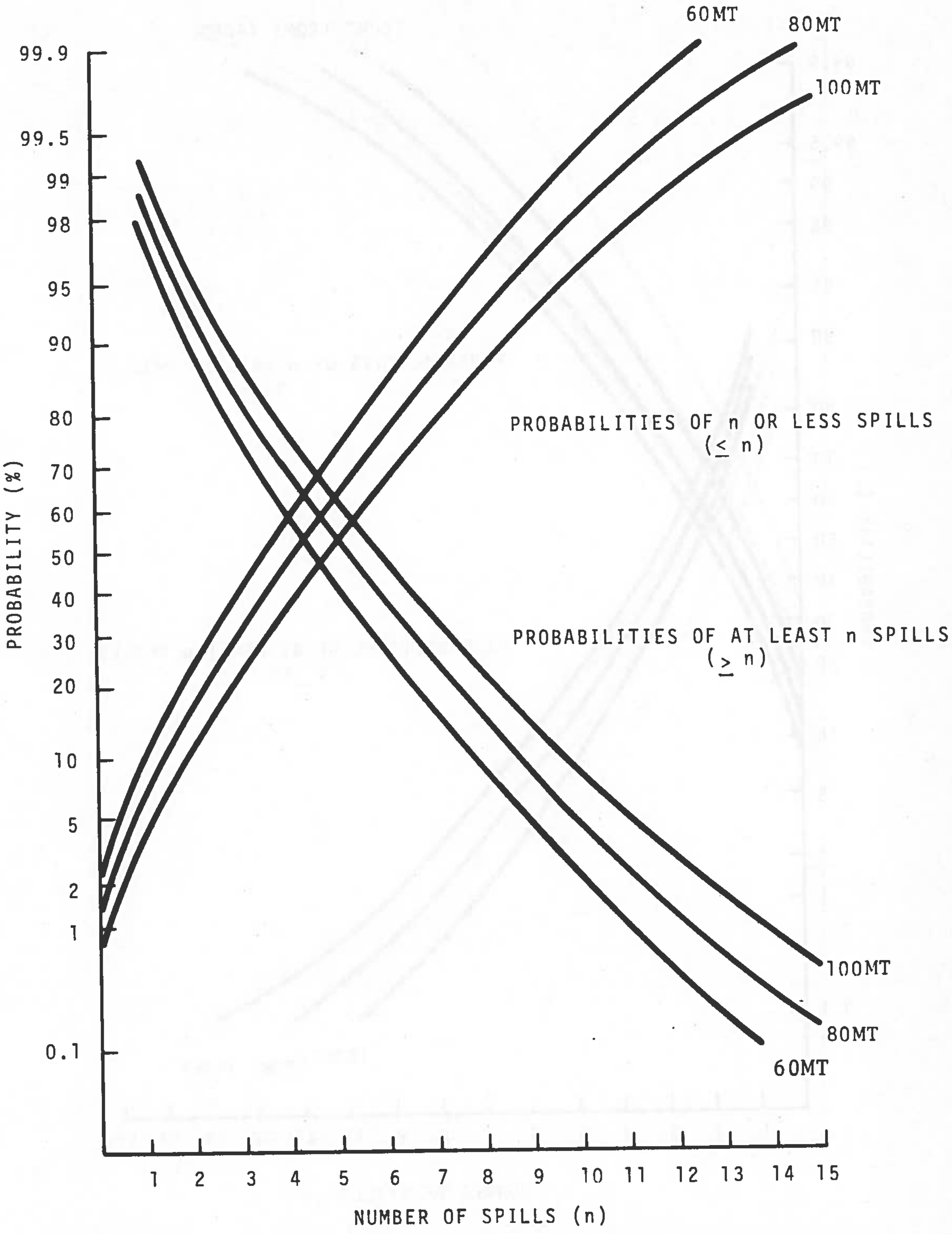


FIGURE 3-17. PROBABILITIES OF SPILLS > 50,000 GALLONS AS A FUNCTION OF PETROLEUM THROUGHPUT IN MILLIONS OF TONS -- LOUISIANA COASTAL REGION

regions taken individually is far from this seeming one-to-one basis. This is evident from the regional spill-throughput statistics as summarized below:

Region	No. of Spills	% of Spills	% of Throughput
Gr. New York	12	15.0	21.5
Delaware Bay	7	8.8	4.7
Louisiana Coast	19	23.8	10.5
No. Texas Coast	8	10.0	15.2

Surprisingly enough, the region that one would intuitively suspect as being the most culpable, Greater New York, has a spill rate much below the nationwide average. This region does, however, rank quite high (number 2) on the basis of the number of spills. This is not at all surprising considering its share of the nationwide throughput. The real culprit, both as to the spill rate and the number of spills, appears to be the Louisiana Coast.

Delaware Bay and the North Texas Coast may be questionable regional choices because of the limited number of spills experienced. These regions have been included, however, to provide some degree of diversity since no other region experienced more than three spills in the time period considered. Of these two "candidates", the Delaware Bay region appears to be the higher risk area, comparable in rate to the Louisiana Coast.

3.4.3 Transient Tankers and Barges

In addition to the spill threat related to petroleum flow in or out of a given region, each region is also subjected to a further threat as a consequence of petroleum movement via transient tankers and barges en route to or from destinations outside the regions. A review of the Environmental Impact Statement for the LOOP deepwater port (Reference 3-7) reveals that spills from transient vessels are quite rare. As derived from that analysis, the expected rate of spills $\geq$ 50,000 gallons from transient tankers and barges is about 0.000245 spills per million tons of petroleum

The West Coast transient flow may increase appreciably with increased movement of Alaskan crude it is quite unlikely, however, that future West Coast flow would exceed that of the Gulf Coast noted above.

3.4.4 Outer Continental Shelf Wellfields

Although numerous oil wells have been drilled in waters off the U.S. coast, large quantities of oil resources remain to be recovered from the Outer Continental Shelf (OCS). Most of the OCS oil recovery activity to date has been concentrated in the Gulf of Mexico with lesser activity off the California coast. Major potential areas off the Atlantic coast have yet to be explored.

In anticipation of the prospect of increased activity in the Gulf of Mexico and the imminent exploratory operations in the Atlantic, the USGS has conducted oil spill risk analyses for the proposed lease areas in the Atlantic and the Gulf of Mexico (References 3-8 and 3-11), These analyses, which address the spill potential over the production life of the lease area, are summarized below:

Area	Production Life (Years)	Total Yield (MT)	Number of Spills*
North Atlantic	20	25-100	2.8
Mid Atlantic	25	60-210	5.6
South Atlantic	25	40-150	3.8
Gulf of Mexico	25	225-300	7.8

The locations of the proposed lease areas are shown in Figures 3-19 - 3-22 (References 3-8 - 3-11). The existing lease areas in the Gulf of Mexico are shown in Figure 3-23 (Reference 3-12) and those off the California coast are shown in Figure 3-24 (Reference 3-13).

---

*Expected number of spills ≥ 50,000 gallons over the production life of the area.

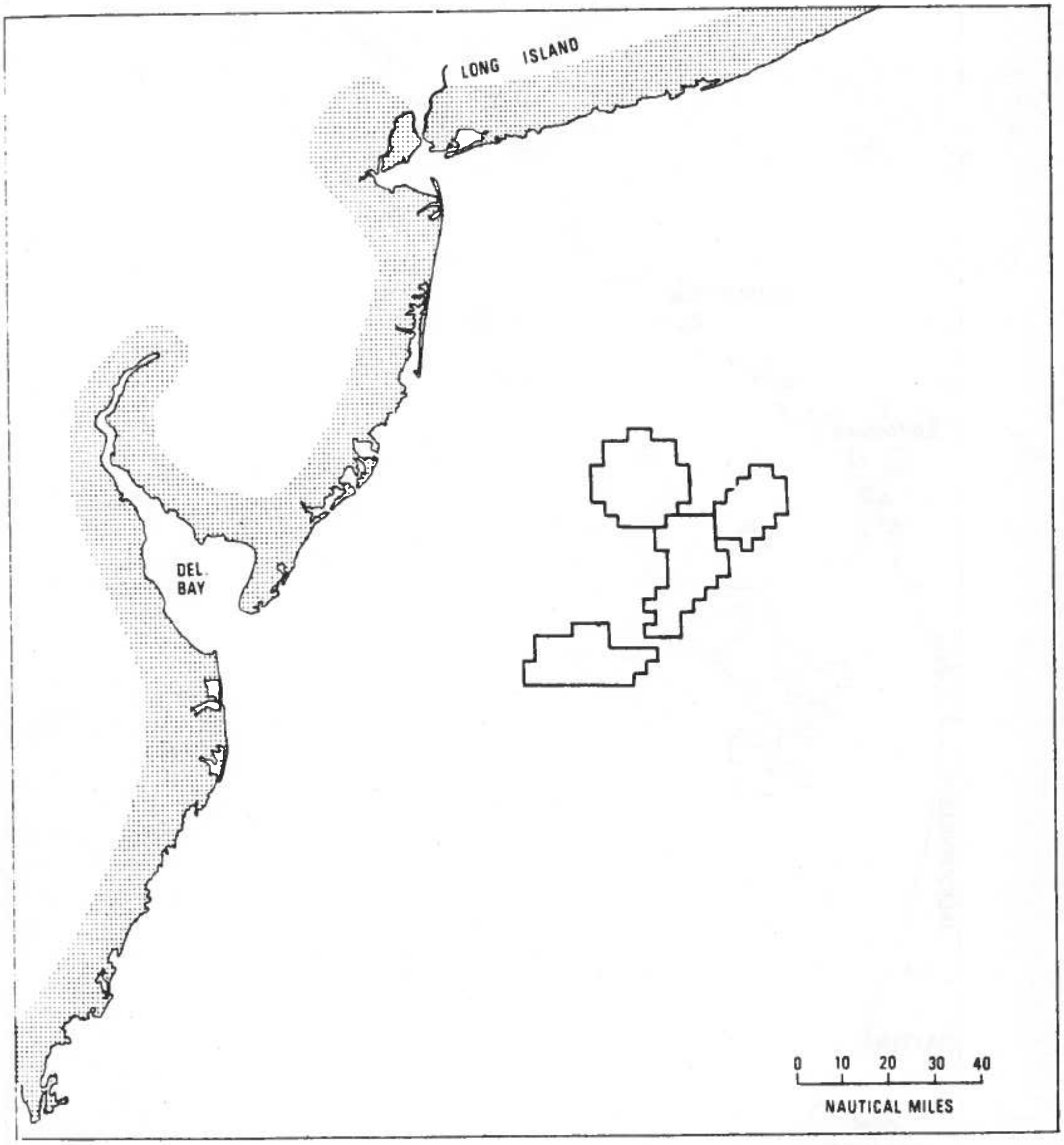


FIGURE 3-20. MAP OF THE MID-ATLANTIC OUTER CONTINENTAL SHELF SHOWING SUBDIVISION OF THE LEASE AREA (REFERENCE 3-9)

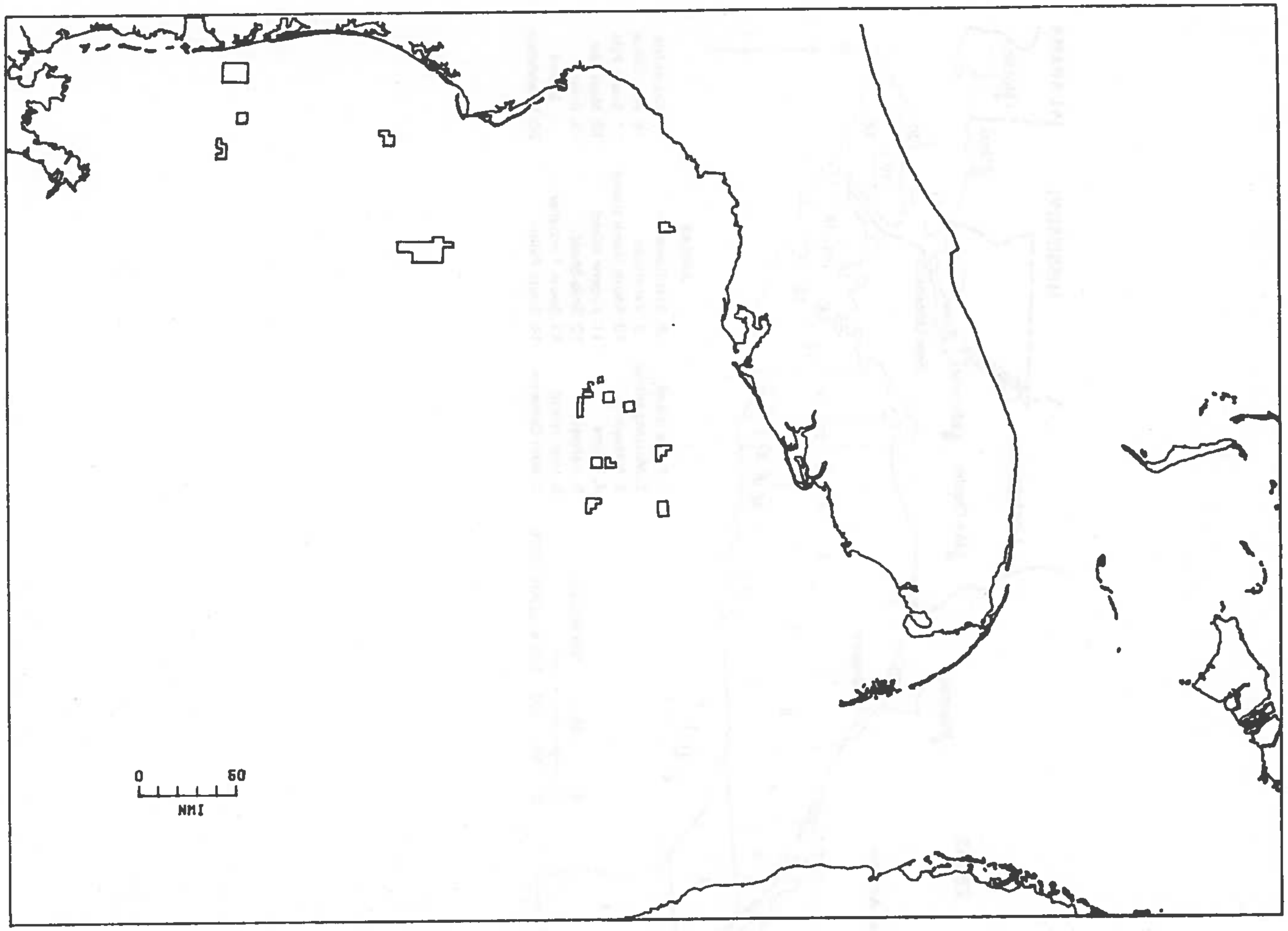


FIGURE 3-22. MAP OF THE EASTERN GULF OF MEXICO OUTER CONTINENTAL SHELF SHOWING SUBDIVISION OF THE LEASE AREA (REFERENCE 3-11)

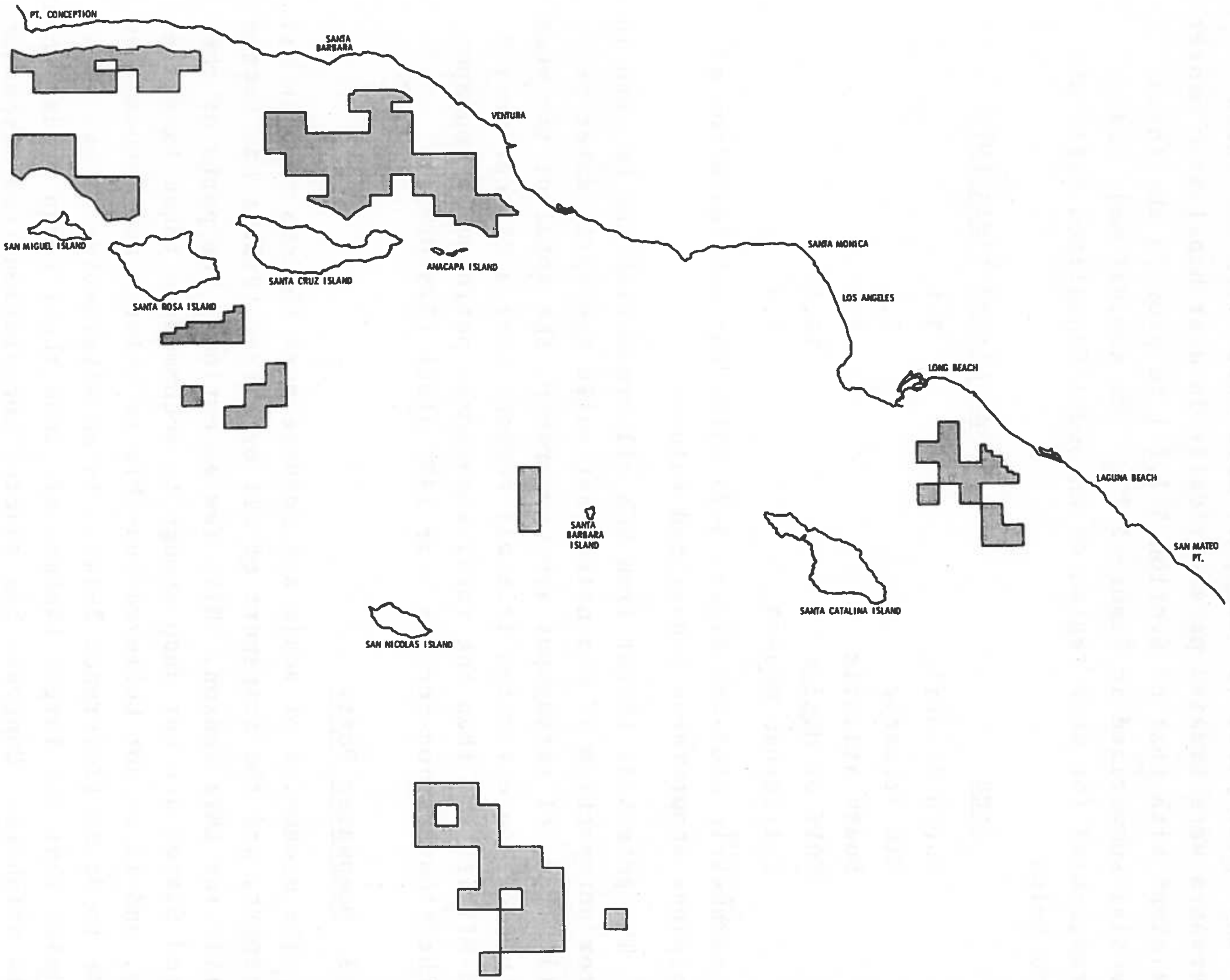


FIGURE 3-24. WEST COAST OUTER CONTINENTAL SHELF LEASE AREAS

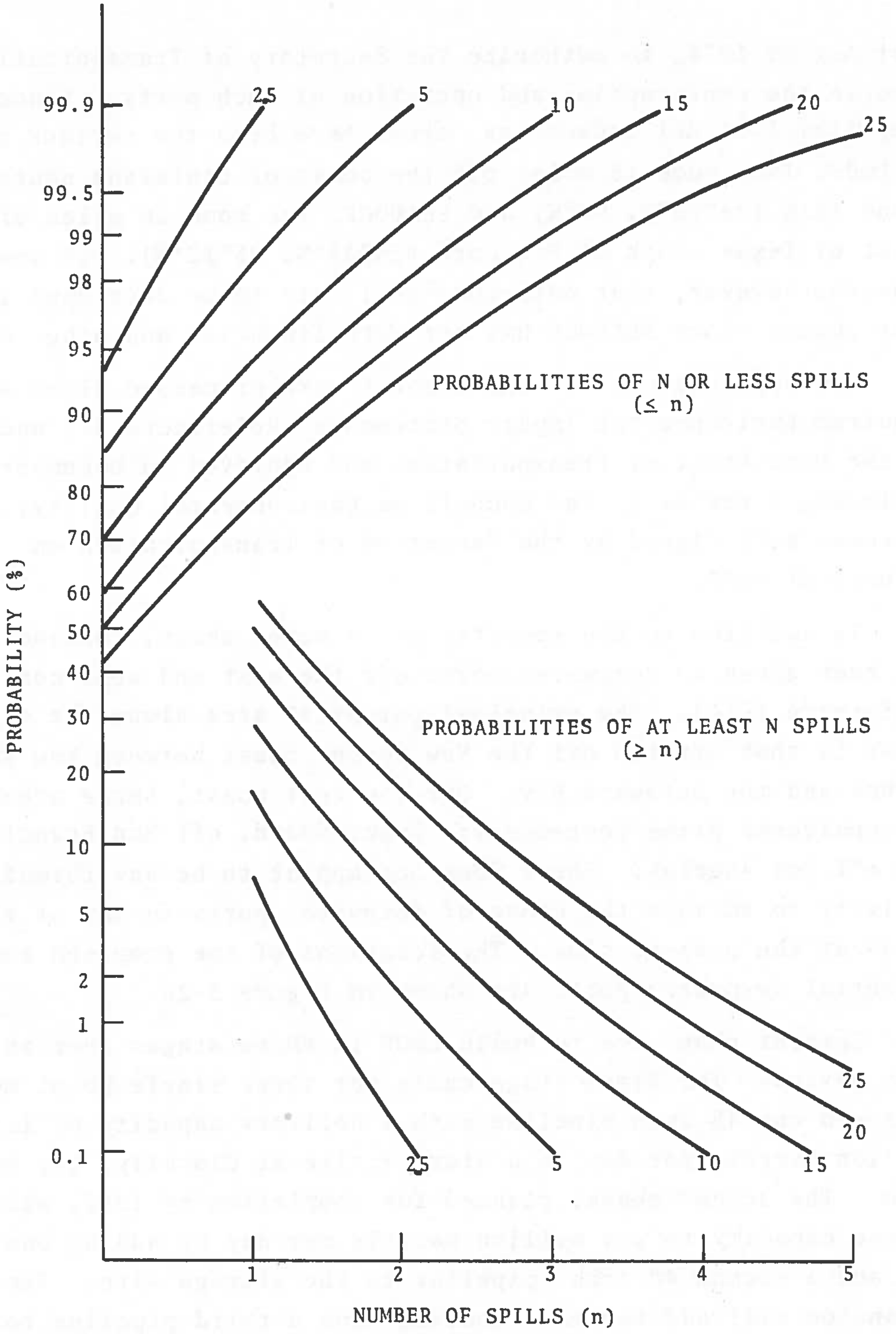


FIGURE 3-25. PROBABILITIES OF SPILLS $\geq$ 50,000 GALLONS FROM OUTER CONTINENTAL SHELF OIL PRODUCTION AS A FUNCTION OF YIELD IN MILLIONS OF TONS

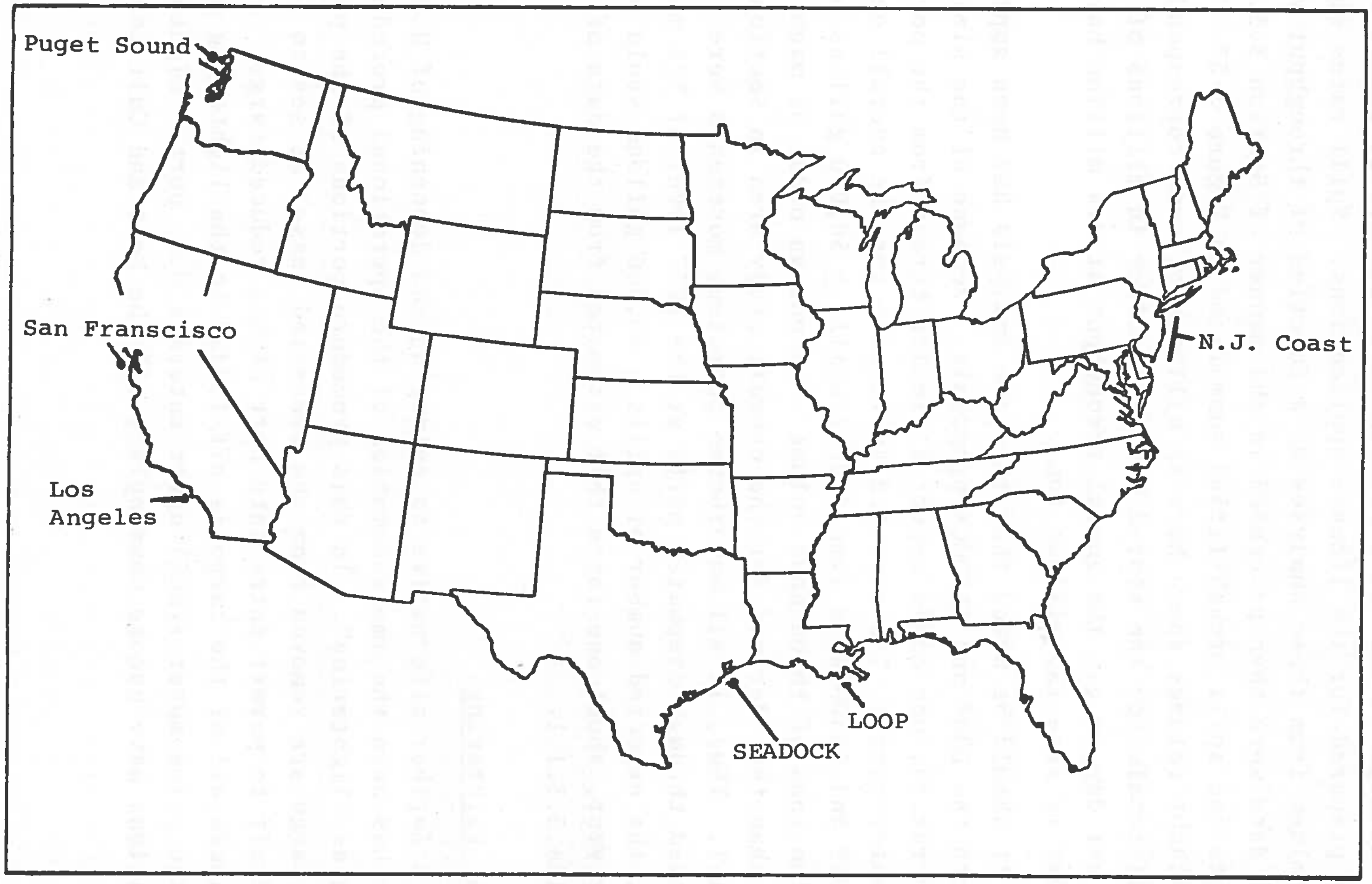


FIGURE 3-26. EXPECTED LOCATIONS OF DEEPWATER PORTS

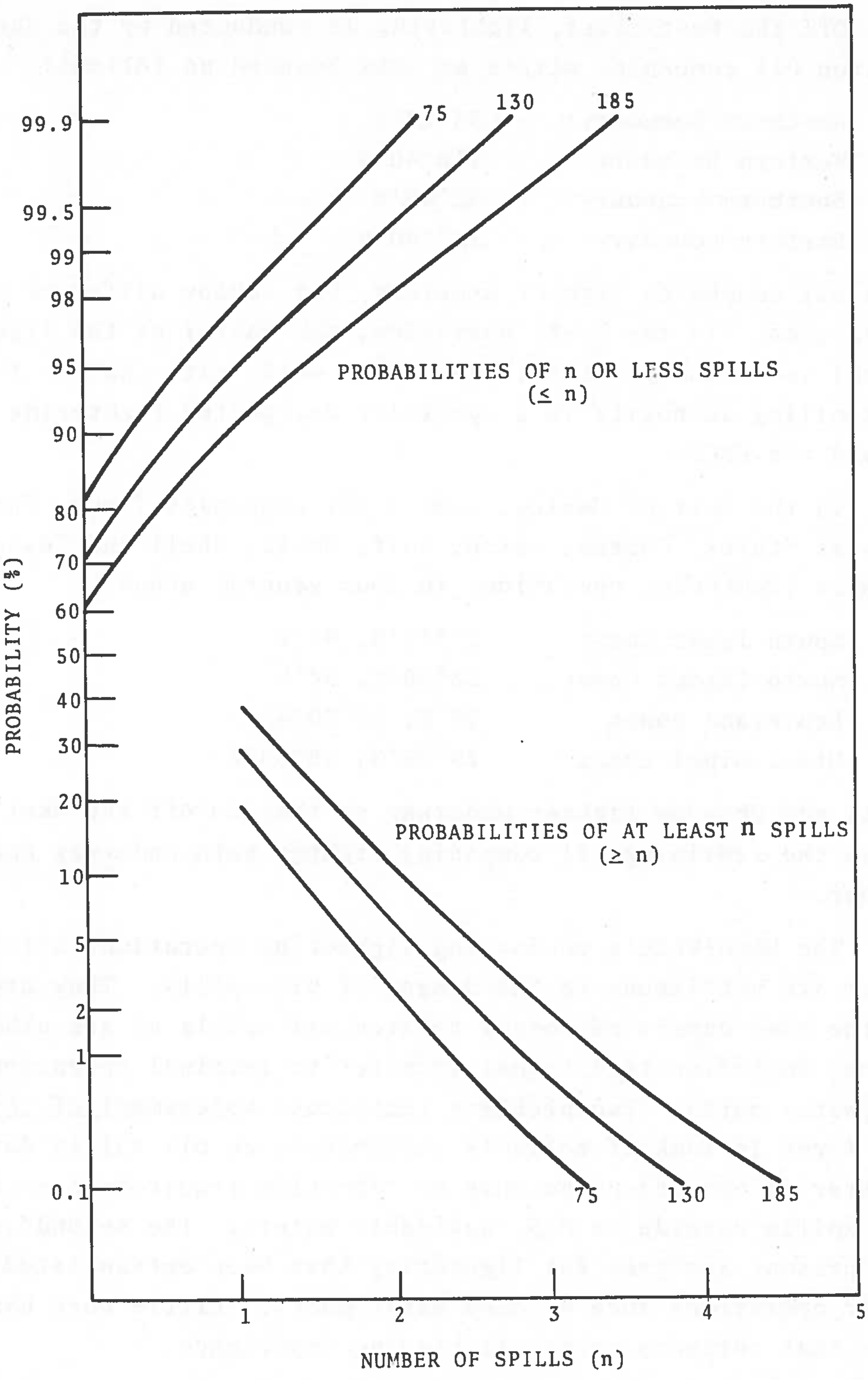


FIGURE 3-27. PROBABILITIES OF SPILLS ≥ 50,000 GALLONS FROM DEEPWATER PORT OPERATION AS A FUNCTION OF THROUGHPUT AND MILLIONS OF TONS

Intuitively it would seem that the risk of smaller operational spills would be somewhat greater for lightering than for Deepwater Ports and the risk of larger catastrophic spills would be the same or slightly greater. However, no reliable data exist to bear out these speculations. While Deepwater ports seem to offer some significant advantages from safety, economic and environmental standpoints, the present lack of such facilities, and the long lead time for their construction, indicate that lightering will continue in U.S. coastal waters from some time to come.

3.5 ISSUE OF CONCERN

There are several issues of immediate concern which may alter the current situation and change the oil spill threat potential in one or more areas. These issues are discussed in depth in Reference 3-16 and summarized briefly here as they pertain to the exposure variable (throughput) used in this analysis.

3.5.1 Disposition of Alaskan Crude

The limited refinery capacity of the West coast, coupled with the inability of some refineries to process Alaskan crude oil because of its relatively high sulfur content, has resulted in a West coast surplus of some 500,000 barrels per day of Alaskan crude. By 1982, this surplus could be as high as 900,000 barrels per day. The question of the disposition of this surplus focuses on the logistics of bringing it to where it is most needed -- the major oil refining and distribution network of the eastern half of the contiguous U.S. Several proposals have been made to this end. The major alternative transportation systems for eastward movement of Alaska crude are shown schematically in Figure 3-28 (Reference 3-16). The individual alternatives shown are discussed briefly below.

The PACTEX pipeline proposal calls for the construction of a new tanker terminal at the Port of Long Beach, California for tankers up to 165,000 DWT. This terminal would be connected to an existing 800 mile, 42 inch natural gas pipeline which would be modified to carry crude in an easterly direction. Some 227 miles of new pipeline would be added at the eastern end to carry the crude to Midland, Texas, where it would enter the crude oil distribution system that emanates from West Texas. Some 500,000 or more barrels per day would be carried eastward under this proposal.

The Northern Tier Pipeline proposal would require the construction of a new tanker terminal at Port Angeles near the entrance to Puget Sound where there is sufficient depth for tankers up to 300,000 DWT. A 40 to 42 inch pipeline would be constructed through the states of Washington, Idaho, Montana, North Dakota, and terminate at Clearbrook, Minnesota. This line would connect with existing pipelines along the way to serve refineries in the Rocky Mountain and Mid-Central States. At Clearbrook, connections with existing pipelines would extend the oil distribution to the Upper Mid-West and the refining center in the Great Lakes area. The initial capacity of the pipeline of some 700,000 barrels per day would ultimately be increased to some 940,000 barrels per day.

The Kitimat Pipeline proposal would require the construction of a tanker terminal at Kitimat, British Columbia, capable of handling tankers up to 320,000 DWT and a 753 mile 36 inch pipeline through which the Alaskan crude would be delivered to Edmonton, Alberta. From this terminus, the crude would be distributed to Montana, North Dakota, Minnesota, Wisconsin and the Great Lakes region. The design capacity of this proposal is some 400,000 barrels per day.

Several direct delivery by tanker alternatives to pipeline transportation have been considered by the petroleum industry. These include routings via LOOP, SEADOCK, Trans-Panama, Trans-Guatemala, and Cape Horn. However, the transport of oil by tanker from Valdez to ports in the Gulf of Mexico is seen by the petroleum industry as a costly, short-term expedient. Tankers of up to 65,000 DWT can pass through the Panama Canal fully loaded and larger vessels (up to some 90,000 DWT) can use the Canal if only partially loaded. Larger tankers would have to be routed via Cape Horn or off-loaded into smaller tankers off the western entrance to the Canal, neither of which is attractive from the standpoint of rate far exceeds the annual waterborne throughput.

This proposal has met with considerable opposition from the independently owned U.S. flag tanker industry and from seafarer's unions. The issue is expected to be resolved by a decision of the Federal Energy Regulatory Commission by mid-1978. If approved, this diversion of petroleum throughput from waterborne commerce could significantly lessen the oil spill potential from such sources in this area.

3.5.3 Petroleum Imports

The U.S. dependency on foreign petroleum has increased markedly over time, and this trend is expected to continue into the future as projected in Table 3-3 (Reference 3-17). With the possible exception of the Mexican supply, the only way this petroleum can be transported is by tanker; primarily to ports in the New York, Philadelphia and Western Gulf of Mexico areas (Reference 3-16). Increased imports (throughputs) will increase the threat of spills from transient tanker movements along the coast (Section 3.4.4) and from operations about the domestic destinations.

REFERENCES FOR SECTION 3

3-1 Gilmore, G. A. et al, Systems Study of Oil Spill Cleanup Procedures, Vols. I and II, Applied Oceanography Division, Dillingham Corporation, La Jolla CA, Feb. 1970.

3-2 Devanney, J.W. III and Stewart, R.J., Analysis of Oil Spill Statistics, in Primary Physical Impacts of Offshore Petroleum Developments, MIT Sea Grant Program Report No. MITSG 74-20, Cambridge MA, Apr. 1974.

3-3 Young, G. K. et al., Major Oil Spills From Tankers and Barges and Other Vessels, Analysis of Recent Trends and Patterns, GKY and Associates, Alexandria VA, May 1977.

3-4 U.S. Army Corps of Engineers, Waterborne Commerce of the United States, District Engineer, New Orleans LA, 1974, 1975, 1976.

3-5 U.S. Department of Energy, Energy Information Administration, Monthly Energy Review, Report No. DOE/EIA-0035/2, Feb. 1978.

3-6 Jimison, J., Congressional Research Service, National Energy Transportation, Vol. I, Current Systems and Movements, U.S. Senate Report No. 95-15, Washington DC, May 1977.

3-7 U.S. Coast Guard, Final Environmental Impact/4(f) Statement, LOOP Deepwater Port License Application, Deepwater Data Ports Project, Office of Marine Environment and Systems, Washington DC, 1976.

3-8 Smith, R., et al, An Oilspill Risk Analysis for the North Atlantic Outer Continental Shelf Lease Area, U.S. Geological Survey, Open File Report 76-620, 1976.

3-9 Smith, R., et al, An Oilspill Risk Analysis for the Mid-Atlantic Outer Continental Shelf Lease Area, U.S. Geological Survey, Open File Report 76-451, June 1976.

4. MASSIVE SPILL POTENTIAL

The Presidential goal of an adequate response within six hours to a spill of up to 100,000 tons of oil requires the U.S. Coast Guard to be prepared to offload or recover massive amounts of oil spilled in U.S. coastal waters. In order to meet this requirement it is necessary to estimate the size, number, location and type of potential massive spills in U.S. waters in the next decade. Of prime importance is the expected total discharge and discharge rates from massive spills, for they affect the amount and location of equipment required to cope with the spill. Also of importance is the nature of the incident, the type of oil involved, and the environmental conditions immediately after the incident. Ideally, one would like to project:

1. Type of incident (or series of incidents)
2. Probable locations
3. Type of oil involved
4. Total quantity of oil involved
5. Quantity of oil discharged
6. Time profile of oil discharge rate
7. Environmental conditions during and after the incident.

The type of incident is of interest because it is often a clue to the other items, and because certain types of incidents affect recovery efforts directly. For example, fires will reduce the amount of oil that must be recovered; explosions can hamper offloading operations; groundings have a different discharge rate profile from collisions.

The probable locations of possible future massive spills, of course, strongly influences equipment placement. While it is not possible to pinpoint such locations, nor estimate the probability of occurrence of a massive spill at a specific point, it may be

4.1 METHOD AND ASSUMPTIONS

The description of possible accidental events that may occur as much as ten years in the future necessarily requires several assumptions, which will limit the reliability of the results. The method of developing estimates of items 1 through 7 is as follows:

1. The types of accident that have produced massive spills are determined from a review of available information concerning historic massive spills. It is assumed that the nature and relative frequency of these incidents will persist into the 1980-1990 time frame. This assumption will most likely lead to an over estimate of the frequency of spills of the types selected for two reasons: (a) it does not allow for improved vessel and offshore production technology and (b) it does not allow for improved regulation, traffic control and safety practices. It has been estimated that from 25 to 78 percent of rammings can be prevented by measures that range from regulations currently proposed for shipboard equipment to more complex shore-based systems (Reference 4-2). However, VLCC's are likely to be less affected by preventive measures than other vessels since such devices as LORAN, on-board radar and improved communications are already common on VLCC'S. It is due to this uncertainty about the effectiveness of preventive measures for VLCC's that the relative frequency of massive spills involving these vessels has not been reduced for future projections.

2. Estimates of typical average outflow rates are made by a analyzing reports of seven selected massive vessel spills.

3. Projections are made of the more likely locations of massive spills in U.S. coastal waters in the 1980-1990 time period, based on estimated shifts of U.S. coastal tanker traffic and expected OCS development

4. Finally, scenarios are constructed describing the time-sequence of events for three typical massive spills. These scenarios will be employed later to determine the additional levels of equipment and logistic support required to meet a massive spill threat.

Some breakdown by location is given, but outflows of all sizes are included.

4. Byer, A.H., and Painter, L.J., "Estimating the Potential for Future Oil Spills from Tankers, Offshore Development and Onshore Pipelines," Proceedings of the Conference on Prevention and Control of Oil Pollution, Washington, D.C., 1977. In this paper, the preceding three papers are re-analysed, with the inclusion of data on Outer Continental Shelf spills and pipeline spills.

A review of these studies reveals that further analysis of the data is necessary to obtain adequate information on historic massive spills of the type that will be dealt with by U.S. Coast Guard equipment. Of the four, that of Card, Ponce, and Snider is the most relevant to our purposes. Of the 3,183 involvements of vessels over 3,000 DWT they found the following:

TYPE OF INVOLVEMENT	% OF ALL INVOLVEMENTS	% OF IMPROVEMENTS PRODUCING OUTFLOW	% OF OUTFLOW PRODUCED
Breakdown	11	2	3
Collision	24	28	18
Explosion	3	7	9
Fire	6	4	0.3
Grounding	25	27	22
Ramming	15	10	1
Structural Failure	16	21	32
Other	0.2	1	4
	100	100	100

Thus groundings and collisions each account for about one-fourth of all involvements, but since each collision produces two involvements (if both were over 3,000 DWT) it appears that the most common type of accident is grounding. Further, it is seen from the second

To answer these two questions, a brief supplementary investigation was undertaken.

4.2.2 Historic Tanker Spills

Table 4-1 summarizes some 68 historic tanker spills of 3,000 tons of oil or more that took place worldwide from 1967 to the present (TORREY CANYON to AMOCO CADIZ). These data were extracted from References 4-3, 4-5, and 4-6 and checked against Reference 4-4. Although the list is extensive, it is not known just how complete it is. It may be said only that it is more complete than any of the component lists, except perhaps for Lloyd's Weekly Casualty Reports, Reference 4-4.

Of the 68 spills listed, 25 occurred more than 50 n.mi. from the nearest coastline and are listed in Table 4-2. Almost all of these vessels sank at sea with their entire cargo. Although they may be classed as massive spills by the 3,000 ton criterion, oil recovery from such spills is usually impossible. For this reason they are not representative of the spills upon which pollution response equipment deployment should be based.

Incident Types

The 68 spills over 3,000 tons have been broken down by type of incident and by location, as shown in Table 4-3. In order to compare this breakdown with that of Card, Ponce and Snider, it is necessary to combine strandings with groundings, and flooding/sinking with structural failure. When this is done, one obtains from Table 4-3 the following percentage distribution:

INVOLVEMENT	HARBOR INTERIOR	HARBOR ENTRANCE	COASTAL AREA	>50 NM AT SEA
Breakdown	0.0%	1.5%	0.0%	0.0%
Collision	0.0	1.5	10.3	0.0
Explosion	0.0	0.0	0.0	2.9
Fire	0.0	0.0	1.5	1.5
Grounding	2.9	10.3	27.9	0.0
Ramming	0.0	0.0	0.0	0.0
Struct. Fail.	0.4	0.4	6.3	29.8
Other	0.0	0.0	0.0	2.9
Total	3.3	13.6	46.0	37.1

TABLE 4-1. WORLDWIDE TANKER SPILLS GREATER THAN 3,000 TONS (Continued) 1967-1978

DATE	VESSEL NAME/YR BUILT	DWT K tons	OIL O/B K tons	SPILLED K tons	OIL TYPE	TYPE(S) OF INCIDENT (2)	LOCATION TYPE (3)
March 20	Othello/			60-100.	Crude	COL	C
April 17	Silver Ocean/1950	19.	18.	18.		STF	S
May 5	Polycommander/1965	50.	49.	.5-5.	Crude	STD,FRE,EXP	HE
June 1	Ennerdale/1963	49.	42.	41.	Light	GND	HE
Oct. 7	Anastasia J.L./1952	18.	18.	18.	Crude	SNK	S
Oct. 23	Pacific Glory/1966	78.	77.	4.-7.	Crude	COL,FRE	C
Dec. 28	Chryssi/1952	31.	31.	31.	Crude	STF,SNK	S
Dec. 27	Ragny/1951	17.	17.	17.	Light	STF,SNK	S
1971							
Jan. 18	Oregon Standard/1944	17.		3.	Heavy	COL	HE
Feb. 27	Wafra/1956	64.	40.	8./32(6)	Crude	BKD,STD,SNK	C
March 29	Texaco Oklahoma/1958	35.	35.	35.	Heavy	STF,SNK	S
July 30	Alkis/1955	20.	19.	19.	Crude	STF,SNK	S
Nov. 30	Juliana/1958	19.	18.	4.	Crude	GND, STD (7)	HE
1972							
Jan. 28	Golden Drake/1950	32.	31.	31.	Crude	EXP,SNK	S
Apr. 1	Giuseppe Giulietti/1954	27.	26.	26.	Light	SNK	S
June 11	Trader/1957	34.	34.	34.	Heavy	SNK	S
Agu. 21	Oswego Guardian/1968	97.	91.	10.	Crude	COL	C
Dec. 19	Sea Star/1968	120.	100.	100(10)	Crude	COL,FRE,EXP	C
April 27	Silver Castle/		18.	<3.	Crude	COL (11)	C

TABLE 4-1. WORLDWIDE TANKER SPILLS GREATER THAN 3,000 TONS (Continued) 1967-1978

DATE	VESSEL NAME/YR BUILT	DWT K tons	OIL O/B K tons	SPILLED K tons	OIL TYPE	TYPE(S) OF INCIDENT (2)	LOCATION TYPE (3)
1976							
Feb. 5	St. Peter/1957	34.	34.	34.	Crude	FRE,SNK	C
May 12	Urquiola/1973	109.	100.	15.(5)	Crude	GND,EXP,FRE	HE
July 28	Cretan Star/1955	30.	29.	29.	Crude	MSG,SNK	S
Oct. 5	Sealift Pacific			4.	Crude	GND	C
Oct. 14	Bohlen/1961	11.	11.	3.	Crude	SNK	C
Dec. 16	Argo Merchant/1955	28.	28.	28.	Heavy	STD	C
1977							
Jan. 18	Irenes Challenge/1956	34.	10.	10.	Crude	STF,SNK	S
Jan. 1-4	Grand Zenith/1953	31.	29.	29.	Heavy	MSG,SNK	S
Feb. 7	Borag/1958	35.		10.	Heavy	STD	C
Feb. 23	Hawaiian Patriot/1965	99.	90.-95.	90.-95.	Crude	STF,EXP,SNK	S
May 27	Caribbean Sea/1958	30.	30.	30.	Crude	SNK	S
Oct. 30	Al Rawdatain/1976	328.		6.	Crude	BKD	HE
Dec. 16	Venoil/1973	326.	307.	23.	Crude	COL	C
Dec. 16	Vendet/1973	326.		3.	Heavy	COL	C
1978							
Jan. 14	Brazilian Marina/1974	318.		12.	Crude	GND	HE
March 17	Amoco Cadiz/1974	228.	220.	220.	Crude	BKD,STD	C

TABLE 4-2. WORLDWIDE TANKER SPILLS 50 N.MILES OR MORE FROM THE COAST

1967-1978

VESSEL NAME	DWT K tons*	AGE Yrs	SPILLED K tons	INCIDENT TYPE
Giorgio Fassio	19.	13	19.	Engine Room flooded, Sunk
Andron	16.	15	16.	Engine Room flooded, Sunk
Keo	30.	25	30.	Broke in two, Sunk
Pacocean	30.	20	30.	Broke in two, Sunk
Sofia, P.	18.	16	18.	Broke in two, Sunk
Albacruz	20.	16	20.	Engine Room flooded, Sunk
Gezina Brovig	16.	19	16.	Engine Room explosion, Sunk
Silver Ocean	19.	20	18.	Broke in two
Anastasia	18.	18	18.	Engine Room flooded, Sunk
Chryssi	31.	17	31.	Broke in two, Sunk
Ragny	17.	19	17.	Broke in two, Sunk
Texaco Oklahoma	35.	13	35.	Broke in two, Sunk
Alkis	20.	16	19.	Cracked and Sunk
Golden Drake	32.	22	31.	Explosion, Sunk
G. Giulietti	27.	18	26.	Engine Room flooded, Sunk
Trader	34.	15	34.	Engine Room leak. Sunk
Nelson	21.	16	20.	Hull cracked, Sunk
Theodorus V	21.	20	20.	Fire, Explosion, Sunk
British Ambassador	45.	17	44.	Engine Room leak, Sunk
Spartan Lady	21.	20	20.	Broke up, Sunk
Cretan Star	30.	21	29.	Missing, Sunk
Irenes Challenge	34.	21	34.	Broke in two, Sunk
Hawaiian Patriot	99.	22	99.	Broke in two, Sunk
Caribbean Sea	30.	19	30.	Engine Room leak, Sunk
Grand Zenith	31.	24	29.	Missing, presumed Sunk

*K tons = thousands of tons

The next step is to analyze the harbor and coastal incidents (See Table 4-4.) Thirty six of the 42 involvements could be classified as groundings, strandings, or collisions. As far as could be determined from the references the JULIANA and POLY COMMANDER grounded and then stranded, so that their classification is somewhat in doubt. The remaining six involvements were primarily structural failures or floodings that occurred within 50 n.mi. of the coast.

Groundings: (24%) Five of the ten incidents listed (Table 4-4) occurred within or at the entrance to a major harbor; of the remaining six, three occurred within 25 n.mi. of a major harbor. Therefore, it seems that about half of historic groundings were within 25 n.mi. of a major harbor. This estimate must be considered approximate because of the smallness of the sample. A typical grounding occurs as the vessel is exiting or entering the harbor (JACOB MAERSK, OCEAN EAGLE, TARIK IBN, URQUIOLA). Not uncommonly, the grounding is followed by a fire or explosion which reduces the amount of oil to be recovered, but hampers its recovery. If the POLY COMMANDER is considered a grounding, then three out of eleven groundings would have resulted in explosion or fire, while none of the seventeen strandings would have so resulted, except for fires deliberately set in the cases of the NAPIER and WAFRA. The data suggest, therefore, that grounding are more likely to lead to explosion or fires than are strandings. Again, the smallness of the sample prevents any firm conclusion.

Strandings: (43%) By far the most prevalent incident type in the data is the stranding. Of these, almost 90% are coastal (although the WAFRA and BORAG were not far from harbors). It is not possible to generalize as to causes of strandings from these data, since a full investigation was not undertaken in every case. The three causes most suspected, however, are navigational error, pilotage error, and breakdown. The TORREY CANYON, POLY COMMANDER, ZOE COLOCOTRONI, METULA, SHOWA MARU, ARGO MERCHANT were strandings due to navigational or pilotage error. Examples of breakdown are WAFRA and AMOCO CADIZ.

TABLE 4-4. TANKER SPILLS OVER 3,000 TONS WITHIN 50 N.MI. OF COAST (Continued) 1967-1978

VESSEL (AGE)	K tons DWT	K tons Spilled	% Cargo Spilled	Location(1) Code	Description
SOFIA M (19)	13.	6. Crude		C	Off Coast of Colombia
ARROW (22)	18.	11. Heavy	(61%)	C	Cerebrus Rock, Chedabucto Bay, N.S.
POLYCOMMANDER (5)	50.	<5. Crude	(<10%)	HE	Grounded, fire and explosion, about 10 miles from Vigo, Spain*
WAFRA (25)	64.	8. Crude	(20%)	C	Broke down, taken in tow, line parted, drifted aground, holed, refloated; off Cape Agulkas (Cape Town) S.A. Towed 170 miles to sea and bombed, sunk
ZOE COLOCOTRONI		5. Crude		C	Stranded off Parraguerra, P.R., offloaded into ocean, refloated
NAPIER (16)	39.	19. Crude	(50%)	C	Stranded, set afire, off coast of Chile, near Folfo Corcovado*
COSMOS PIONEER (22)	14.	13. Light	(100%)	C	Stranded off cost of India
OCEAN EAGLE (15)	19.	7. Crude	(39%)	HE	Stranded and broke in two off El Moro Castle at entrance to San Juan harbor, P.R.
METULA (5)	207.	52. Crude	(27%)	C	Aground and stranded in Straits of Magellan
TRANSHURON (28)	20.	5. Heavy	(28%)	C	Stranded on Kiltan I., S.W. coast India
SHOWA MARU (2)	238.	4. Crude	(2%)	C	Stranded, in Straits of Singapore, offloaded 36 MT, refloated
ARGO MERCHANT (23)	28.	28. Crude	(100%)	C	Stranded 29 n.mi. S.E. of Nantucket
BORAG (19)	35.	10. Heavy		C	Stranded 10 n.mi. N of Tai-pei, Taiwan

TABLE 4-4. TANKER SPILLS OVER 3,000 TONE WITHIN 50 N.MI. OF COAST (Continued)

VESSEL (AGE)	K tons DWT	K tons Spilled	% Cargo Spilled	Location Code[(1)]	Description
BOHLEN (15)	11.	3. Crude	(27%)	C	Sunk off Brittany coast, about 45 n.mi. S.W. of Brest; most of cargo offloaded
ST. PETER (19)	34.	34. Crude	(100%)	C	Caught fire in engine room, sunk, 30 miles N.E. of Esniaraldes, Ecuador about 16 n.mi off shore*
AL RAWDATAIN (1)	328.	6. Crude	(2%)	HE	Leakage from broken valve outside Genoa harbor

(1) C = coastal, HI = harbor interior, HE = entrance to harbor.

(*) Indicates fire or explosion.

(Referenced above) have shown the sharp increase in incidence of structural failure for tankers between 10 and 20 years of age. When the six involvements above are viewed in relation to Table 4-2 above and Figure 16 of Ponce et al., it appears that these involvements are merely the coastal and harbor portion of widespread structural and mechanical failures that affected tankers of age 10-20 years in the 1967-1977 period.

4.2.3 Historic Massive Spills - Outflow Rates

Seven incidents were selected from Table 4-4 and analyzed in some detail in order to estimate the outflow rates. The selection was made on the basis of the size of the spill and the availability of data. The larger size spills were given preference in the selection because equipment levels are paced by spills of the 100,000 ton variety. Fortunately, the larger historic spills are also the better documented. The seven spills analyzed consisted of six strandings and one grounding. Adequate estimates could not be made for any of the collisions, because of inadequate information. This lack of data is possibly due to the fact that many of the collisions were attended by spectacular fires which made it difficult to observe or estimate the amount of oil reaching the water.

The seven spills are analyzed in Appendix B, and the results are summarized in Table 4-5. Some observations:

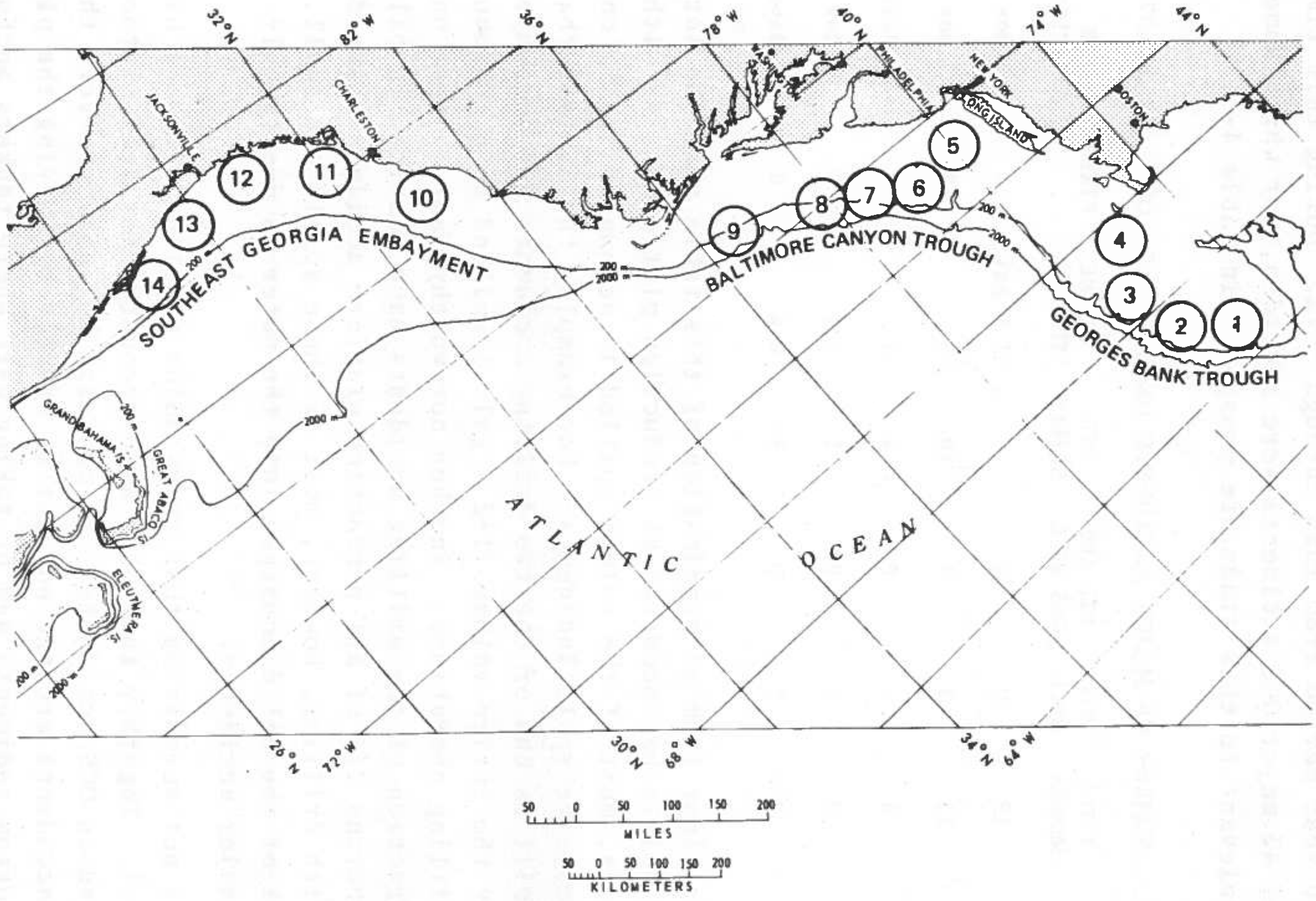
1. The minimum rates have little significance, and are included only to show the range of estimates within a single spill.
2. The AMOCO CADIZ far exceeded the other six incidents in all categories: minimum, mean, and maximum outflow rate.
3. The mean outflow rates are probably better design parameters than the maximum outflow rates because (a) they are more accurate and (b) sudden discharges can not be accommodated in real time by a practical skimming system.

It is clear from Table 4-5 that even excluding the AMOCO CADIZ, average outflow rates in excess of 100 tons per hour can be expected from strandings and groundings (the URQUIOLA is the only grounding in the Table; the other six are all strandings). Further, since tankers of the size of the AMOCO CADIZ, (228,000 DWT) are common today and will be even more common in 1980-1990, there is every reason to include the AMOCO CADIZ spill when estimating historic worldwide tanker spill outflow rates. Therefore, the data certainly suggest that outflow rates of the order of 200 to 500 tons per hour have been characteristic of the largest massive tanker spills (60-150 Kgals/hour).

Table 4-6 shows the seven tanker spills with their DWT, outflow amount (oil burned or sunk not included) and the time of outflow. Five incidents were strandings not accompanied by fire or explosion: WAFRA, SHOWA MARU, METULA, ARGO MERCHANT, AMOCO CADIZ. One notices that the two strandings in which the vessel broke up on the spot by wave action (ARGO MERCHANT, AMOCO CADIZ) both took about 350 hours, although the average outflow rates were different by a factor of almost ten.

TABLE 4-6. ESTIMATED OUTFLOW TIMES FOR SEVEN SELECTED TANKER SPILLS, 1967-1978

VESSEL	DWT K TONS	AMOUNT SPILLED TONS	OUTFLOW TIME HRS	MEAN RATE OF OUTFLOW TONS/HR
POLYCOMMANDER	50.	1,050	168	6.25
WAFRA	64.	8,000	226	35.4
SHOWA MARU	238.	3,300	31	106.5
URQUIOLA	109.	50,000- 60,000	312	170.
METULA	207.	54,000	1,092	49.
ARGO MERCHANT	28.	25,333	360	70.
AMOCO CADIZ	228.	220,000	348	611.



Source: OCS Oil and Gas, A Report to the President, Vol. I, p. 22, April, 1974.

FIGURE 4-1. PROPOSED ATLANTIC DRILLING SITES

Examination of Table 4-7 and additional data to 1975 thus lead to the following general observations:

1. It is very unlikely that a massive oil spill will be caused by a drilling accident. In the Gulf of Mexico, from 1965-1975 only two large spills resulted from drilling incidents, and both were in the 50,000 gal. range. All remaining spills from this cause discharged less than 2,000 gals. of oil into the water. During the same period drilling activity was at the rate of 500-1,000 wells per year.

2. Collisions of ships with either drilling rigs or production platforms, and weather induced major accidents are rare and historically have not resulted in massive spills.

3. Production platform and pipeline accidents are the sources of most spills and have resulted in the largest volumes of oil spilled. They will be discussed in more detail below.

4.2.5 Historic Platform/Pipeline Spills

The purpose here is to review historic spills from offshore platforms and associated underwater pipelines in order to ascertain their potential for future massive spills. As was done for massive tanker spills, a massive spill is taken to be one over 3,000 tons (1,000,000 gallons, or 25,000 BBL). No restriction is placed on time or location of occurrence.

The U.S. Geological Survey collects data on all U.S. OCS spills (References 4-13, 4-14). No spills over 1,000,000 gallons are recorded for the years 1971-1975. Reference 4-13 lists four platform spills and four pipeline spills worldwide from 1967 through 1972. They are not claimed to be a complete list for the period. Three of nine platform spills and three of the nine pipeline spills listed in Reference 4-15 were over 1,000,000 gallons. These six, plus one other, are listed in Table 4-8. Investigation of the platform spills yielded enough information to estimate the outflow rates shown in Table 4-9. It should be noticed that the Main Pass Field (Platform Charlie) incident and the Bay Marchand

TABLE 4-9. ESTIMATED OUTFLOW RATES FOR SOME PLATFORM SPILLS OVER 1 MILLION GALLONS, WORLDWIDE, 1967-1978

SPILL LOCATION (Date	DURATION (DAYS)	QUANTITY (GALS.)	AVERAGE OUTFLOW RATE GAL/DAY	AVERAGE OUTFLOW RATE TONS/HR
Santa Barbara, CA (January 1969)	10	3.25×10^6	325,000	45.1
Bay Marchand, LA (December 1970)	56	2.26*	90,360	5.6
Main Pass Field, LA (March 1970)	21*	2.73*	130,000	18.1
Ekofiske Field, N. Sea (April 1977)	12	7.8 - 12.	650,000 -1,000,000	90 -140

*Adjusted for fire

incident were accompanied by fires, which burned off a large part of the outflow. The rates shown for these two incidents, however, have been adjusted for the amount burned off, by means of the information in Notes (2) and (3) of the Table. In the case of the Bay Marchand incident the fire burned for the full 56 days and the quantity shown is that oil which reached the water despite the fire. Hence the outflow rate is lower than would have occurred without the fire. In the case of the Main Pass Field, the duration and quantity shown in the Table refer to the outflow after the fire was extinguished; the rate of discharge of the well during the fire was probably higher, so that the average outflow rate, had not the fire occurred, would be greater than the 18.1 tons per hour shown.

No outflow rates could be calculated for pipeline ruptures.

The conclusion to be drawn from the two Tables, therefore, is that OCS platform blowouts, in the absence of fires, can reach 100 to 200 tons per hour outflow levels.

TABLE 4-10. PERCENTAGE DISTRIBUTION OF CRUDE/PRODUCT FLOWS IN U.S. COASTAL WATERS, 1985

To From	East Coast	Gulf Coast	West Coast	Canada (Atlantic)
Ecuador	Mona Pass 0.0/0.0	Yucatan Ch to Gulf Coast 0.0/0.0	Pacific Coast 1.3/0.0	
Caribbean	PR-VI 6.4/38.0 (3.9)	PR-VI and Str. of Florida 8.5/3.0 (6.0)	Pacific Coast 0.7/1.1	East Coast 2.3/4.1
N. Europe	N. Atlantic 0.1/2.2	Str. of Florida 0.1/0.1	0.0/0.0	
Mediteranean	Atlantic Ocean 6.5/4.9	Str. of Florida 2.8/0.2	Pacific Coast 0.1/0.1	
SW Pacific			Pacific Ocean 6.6/0.4	
Persian Gulf	Atlantic Ocean 3.7/0.1 (6.2)	Str. of Florida 8.6/0.3 (11.1)	Pacific Ocean 7.1/0.2	
W. Africa	Atlantic Ocean 11.5/0.4	Str. of Florida 5.8/0.0	Pacific Ocean 0.0/0.0	
Canada	E. Coast 0.1/1.5	E. Coast and Str. of Florida 0.0/0.0		
Alaska	2.5/0.0	2.5/0.0	Pacific Coast 20.2/0.0	
Gulf Coast	Str. of Florida 2.2/27.3			Str. of Florida East Coast 0.0/0.1
West Coast	Windward Pass. to Gulf Coast 0.0/9.1	Yucatan Channel to Gulf Coast 0.0/3.6		

3. Pacific Coast Receipts of Crude are mainly:

    25.5% from Alaska (North)

    15.8% from South and Southwest

4. Most petroleum <u>product</u> movement is of 3 types:

    38% up the East Coast from the Caribbean

    27% through the Straits of Florida up the East Coast

    13% out of refineries on the West Coast.

The conclusions to be drawn from the above projections, if they are correct, are that there are two coastal areas where crude oil traffic will substantially increase, and, in fact, dominate U.S. coastal crude oil movements. These are

- The Straits of Florida
- West coast from Alaska

Secondarily, heavy crude and product traffic will move up the East Coast from the Caribbean, from the Straits of Florida, and from West African ports, in addition to possible large crude carriers from the Persian Gulf to Deepwater ports in the northeast U.S. via the South Atlantic.

4.3.2 <u>Outer Continental Shelf Spill Locations</u>

During the 1980-1990 time period a massive spill could occur in any one of three OCS regions: the Gulf of Mexico, off the coast of Southern California, or over the U.S. Atlantic OCS. Since the last of these has as yet experienced only a limited amount of exploratory drilling, it is not possible to predict with any certainty the risks which may be associated with platform production in this "frontier" area. In the Gulf of Mexico and in the Santa Barbara Channel these risks have already been prepared for and perhaps discounted to a certain extent. On the Atlantic coast, however, they pose an unaccustomed threat. That threat seems most immediate to the mid-Atlantic region, where exploration is already underway.

- A massive spill in this area will attract nationwide attention.
- The mid-Atlantic in mid-summer would probably present the most favorable opportunity for an effective OCS spill response operation and would thus present a maximum challenge to the Coast Guard oil spill response system.

4.4 MASSIVE SPILL SCENARIOS

4.4.1 Tanker Spill Scenarios

The previous sections have brought out the following:

1. Massive tanker spills have historically occurred more frequently outside harbor areas than in them.
2. Massive tanker spills have been predominantly strandings (43%) and groundings (24%) and collisions (19%), based on historic spills over 3,000 tons within 50 n.mi. of a coast.
3. Massive spills have been predominantly crude and heavy oils.
4. For strandings and groundings, outflow rates in the 200-600 tons per hour range have occurred.
5. Offshore well blowouts have produced spills of up to 40,000 tons and rates of about 100-200 tons per hour (compared to 200,000 tons and 600 tons per hour for the largest tanker spills).
6. The areas most likely to see heavy tanker traffic in the 1980's are the Straits of Florida, the Pacific Northwest, and the southeast approaches to the East Coast (Cape Hatteras).
7. Explosion and/or fire are not uncommon accompaniments to groundings and collisions, and well blowouts, but not as common in the case of strandings.

Date, Time:	**Event/Data**
Feb. 2, 1800	**PACIFIC PIGEON at 48 28N, 124 56W approaching staging area for entrance to Straits of Juan de Fuca the next day, experiences pump failure, due to fracture in circulating pump. Engine stops, vessel drifting SE. Winds 20 knots, gusting to 40, from the NW; current 1.9 knots at 290T, waves 4 ft, swell 4 ft.**
1805	Master alerts VTS. Vessel speed 5 knots in SEasterly direction. Vessel position about 10 miles west of entrance, just south of Swiftsure Bank.
1810	Tug Heroic receives notification, presently 5 miles east of entrance to Straits of Juan de Fuca, immediately proceeds to assist at 10 knots. Estimated time of arrival 1940.
1840	PACIFIC PIGEON at 48 27N 124 55W, drifting SE at about 7 knots, wind 30 knots, swell from N west at 5-10 ft, waves 5 ft.
1940	Vessel at 48 25N, 124 51W, tug Heroic arrives.
2010	Heroic secures line to vessel;
2030	Line parts; PACIFIC PIGEON continued drift to SEast. coordinates 48 25N, 124 50W. Winds increase to 40 knots, seas to 6 ft.
2200	Heroic re-secure line.
2300	Line parts a second time.
Feb. 3, 0100	PACIFIC PIGEON continues to drift toward SEast. Presently about 2 miles from Duntze Rock. 2nd tug arrives, but neither is able to approach PACIFIC PIGEON because of heavy seas. Crew removed by helicopter.

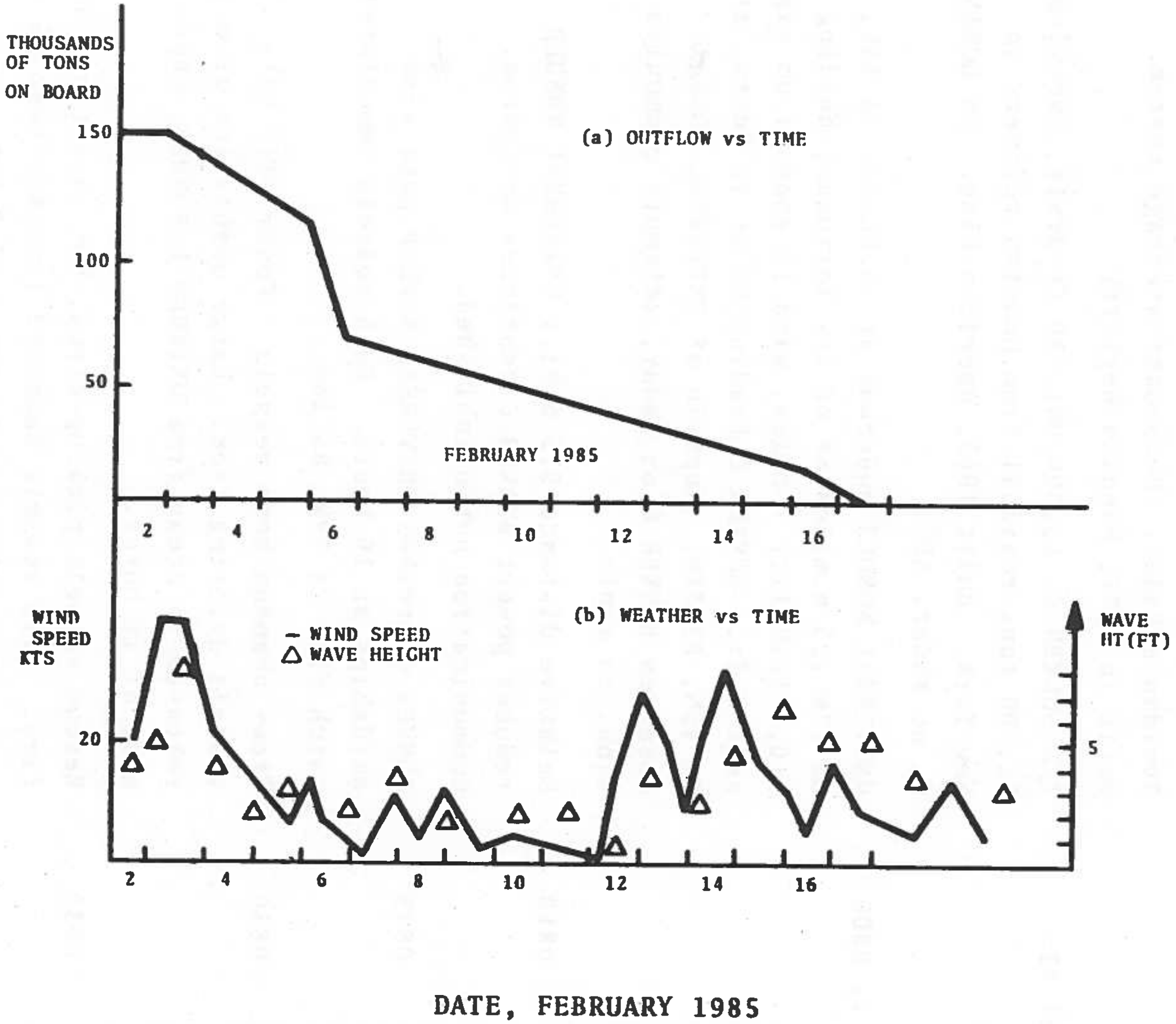


FIGURE 4-2. OUTFLOW AND WEATHER CHART FOR PACIFIC PIGEON SCENARIO A

July 2, 1000	Fire on UNIVERSAL WONDER extinguished. Heavy oil leakage continued from UNIVERSAL WONDER, but ceases from BUNKER C. Slick spreads in westerly direction extends from 2 miles east of vessels to 5 miles west of vessels. Both vessels continue to smoke heavily.
July 3, 0800	Both vessels taken under tow as smoke subsides. Since UNIVERSAL WONDER continues to leak heavily, it is decided to tow her to the west and sink her in the Gulf of Mexico.

Leakage and burn rates are shown in Figure 4-3 together with wave and wind profiles.

July 4, 0900	Several slicks are observed in 20 x 20 n.mi. area, ranging in size from 1/2 x 1/2 mile to 10 x 5 miles.
	Witnesses said BUNKER C's port bow struck the UNIVERSAL WONDER about 200 ft forward of the bridge. "UNIVERSAL WONDER had a hole about 100 feet long above the waterline, extending down into the water." Both vessels remained afloat.
1200	Winds shift to south east, drop to 5 knots. Leakage of heavy oil now detected from BUNKER C; cannot enter Key West harbor, remains 10 n.mi. outside Key West; leakage rate approximately 100 gallons/hr. UNIVERSAL WONDER 120 n.mi. west of Key West, under tow due westerly direction.
July 5, 0800	Seas rise to 5 ft, wind to 30 knots, from the south east; heavy rain, thunder and lightning. Towing of UNIVERSAL WONDER stops.
July 6	Towing operation recommences.
July 7, 1000	UNIVERSAL WONDER bombed and sunk at 24 30N, 86 00W with approximately one-half her original cargo still aboard. Leakage ceases on BUNKER C,

which is towed into Key West harbor for offloading and eventual scrapping.

Heavy oil slicks come ashore on Garden Key and Loggerhead Key, FL. Giant oil slicks to west and north.

Approximate total areas covered by slick over the seven days are as follows, (n.mi. x n.mi.):

July 1	1 slick	1/2 x 1/2
2	2 slicks	10 x 5 each
3	2 slicks	20 x 15 each
4	2 slicks	30 x 15 each
5	3 slicks	40 x 10 each
6 7	several slicks	150 square miles total

4.4.2 OCS Massive Spill Scenario

Before a detailed OCS massive spill scenario can be fully developed, two additional circumstances must be considered. They are (1) the immediate cause of the production platform blowout, and (2) whether or not the blowout is accompanied by fire.

We have already seen that neither a ship collision nor severe weather is likely to lead to a massive spill. Aside from human error, the only other possibility is an earthquake. Earthquakes of magnitude comparable to Richter 7 have been reported(4-12) in the last few centuries in the northern sector of the U.S. Atlantic coast. Only one has been reported in the southern sector. On the average such earthquakes have happened about once per century. There is therefore a 25% chance that one severe shock will occur during the 25-30 year life of a mid-Atlantic oil field. If the platform structure is designed to withstand an earthquake of magnitude 7.2 Richter with a safety factor of 1.5, then according to Reference 4-12, there is a 15% chance that it will fail if an latitude near production platform "A" in the Central Baltimore Canyon Trough, 50 miles east of Atlantic City, New Jersey. Local slumping of the underlying soil caused the foundation of the platform to fail, and the platform slowly collapsed, shearing all of the 12 well pipes feeding the platform.

July 5 All surviving platform personnel have been rescued by helicopter. It has been learned that there was no opportunity to operate the manual safety valves. Since two separated oil slicks have been reported by helicopter pilots, it is assumed that 2 of the 12 subsurface automatic safety valves failed to operate properly and that two well-pipes are leaking oil.

July 6 Estimates from nearby ships and overflying aircraft indicate that oil is leaking to the surface at the rate of 50 bbls/hour from each of the two wells, which have now been identified as wells No. 4 and No. 7. Their combined spill rate is about 100,000 gals per day.

July 7 The weather continues fair. Seas are favorable with wave heights less than 2 feet. The water temperature is 68°F, and the surface current speed is 2 knots toward the northwest. The oil slick is spreading and drifting shoreward. A semi-submersible drilling rig is under tow to the spill site to begin drilling a relief well.

	No. 4 by noon. Well No. 7 continued to leak, but at a reduced rate.
Aug. 7	The second relief well has been completed and it is expected that No. 7 well will be plugged by tomorrow.
Aug. 8	Both wells plugged. No further oil leakage is observable. Estimated volume of oil spilled, 3.5 million gallons. Remaining oil slick broken into large patches scattered over many square miles of ocean. Tar balls continue to come ashore in New Jersey and southern Long Island.

Oil outflow rates and weather profiles for Scenario C are shown in Figure 4-4.

REFERENCES FOR SECTION 4

4-1 International Petroleum Encyclopedia, 1977, Vol. 10, published by the Petroleum Publishing Co. Tulsa OK.

4-2 U.S. Department of Transportation, Transportation Systems Center, Offshore Vessel Traffic Management Study, Report No. CG-D-55-78, Vols. I, II, III. Final Report, August, 1978.

4-3 Tanker Advisory Center, Inc. Newsletter, March 21, 1978.

4-4 Lloyd's Weekly Casualty Reports, published by Lloyd's of London Press, Ltd.

4-5 U.S. Coast Guard Worldwide Tanker Casualty Database, for years 1969-1973, plus supplements for 1974-1976, U.S. Coast Guard Marine Technical Division.

4-6 Center for Short-Lived Phenomena, Spill Reports, prepared for U.S. Department of Transportation, Transportation Systems Center, Cambridge, MA 02142.

4-7 Cockroft, A.N., "Statistics of Collisions at Sea," J. Institute of Navigation, Vol. 29, No. 3, July, 1976.

4-8 Wheatley, J.H., "Circumstances of Collisions and Strandings," Marine Traffic Engineering, Proc. of the Royal Institute of Navigation and the Royal Institute of Naval Architects Conference, 1972.

4-9 Mathews, C.D., "Oil Spill Risks in Perspective," Oil and Gas Journal, September 9, 1974, p.65.

4-10 Danenberger, E.P., Oil Spills, 1971-1975, Gulf of Mexico OCS, Geological Survey Circular 741, 1976.

4-11 Smith, R.A., Slack, and Davis, An Oil Spill Risk Analysis for the Mid-Atlantic OCS Lease Area, U.S. Geological Survey, Open File Report No. 760451, June, 1976.

4-12 OCS Oil and Gas - An Environmental Assessment, Council on Environmental Quality, Vol. I, April 1974, p. 69.

5. ENVIRONMENTAL CONDITIONS

5.1 THE OCEAN ENVIRONMENT AND ITS RELATION TO SPILL RESPONSE

Numerous factors contribute to the effectiveness of efforts to respond to major oil spills in coastal waters. Some of these are subject to a measure of control, such as advance planning, the availability of equipment and trained personnel, and prompt logistical support; other circumstances cannot be controlled since they depend on the location of the spill, the season of the year, and the local weather. These environmental factors can only be anticipated in a probabilistic way. Two sets of circumstances do provide bounds on the planning possibilities, however. These are the favorable conditions of mid-summer and the adverse ocean environment of mid-winter. Within the present state-of-the-art only limited response possibilities are available during worst case situations. Present day equipment is most effective in more moderate circumstances. Thus, one planning approach is to provide the resources needed when all the available equipment can be used to advantage and then to estimate how these resources may fall short in worst-case situations and how the short-fall may be compensated. It is the purpose of this chapter to define where and when these contrasting conditions are likely to exist.

In coastal waters the casualty most likely to befall a large tanker is a stranding or grounding. Although a grounding (transient contact with the bottom) may result in a ruptured tank, the integrity of the vessel itself is often not impaired so that, except in severe weather, it can proceed either under its own power or under tow to a safe anchorage where it can be unloaded by lightering. A stranding, on the other hand, immobilizes a leaking tanker on rocks or shoals, subjects the ship to severe structural stresses due to tides, waves, and currents and requires that the vessel be refloated as rapidly as possible if the situation is to be saved.

1. Surface winds
2. Sea-waves and swell
3. Surface water temperature
4. Surface water current.

All of these factors vary with the seasons of the year and are least favorable in the higher latitudes in winter, where the hours of available daylight may also severely limit the response operations.

The ultimate source of most compilations of ocean data is the marine data tape file, Tape Data Family-11 (TDF-11), maintained at the National Climatic Center. TDF-11 contains more than 31 million surface marine observations from transient ships, fixed ocean weather stations, buoys, and other sources. The observations come from all parts of the world's oceans and extend in time over more than a century. They have varying degrees of reliability and are known to be subject to a number of biases. For example, most modern observations were made along shipping lanes, with little or no data available from other areas. Also, recent data, especially in higher latitudes, is subject to a "fair weather bias" since ships are frequently diverted from areas of bad weather. For this reason environmental conditions in the more northerly regions, where bad weather is a more frequent occurrence, may be somewhat worse than is shown by the data.

5.2.1 Surface Winds

Winds at sea affect response operations both directly and indirectly. Local winds induce surface waves, and the wind speed is directly related to the sea state (wave height). More distant winds result in ocean swell waves, usually of relatively small amplitude but long wavelength. In addition to these indirect effects, the wind influences the movement of spilled oil imparting to it a velocity component equal to approximately 3% of the wind speed in the direction of the wind vector. In a 20 knot wind this component may be as much as 0.5 knot. High winds also impede

TABLE 5-1. SEA-SWELL CHARACTERISTICS

U.S. ATLANTIC COAST

Month	Percentiles		Direction
	< 6 FT	> 12 FT	
Feb.	50.0	5.0	Off-shore
Aug.	80.0	2.0	Parallel to coast

U.S. PACIFIC COAST

Month	Percentiles			Direction
	< 6 FT	7-12 FT	> 12 FT	
Feb.	15.0	20.0	65.0	On-shore
Aug.	75.0	15.0	10.0	Parallel to onshore

5.2.3 Surface Water Temperature

The water temperature at the surface of the sea exerts a variety of influences on both spilled oil and on subsequent response operations. In a warm, sunlit ocean most of the lighter fractions of crude oils spilled on the water will evaporate in a short time, leaving behind a viscous residue to be recovered. On the other hand, if the surface water is cold, evaporation is slower, and the viscosity of the residue increases exponentially with decreasing temperature, quickly reducing the efficiency with which the skimming and transfer of recovered oil to storage containers can be accomplished.

In order to off-load crude oil from a stricken tanker, the oil in the tanks must be maintained at a pumpable viscosity, which requires heat to be supplied either by the ship itself or by an external source. Lacking such heat, the oil will slowly cool until its viscosity is higher than the maximum pumping viscosity (~ 1000 centistokes). No. 6 fuel oils reach this value when allowed to cool to a temperature between 80 and 100 degrees F. For some No. 5 oils this viscosity is not reached until the temperature has dropped to about 30 degrees F. At lower temperatures, pumping becomes difficult and inefficient, if not impossible.

d. Pacific Coast (South)
San Diego, CA to Pt. St. George (42°N)

e. Pacific Coast (North)
Pt. St. George to Canada.

Although the tabulated physical quantities tend to vary in a smooth and unexceptional way between coastal zones, it should be noted that there is a marked and rather steep change at Cape Hatteras, which may have implications for response planning.

5.3.1 Wind and Waves

Basic data on wind and waves are presented in Table 5-3 for the mid-winter month of February and in Table 5-4 for the mid-summer month of August. The data are interpolated percentiles derived from the tabulations of Marcus.[5-1] The first column of data shows the percent of all observations of wind speed in the data base which were less than 20 knots. At this speed the wind is termed a "fresh breeze" (Beaufort number, 5) and marks the onset of rough seas (5 foot waves with whitecaps). Column 2 shows similar percentiles for waves less than 5 feet high. These generally follow the wind data, although the percentiles are smaller, most noticeably so in winter. During February in the Atlantic the waves are 5 feet high or higher in 50% or more of all observations, and the seas are considerably rougher south of Cape Hatteras than they are to the north. A similar tendency manifests itself along the Pacific coast where the seas are noticeably rougher north of the 42nd parallel. In August, along the Atlantic and Gulf coasts, no more than 5% of the observed wind speeds exceed 20 knots, except in the most northerly sub-regions of the Atlantic, and the seas, of course, are significantly calmer. The change from winter to summer is not so great along the Pacific coast where strong winds and rough seas are often recorded in August.

5.3.2 Water Temperature

The last four columns of Table 5-3 and 5-4 present selected aspects of the surface water temperature. These selections are

TABLE 5-3. FEBRUARY ENVIRONMENT

SUB REGION NUMBER	PERCENTILES				DEGREES F	
	WIND SPEED <20 KTS	WAVE HEIGHT <5 FT	WATER TEMP. <35 F	WATER TEMP. <50 F	*MEDIAN WATER TEMP	**1% ILE WATER TEMP
ATLANTIC COAST (NORTH)						
4	57.1	50.0	25.0	99.0	38	29
5	59.4	50.0	5.0	95.6	42	31
6	75.0	62.5	15.0	96.6	40	29
7	75.0	50.0	3.0	75.0	46	33
8	75.0	58.3	1.0	50.0	51	35
ATLANTIC COAST (SOUTH)						
9	58.3	41.8	0.3	9.7	67	40
10	58.3	41.7	0.0	0.5	72	54
11	75.0	50.0	0.0	0.0	75	64
12	78.6	62.5	0.0	0.0	75	65
GULF COAST						
13	83.6	75.0	0.0	0.0	75	63
14	85.0	75.0	0.0	0.0	72	61
15	79.0	62.5	0.0	0.0	70	56
16	77.0	58.3	0.0	0.5	71	55
17	77.9	58.3	0.0	0.6	70	57
18	77.5	58.3	0.0	0.6	66	52
19	77.0	62.5	0.0	0.0	68	54
PACIFIC COAST						
22	91.7	75.0	0.0	0.8	59	51
24	83.9	58.3	0.0	3.0	56	49
25	76.7	50.0	0.0	10.0	54	47
26	78.1	50.0	0.0	20.0	53	47
27	75.0	50.0	0.0	25.0	52	47
28	75.0	37.5	0.0	50.0	50	45
29	70.8	25.0	0.0	62.5	49	44
30	70.8	25.0	0.0	81.7	48	40
31	76.4	37.5	0.0	95.8	46	39

Notes:

*The MEDIAN WATER TEMP. is the 50 percentile for February.

**The monthly minimum 1% ILE WATER TEMP. occurs in February in almost every sub-region. Otherwise in March.

based on some general features that can be found in 5-2. For example, the minimum (5%) observed sea surface temperature for February in the coastal waters of the Atlantic is less than 32°F from the Bay of Fundy south to latitude 40°N (somewhat south of Long Island). From thereabouts, the 34°F, 5% isotherm parallels the coast, 60 nautical miles from shore, south-westerly to the entrance to Chesapeake Bay at latitude 37.5°N. Further south the 5 percentile temperature rises rapidly to 50°F at latitude 35°N, near Cape Hatteras. These geographical "break-points" suggest divisions by temperature at 35°F and at 50°F.

A further consideration has to do with the pumpability of No. 5 and No. 6 residual fuel oils, which are common cargoes in coastal waters. Type B, No. 5 residual fuel oil (a blend of distillate and vacuum still residual crude) is the heaviest oil which can still be pumped easily at 50°F (viscosity = 2000 SSU or 450 centi-stokes).[5-4] For this oil the maximum pumping viscosity of 1000 centistokes (5000 SSU) occurs at about 30°F. All No. 6 oils already reach their maximum viscosity when cooled to temperatures between 80°F and 100°F. It may also be noted that the pour point of many No. 6 oils is in the neighborhood of 50°F.

Thus, data columns 3 and 4 for February show respectively the percentiles of observations (and times) for which even Type B, No. 5 cannot be pumped and all No. 6 ceases to behave as a liquid. Note that these frequencies are insignificant south of Cape Hatteras on the east coast. Along the Pacific coast, the surface temperature never falls below 35°F, but the 50°F percentiles vary from nearly zero at the southern limit to almost 100% at the Canadian border, with a sharp break at latitude 42°N.

Finally, the last two columns list the 50 percentile (median) and 1 percentile water temperatures. The break near Cape Hatteras is again evident in the data. Summer observations on the Gulf Coast show that even No. 6 is pumpable at the surface water temperatures that are likely to be encountered there.

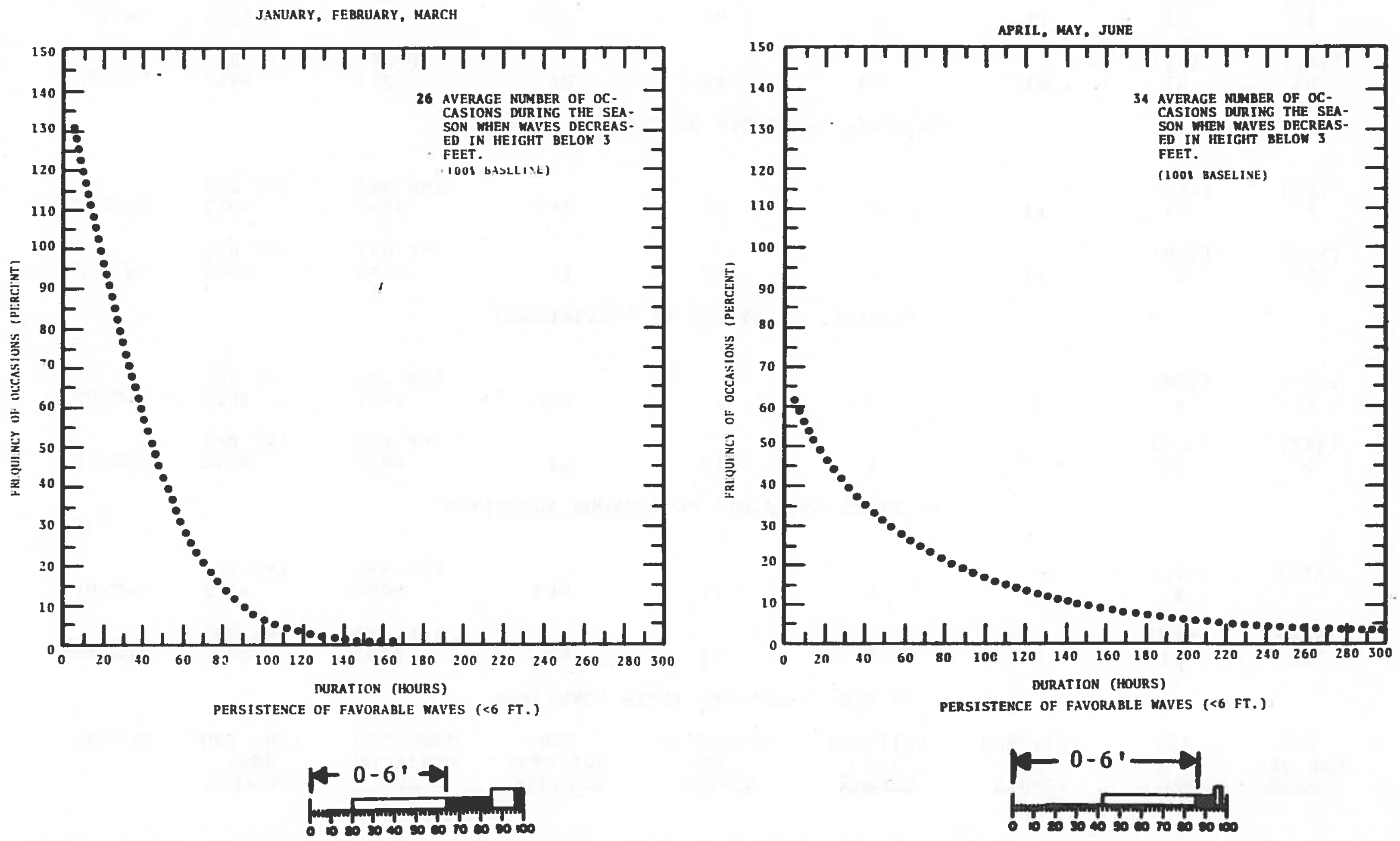


FIGURE 5-1. PERSISTENCE OF FAVORABLE SEAS <6 FEET FOR EAST COAST LIGHTSHIPS: DIAMOND SHOALS, NORTH CAROLINA

5.3.4 Surface Current Speed

Surface currents in open water may affect oil spill response operations in two ways. First, in combination with the wind, they determine the direction in which an oil slick will drift. Different response actions may be required if the set of the current is on-shore rather than off-shore. Second, containment and concentration of the oil by curtain barriers is effective only if motion relative to the water does not exceed one knot. Above this speed oil is entrained in the water flow and escapes under the curtain. Thus, in currents under 1 knot booms may be anchored down-current from the source of the spill in order to stop the drifting oil and concentrate it for skimming. Above this speed the boom must be allowed to drift with the current in order to reduce its speed relative to the water.

Tables 5-6 and 5-7 present surface current speed statistics for winter and summer as determined from TDF-11.[5-1] It is clear from these data that currents in excess of 2 knots occur with low frequency and at few locations: occasionally around Cape Hatteras and off the southern portion of the Pacific coast, with an exceptionally high frequency, both winter and summer, between latitudes 38°N to 40°N (sub-region 26). Average speeds are generally under one knot. Prevailing directions vary from offshore along the northern portion of the Atlantic coast to northerly around Cape Hatteras to onshore in the south. Along the Pacific coast the prevailing directions are almost always onshore.

TABLE 5-7. SURFACE CURRENT SPEED STATISTICS (SUMMER)

Area No.	Speed, (kts), percent occurence 0	0.1-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9	Speed, V, (kts) $\overline{V}$	98%	Prob. Max.	Max. Obs.	Prevailing Direction
4	4	58	32	5	1	--	0.93	2.6	3.7	4.2	SE
5	4	59	33	4	--	--	0.90	2.3	3.1	3.6	NW,SE
6	4	90	6	--	--	--	0.96	1.6	2.2	6.0	SE
7	3	52	33	10	2	--	1.07	3.2	4.0	5.5	NW
8	4	44	38	12	2	--	1.16	3.6	4.7	5.5	N
9	4	53	32	10	1	--	1.03	2.7	3.2	3.6	N
10	4	66	27	3	--	--	0.97	2.3	3.1	3.6	W
11	8	69	21	2	--	--	0.72	2.1	2.8	6.0	NW
12	7	72	19	2	--	--	0.70	2.0	2.6	3.5	W
13	3	78	19	--	--	--	0.66	1.6	1.9	2.5	W
14	8	68	22	2	--	--	0.92	2.1	2.6	2.5	W
15	3	74	21	2	--	--	0.74	2.1	2.8	2.5	N,W
16	7	87	6	--	--	--	0.52	1.5	2.0	---	-
17	6	61	30	3	--	--	0.83	2.2	2.8	2.8	SW
18	6	83	9	2	--	--	0.60	2.5	3.2	2.6	NW
19	7	79	12	2	--	--	0.62	2.3	3.0	2.6	W,N
22	7	66	24	2	1	--	0.78	3.3	4.4	6.5	SW
24	6	64	19	8	3	--	0.81	3.7	4.2	5.1	SW
25	8	67	22	3	--	--	0.74	2.7	3.2	4.3	NE
26	2	13	19	28	30	8	2.64	4.8	5.5	6.5	N
27	5	57	29	8	6	3	1.26	4.4	5.0	3.0	N
28	1	19	31	34	14	1	2.14	4.0	4.7	5.8	NE
29	9	73	15	3	--	--	0.66	2.5	3.2	4.5	S
30	8	83	9	--	--	--	0.55	2.0	2.4	4.0	S
31	2	86	11	1	--	--	0.62	2.2	2.7	4.0	E

6. EQUIPMENT BASELINE

The equipment required for an effective response to a major oil spill in open water has two major functions - to offload oil before it leaks from a stricken tanker and to recover spilled oil from the surface of the sea. The elements of a complete response system capable of performing these functions are well-defined and consist of:

1. Pumps to offload and transfer oil.
2. Barrier booms to contain and concentrate the spilled oil.
3. Skimmers to recover oil from the surface of the sea.
4. Flexible bags or tank barges as containers to hold the offloaded or recovered oil until it can be transferred to land for disposal.

Many factors enter into the selection of specific items of equipment from among those available to fulfill these functions. Most important among these factors are:

1. Performance characteristics such as capacity, environmental limits, and reliability.
2. Physical characteristics such as size, weight, packaging, and transportability by land, sea, and air.
3. Costs for acquisition, upkeep and maintenance.
4. Auxiliary requirements such as support equipment and operating personnel.

Since some candidate subsystems are still being developed and others have not yet been fully tested under operational conditions, it would be premature at this stage to attempt to make a final selection of all the elements of an effective future response system. For this reason, the Coast Guard has designated the elements of a baseline system as a term of reference for this study. To the extent that they are known, details of these specific items will be presented in this chapter. Other

6.1.2 Containment

Containment describes an action taken to limit the continued spreading and migration of oil on the surface of the water or to confine the flow of spilled oil to a small area in the vicinity of the source. It is the critical first step in any controlled and coordinated recovery and clean-up operation.

In open waters physical barriers, or floating curtains, are the most common means of containing oil. These curtains are known as oil containment booms. They also serve to increase the thickness of an oil slick and, as a result, to facilitate recovery operations. Booms designed for use in open water are usually solid, continuous obstructions to the spread and migration of oil. They typically include floats for buoyancy, a skirt for containment, ballast for stability, and a tension member for strength (Figure 6-1).

Oil containment booms are available in many sizes and configurations. Individual lengths can usually be connected with leak-proof joints to form a long, continuous barrier. The boom's free board must have sufficient height and the cross-sectional geometry to prevent oil from washing or splashing over its top. The skirt must be deep enough to prevent oil from draining out from underneath, yet not so deep that the drag forces become excessive. Here there is a tradeoff between the draft required for effective containment of the oil and the drag force produced by that draft. Along with adequate, but not excessive draft, a good boom design will provide reserve buoyancy, roll stiffness, and a strong tension-member.

The containment boom that has been selected by the Coast Guard as best meeting the requirements of this element of the baseline response system is the Open Water Oil Containment System (OWOCS) currently in its inventory. It is packaged in 612 foot lengths and can be delivered to a spill site by air (C-130) or by sea (buoy tender or fast surface delivery sled).

6.1.3 Recovery

The second, and perhaps most complex step in the process of removing spilled oil from the surface of the sea is recovery. The most common means available to accomplish this task in open water is by mechanical skimming from the surface. The primary objective of a skimmer is to pick up as much of the oil it encounters together with as little water as possible over a wide range of surface thicknesses, product types, wave heights, currents and debris size and density (including ice). Unlike booms, all skimmers do not operate on the same engineering principles, nor do they all degrade to marginal performance for the same reasons.

6.1.3.1 Skimming Devices - The types of skimmers most commonly used in recovery operations are:

1. Floating weirs
2. Vortex devices
3. Endless belts
4. Suction devices
5. Rotating discs.

Skimmers that use weirs and suction devices tend to pick up a high percentage of water with the oil. Endless belts and rotating discs are more selective in the products recovered and in general, can tolerate higher sea states. However, in rough water the oil may become emulsified or mixed into a watery slurry, in which case little can be done to reduce the total volume of oil and water requiring temporary storage at the spill site.

From these considerations it should be clear that high-performance oil skimmers are complex devices. As a minimum they must (1) pick up a large fraction of the oil they encounter, (2) incorporate some means of separating the recovered oil from water, (3) have the capacity to store the recovered oil temporarily or to pump it off into external storage containers, and (4) be able to operate effectively for many hours in moderate sea states and

The skimming barrier described above, with six weirs and three pumps, is being developed by the Coast Guard as an element of its baseline open water oil pollution response system. Preliminary tests indicate a flow rate of 600 gpm with a recovery efficiency of 75% at one knot in calm water, dropping to 50% in 1.5 foot waves.

6.1.4 Storage

Oil skimmed from the surface of the sea must be stored in suitable containers for transport to shore and thence to a suitable disposal site. Skimming devices and skimming barriers have no significant storage capacity of their own, and the capacity of available skimming vessels is severely limited. The largest vessel skimmer has a capacity of about 70,000 gals., which is at the lower end of the spill size range considered in this study. Such large vessels would represent a major commitment of resources (3-4 M$ each), yet their oil recovery rates are not greater than those of the devices described above, so they are not an attractive option. On the other hand, interstate tank barges, operated by commercial firms, have capacities as large as a few hundred thousand to a few million gallons. In the event of a massive spill in open water, tank barges or tank ships of this size would be required at the recovery site. However, the time needed to locate an empty tank vessel (or unload one) and bring it to the spill site cannot be time lost to the recovery operation.

To fill this gap the Coast Guard has selected a series of flexible containers called Portable Oil and Hazardous Substance Storage Containers (POHSSC), as the storage element of its response system. These flexible containers are constructed from synthetic rubber coated nylon fabric and cord. They are towable and can be palletized and delivered to the spill site by air. The nominal capacities that will be considered for the Coast Guard inventory are 12,000 gals., 50,000 gals., and 290,000 gals.

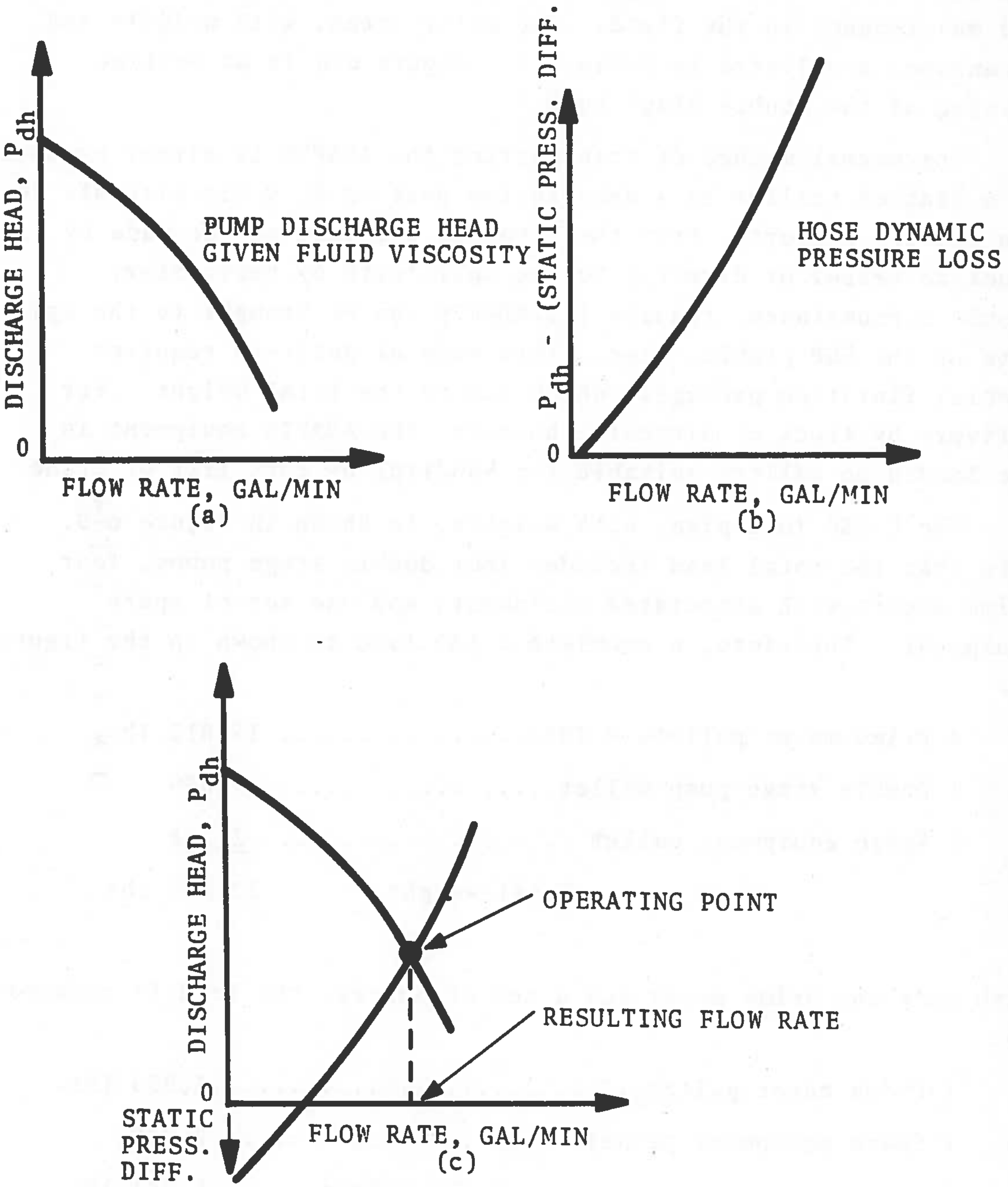


FIGURE 6-2. GRAPHICAL DETERMINATION OF PUMPING SYSTEM OPERATING POINT

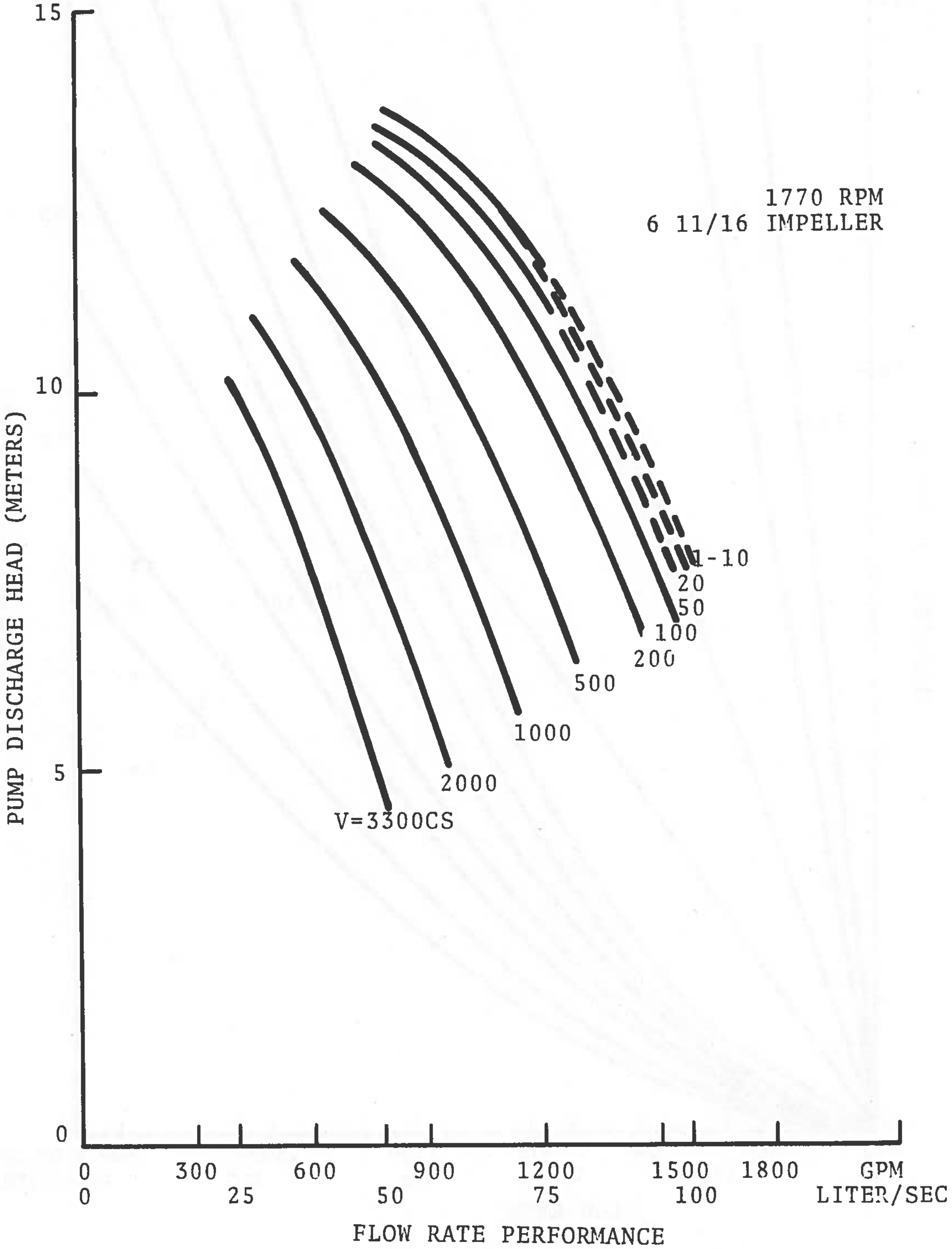


FIGURE 6-3. ADAPTS TWO-STAGE PUMP PERFORMANCE

200 FEET OF 6 INCH HOSE

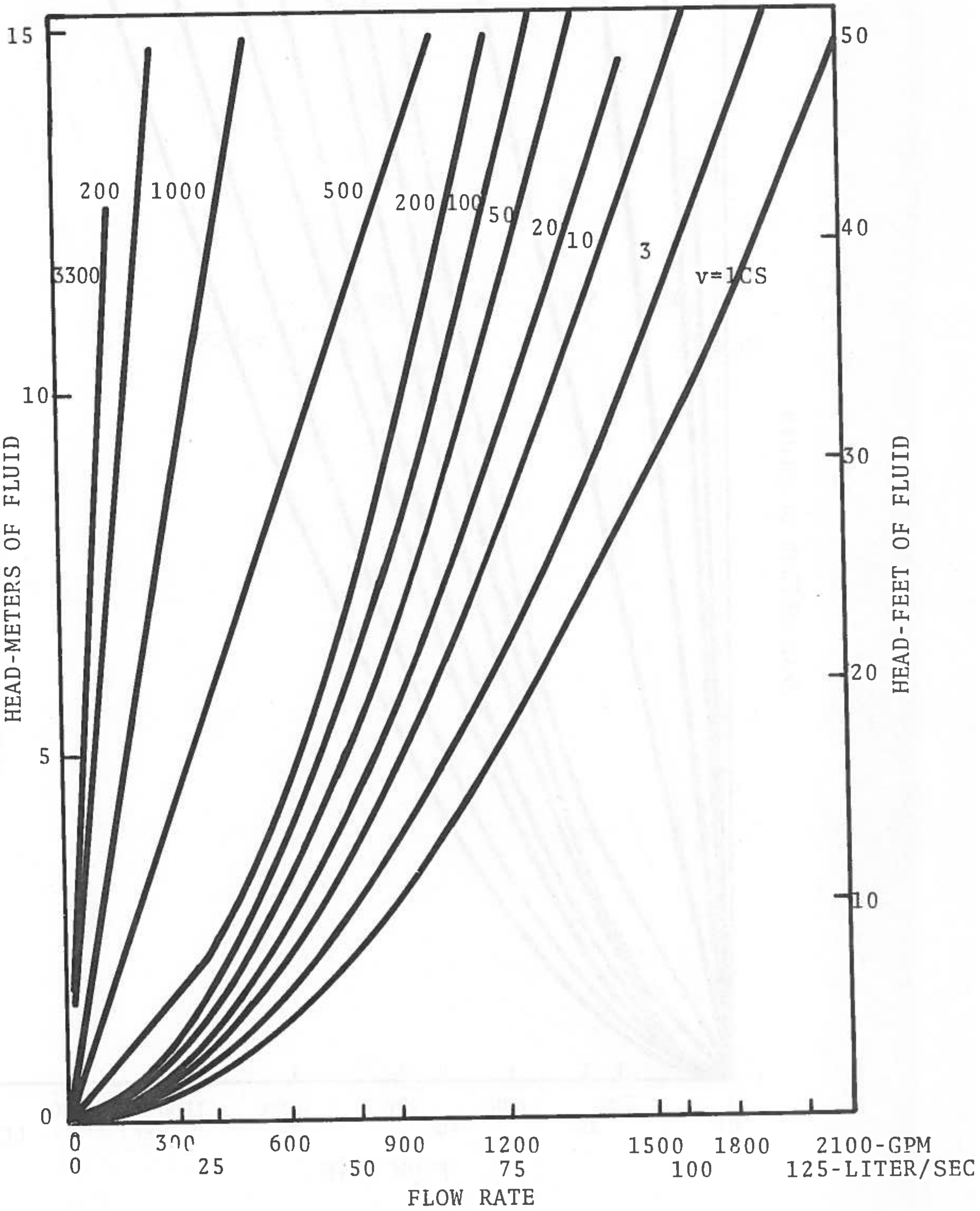
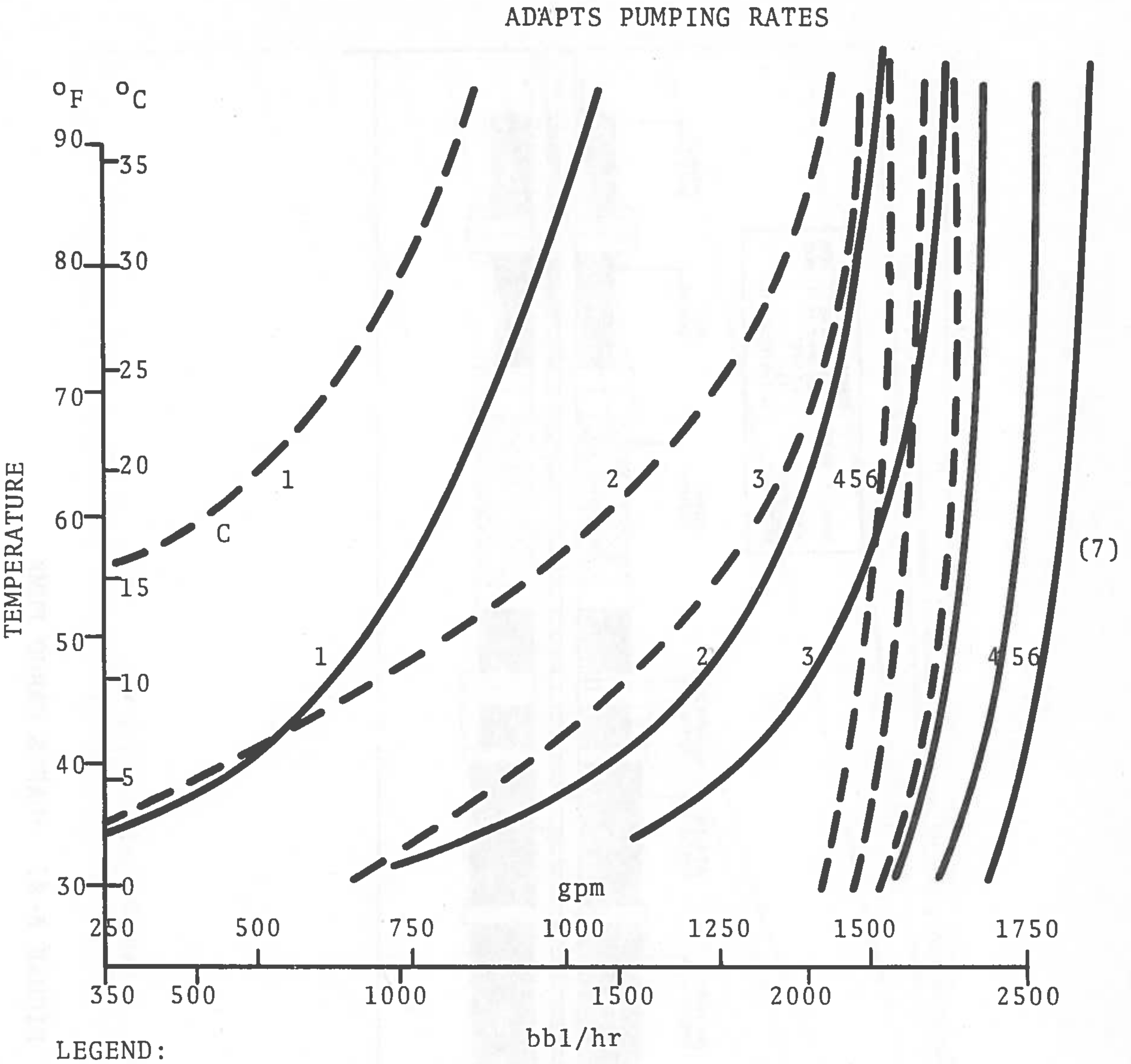


FIGURE 6-5. DYNAMIC PRESSURE DROP IN ADAPTS HOSE - 200 FT



LEGEND:

– – – – SINGLE STAGE & STRIPPER PUMP

——— DOUBLE STAGE PUMP

Baseline Geometry
35' Head
300' hose

1 - BUNKER "C" (HEAVY BLACK FUEL OILS,
2 - LIGHT FUEL OILS AND LUBE OILS
3 - SANTA BARBARA CRUDE
4 - PRUDHOE BAY CRUDE
5 - DIESEL AND NO 2 FUEL OIL
6 - KEROSENE AND JET FUELS
7 - WATER AND GASOLINES IN EXCESS OF 200 gpm (2800 bbl/hr)

FIGURE 6-7 ADAPTS SYSTEM PERFORMANCE

TABLE 6-1. ADAPTS EQUIPMENT SUMMARY [REFS 6-2 AND 6-3]

ITEM	WEIGHT (LBS)	DIMENSIONS (INS.)	VOLUME (CU. FT.)	($)COST**
Diesel/Hydraulic Prime Mover	1122	41"x34"x44"	35.5	31,000
Submersible Double Stage Pump	896	20 x20 x113	26.1	10,000
55 GAL. Fuel Container	460	36 x24 diam	9.4*	200
Tripod Module	190	98 x14 diam	8.7*	2,000
6 Sections 50'x6" Discharge Hose	720	36 x 36 x 72	54.0	600 per section
Submersible Single Stage Pump	340 w/box	20 x 18 x 66	10.9	8,000
Submersible Stripping Pump	370 w/box	20 x 18 x 66	13.8	8,500
Tripod Rigging Gear	200	14 x 32 x 17	4.4	2,000
Universal Flange Kit	290	14 x 48 x 26	10.1	300
Spare Parts	500	14 x 32 x 17	4.4	100
Tool Box	85	11 x 18 x 11	1.3	200
Flowmeter	230	16 x 25 x 30	6.9	
600' Hydraulic Hose (6 lengths)	810	28 x 28 x 48	21.8	
Hydraulic Oil (5 GALS)	46	20 x 14 x 7	1.1	40
Lubricating Oil (5 GALS)	45	20 x 14 x 7	1.1	20
Dual Rail Pallets ea.	290			

*The fuel module is a collapsible rubber coated fabric container for #2 Diesel. The operating time on one tank-full is approximately 18 hours.

**Procurement costs are best estimates, where available, in 1976 dollars.

6.2.2 Containment Booms

Coast Guard Open-Water Boom - The Coast Guard open water containment boom is a barrier with a 27 inch draft and a 21 inch freeboard. It is packaged in sections 612 feet long and weighs 16 lbs. per foot. The barrier is maintained at the proper level and orientation on the surface of the water by 102 flotation bags, inflated during deployment by individual CO_2 cylinders. It is designed to contain oil in a 20 knot wind, 4-6 foot seas and 1-2 knots of current.

The packaged boom can be transported by C-130 aircraft, or over the road by truck. For water transport to a spill site, either a buoy tender (with crane) or an FSD planing sled may be used. At the spill site deployment may be from a vessel or in the water from the container.

Performance Characteristics

The ability of an oil boom to concentrate oil for recovery depends in large measure on the loss rate of the barrier. No open water data are available for this exact barrier configuration, but a similar design, differing primarily in that it had floats on the oil side as well as the back side, was tested at Point Conception, California, on March 8 and 10, 1972, using Soybean oil. (Ref. 6-4) At relative speeds in the range 0.71 - 0.77 knots, the loss rate in calm water was less than 1 gallon/min out of 24,000 gallons. These losses were due mainly to agitation by the interior floats, which have been removed in the most recent design. At a speed of about 1.06 knots, the loss rate in calm water was about 50-70 gal/min out of about 22,000 gallons, primarily from the headwave. Finally, as towing speeds increased to 1.6 knots the loss rate in calm water increased to about 680 gal/min.

In rough water (about 2 feet significant wave height, swell of 8 feet with a ten second period), the loss rate was about 35 gal/min out of 5,700 gallons contained at an average speed of 0.4 knots. At an average speed of 0.6 knots the loss rate was 70 gal/min with about 4,000 gal contained. At 1.6 knots the loss rate

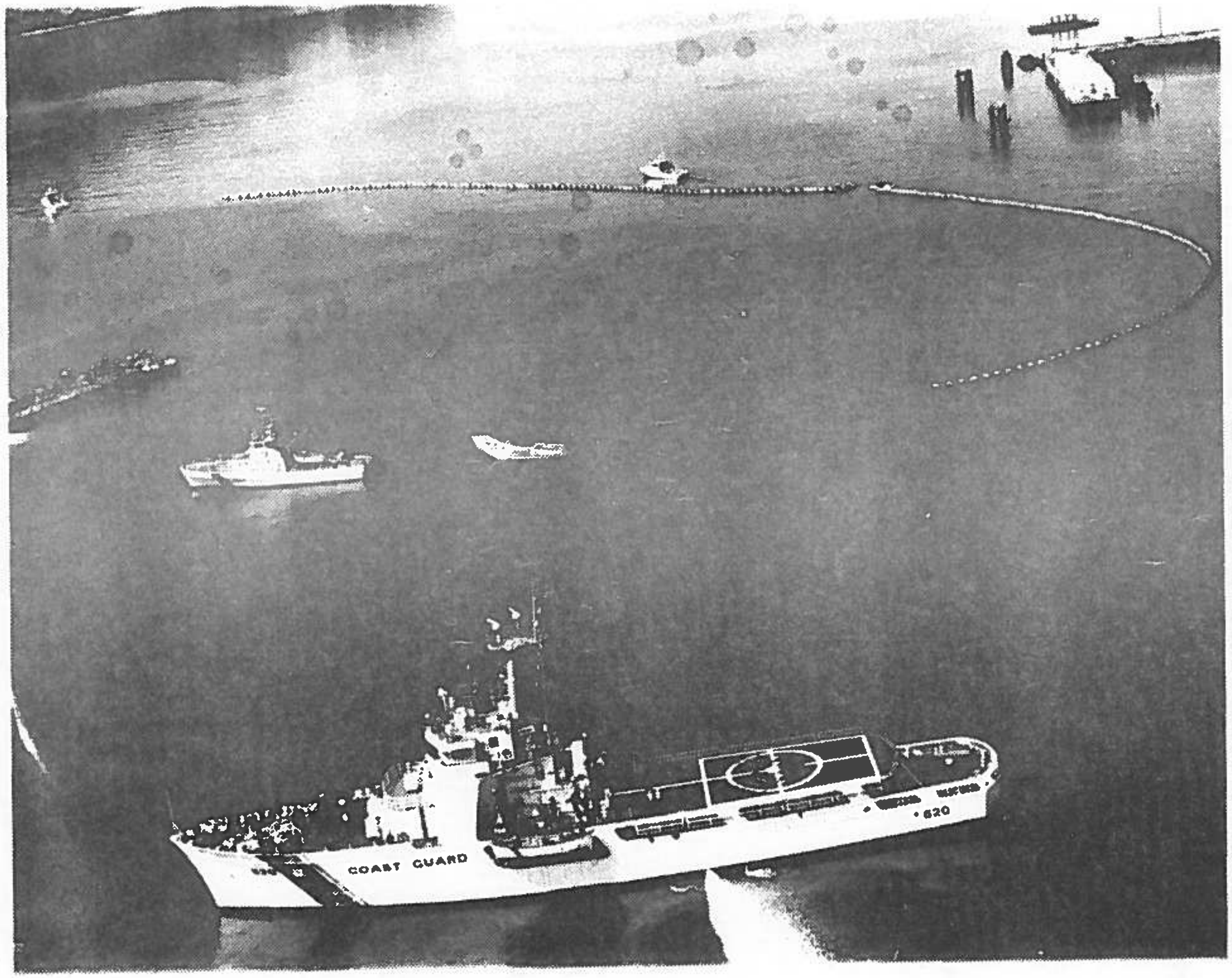


FIGURE 6-10. COAST GUARD BOOM DEPLOYMENT FROM A FAST SURFACE DELIVERY (FSD) PLANING SLED.

6.2.3 Skimming Barrier and Skimming Devices

6.2.3.1 Coast Guard OWOCRS, Open Water Oil Containment and Recovery System - The skimming barrier and pumping system being developed by the U.S. Coast Guard[6-1] is a modification of the baseline containment boom previously described. The skimmer that was integrated into the boom design is a simple weir skimmer consisting of a partly submerged slot in the barrier curtain through which oil and some water pass and fall into a sump tank on the other side from which it is pumped. The prototype design, containing 6 weirs and 3 floating pumps with 2 inlets each, was tested at the EPA's OHMSETT facility with respect to oil recovery and in sea trials off Florida for operational practicality. Although the system has not yet entered the Coast Guard inventory, it may be considered state-of-the-art and shows promise for the future.

Performance Characteristics

In the OHMSETT tests the recovery efficiency (oil/(oil + water)) of the skimmer portion of the boom-skimmer combination was found to be as high as 76% in calm water and as low as 24% in 1.5 ft waves. The results of the OHMSETT tests are summarized in Table 6-4. No tests have yet been performed in open water of the skimming barrier under tow using a suitable oil substitute.

Physical Characteristics

Although no production models of the skimming barrier are available as yet, it is expected that their physical characteristics will be closely similar to those of the open-water boom alone (Table 6-3).

6.2.3.2 The Lockheed Open Water Skimmer (Ref. 6-5) The Lockheed skimmer is a disc-drum recovery system that consists of an oil recovery drum mounted in a captive catamaran. The catamaran hull consists of 4 large inflatable pontoons which support a rigid midships section that contains the oil collection disc-drum, oil

Physical Characteristics

TABLE 6-5. OWORS PHYSICAL CHARACTERISTICS

Dimensions:	Deflated - 7'x28'x8.5' Inflated - 26'x28'x11.5'
Weight:	15,000 - 17,000 lbs.
Max. Operating Conditions:	Wind 20 kts Waves 6 ft Current 2 kts
Max. Survival Conditions:	Wind 40 kts Waves 10 ft Current 5 kts
Cost:	$800,000 (approximate, 1976 dollars)

6.2.4 Containers

6.2.4.1 The Dunlop Dracone Flexible Container - To provide storage for offloaded or recovered oil pending the arrival at the scene of large lightering vessels, the Coast Guard has selected a series of containers as the storage element of its baseline response system. These containers are listed with their basic characteristics in Tables 6-6 and 6-7.

In normal use the bag is packed on a pallet and taken to the response site on a buoy tender or planing sled. The empty bags have positive buoyancy so that they remain afloat during deployment. If a bag is to be towed, it is filled to no more than 85% of design capacity in order to keep the dynamic stresses below design limits in the presence of wave action. The fact that the bag is almost completely submerged renders it relatively immune to sea states and winds while moored at the site or while under tow. The bag does, however, present a fairly high drag force and cannot be towed at speeds in excess of a few knots without risk of damage.

Performance Characteristics

TABLE 6-6. BASELINE STORAGE BARGES, CAPACITIES

Dracone Type	OW	F	D10
Nominal Cap. (gals.)	290,400	50,400	12,000
97% Load (gals)	282,000	48,900	11,600
at wave height (ft)	≤7	≤4	≤2.5
85% Load (gals)	246,800	42,800	10,200
at wave height (ft)	>7	>4	>2.5

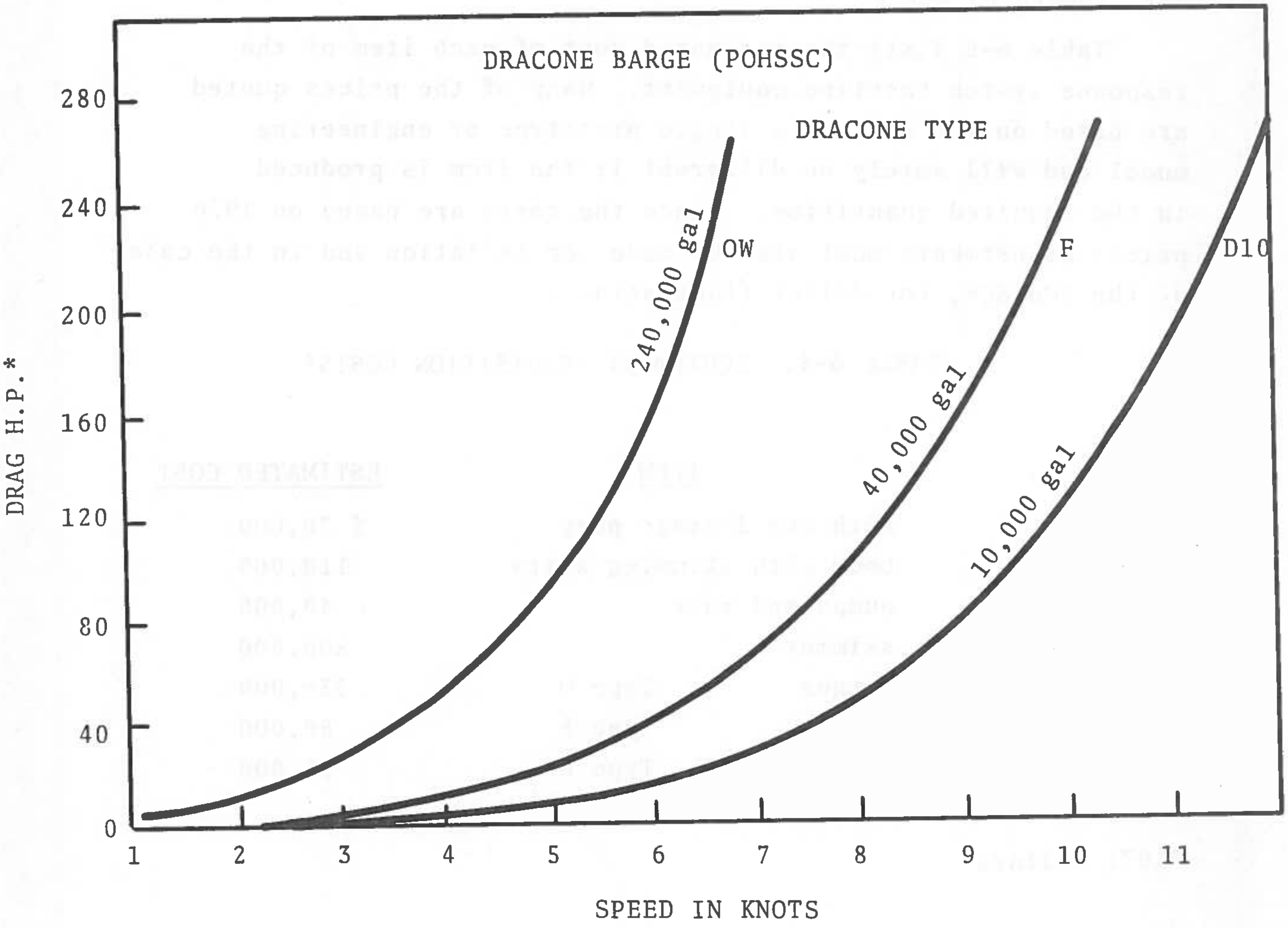
The physical characteristics of the three baseline barges are given in Table 6-7. Figures 6-12 and 6-13 show the tow-line tension and drag horsepower requirements under tow. The drag of the empty bag with buoyancy tubes inflated is approximately 75% of the drag when filled.

Physical Characteristics

TABLE 6-7. BASELINE STORAGE BARGES, PHYSICAL CHARACTERISTICS

	Dracone Type		
Packaged	OW	F	D10
Length	19'2"	12'3"	9'2"
Width	6'4"	5'4"	5'4"
Height	5'10"	3'5"	3'5"
Volume (cu. ft.)	709	223	167
Weight (lbs)	13,104	8,064	3,052
Deployed			
Length	260'	160'	100'
Diameter	13.8'	7.4'	4.5'
Weight (lbs)	9521	5016	1638
Max Draft	11.8'	6.25'	4.23"
Cost*	$236,300	$85,650	$36,000

*These costs are in 1976 dollars. Approximately 35% must be added to convert to 1979 dollars.



*To convert LBS. DRAG x KNOTS to DRAG HORSEPOWER multiply by 1/330.

FIGURE 6-13. CURVES OF DRAG HORSEPOWER

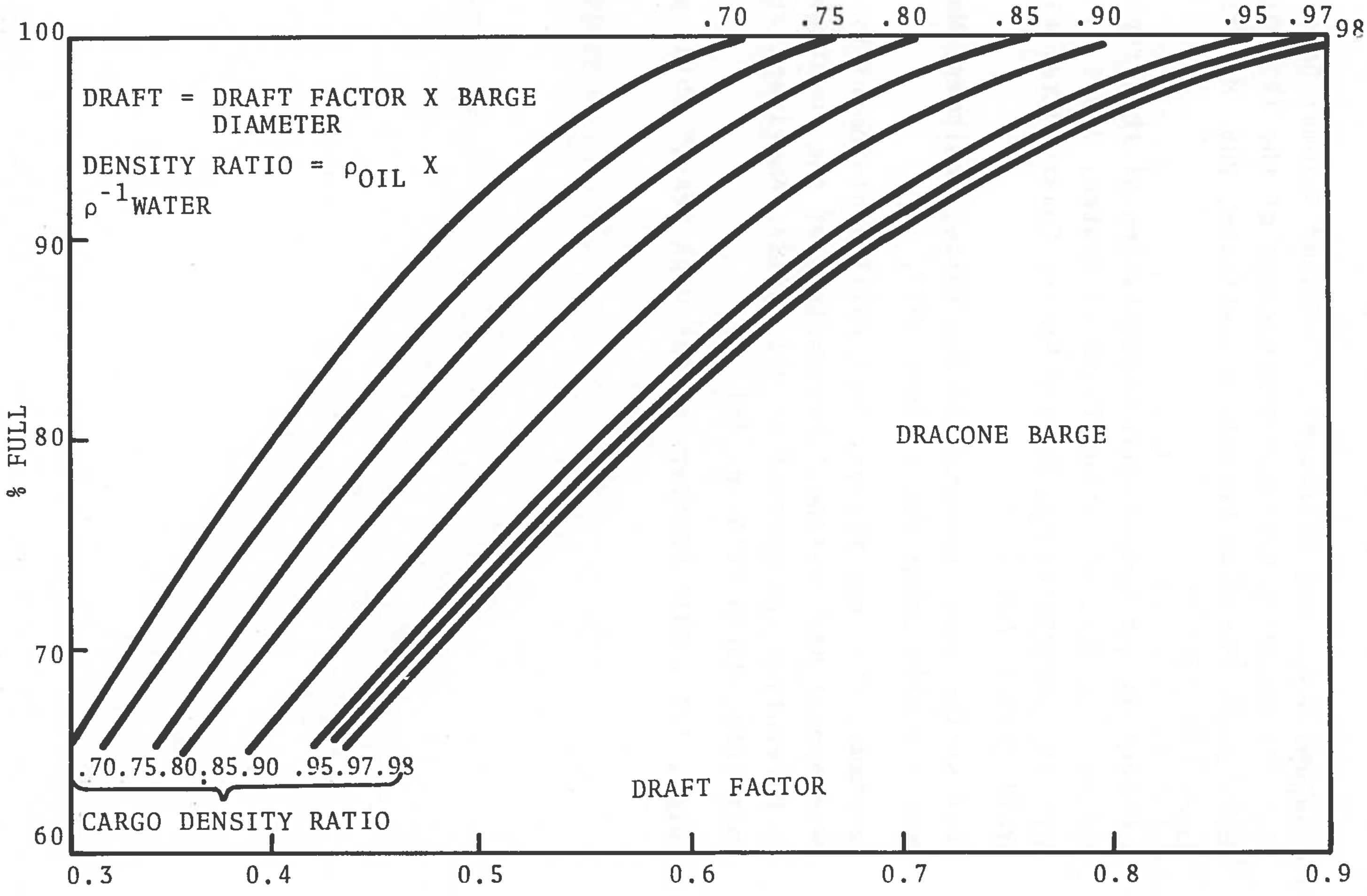


FIGURE 6-14. CURVES OF DRAFT FACTOR/% FULL FOR CARGO DENSITY RATIOS 0.70-0.98

7. LOGISTICS

The preceding sections of this report have investigated the potential for oil spills in U.S. coastal waters and some of the equipment available to combat them. In this section the various logistic options available to bring the equipment to a suitable debarkation point will be examined. The purpose is to estimate the range of each transport option within the specified 6- hour response time. These ranges, and corresponding equipment payloads, will be employed in the following sections to select sites and equipment levels. While the estimates developed in this section are aimed primarily at single-site response to non-massive spills, the information may also be applied to multi-site response to massive spills, as will be done in Section 10.

The procedure to be followed in this logistics study is as follows. First, the transport characteristics (weight, size, etc.) of the baseline equipment are assumed from Section 6. Next, the various vehicles that may be employed to carry the equipment are examined, in order to estimate their ranges, payloads, speeds and other characteristics. Finally, several logistic options (i.e., vehicles or combinations of vehicles) are selected and their payload-range characteristics developed. A review of these characteristics leads to the selection of three transport options (truck, air/truck, waterborne) for primary consideration in the site selection study of Section 8.

7.1 BASELINE RESPONSE SYSTEMS

The Baseline Response systems described in the preceding section will be assumed for the logistics investigation. In summary, the logistics characteristics of these units are as follows

	Weight	Size	Cost
OWOCS/Skimmer			
Boom & Weirs	16,000 lbs	18 x 9 x 5	110,000
Pumps	700	5 x 9 x 3 1/2	40,000
Prime Mover	1,200	4 x 4 x 4	31,000
Hose, Connectors	600	3 x 3 x 6	3,600
Fuel Cell	460	2 x 3 x 2	200
	19,000 lbs	1100 Cu. Ft.	$175,000
OWORS/Barrier			
Skimmer 400	16,000	7 x 28 x 8.5	800,000
Barrier	16,000	18 x 9 x 5	100,000
Fuel Cell	460	2 x 3 x 2	200
600' Discharge Hose	720	3 x 3 x 6	3,600
	33,200 lbs	2070 Cu. Ft.	$904,000
POHSSC			
Type OW & Pallet	13,000	19 x 6 x 6	236,000
Type F & Pallet	8,064	12 x 6 x 4	86,000
Type D	3,052	9 x 6 x 4	36,000
600' Discharge Hose	720	3 x 3 x 6	3,600
	24,8361bs	1242 cu. ft.	$361,600

TABLE 7-1 VESSEL CHARACTERISTICS

	Max Load					Cruise at Max Load		
Vehicle	Wt 10^3lb	L ft	W ft	H ft	Area ft^2	Speed kts	Range n.mi.	Draft ft
SLED/TOW								
FSD/HH3F(1)	17	27	9.0	-	243	46(2)	75(3)	1.5
FSD/RH53(1)	17	27	9.0	-	243	57(4)	-	1.5
FSD/82'WPB(1)	17	27	9.0	-	243	17(5)	419	6.0
FSD/210'WMEC(1)	17	27	9.0	-	243	17(5)	5800	10.0
FSD/41'UTB(8)	17	27	9.0	-	243	12	150	4.0
FSD/270'WMEC	17	27	9.0	-	243	19	4200	14.0
FSD/378'WHEC	17	27	9.0	-	243	28	2400	21.0
CUTTERS(6)								
52'MLB	10	LOAD DIMENSIONS NOT STANDARD			100	11	430	6.0
63'ANB	16				375	15	210	4.5
82'WPB	6				200	24	470	6.0
95'WPB	8				400	20	440	6.0
210'WMEC	20				1500	16	6200	10.0
270'WMEC	60				2500	20	4130	14.0
378'WHEC	100				2500	16	10300	21.0

NOTES TO TABLE 7-1

(1) Reference 7-1. Although the FSD sled was designed to carry 20,000 lbs. (Ref. 7-2, p. 418) tests were performed with 17,000 lbs or less, as described in Reference 7-1. The lower figure is used here because the speed and range figures were obtained using 17,000 lbs.

(2) Significant wave height 1.5 ft. in tests.

(3) Estimate via USCG Aviation Branch, Search and Rescue Division. This estimate is based on 3,000 lbs of fuel employed in the Panama City tests, Ref. 7-1, and in the tests of Reference 7-3. Further investigation would be needed to determine if this range can be increased.

(4) Significant wave height 2.0 ft. in tests.

(5) Significant wave height 1.0 ft. in tests.

(6) Reference: Publication USCG-197, "Register of Cutters of U.S. Coast Guard."

(7) 9.0 knots applies to the 303 class; 11.3 knots applies to the 400 class.

(8) Reference 7-1, pE-24.

TABLE 7-2(a) ESTIMATED AVERAGE TOWING SPEEDS, SELECTED USCG VESSELS TOWING FSD

VESSEL TYPE	UNDERWAY AND STANDBY HOURS IN 1975	TOWING SPEED KTS(1)
WHEC/327	$18.7\text{x}10^3$	20 knots
WHEC/378	51.3	20
WMEC/210	100.3	17
WMEC/213	6.7	17
WMEC/205	15.0	17
WMEC/143	13.0	17
WMEC/-	6.0	17
WPB/95	148.2	17
WPB/82	362.3	17
WLB/180	201.3	13
WLM/177	25.0	12
WLM/157	46.5	12
WLM/133	41.0	9
WLI/100	14.9	10
WLI/100	14.3	10
WLI/65	42.4	10
WYTM/110	80.8	10
WYTL/65	103.8	10
WYTM/UNK	8.7	10
BU/40	11.0	5
BU/45	142.2	5
MLB/44	870.9	5
MLB/52	37.2	5
UTB/40	1147.9	17
OTH/>40	513.5	10

(1) See text   Mean towing speed 12.16 knots

leaves open the question of whether the UTB/41 can maintain planing speeds while towing. The question is significant because the UTB/40 is about 29% of the eligible towing fleet on the basis of 1975 hours underway or on standby.

The FSD is not the only vehicle capable of carrying the largest piece of pollution response equipment (Open Water Barrier and Container, 17,000 lbs) behind a USCG cutter. To allow for the possibility that other non-planing vessels may be employed, theoretical towing capabilities of some USCG cutters are listed in Table 7-2(b). This table is based on towing a vessel of either 60,000 lbs or 30,000 lbs displacement. The assumptions made in deriving the maximum theoretical towing speed are that the horsepower required to move either vessel is proportional to its displacement and to the cube of its speed, and that the total horsepower required is applied entirely by the towing vessel. The design speeds of both vessels were assumed equal for simplicity. Average practical towing speeds will vary according to the design of the two vehicles, and will probably be less than shown in the table.

The next seven vehicles in Table 7-1 are USCG cutters alone. Almost every cutter has some deck space and cargo capacity that may be employed to carry pollution response equipment. The major limitations are: (a) cargo capacity, (b) availability of loading and unloading devices, (c) usable deck area and (d) sea state limits of the smaller vessels. Table 7-1 lists USCG cutters with load carrying capacity of 6,000 lbs or more. All of these require a crane or lift or equivalent device for loading and unloading. Therefore, they may be considered for transporting equipment only between ports that have such devices, and which can accommodate their draft. There are approximately 150 potential debarkation ports in the U.S. (Atlantic Coast, Gulf Coast, Pacific Coast, Great Lakes, Puerto Rico) that have cranes or lifts. They are listed, with draft information in Appendix E. The effective cruise range for the seven cutters listed in Table 7-1 was obtained by multiplying the normal (unloaded) range of the vessel by D/(D+L) where D is vessel unloaded displacement and L is equipment load.

TABLE 7-3 PAYLOAD AND RANGE RELATIONS FOR USCG AIRCRAFT

Vehicle	P_o 10^3 lbs	R_{max} n.mi.	P_{max} 10^3 lbs	Speed V kts	f lbs/hr	C_T lbs
HH52A	1.5	300	0.0	80	409	2,112
HH3F	6.3	660	0.0	126	1,200	7,200
HC130B	58.6	3,250	13.3	290	4,030	45,240
HC130H	87.9	3,850	25.0	300	4,900	62,920
HU16E	8.5	2,054	0.0	145	600	10,000
HC131A	34.9	1,580	25.6	170	990	9,180
HU25A	10.2	2,200	0.3	405	1,820	9,910

NOTES:

(1) P_o = Payload at zero range = Maximum gross weight minus (empty weight + crew weight weight at 200 lbs per crewmember + reserve fuel for 45 minutes if fixed wing, for 20 minutes if helicopter)

(2) R_{max} = Range when fuel is limited by either (a) payload, when used to carry fuel, or (b) capacity of fuel tank, = min $(VP_o/f, VC_T/f)$, where C_T is capacity of fuel tank (excluding auxiliary tanks)

(3) P_{max} = payload at R_{max} = max $(0, P_o - C_T)$

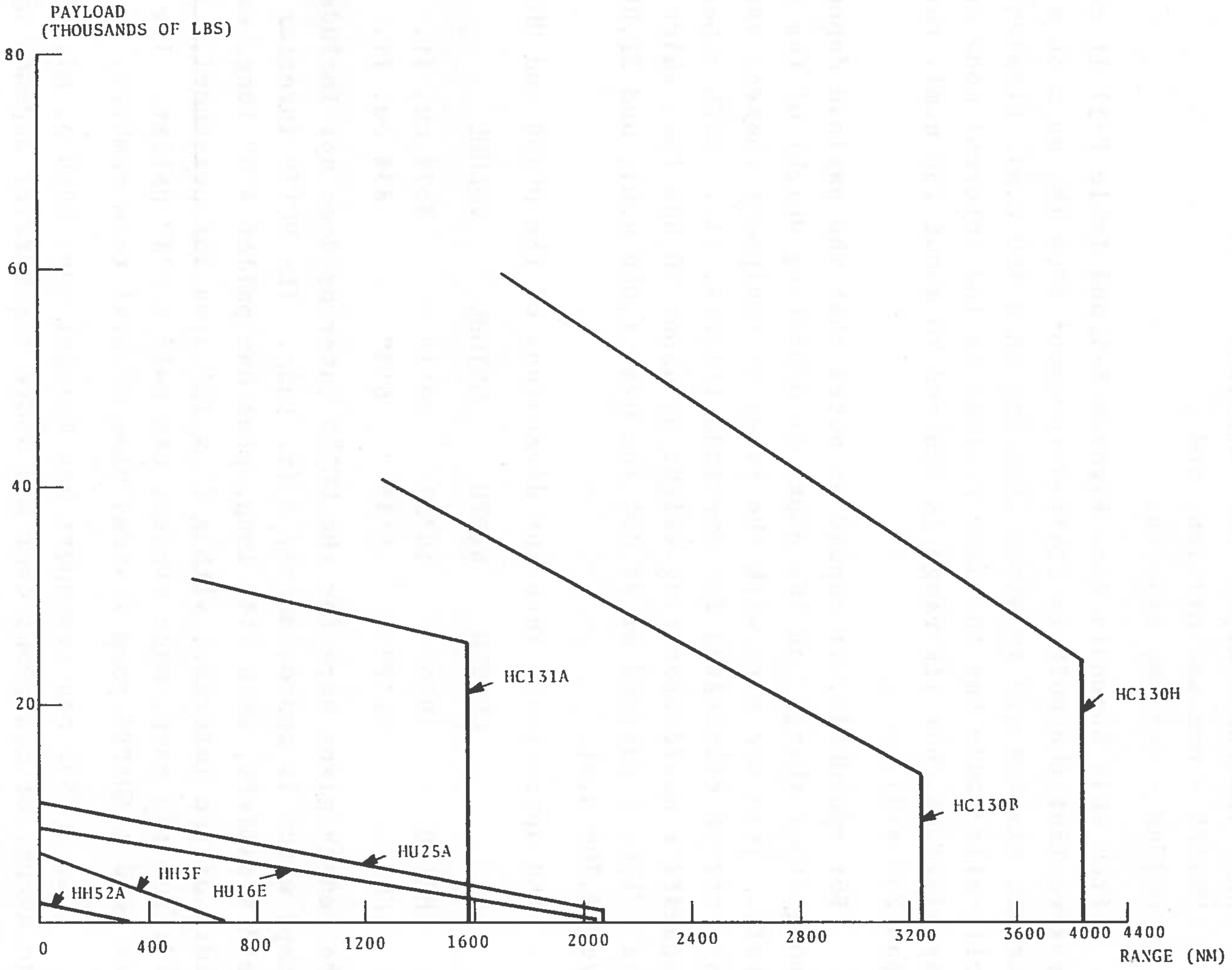


FIGURE 7-1(a) APPROXIMATE RANGE-PAYLOAD CHARACTERISTICS OF CURRENT USCG AIRCRAFT

The HC130H can carry two barriers over a 1000 n.mi. range, or one barrier over a 3400 n.mi. range, with approximately 5,000 lbs of additional cargo, assuming a gross weight of 90,000 lbs without fuel or payload. Additional cargo can be added when the required range is less than 3400 n.mi. Because the dimensions and weight of the skimmer, barges, and ADAPTS are less than those of the barrier, numerous combinations of equipment can be accommodated if the barrier is not loaded.

Aircraft not in the present USCG inventories are also relevant to air transport of pollution response equipment in the 1980-1990 time frame. These may either be borrowed from other services, or purchased by the USCG. In the latter category, it should be noted that the HH3F is expected to be replaced about 1980. The task of transporting pollution response equipment is likely to fall upon the replacement vehicle at least to the same extent that it has fallen upon the HH3F. In order to assess the impact of these future helicopters on the pollution response mission (and vice-versa) several heavy duty U.S. military helicopters currently in production or in late development, are listed in Appendix G. This Appendix shows the approximate range-payload characteristics of five such helicopters,(not including the HH3F and variants of it). While some of these offer payloads well in excess of the HH3F's, the one-way distances are not necessarily greater. This can be seen in Figure 7-1(b), showing payload-range points for the CH-47C Chinook, S-64 Skycrane, CH-53A/2-Turbine, and CH-53E/3-Turbine, as well as the payload-range line for the HH3F. Obviously, more information is needed for a complete comparison.

Since specific vehicles for the 1980-1990 period cannot be designated, it is necessary to consider several generic types, including one similar to the HH3F, for pollution response work. The three classes considered are:

Class A:
6,350 lb payload at 0 n.mi., one-way
5,000 lb payload at 200 n.mi., one-way
6,000 lb payload at 100 n.mi., two-way

Class B:
20,000 lb payload at 0 n.mi., one-way
10,000 lb payload at 200 n.mi., one-way
12,000 lb payload at 100 n.mi., two-way

Class C:
37,000 lb payload at 0 n.mi., one-way
20,000 lb payload at 200 n.mi., one-way
24,000 lb payload at 100 n.mi., two-way.

The first group, Class A, is characteristic of the HH3F; Class B is typical of the CH-47C and CH-53A; Class C is representative of the CH-53E. The ability of helicopters in these three classes to transport the baseline system elements is given in Tables 7-4 and 7-5. These tables give several combinations of equipment and men that can be carried on a single one-way trip of various ranges by the three classes of helicopter. The combinations have been selected so as to stay within the volume and payload capabilities of the helicopters (with a 1,000 lb margin on the weights taken from Figure 7-1(b)). Except for the Class C helicopter, the range is limited by helicopter capability rather than by response time. It will be seen in Section 7.4 and in Figure 7-6 that the Class C helicopter, on a 300 n.mi. mission, would be limited in range by the 6-hour response time. Hence it is shown in Table 7-4 for the 12-hour response time (or 6-hour response with a 30-minute load time).

Land Vehicles

Land transport may be by conventional truck or by any number of specially designed vehicles. Conventional trucks may be Coast Guard equipment, borrowed from other services, rented, or drawn from the GSA motor pool. Conventional tractor-trailers are available with gross combined weights (tractor, trailer, load, fuel, driver) of 80,000 lbs. The corresponding load may be estimated

TABLE 7-5 TYPICAL BASELINE EQUIPMENT-RANGE COMBINATIONS - 12-HR RESPONSE TIME, OR 6-HR RESPONSE WITH 30-MINUTE LOADING TIME-

HELI-COPTER CLASS	RANGE n.mi.	Barrier 17,000	OW Barge 13,000	F Barge 8,000	ADAPTS 5,500	1/2 ADAPTS 3,000	D10 Barge 3,000	Skimmer 3,000	Team Member 200	TOTAL (lbs)
C	300		1							13,000
	300				2				10	13,000
	300			1	1					13,500*

*This combination is less than 1,000 lbs under the estimated max payload.

helicopter, fixed wing). The latter case occurs when the equipment is stored on a vessel in a port of high spill potential, and a spill occurs at a great enough distance from the port to make it necessary to transport the equipment by land or by air instead of by water. It is then necessary to remove the equipment from the water (perhaps with the vessel) and transport it by land or by helicopter to the debarkation point, or to an intermediate airport. The time lost in the transfer must be balanced against the cost of storing a duplicate set of equipment on land.

Land Storage

If the equipment is stored on land, it may be brought to the debarkation point by either single-mode or dual-mode transport. Three-mode schemes may be ruled out for six-hour response because of the interface times. The only possibilities for single-mode transport originating on land are (a) truck, (b) helicopter, both of which will be considered.

Of the two-mode schemes, one may eliminate truck/water and helicopter/water because waterborne transport to the debarkation point cannot be superior to truck when an interface is required. In other words, since truck speeds almost always exceed water speeds, truck/water will usually be inferior to all truck, and helicopter/water will usually be inferior to helicopter/truck.

The only other two-mode possibilities are (a) fixed wing/truck, (b) fixed wing/helicopter, (c) helicopter/truck and (d) truck/helicopter. The last two are limited in capacity by the helicopter. If the time required to transfer from helicopter to truck is equal to the time required to refuel the helicopter, then nothing would be gained by the truck leg in the helicopter/truck option unless the debarkation point were inaccessible by helicopter. Similarly, the truck/helicopter option would be inferior to a multi-leg helicopter trip unless there were some reason that the helicopter could not operate from the equipment site. Both situations are unlikely because the storage sites are selectable, and

Before discussing the above logistic options, some qualifications should be noted.

First, not all schemes apply to all pieces of equipment. For example, the current USCG helicopters cannot lift the CG barrier. Dedicated skimmers must be stored on or near the water-borne vehicle, while the ADAPTS and other pumps would present severe maintenance problems if stored aboard any but a large vessel. Also, local facilities and geography may make some options more attractive at one location than at another. It is possible that some equipment should be transported by one method and other equipment by some other method.

Second, it should be emphasized that these options all refer to delivery of equipment to the debarkation point, rather than to the spill location. By debarkation point is meant the waterside location from which the equipment may be loaded or launched for delivery to the spill location. Except for Option 1, unloading time at the debarkation point is not inlcuded in the response time. In Option 2, the equipment site may be a garage or storage area close to the pierside or launch ramp, but still far enough away to require a delivery device such as a loader, truck, or crane.

Third, the quantity of equipment required will affect the choice of delivery option. The number of aircraft available in the present USCG inventory, in particular, is such as to restrict the amount of equipment that can be delivered in the specified response time.

Finally, the transport of the response team itself must be considered. It is desirable, but not essential, that the response personnel move with the equipment if not before it.

The following sections give the assumptions and approximations made in estimating the relation between distance and response time for each of the above options.

vessel with the submersible feature of the FSD is a difficult design problem. (Reason (1) will be substantiated in what follows.)

It is assumed, then, that in the Direct Waterborne option, the equipment is stored on FSD sleds or similar submersible planing hulls, which are either moored or stored on a launch ramp at a USCG installation. Storage in a shed or on the dock is <u>not</u> covered in the following analysis, but is treated as Single-Mode Land. It is also assumed that equipment stored on a vessel is in a functioning, ready-to-go condition, equivalent to what can be achieved on shore.

The major time intervals associated with the Direct Waterborne option are:

a. Alert time: Time elapsed during receipt and recording of OSC message, notification of response team commander, notification of other base officers and issuance of request for a towing vessel	15 min
b. Notification and assembly of response team personnel, initial assignments to officers	45 min
c. Personnel briefing	15 min
d. Equipment check and launch (sled on ramp)	25 min
e. Equipment check (sled afloat)	30 min
f. Availability of towing vessel	60 min
g. Securing of tow line	5 min
h. Response Range R/Mean Speed	R n.mi./12.2 knots

Item f. is a highly variable time, depending on whether the storage vessel is at a large USCG installation or not, as well as upon the District in which it is located. The value shown is typical for most Districts in the U.S., except Hawaii, Alaska and District 2, which has no seacoast. The estimate for each District is derived in Appendix H. The curves developed in that Appendix give the probability of one or more suitable towing vessels being available

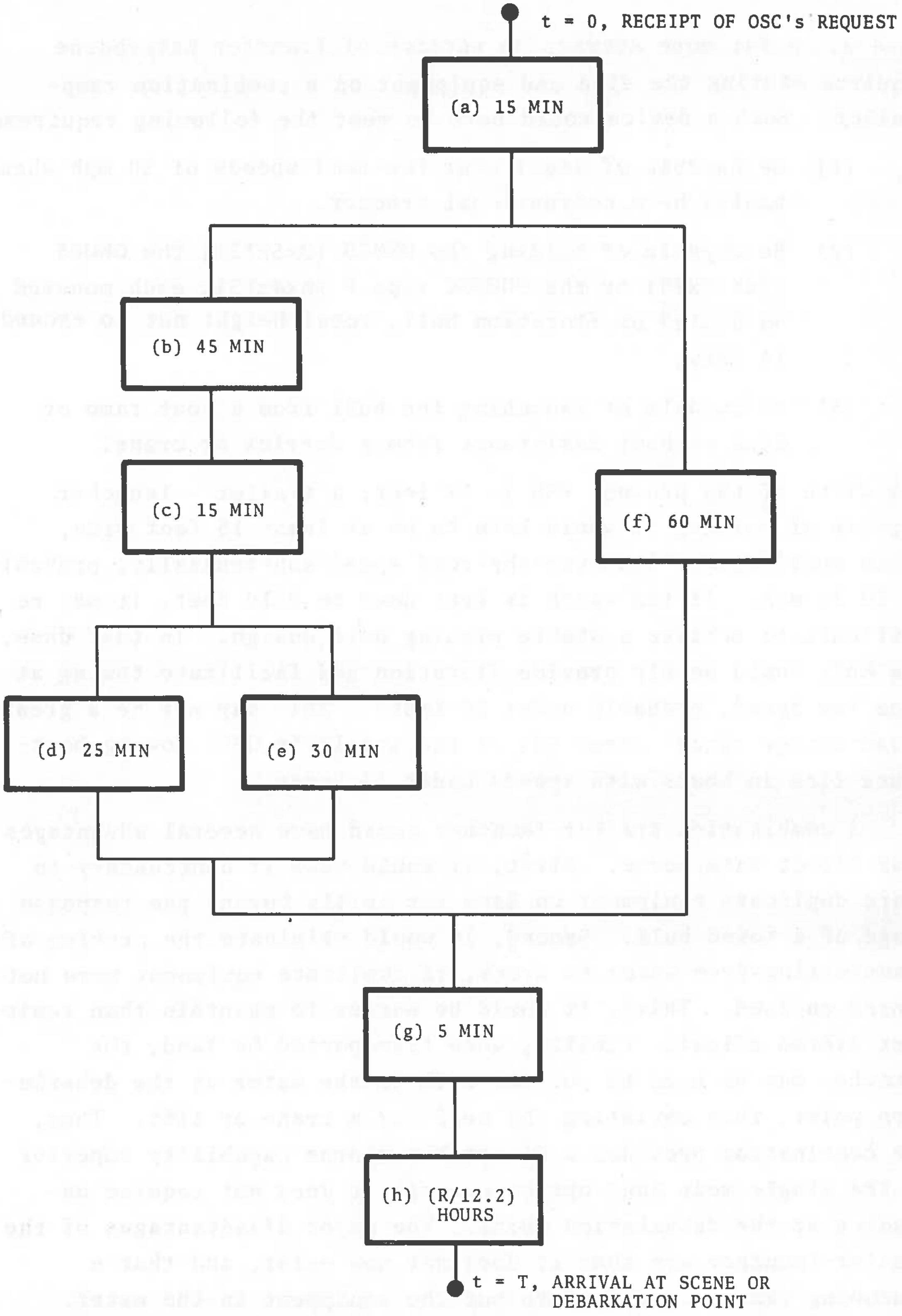


FIGURE 7-2 TIMING DIAGRAM FOR SINGLE-MODE WATER (DIRECT WATERBORNE)

The major time intervals associated with Transfer Waterborne by trailer-launcher are all sequential:

1. For waterbased response:
   - a. Alert time, as for Direct Waterborne. . . . . 15 min
   - b. Response Team assembly. . . . . 45 min
   - c. Briefing. . . . . 15 min
   - d. Equipment check . . . . 20 min
   - e. Launch. . . . . 10 min
   - f. Response Range/Mean Speed . . . . R n.mi/10 knots
2. For over-land response to debarkation point,
   - a. Alert time, as above. . . . . 15 min
   - b. Response Team assembly. . . . . 45 min
   - c. Briefing of response personnel. . . . . 15 min
   - d. Equipment check . . . . 20 min
   - e. Overland Range/Mean Speed . . . . R n.mi/33.3 knots

The time interval e, is the same as that for Single Mode Land (truck) to be discussed next.

7.4.2 Option 2, Single-Mode Land

In this option, the equipment and, perhaps, personnel are loaded into a motor vehicle(s), driven to the debarkation point, and unloaded at dockside or launch site. If the storage site is located at the debarkation point, the motor vehicle may be a fork lift, crane, or other loading/transporting device. These cases will be treated separately. The primary case to be examined is that of transport by truck, or tractor-trailer over a greater distance than the diameter of a military base.

The time intervals and speeds assumed below are based on USCG experience, discussions with Strike Team officers, and in some cases on subjective judgment. It will be assumed that all equipment has been pre-loaded on flat-bed trailers dedicated to pollution

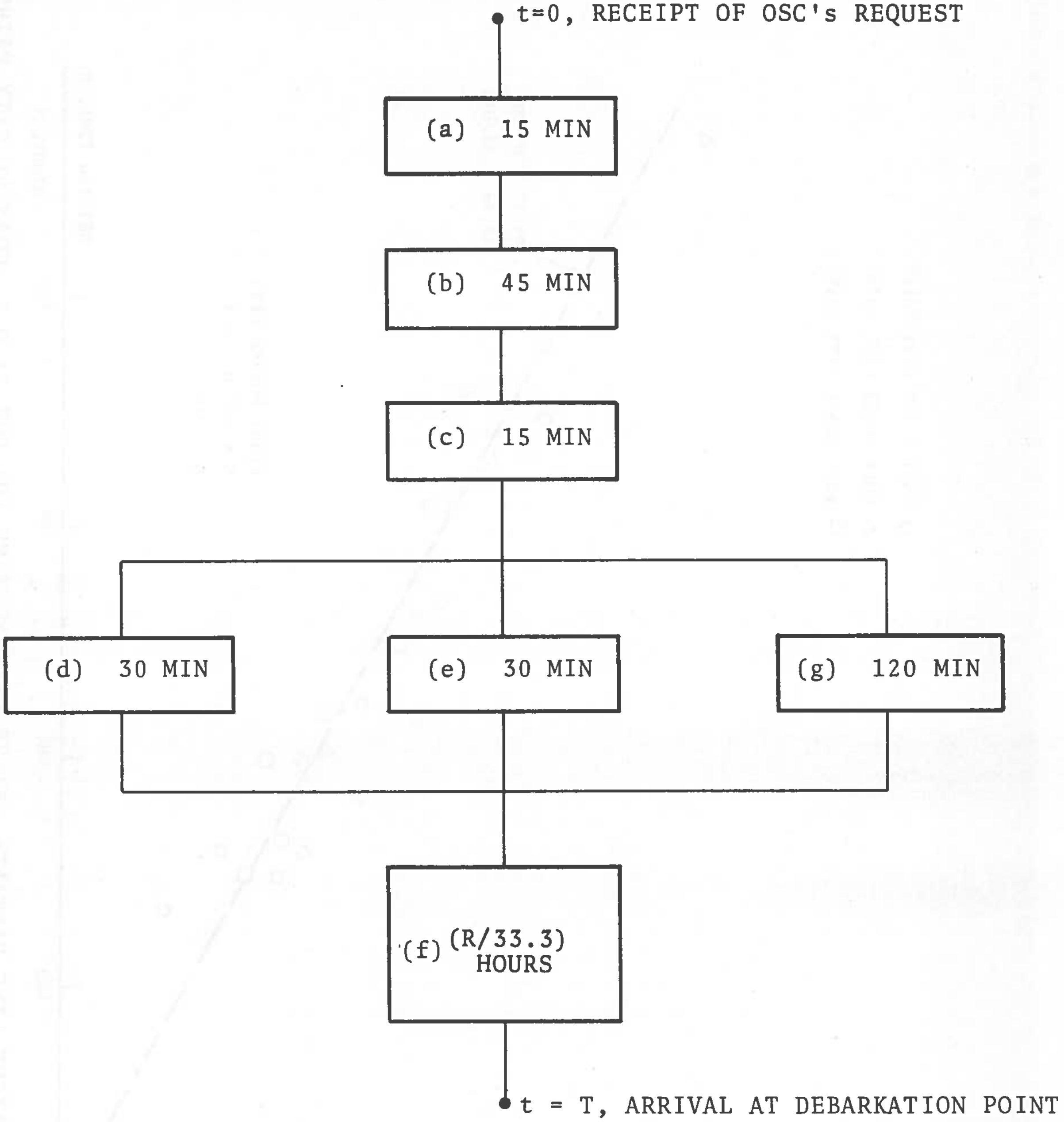


FIGURE 7-3 TIMING DIAGRAM FOR SINGLE-MODE LAND

When the above assumptions are combined the result is a plot of response range R as a function of response time T, given in Figure 7-5. The response time is measured from the time the OSC makes his request for assistance to the time the equipment arrives at the debarkation point. Unloading time at the debarkation point is not included in the response time. It will be seen from Figure 7-5 that the single-mode land response range is 140 n.mi. for 6 hours and 340 n.mi. for 12 hours, assuming pre-loaded semi-trailers. If the semi-trailers (or trucks) are not preloaded, the ranges drop to 90 n.mi. and 290 n.mi., respectively, for the first load, and 35 n.mi. less for each subsequent load.

7.4.3 Option 3, Single-Mode Air

In this scheme, the equipment (or part of it) is carried by helicopter from storage site to debarkation point, The storage sites thus should be helicopter bases, in order to avoid having to ferry the helicopter to the equipment base. [An exception to this rule occurs when the equipment site is located between two helicopter bases in order to improve helicopter availability at the expense of response time.] Although the helicopter assignments at present USCG bases may be different in 1980-1990, it is not likely that the bases themselves will be drastically relocated, so that the response ranges to be calcualted will apply for the most part to existing USCG air bases as equipment sites.

The major time intervals in helicopter response are estimated as follows:

a. Alert time: Time required to receive OSC request, notify team commander and alert key base personnel at destination. . . . . 15 min

b. Notification and assembly of response team members and loading crews and equipment . . . . 45 min

c. Personnel briefing. . . . . 15 min

d. Reconfiguration of helicopter from SAR to pollution response, and loading of pollution response equipment . . . . minimum 180 min
maximum 240 min

e. Pilot and crew availability . . . . .30 min

f. Response Range R/Mean speed . . . . . . (R/130) hrs.

The largest single interval, and the most difficult to predict, is the time to reconfigure and load. The time shown here is that for the present HH3F, as estimated by USCG/OSR. Future USCG helicopters may be specified for faster conversion and this time may drop drastically. As an alternative, therefore, a reconfiguration/load time of 30 minutes will be considered.

The relations among the above intervals are shown in Figure 7-6 and the resulting response range-time plot is shown in Figure 7-7. It may be seen in Figure 7-7 that the response range with present loading capability is between 130 and 260 n.mi. in 6 hours, with an average of 195 n.mi. For 12 hours, or for 6 hours with a 30-minute load capability, the range is limited not by the response time, but by the payload, which diminishes rapidly with range. The one-way payload lines that have been assumed for the three classes of future USCG helicopters were given in Figure 7-1(b). They are re-plotted on Figure 7-8, along with the weights of the various elements of the baseline response system. (The three solid lines are carried to zero payload, but in actuality will be cut off by fuel tank capacity. A slightly more conservative value has been used for the Type C helicopter zero-range payload.)

It can be seen from Figure 7-8 that typically:

In 6 hours, with a 210 min. load time,

Class A can deliver 5,000 lbs to 200 n.mi.

Class B can deliver 10,000 lbs to 200 n.mi.

Class C can deliver 20,000 lbs to 200 n.mi.

In 12 hours, or in 6 hours with a 30-minute load time,

Class A can deliver 4,000 lbs to 400 n.mi.

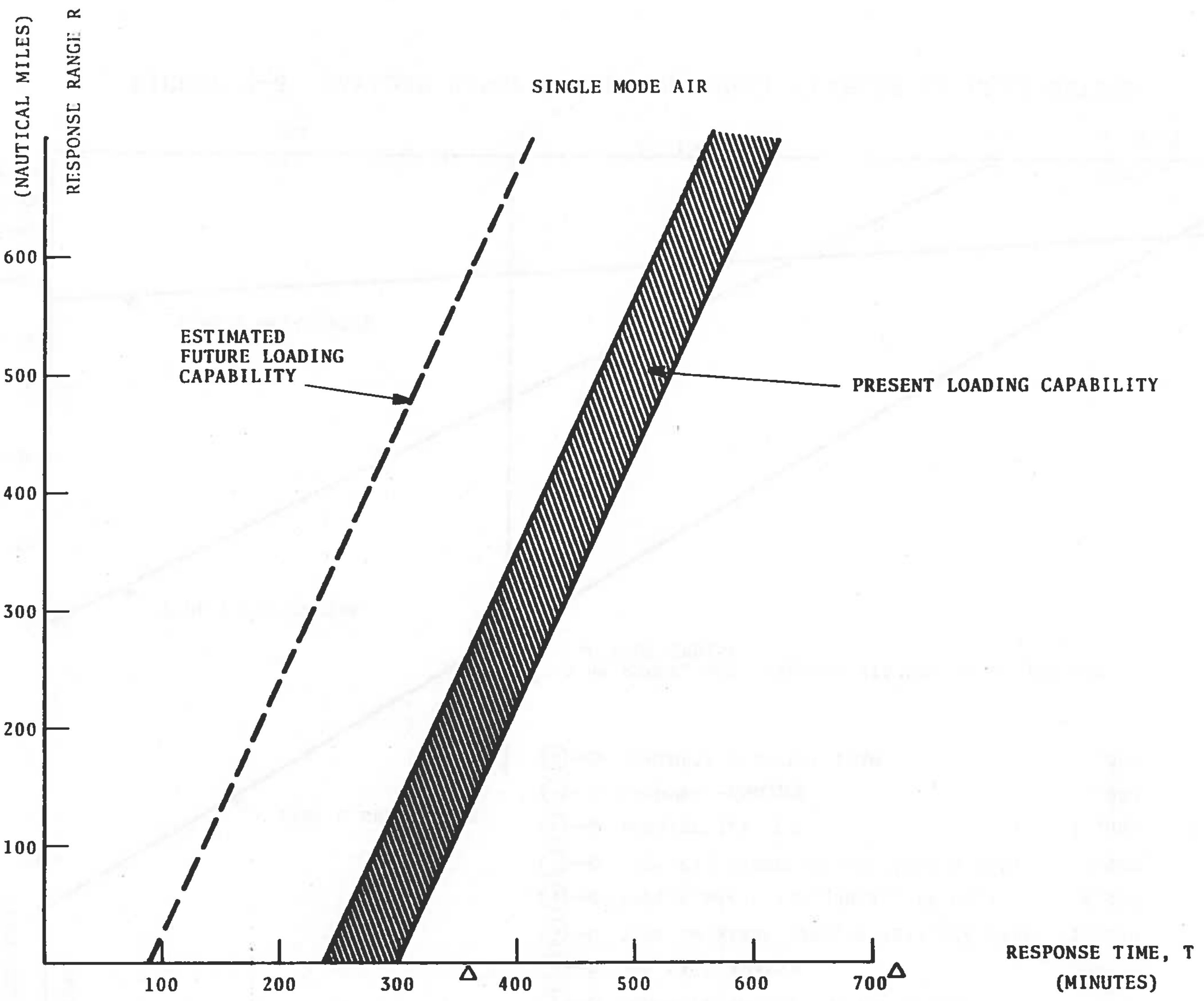


FIGURE 7-7 RESPONSE RANGE VS RESPONSE TIME, AIR

Class B can deliver 5,000 lbs to 300 n.mi.

Class C can deliver 14,000 lbs to 300 n.mi.

In other words, reduction of the loading time to 30 minutes has the same effect on delivery range as allowing 12 hours to respond, since in both cases the range is limited by the helicopter payload-fuel capacity.*

7.4.4 Option 4, Dual-Mode Air/Land

In this scheme, the equipment is flown by fixed wing aircraft from the equipment storage site to an intermediate airport where it is ferried by truck to the debarkation point. The intermediate airport may be a USCG, DOD or commercial field. The density of DOD airports (Appendix I) is such as to make them attractive as intermediate airports. This option requires loading at the original site, transfer at the intermediate airport, and unloading at the debarkation point.

The major time intervals in this scheme are estimated to be the following for the fixed wing/truck scheme:

a. Alert time: Same as for Options 2 and 3 . . . . 15 min

b. Notification and assembly of response team members and loading crews and equipment . . . . 45 min

c. Briefing. . . . . 15 min

---

*This suggests the following procedure to trade-off equipment loading time and payload: First, the range is selected on the payload-range chart so as to deliver enough equipment to perform the offloading function [e.g., 1 ADAPTS, 1 Type F barge, 6 team members] or the recovery function [e.g., 1 barrier, 1 skimmer, 1 barge, 5 team members]. The point on Figure 7-7 corresponding to this range and the required 6-hour response time is marked, and a line drawn through the mark parallel to the dashed line. This new line will intersect the response time axis at a time t_x. Subtracting 60 minutes (the non-loading ground time) from t_x gives the desired loading time, i.e., the loading time that will maximize the range for the given payload without exceeding the specified response time. Shorter loading times reduce the response time, but do not increase range.

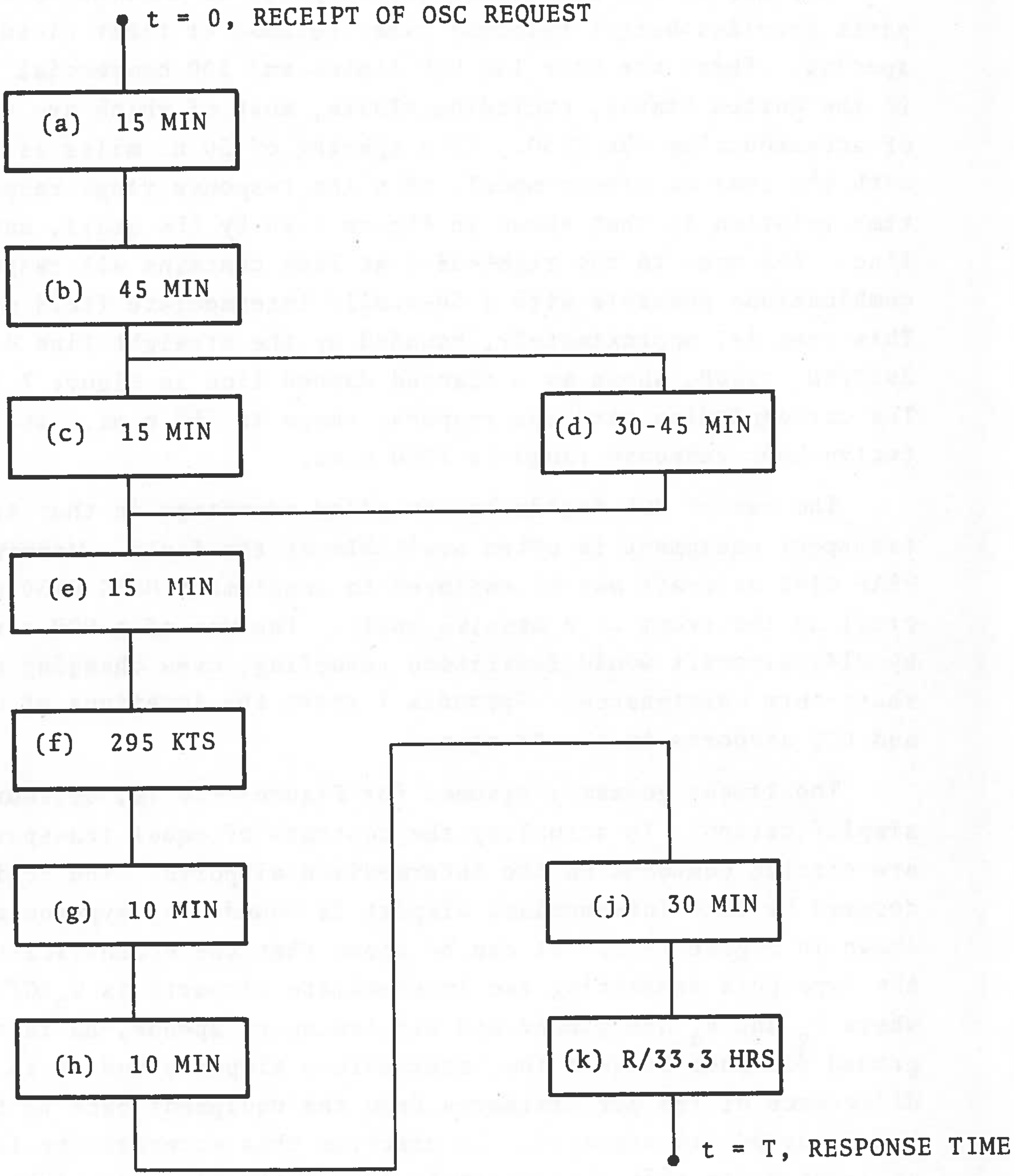


FIGURE 7-9 TIMING DIAGRAM FOR DUAL-MODE AIR/LAND

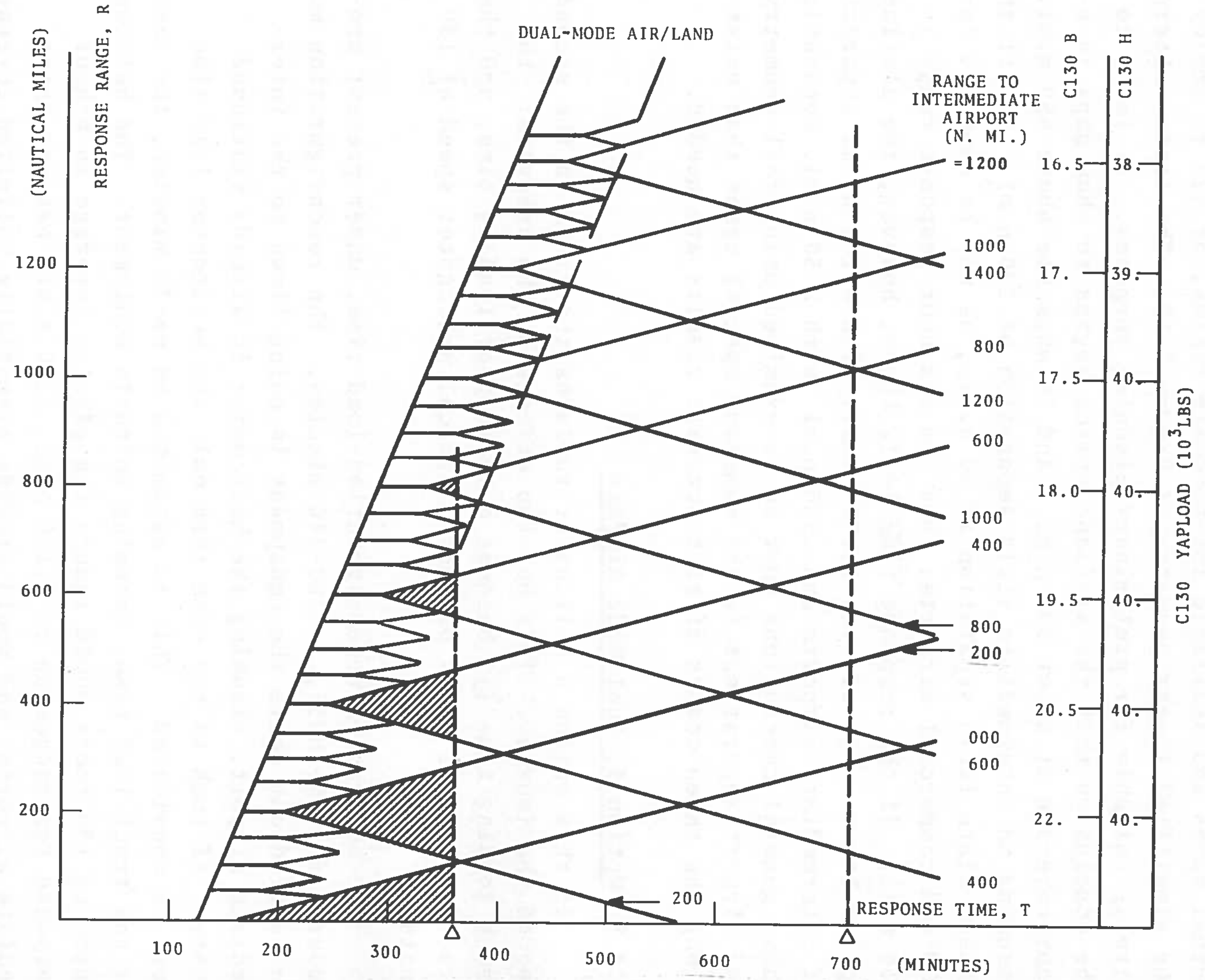


FIGURE 7-10. RESPONSE RANGE VS RESPONSE TIME, AIR/LAND

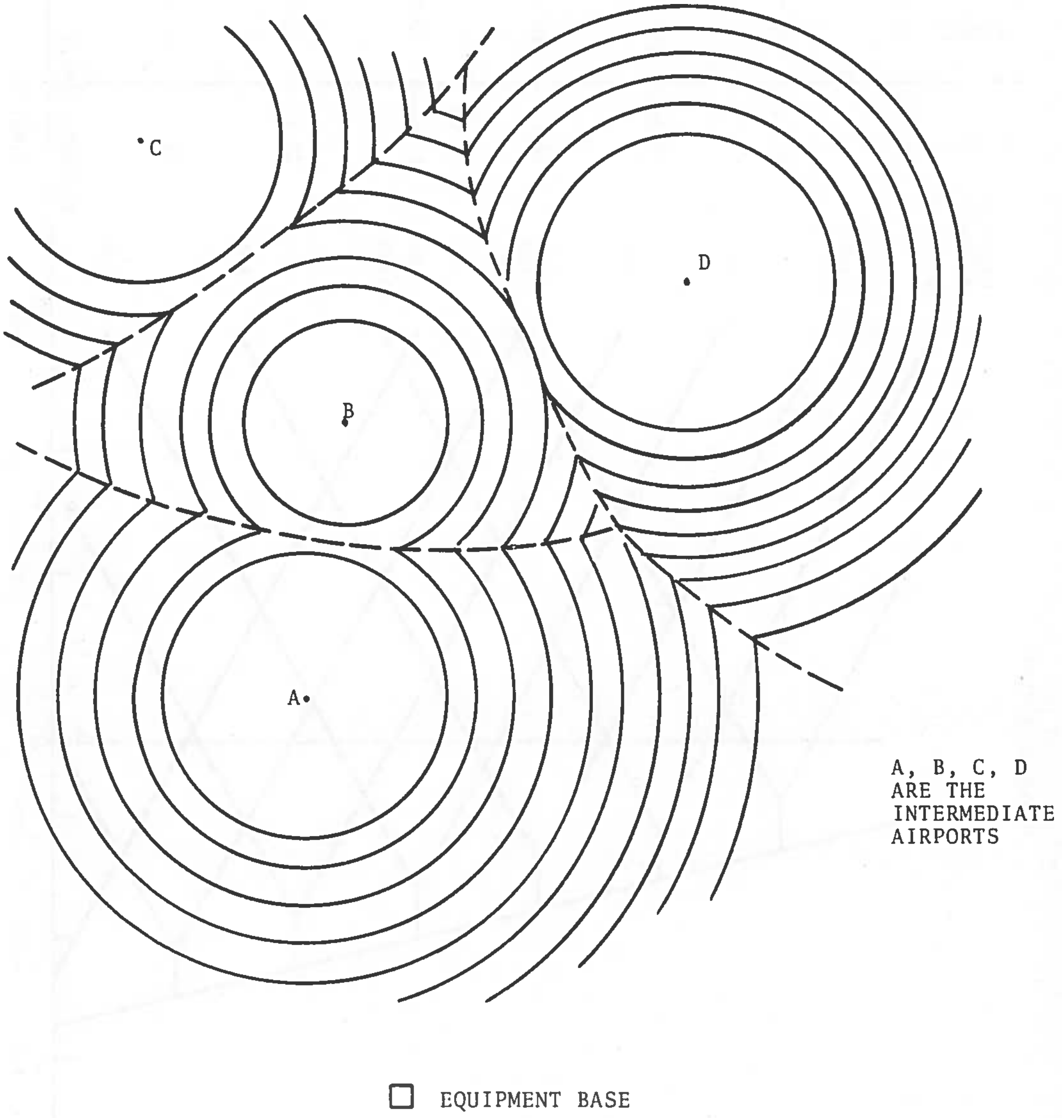


FIGURE 7-11 CONTOURS OF EQUAL TRANSPORT TIME DUAL-MODE AIR/LAND

As in the single-mode air option the air/air option assumes helicopter landing and refueling capability at the debarkation point. It is likewise limited by the payload-range lines of typical helicopter classes as shown in Figure 7-8, although the ranges required are closer to 100 n.mi. than the 200 n.mi. that is needed for the single-mode air 6-hour response.

7.5 COMPARATIVE RESPONSE TIMES

The response time is defined to be the time from receipt of the OSC's request at the equipment site to arrival of the requested equipment at the debarkation point. It does not include time to unload the equipment at the debarkation point, to load it onto a vessel or helicopter, and to transport it to the spill location. In the Direct Waterborne option, however, the equipment is either delivered to the debarkation point, by water (on a vessel such as the FSD), already prepared for transport to the spill, or it is delivered directly to the spill by water. In Transfer Waterborne a similar difference exist, since for that option the equipment is delivered on a mobile launcher to the debarkation point, ready to be launched without unloading and reloading.

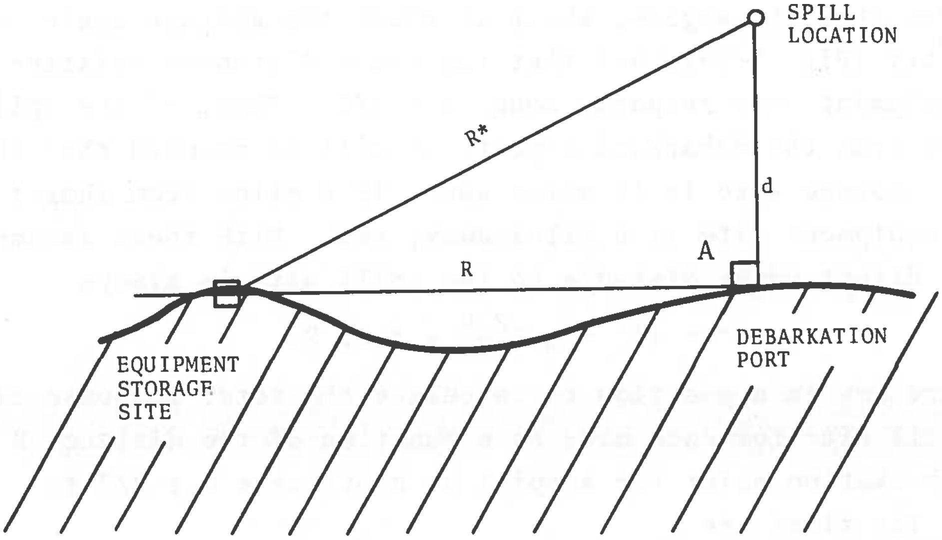
In order to make comparisons among all options on an equal basis it is necessary to reduce them all to delivery to a common location and condition. The only point common to all options is the spill site, ready to be deployed. For the OWOCS, OWORS and POHSSC this means in the water at or near the spill; for the ADAPTS it means on the deck of the stricken vessel. To make these estimates the travel and transfer times of Table 7-6 were assumed. From the travel and transfer times it is possible to estimate the time to deliver the equipment to the spill (assumed to be a stricken vessel) for each logistic option. These times are shown in Table 7-7 and are to be added to the times previously calculated for each option in order to bring the equipment to the spill, ready to be deployed.

TABLE 7-7 ADJUSTMENTS TO RESPONSE TIMES OF TRANSPORT OPTIONS TO ACHIEVE DELIVERY TO THE SPILL

	-Method of Transport to Spill-		
OPTION	Buoy Tender	Towed Sled	Helicopter (Estimated)
1. SINGLE MODE, WATER			
(a) Direct Waterborne			
-To debarkation point	$30 + 60d/10$	$5 + 60d/12.2$	$35 + 60d/65$
-To spill location	-	5	-
(b) Transfer Waterborne -To debarkation point	-	$20 + 60d/12.2$	$25 + 60d/65$
2. SINGLE MODE, LAND			
(a) Tractor-Trailer	$30 + 60d/10$	$35 + 60d/12.2$	$25 + 60d/65$
3. SINGLE MODE, AIR			
(a) Helicopter (Internal)	$55 + 60d/10$	$55 + 60d/12.2$	$45 + 60d/65$
4. DUAL-MODE, AIR/LAND			
(a) Fixed Wing/Truck	$30 + 60d/10$	$35 + 60d/12.2$	$25 + 60d/65$
5. DUAL-MODE, AIR/AIR			
(a) Fixed Wing/Helo (Internal)	$55 + 60d/10$	$55 + 60d/12.2$	$45 + 60d/65$
FOR DELIVERY OF ADAPTS TO VESSEL ADD:	20	30	5

NOTES: All adjustments in minutes

d = distance from debarkation point to spill in nautical miles.



Note: Because most spills occur close to the shore the angle A will most often be close to zero degrees or 180 degrees with 90 degrees as an average.

FIGURE 7-13 GEOMETRY FOR COMPARING DIRECT WATERBORNE AND LAND OPTIONS.

more than about 25 minutes. Of course, any increase in the fixed delays for the land mode will increase this advantage minute for minute. For example, if the debarkation point is 10 miles from the equipment site and if the transfer time at the dock from truck to buoy tender takes one hour instead of 30 minutes, the direct FSD advantage would increase from 18 minutes to 48 minutes.

Beyond 36 n. miles the assumption that d=R/2 is unrealistically large with the number of debarkation points available along the U.S. coast. Beyond this range, therefore, the spill distance, d, is assumed constant at 18 n. mi and the direct water response time was calculated from

$$T_{DW}^* = 110 + (60/12.2)\ (R^2 + 18^2)^{1/2}, \quad R \geq 36 \text{ n. mi.} \qquad (3)$$

$$T_L^* = 243 + 1.8\ R \qquad , \quad R \geq 36 \text{ n. mi.} \qquad (4)$$

In this range the land mode has a large and growing advantage with increasing R. For example, when the debarkation point is 100 n. mi from the equipment storage site, the land mode would make it possible to have equipment at the spill site via a buoy tender as much as 3 hours before the FSD sled could arrive.

A similar calculation may be done for the dual air/land logistic mode. The total response time to the spill is

$$T^*_{AL} = \text{Fixed Delays} + \text{Air Transit}$$

In this mode the fixed delay is composed of

Ground operations (Figure 7-9)	170 min
Transit from destination airport to debarkation port (50 n. mi. @ 33 1/3 kts)	90
Total fixed delay to debarkation point	260 min
Transit from debarkation port to spill site (18 n. mi. @ 10 kts)	107
Total fixed delays to spill site	367 min

With a cruise speed of 295 knots for the C-130 aircraft, the total response time to a spill site 18 n mi. from the debarkation port is

$$T_{AL}^{*} = 397 + 0.2R \qquad (5)$$

Equations 1-5 are plotted in Figure 7-14

An alternative means of comparing these three logistic modes is to calculate their response times to the debarkation point. This approach requires that the direct water mode be reduced to a basis comparable to the other two, which can be done by subtracting the buoy tender loading and transit time from all three spill transit times. From Table 7-8, this value is found to be 30 + 60d/10 so that:

$$T_{DW} = 80 + 2.5\,R \quad , \quad R \leq 36 \text{ n. mi.} \qquad (6)$$

$$T_{L} = 105 + 1.8R \quad , \quad R < 36 \text{ n. mi.} \qquad (7)$$

$$T_{DW} = 28 + 4.9\,(R^2 + 18^2)^{1/2}, \quad R \geq 36 \text{ n. mi.} \qquad (8)$$

$$T_{L} = 105 + 1.8\,R \quad , \quad R \geq 36 \text{ n. mi.} \qquad (9)$$

$$T_{AL} = 260 + 0.2\,R \quad , \quad R \geq 36 \text{ n. mi.} \qquad (10)$$

These equations are plotted in Figure 7-15. Note that the air/land mode becomes advantageous when the equipment site is more than 100 n. mi. from the debarkation port and there is an airport no more than 50 n. mi away. At 150 n. mi. the advantage over the land mode is more than one hour, provided there are no unaccounted for delays on the ground.

7.6 SUMMARY OF LOGISTICS

The logistic information developed in the previous subsections includes three off-loading and the two recovery systems which differ only in the size of the temporary storage barges. The collection rates are similar, but total oil capacities differ. The delivery of additional barges, of course, increases the total capacity. The largest package for off-loading systems is the Dracone barge; the largest package for recovery systems is the barrier.

The five basic response systems include three versions of the off-loading system and two of the recovery system. Several observations may be made relative to their delivery:

a. None of the single mode helicopter options can deliver the barrier because of its 9' width, with one exception not shown in the table. This is the Skycrane (a Class B) which can accommodate the barrier in place of its external pod.

b. Single mode helicopters of all classes are uniformly inferior to single-mode truck in payload and range for both 6- and 12-hour responses. This is because the trucks are assumed to be pre-loaded, while the helicopters must be converted from SAR.

c. The dual-mode air/land option provides about three times the range of the single-mode truck option, but with payloads limited by the C130B to 40% of the truck load, and by the C130H to 80% of the truck load.

d. No dual-mode air/air can deliver a complete recovery system because none of the helicopters can deliver the barrier, with the exception noted above.

e. The C130B/Helo/C can deliver the same payloads as the C130B/truck because the payloads are limited by the aircraft (assuming a 90,000 lb operating weight for the C130B). Also the C130B/Helo/C has greater ranges than the C130B/truck for both 6- and 12-hour responses.

f. The C130H/Helo/C has greater ranges but lower payloads than the C130H/truck option.

The conclusions to be drawn from the above observations are fairly clear.

REFERENCES FOR SECTION 7

7-1 Ward, Russel S., "Towed Planing Sled for Delivery of Oil Pollution Control Equipment," prepared for Naval Coastal Systems Laboratory, Panama City, Fla., March 1976, Report No. CG-D-59-76.

7-2 Proceedings of the 1977 Oil Spill Conference, March 8-10, 1977, New Orleans, Louisiana. American Petroleum Institute publication No. 75-4161, American Petroleum Institute, 2101 L Street, N.W., Washington, D.C. 20037.

7-3 "Development of Tow Capability for HH-3 Helicopter," U. S. Naval Test Center, Patuxent River, Md.

7-4 Abrahams, Cmdr. R. N., and E. R. Miller, Jr., "Oil Spill Containment System Development and Testing Program," in the Proceedings of the Joint Conference on Prevention and Control of Oil Spills, March 13-15, 1973. Published by American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20037.

7-5 Milgram, J. H., and R. A. Griffiths, "Combined Skimmer-Barrier High Seas Oil Recovery System," 1977 Oil Spill Conference, New Orleans, La., published by American Petroleum Institute, 1801 K Street, N.W., Washington, D.C. 20037.

4. Deepwater port throughput
5. Lightering of vessels off the coast.

The total spill potential in the study area is taken to be the sum of the petroleum movements times the corresponding spill rate. From Section 3, it is seen that the approximate total threat levels of these five sources vary widely, as shown in Table 8-1.

By far the greatest spill potential originates from port flows, which are currently somewhat larger than the 775. million tons shown. Moreover, the 3-4%/year increase in petroleum consumption expected world-wide over the next ten years has been projected to a 50% increase in U.S. imports from 1977 to 1985 (See Table 3-3), from 775 x 10^6 tons/year shown in Table 8-1 under port flow volume to 1160 million tons in 1985. Of this amount about 440. x 10^6 tons may be expected to flow through deepwater ports, at the lower spill rate of .0027 spills per 10^6 tons, as shown in Table 8-1, while the remainder, 760 x 10^6 tons, would flow through ports at the spill rate of .0314 shown in the Table. The net effect, then, is to reduce the port flow spills by .48 spills/year to about 23.86 spills/year in 1985 while adding about 1.08 spills/year due to deepwater ports, a new increase of about .6 spills/year, or 3%. For the most part, the 4 projected deepwater ports coincide with the major oil ports (New Orleans, New York/Philadelphia, Los Angeles, Galveston) so that the effect on 1985 spills of changes in imports plus installation of four DWP's tend to cancel, the net result being equivalent to a slight increase in present port flows, without deepwater ports. The exception to this is the Puget Sound area, where a deepwater port facility may not replace the Seattle-Anacortes-Port Angeles-Bellingham-Cherry Point complex by 1985. The approach to be taken, then, is to employ current port flow data, with a slight upward adjustment from that shown in Table 8-1, to allow for deepwater ports and increased imports in 1985. An adjustment for the Puget Sound area will be made at the conclusion of the analysis (Section 9.0). To this will be added the spill potential from OCS production projecting to 1985. The spill effects of transient tankers are small compared to that for port flows, and may be assumed to have the same geographic distribution of debarkation points. Similarly, lightering may be expected to be less in 1985 than at present if the projected deepwater ports are installed. Since the data needed to establish lightering spill rates are lacking, lightering spills will not be explicitly treated in deriving site locations.

Finally, Alaska Crude must be taken into account. The expected volume (see Appendix C) may enter the West Coast through deepwater ports, (spill rate 0.0027), through conventional ports (spill rate .0314) or through some combination. The assumption made is that 2/3 of it will enter through a DWP in the Los Angeles area, with only about 20 x 10^6 tons/year entering Puget Sound. The part entering Los Angeles is accounted for in the above DWP estimates, while the part entering Puget Sound will be accounted for separately.

With the above assumptions and approximations, spill potential estimates for 1985 were made up based on a total oil port flow of 900 x 10^6 tons/year, plus a projected 40 x 10^6 tons/year of OCS production in 1985. The oil port movement data were extracted from Reference 3.4, the Army Corps of Engineers "Waterborne Commerce of the United States", for 1976, with adjustments for the study area. To this was added approximately 40 x 10^6 tons/year of OCS projection from East, Gulf and West Coast fields in 1985 and 20 x 10^6 tons/year entering Puget Sound. Details of the resulting data base are given in Appendix J. The data give, for each oil port or waterway in the study area, the amount of oil received, shipped, or passed through, broken down by type of oil and by type of passage. The oils were classified as either (1) heavy, residual, and crude, or (2) light and distillates. The

It will be noted that there are (at present) three USCG strike teams, located at Elizabeth City, NC, Bay St. Louis, MS, and Hamilton AFB, CA. The Elizabeth City and Hamilton locations are large USCG bases, as well. Siting schemes that place equipment at one or more of these locations are more easily implemented and, other things equal, will be given preference.

8.3 METHOD OF CONSTRUCTING SITE CONFIGURATIONS

Two approaches were taken to producing candidate site configurations: one based on meeting the six hour response criterion by means of land transport alone, the other based on placing equipment as close as possible to the areas of major spill potential, employing both water and land transport.

Both approaches are related to the distribution of spill response times, as seen in Figure 8-1. This Figure is a hypothetical frequency distribution of response times achieved with a given configuration of sites. The response times include the times to all potential spills from the nearest equipment site (i.e., the site from which the most rapid response can be made). The first approach starts out with a site configuration such that the distribution lies entirely to the left of the 6-hour response time. The second approach starts with a configuration designed to concentrate the distribution close to the origin, i.e., to minimize the average value of response time, without specifically prohibiting response times greater than 6 hours.

In practice each approach is just the starting point for a series of configurations, each obtained from the previous by a trial-and-error process aimed at improving the evaluation measures. Before describing the evaluation measures, the two approaches to site configurations will be described in more detail.

8.3.1 Debarkation Point Method

In this approach site selection is based on the requirement that the requested equipment be delivered to the debarkation point within the specified response time by land. At one extreme, this requirement may be met simply by storing all the equipment that may be required at every potential debarkation point. It was seen (Appendix E) that the number of potential debarkation points in the study area is very large (100 or more), so that the cost of such a solution would be prohibitive. Moreover, it provides greater protection than required by the site selection criterion. Costs may be reduced, and the response time still met, by locating the equipment at sites from which it can be transported to several debarkation points. One simple solution is to locate the sites so that every potential debarkation point is within the response range of one, and only one, equipment site. The procedure is to locate the potential debarkation points on a map, superimpose circles of coverage with radii equal to the response range in such a way that every debarkation point is within at least one circle, and then select equipment storage sites at, or near, the centers of these circles. For brevity, the geographic area covered by a single site will be termed a region. These regions depend on the transport method and response time chosen.

The above procedure is simple but must be modified to make it practical:

a. The response range for trucks developed in the preceding section is only approximate, and must be checked against actual road access in the region. Lakes, bays, and rivers must be allowed for.

b. Only an integral number of sites is possible. Therefore, any set of sites covering the study area will almost inevitably result in some overlap in coverage, or some gaps in coverage, or both.

c. Equipment sites should be located at USCG installations if possible. It has been found possible to do so in most cases investigated without substantially altering coverage areas.

It should be clear from this description that the proposed procedure produces not a single site but a set of sites covering the entire U.S. coastline or, at least, a large section of coastline. Three U.S. geographic areas have been selected as being

TABLE 8-2. SITE CONFIGURATION A

LOCATION	USCG FACILITIES	USCG DISTRICT
EAST AND GULF COASTS		
Boothbay Harbor, ME	Station	1
New Haven, CT	Station, COTP, Group Office	3
Dahlgren, VA	Station	5
Charleston, SC	Base, MSO, Group Office	7
Clearwater, FL	Station, Air Station	7
Miami, FL	Base, COTP, Group Office	7
New Orleans, LA	Station, Base	8
Galveston, TX	Base, MSO	8
Corpus Christi, TX	MSO, Air Station	8
GREAT LAKES		
Sackets Harbor, NY*	Station	9
Erie, PA	Station, MSD	9
Bay City, MI	Station	9
Milwaukee, WI	Base, Station, COTP, Group Office	9
Duluth, MN	Station, MSO, Group Office	9
WEST COAST		
Seattle, WA	Base, Air Station, COTP, Support Center	13
San Francisco, CA	Station, MSO, Group Office	12
San Pedro/Long Beach, CA	Base, COTP	11

---

*This is a seasonal auxiliary station. The preferred alternate is Oswego, NY.

An alternative to Clearwater is Port Canaveral, which gives satisfactory coverage to Jacksonville, Tampa and Palm Beach, but is not itself a major oil port (2.68 million tons in 1976).

Working up from Mexico, it was found that three sites are required to cover all debarkation points in the Gulf Coast. The same result obtains if one works down from Mobile, Alabama.

The Great Lakes were covered as follows: Bay City, MI is the southernmost facility that will cover Mackinaw City, MI. Two more sites are required eastward of Bay City because one site alone (at Buffalo, NY) would not satisfactority cover Cleveland and Lorain, OH in six hours.

Towards the west of Lake Michigan, at least two sites are required: Milwaukee covers Chicago and Green Bay as well as itself, and Duluth covers Lake Superior.

The West Coast offers only one configuration that covers all debarkation points.

Configuration B: Minimum Overlap

The substantial number of debarkation points lying in two regions of Configuration A suggests that good coverage may be obtained with fewer sites. In addition, it is noted that several large oil ports, such as New York and Philadelphia, do not have direct coverage. Accordingly, Configuration B was devised as follows:

The Northeast was covered by sites at New York, NY (a major oil port) and Portland, ME (which handles more crude and heavy oil than any other New England port). This allows dropping the Dahlgren, VA site to the Norfolk, VA area, also a prominent oil port.

The remainder of the East Coast is covered by two sites: one at Savannah, GA and one at Ft. Myers Beach, FL. While the latter site has no substantial oil movement or port facilities, it does cover both Tampa/St. Petersburg and Miami/Palm Beach, Unfortunately, Key West is not reachable in 6 hours at normal highway

TABLE 8-3. SITE CONFIGURATION B

LOCATION	USCG FACILITIES	USCG DISTRICT
EAST AND GULF COASTS		
South Portland, ME	Base, Group Office	1
New York, NY	Station, COTP, Group Office	3
Norfolk/Portsmouth, VA	Station, Base, MSO, Support Center, Group Office	5
Savannah Beach, GA	Station	7
Ft. Myers Beach, FL	Station	7
New Orleans, LA	Station, Base	8
Freeport, TX	Station	8
GREAT LAKES		
Buffalo, NY	Base, MSO, Group Office	9
Bay City, MI	Station	9
Milwaukee, WI	Base, Station, COTP, Group Office	9
WEST COAST		
Seattle, WA	Base, Air Station, COTP, Support Center	13
San Francisco, CA	Station, MSO, Group Office	12
San Pedro/Long Beach, CA	Base, COTP	11

The list of sites in Configuration C is given in Table 8-4. The sites are plotted in Figure 8-4.

Configuration D: 11-Site Coverage

The number of sites was restricted to 11 in this configuration, allotted as follows:

2 on the Northeast Atlantic Coast

2 on the Southeast Atlantic Coast

2 on the Gulf Coast

3 on the Pacific Coast

2 in the Great Lakes Region

This allotment is somewhat arbitrary, being based on relaxing the 6-hour response requirement for certain low oil traffic density coastal areas: Northern Maine, Lake Ontario, and Lake Superior. It also provides only marginal coverage for the Wilmington, NC area, northern Lake Michigan, and upper Lake Huron. Finally, it provides double coverage for the New York and Jersey City areas, but at the limit of the 6-hour criterion.

The configuration is shown in Figure 8-5 and the sites are listed in Table 8-5.

The Providence, RI location has logistic advantages over Newport, RI and Narrangansett, RI, both of which are close to it. The advantage of Providence is proximity to I-95, which connects with Portland ME and New York, NY. The physical facilities at MSO Providence, however, may not be able to handle the required equipment, and one of the two alternates should then be employed.

The Savannah, GA location may be shifted to Charleston, SC, if necessary, affording better protection to Wilmington, NC rather than Jacksonville, FL.

The Great Lakes are covered, to an extent, by the Chicago site, which serves both sides of Lake Michigan, and the Cleveland site which must serve Lake Erie and Lake Ontario as well as the lower part of Lake Huron.

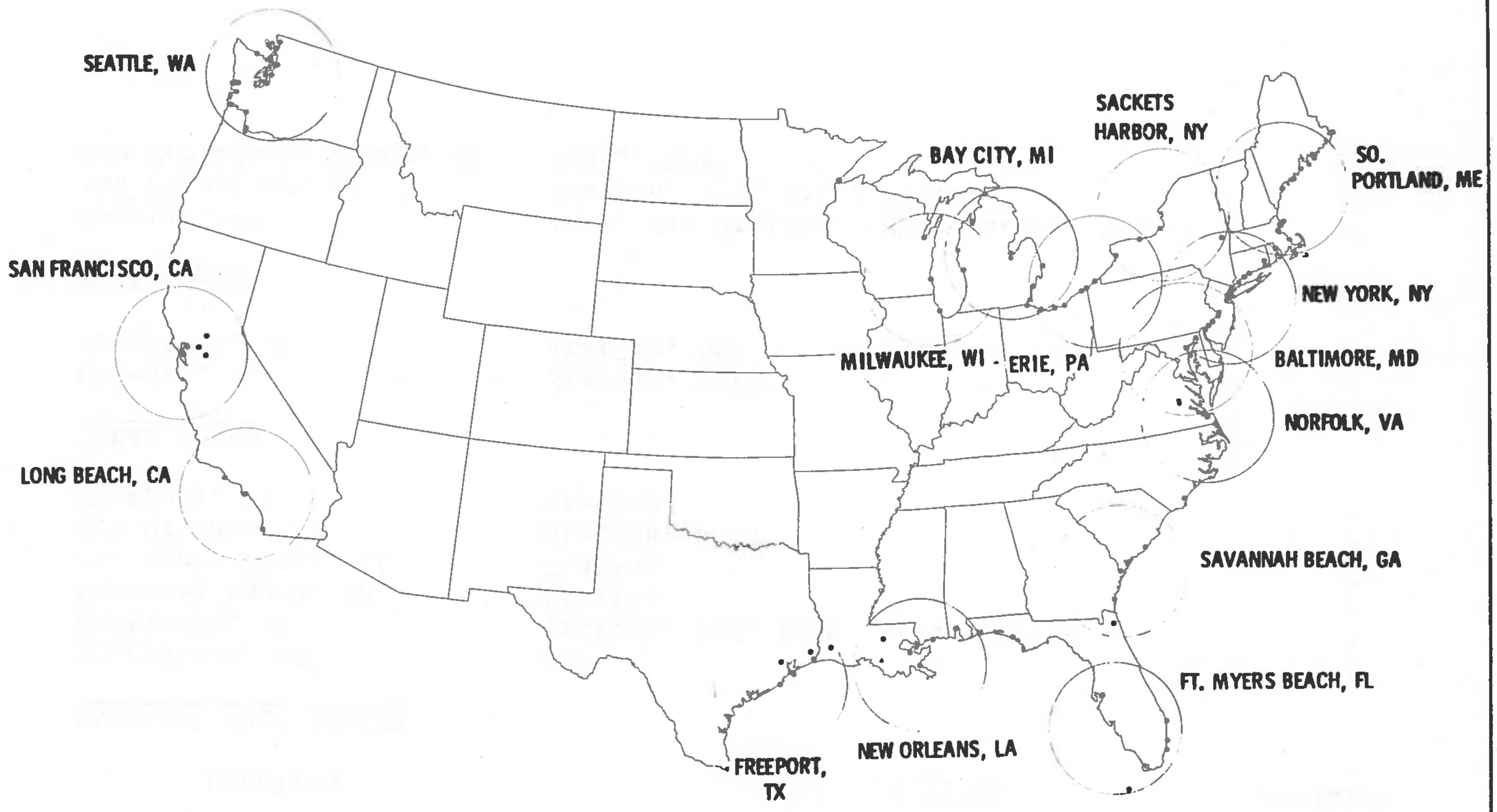


FIGURE 8-4. DEBARKATION POINTS WITHIN RESPONSE RANGE OF EQUIPMENT SITES - CONFIGURATION C

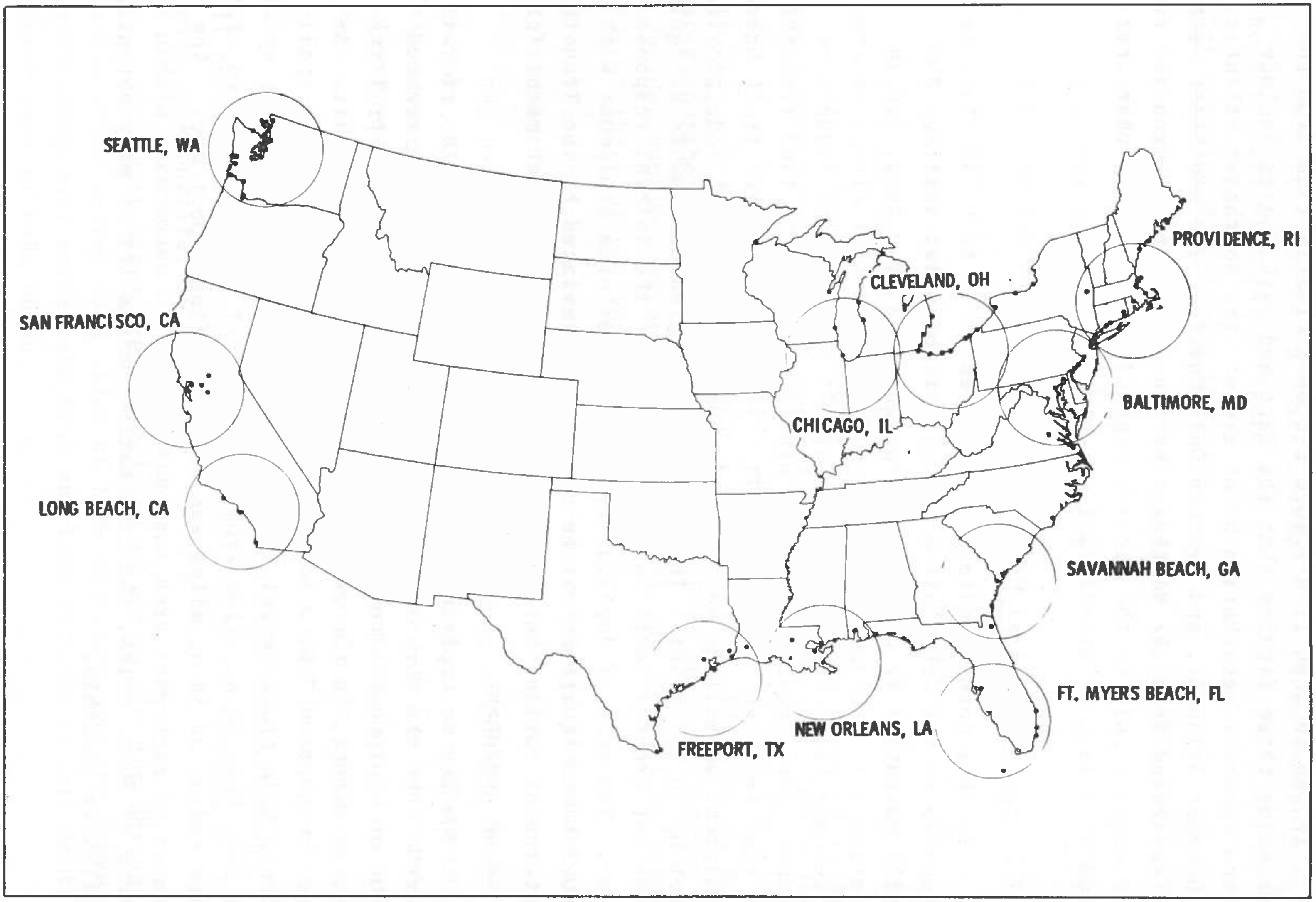


FIGURE 8-5. DEBARKATION POINTS WITHIN RESPONSE RANGE OF EQUIPMENT SITES - CONFIGURATION D

There are several measures of spill potential, given spill rates and oil flows. One may apply the spill rates to crude oil flows only, to heavy oil flows only, to light oil flows only, or to all types aggregated. Further, one may employ only coastal, foreign and Great Lakes oil movements (representing the potential for open water spills) or one may add to these the internal and local oil movements (the total representing the potential for harbor spills). In applying this method only heavy and crude oil movement was considered since the lighter oils present much less opportunity for pollution response. Further, the total of domestic and foreign oil movements was employed so that site selection would be based on both open water and harbor spill potential, it being considered impractical to segregate equipment sites on that basis. With the above choices for spill potential measures, the major "oil ports" within the study area were ranked in order of descending spill rate, as given in Table 8-6. It will be noted that OCS sites are included under their nearest debarkation point. Some ports show zero spill potential, based on heavy and crude flows, but are included to show the geographic extent of the port area. Some have substantial flows of light oils.

San Juan, Puerto Rico, and Barbers Point, Hawaii, have been included to show their spill potential and that of the surrounding harbors. In many cases, however, these surrounding harbors are more than 36 n. miles away.

Finally, it should be noted that the spill potentials of the Puget Sound port areas of Seattle and Anacortes have been adjusted for future Alaskan crude flows, as described above.

Figure 8-6 shows the cumulative value of expected spills/year over 50,000 gallons when the major oil port areas of Table 8-6 are taken in descending order. The total spill potential for all ports in the data base is 22.9 while the 26 major ports shown in Table 8-6 together account for 21.2 potential spills/year, or 92.5% of all potential spills. Twenty-one port areas alone account for 90% of all spill threat. These data, it will be recalled from Section 8.1, have been adjusted to 1985 for DWP's, trade shifts, OCS production, transient tankers and lightering.

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
Baltimore Canyon Trough 2920,7239 (New York DBKPT)	0.0366
Baltimore Canyon Trough 3916 (New York DBKPT)	0.0366
Baltimore Canyon Trough 3907,7223 (New York DBKPT)	0.0366
Baltimore Canyon Trough 3845,7250 (New York DBKPT)	0.0366
LOS ANGELES, CA	1.1889
Long Beach Harbor CA	0.5438
Los Angeles Harbor CA	0.5213
Huntington Beach 3340,11805 (Long Beach)	0.0178
Wilmington 3346,11811 (Long Beach)	0.0906
Santa Barbara Island 3330,11905 (Los Angeles)	0.0154
RICHMOND, CA	1.1502
San Francisco Harbor CA	0.0125
Redwood City Harbor CA	0.0000
Oakland Harbor CA	0.0324
Richmond Harbor CA	0.4722
San Pablo Bay and Marie Island Strait CA	0.1282
Carquinez Strait CA (Benicia, Martinez)	0.3619
Suisun Bay Channel CA (Pittsburg, Antioch)	0.0399
Other San Francisco Bay Area Ports CA (Estero Bay)	0.1031
PASCAGOULA, MS	1.1205
Mobile Harbor AL	0.3477
Pascagoula Harbor MS	0.7642
Biloxi Harbor MS	0.0035
Gulfport Harbor MS	0.0006
Eastern Gulf of Mexico 3000,8730 (Mobile AL)	0.0008
Eastern Gulf of Mexico 2935,8715 (Mobile AL)	0.0008
Eastern Gulf of Mexico 2915,8750 (Mobile AL)	0.0008
Eastern Gulf of Mexico 2918,8610 (Mobile AL)	0.0008
Eastern Gulf of Mexico 2830,8545 (Mobile AL)	0.0008
BATON ROUGE, LA	1.0660

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
BOSTON, MA	0.3006
Salem Harbor MA	0.0433
Port of Boston MA	0.2460
Plymouth Harbor MA	0.0113
Beverly Harbor MA	0.0000
Glocester Harbor MA	0.0000
CHICAGO, IL	0.2751
Port of Chicago IL	0.1423
Indiana Harbor IN	0.1328
BALTIMORE, MD	0.2708
Baltimore Harbor and Channels MD	0.2352
Washington Harbor DC	0.0349
Annapolis Harbor MD	0.0006
Chester River MD	0.0001
Middle River and Dark Head Creek MD	0.0000
Susquehanna River above and below Havre de Grace	0.0000
ALBANY, NY	0.2484
Hudson River, Upper Bay in NY Harbor to Waterford NY	0.2484
JACKSONVILLE, FL	0.2458
St. Marys River GA and FL	0.0059
Fernandina Harbor FL	0.0105
Jacksonville Harbor FL	0.1747
Rice Creek FL	0.0058
Southeast Georgia Embayment 3045,8030	0.0163
Southeast Georgia Embayment 3025,8035	0.0163
Southeast Georgia Embayment 3029,8018	0.0163

TABLE 8-6. MAJOR PORT AREAS RANKED BY SPILL POTENTIAL (Continued)

MAJOR PORT AREA AND CONSTITUENT PORTS	SPILLS/YR
SAN JUAN, PR	0.0939
San Juan Harbor PR	0.0823
Ponce Harbor PR	0.0006
Mayaguez Harbor PR	0.0001
St. Thomas Harbor VI	0.0031
Christiansted Harbor VI	0.0078
Fajardo Harbor PR	0.0000
TAMPA, FL	0.0885
St. Petersburg Harbor FL	0.0057
Tampa Harbor FL	0.0325
Weedon Island FL	0.0431
Eastern Gulf of Mexico 2840,8325 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2724,8405 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2705,8415 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2715,8355 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2705,8335 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2645,8326 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2642,8405 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2612,8410 (Tampa FL)	0.0008
Eastern Gulf of Mexico 2610,8326 (Tampa FL)	0.0008

*Based on crude and heavy oil flows and spills larger than 50,000 gallons from 1974-77, adjusted to 1985. The values of SPILLS/YR. are shown to four decimal places only to facilitate ranking; their accuracy is no better than two decimal places.

Configuration 1: 17 Sites

Since it appears that good land coverage can be achieved with 17 sites, a configuration based on this number, plus one each for Hawaii and Puerto Rico, was constructed using the second site-selection criterion. If the top 17 sites of Table 8-6 were selected, however, the result would be seven sites in the Louisiana-Texas area, non in the Georgia-Alabama-Florida area, and only one in the Great Lakes. Furthermore, the two New England sites (Boston, Portland) would be in close proximity.

To remedy the apparent deficiencies of straight ordering, the Baton Rouge site was eliminated because of its proximity to New Orleans, and one in Florida substituted. Of the three possible sites in Florida (Jacksonville, Tampa, Port Everglades) Tampa was selected because of its central location. Next, the Lake Charles site was eliminated because of its proximity to Port Arthur, and a Great Lakes site substituted. This was chosen to be Buffalo NY in order to cover both lake Erie (along with the Chicago site) and Lake Ontario. Finally the Boston site was moved to Providence RI to cover Woods Hole and the Georges Bank area.

The resulting configuration is shown in Table 8-7, and plotted in Figure 8-7. The smaller circles in the Figure show the effective range of Direct Waterborne. In associating oil ports with USCG installations some adjustments in location were made:

1. Hampton Roads was taken as Portsmouth/Norfolk, VA. The USCG and Navy installations in this area are numerous, have large capacity, and excellent access to Chesapeake Bay and the Atlantic Ocean. They also cover the Hampton Roads and York River approaches.

2. Clearwater FL was substituted for Tampa, because of the large storage facilities and air base. It is nevertheless desirable to use Tampa for direct water coverage of Tampa Bay, if a water location can be found. The Tampa direct water site, how ever, is not essential.

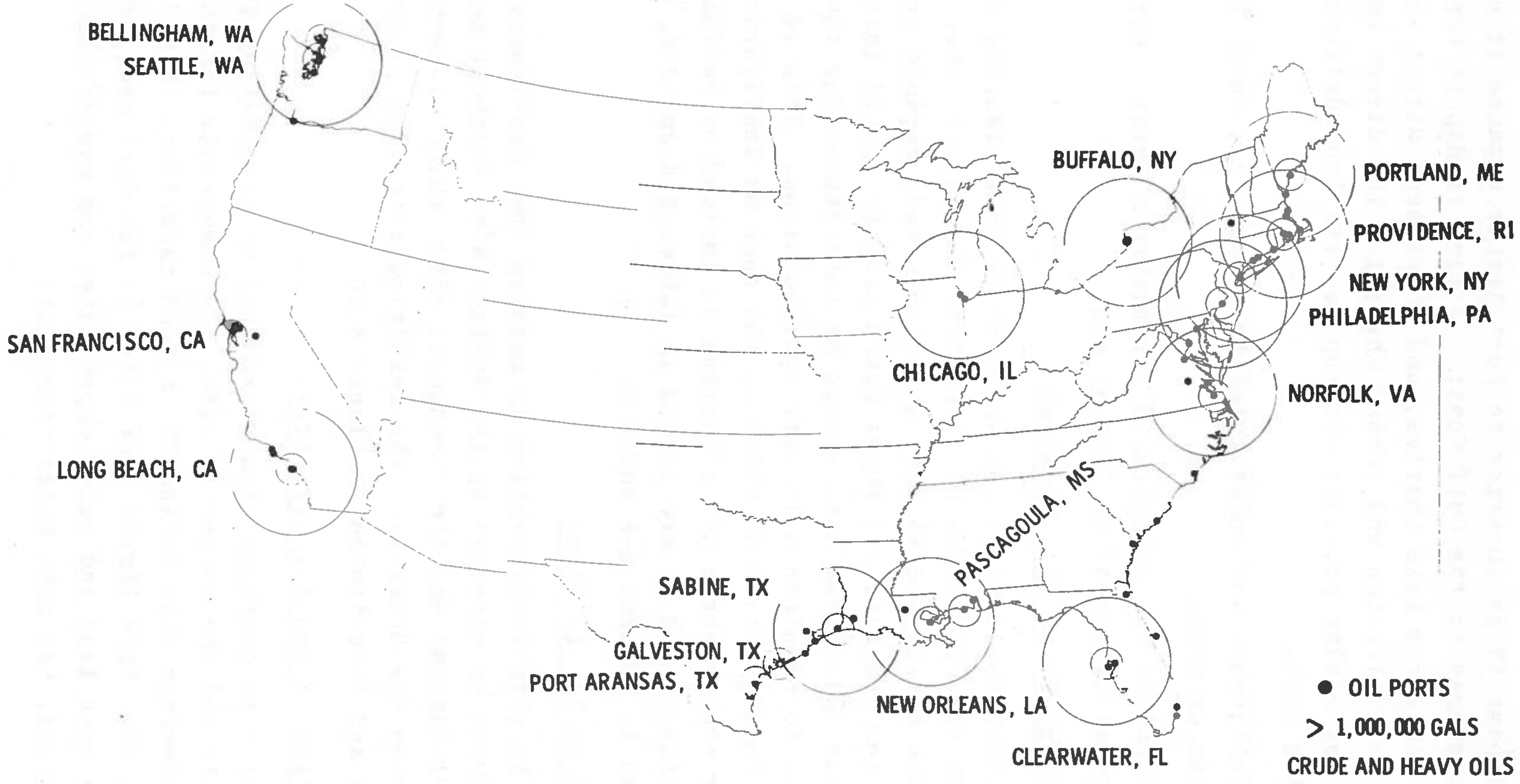


FIGURE 8-7. SPILL THREAT RESPONSE COVERAGE (CONFIGURATION 1).

TABLE 8-8. SITE CONFIGURATION 2

LOCATION	USCG FACILITIES	TYPE
EAST COAST		
Boston, MA	Station, MSO, Group Office, Support Center	L,DW*
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfolk, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air base	L,DW
Pascagoula, MS	Station	DW
New Orleans, LA	Station, Base	L,DW
Sabine, TX	Station, Group Office	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	DW
Corpus Christi, TX	Station, Group Office	DW
WEST COAST		
San Pedro/Long Beach CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COPT, Large Air Station, Group Office, Support Center	L,DW
GREAT LAKES		
Chicago, IL	Station, COTP	L
Buffalo, NY	Base, MSO, Group Office	L
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode, Land
DW = Direct Waterborne

TABLE 8-9. SITE CONFIGURATION 2a

LOCATION	USCG FACILITIES	TYPE
EAST COAST		
Boston, MA	Station, MSO, Group Office, Support Center	L,DW*
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfold, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air Base	L,DW
Pascagoula, MS	Station	DW
New Orleans, LA	Station, Base	L,DW
Sabine, TX	Station, Group Office	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	DW
Corpus Christi, TX	Station, Group Office	DW
WEST COAST		
San Pedro, Long Beach, CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COTP, Large Air Station, Group Office Support Center	L,DW
Bellingham, WA	Station	DW
GREAT LAKES		
Chicago, IL	Station, COTP	L
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode, Land
DW = Direct Waterborne

TABLE 8-11. SITE CONFIGURATION 4

LOCATION	USCG FACILITIES	TYPE
EAST COAST		L,DW*
Boston, MA	Station, MSO, Group Office, Support Center	L,DW
New York, NY	Station, COTP, Group Office	L,DW
Philadelphia, PA	Base, COTP	L,DW
Portsmouth/Norfolk, VA	Station, Base, MSO, Support Center	L,DW
GULF COAST		
Clearwater, FL	Station, Large Air Base	L,DW
New Orleans, LA	Station, Base	L,DW
Galveston, TX	Base, MSO, Group Office, LORAN Station	L,DW
Corpus Christi, TX	Station, Group Office	DW
WEST COAST		
San Pedro/Long Beach, CA	Base, COTP, Small Air Station	L,DW
San Francisco, CA	Station, MSO, Large Air Station, Group Office	DW
Seattle, WA	Base, COTP, Large Air Station, Group Office Support Center	L,DW
GREAT LAKES		
None	-	-
HAWAII		
Honolulu, HI	Base, COTP	DW
PUERTO RICO, VI		
San Juan, PR	Base, MSO	DW

*L = Single Mode, Land
DW = Direct Waterborne

The sites of Configuration 4 are listed in Table 8-11 and shown in Figure 8-11.

Since an 11-site configuration is likely to have poor coverage within six hours of the Great Lakes, Lower East Coast, parts of New England, and the West Coast, it was conjectured that one or more air sites, colocated with some of the 11 sites, would improve response times. Since the air speeds are comparatively large (average of 295 kts for C130H and C130B), the location of an air base in not critical. A single air site was located at Clearwater FL in Configuration 4a. It may have also been placed at Elizabeth City, NC, Belle Chasse, LA or in the Los Angeles or San Francisco areas. Clearwater was chosen because (1) San Francisco or Los Angeles would not serve the East Coast as well, (2) Elizabeth City is not a site in Configuration 4, (3) Belle Chasse LA is not a site in Configuration 4, (4) Los Angeles is a small air station. The placement of an equipment site at Elizabeth City, NC however, would provide slightly better Great Lakes coverage than Clearwater, FL.

The sites of Configuration 4a are listed in Table 8-12

8.4 METHOD OF EVALUATING SITE CONFIGURATIONS

The most important measures of site configuration effectiveness are those extracted from the distribution of the response times, such as is illustrated in Figure 8-1. The measures selected are

1. Mean value of response time T
2. Fraction of responses in excess of 6 hours.

These are independent measures, within limits, as may easily be shown. Of the two, primary value will be placed on the first, since it is most closely related to spill recovery effectiveness. A third measure will also be applied, namely

3. Fraction of historic spills responded to within 6 hours.

1. Average Response Time

This measure is simply the average of the distribution of response times T, such as shown in Figure 8-1. If in a one year period there are n_j spills in region j, with response times T_j from the nearest storage site, then the average response time $\overline{T}$ is:

$$\overline{T} = \sum_j T_j n_j \Big/ \sum_j n_j$$

where the summations are over all regions j. In actuality, the exact values of n_j are never known, but the average values $\overline{n}_j$ may be used since they were calculated from the spill rates of Section 3 and are available in the spill potential data base described previously.

The average response time, as above, was calculated for expected spills of crude and heavy oil, both coastal, foreign, inland, local and Great Lakes, throughout the study area, as contained in the spill potential data base. The average response time for each site as well as a national average was calculated. In addition, the frequency distribution of response times was tabluated for the entire study area for each configuration.

Since the candidate configurations include land and water modes, each potential spill location was assigned to either a land (L) or direct waterborne (DW) site, depending on which provided the shorter time T* from site to spill as given in Section 7.5. The equivalent response time T from storage site to debarkation point was then calculated, from the formulas in the same Section, in order to obtain the contribution of that spill potential to $\overline{T}$.

2. Percent of Response Times Greater Than 6 Hours

If the time to respond to each projected spill is analyzed into intervals of 0-1 hrs, 1-2 hrs, 2-3 hrs, etc., a histogram of response times may be obtained such as Figure 8-1. The fraction

In determining whether a spill would have been covered by a configuration in six hours, it is necessary to assign to each spill a debarkation point, and then to determine if the debarkation points lie in the coverage area of one or more sites. Since we are interested primarily in open water spills, the 149 ports with crane or lift service are appropriate debarkation points, because they can handle the barrier and Type O barges.

Tabulation and Evaluation of Results

Table 8-13 shows the results of applying the three evaluation measures to the ten configurations A, B, C, D, 1, 2, 2a, 3, 4, and 4a previously devised. Examination of that Table shows the following:

All configurations derived by the spill potential method produced lower average response times than any produced by the debarkation point method. But the alpha configuratiuons were superior to the numeric configurations with regard to the 6-hour response criterion. It is clear, then, that each method produced results in accordance with its intent.

The distributions of response times (by spill, not by port) are plotted in Figures 8-12 and 8-13. In Figure 8-12 it is apparent that as the number of sites is reduced in the sequence A, C, B, D, the distribution moves to the 6-hour line, but does not cross it to any great extent. The same occurs in the 1, 2, 3, 4 sequences, in Figure 8-13, except that Configuration 4 exceeds the nominal 5% level set for response times greater than 6 hours. Configuration 4a, however, dramatically reduces the percent responses greater than 6 hours to 1.29%, due to the addition of air capability.

The Configuration with the lowest average response time is Configuration 1, as expected, because it involves the maximum number of sites. A measure of cost or resources expended should be introduced to account for the better results achieved with more sites. Simply counting the sites does not allow for the fact that at some sites both a land and a water capability are deployed.

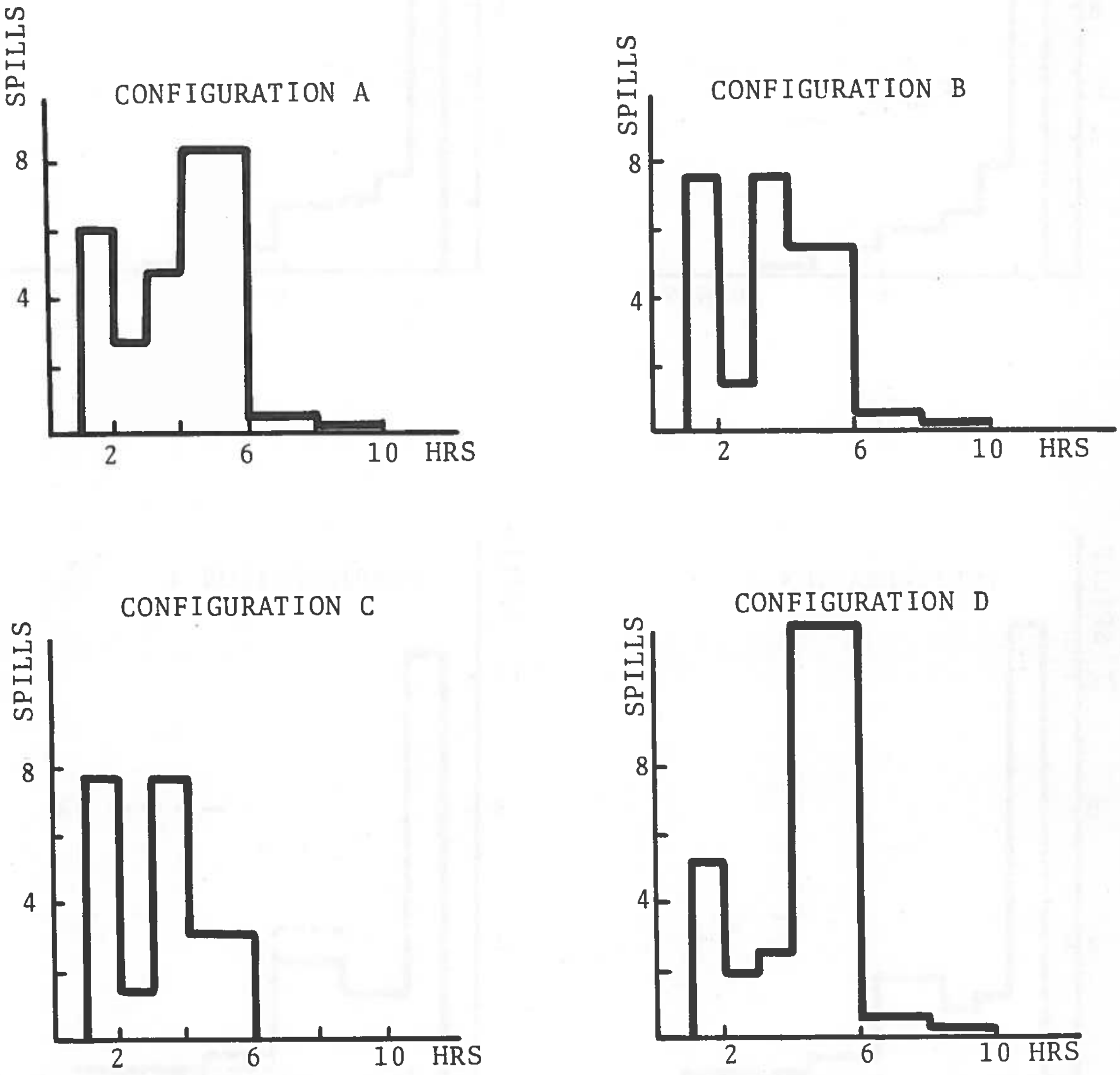


FIGURE 8-12. DISTRIBUTION OF RESPONSE TIMES FOR CONFIGURATIONS A, B, C, AND D

A better measure is the number of separate capabilities deployed, counting each land and water capability separately in Tables 8-7-8-12. With this as an independent variable the average response time and percent of response times greater than 6 hours are plotted in Figure 8-14.

From Figure 8-14 is apparent that as more sites are added the average response time drops. Except for Configuration A, the drop is surprisingly smooth, which indicates that effectiveness is not an erratic function of capability. While the spill potential method of site selection produces a gradual improvement in response time, it also produces close to the nominal 5% tolerance on response times greater than 6 hours. The sharp drop in that measure due to the 4a air site is very apparent. It seems clear, then, that the addition of air sites to the 1, 2, 3, 4 configurations will markedly reduce the number of spill responses that take over six hours.

It should be noted that the asymptote for the response time curve of Figure 8-14 is about 1.77 hours, the value obtained with 30 sites, each having both land and water capability. This asymptote represents might be achieved by introducing direct waterborne capability to all sites.

8.5 SITE SELECTION

It is now possible to analyze the previous ten combinations and to select one, or a combination of several, that provides good average response time and also achieves about 95% of the spill responses in less than six hours. The analysis consists of examining for each site the average response time and the expected number of spills, by land and by water. This was done for configurations 1, 3,4, and 4a, as shown in Tables 8-14, 8-15, 8-16, 8-17. The effect of the different configurations on the four major US Coastal areas plus Hawaii and Puerto Rico areas will be examined.

East Coast

There are two different site arrangements for the East Coast, represented in Table 8-14 (Configuration 1) and 8-15 (Configuration 3). In the first configuration, New England is covered by land and water sites at Portland ME and Providence RI. It is seen that the land capability at Portland ME responds to an average of .09 spills per year, and the water capability at Providence to an average of .13 spills per year. These are very low utilization rates for the equipment. One possible remedy is to eliminate the land capability at Portland and the water capability at Providence. Another is to combine both sites into one at Boston. The latter approach is taken in Configuration 3, Table 8-15. The new site at Boston has an average land response time of 4.0 hours, longer than either of the original two. In addition, the average land response time at New York goes up from 3.3 hours to 4.8 hours because it now covers some of the locations on the Connecticut coast formerly served by Providence. Philadelphia and Portsmouth VA are relatively unaffected. The net response time for an expected 9.88 spills per year on the East Coast is increased from 1.9 hours in Configuration 1 to 2.2 hours in Configuration 3. Thus the consolidation of the two New England sites into one has relatively little effect on the average East Coast response time.

TABLE 8-14 CONFIGURATION 1 ANALYSIS

	LAND		WATER	
EAST COAST	Response Time	Spills	Response Time	Spills
Portland, ME	3.5 Hrs	0.09	1.3 Hrs	0.66
Providence, RI	3.6	0.81	1.7	0.13
New York, NY	3.3	0.12	1.3	1.79
Philadelphia, PA	4.2	0.28	1.3	5.07
Portsmouth/Norfolk, VA	7.1	0.43	1.9	0.41
GULF COAST				
Clearwater, FL	6.9	0.73	1.8	0.09
Pascagoula, MS	---	----	1.8	1.15
New Orleans, LA	3.6	1.08	1.3	2.70
Sabine, TX	3.1	0.42	1.7	0.88
Galveston, TX	---	----	2.6	1.02
Port Aransas, TX	---	----	2.2	0.76

TABLE 8-15 CONFIGURATION 3 ANALYSIS

	LAND		WATER	
NORTHEAST	Response Time	Spills	Response Time	Spills
Boston, MA	4.0 Hrs	1.13	1.4 Hrs	0.30
New York, NY	4.8	0.39	1.3	1.79
Philadelphia, PA	4.4	0.29	1.3	5.08
Portsmouth, VA	7.1	0.43	1.9	0.41
GULF COAST				
Clearwater, FL	6.9	0.73	1.8	0.09
New Orleans, LA	4.1	2.23	1.3	2.70
Sabine, TX	3.1	0.42	1.7	0.88
Galveston, TX			2.6	1.02
Port Aransas, TX			2.2	0.76
WEST COAST				
San Pedro/Long Beach, CA	4.0	0.42*	1.4	1.19*
San Francisco, CA			2.0	1.23*
Seattle, WA	4.1	0.24*	1.8	0.28*
GREAT LAKES				
Chicago, IL	3.2	0.18		

*Not adjusted for 1985 oil flows

TABLE 8-17 CONFIGURATION 4a ANALYSIS

	LAND		WATER	
	Response Time	Spills	Response Time	Spills
EAST COAST				
Boston, MA	4.0 Hrs	1.13	1.4 Hrs	0.30
New York, NY	4.6	0.37	1.3	1.78
Philadelphia, PA	4.2	0.28	1.3	5.06
Portsmouth/Norfolk, VA	4.6	0.20	1.9	0.40
GULF COAST				
Clearwater, FL	4.1	0.03	1.8	0.08
New Orleans, LA	4.0	2.19	1.3	2.70
Galveston, TX	3.4	2.04	1.7	0.27
Port Aransas, TX			2.1	0.74
Clearwater (Air)FL				
WEST COAST				
Los Angeles, CA	4.0	0.41	1.4	1.18*
San Francisco, CA			2.0	1.23*
Seattle, WA	3.9	0.24	1.8	0.28*

*Not adjusted for 1985 oil flows

site not only has the greatest oil movement but also has the advantage of having three C130B's stationed there. This air mode may be adaptable to cover the islands to the north and south of Oahu.

Puerto Rico's main spill threat occurs at San Juan Harbor. Substantial traffic along the west and south coasts, however, presents an additional threat, as do the lightering operations off the Virgin Islands. These can be met only by water from San Juan, which is the station for the Buoy Tender Sagebrush and one or more WPB's. While the dimensions of Puerto Rico (about 30 n.miles by 90 n.miles) suggest land transport to the west and south coasts, this would be ineffective without vessel support, which is centered at San Juan.

Combined Configuration

The results of the above analysis are combined in Configuration 5, shown in Table 8-18. This Configuration has 14 sites, plus Hawaii and Puerto Rico. There are 10 land mode sites and 12 direct waterborne sites, with an overlap of 6. It can be seen from the bottom line that about 73% of the potential spills are handled by direct waterborne at an average response time of 1.6 hours, while the remaining 27% are handled by land at an average response time of 4.3 hours.

The West Coast sites show oil spill potential before adjustment for Alaskan crude movements in 1985. With the assumptions given in Appendix J for the disposition of Alaskan crude, the spill expectation for Seattle would be approximately twice the 0.52 spills/year shown. If this increased spill potential is realized in 1985 then the addition of direct waterborne sites in the Seattle and Bellingham/Anacortes areas would become advantageous as discussed previously.

The configuration presented has duplicate water and land capability at six sites: Philadelphia, New York, Los Angeles, New Orleans, Sabine TX, Portsmouth/Norfolk VA, which have substantial potential spills to be serviced by both modes. This substantially increases the amount of equipment required. There are at least two approaches to reducing the cost of such duplication:

TABLE 8-18 (CONT.)

	LAND		WATER		TOTAL	
HAWAII	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Barbers Point, HI	---	----	1.8	0.19	1.8	0.19
PUERTO RICO/VI						
San Juan, PR			2.0	0.09	2.0	0.09
	4.3	6.00	1.6	16.50	2.3	22.50

*Not adjusted for 1985 Alaskan Crude oil flows

Net Response Time, All Modes . . . . . 2.3 Hours

Percent Responses over 6 hours 4.4

Air Response

The requirement that the six-hour response be achieved without dependence on air transport is met by the combined configuration (5) just described, in the same sense as it is met by the other configurations, i.e., 95% or more of the spills are responded to in less than six hours. For Configuration 5 about 4.5% of the spill responses exceed six hours. This number is due to the gaps in coverage along the Great Lakes and Southeast coast. It can be seen from Table 8-18 that Portsmouth/Norfolk VA and Clearwater FL have land response times that reflect their coverage of the Southeastern coast, while Philadelphia and New York have response times that include coverage of Oswego, Buffalo and parts of Lake Erie.

The response times over six hours just described can be substantially eliminated by the addition of an air site in the eastern United States. Table 8-19 shows the effect of a single air site (Clearwater FL) on the response times. The major land mode time reductions are as follows:

	(Configuration 5) No Air Site	(Configuration 5a) Air Site at Clearwater FL
Portsmouth/ Norfolk VA	7.1 hrs	4.6 hrs
Clearwater FL	6.4	2.7
Philadelphia PA	4.4	4.2
New York NY	4.8	4.6
Chicago IL	3.2	2.1

The same sharp reductions are achieved if the air site is placed at Elizabeth City NC yielding Configuration 5b, Table 8-20.

TABLE 8-19 (CONT.)

	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
GREAT LAKES						
Chicago, IL	2.1	0.14	---	----	---	----
HAWAII						
Barbers Point, HI	---	----	1.8	0.19	---	----
PUERTO RICO/VI						
San Juan, PR	---	----	2.0	0.09	---	----
	3.6	5.01	1.6	16.48	5.3	1.05

Net Response Time, All Modes . . . 2.2 Hours

Percent Responses over 6 Hours . . 0.67

TABLE 8-20 CONFIGURATION 5b ANALYSIS

	LAND		WATER		AIR/LAND	
EAST COAST	Resp. Time	Spills	Resp. Time	Spills	Resp. Time	Spills
Boston, MA	3.5 Hrs	1.39	---	----	---	----
New York, NY	4.6	0.37	1.3	1.79	---	----
Philadelphia, PA	4.0	0.25	1.4	5.07	---	----
Portsmouth/Norfolk, VA	3.8	0.05	1.9	0.41	---	----
Elizabeth City, NC	---	----	---	----	5.7	1.16
GULF COAST						
Clearwater, FL	3.8	0.21	---	----	---	----
Pascagoula, MS	---	---	1.8	1.15	---	----
New Orleans, LA	3.6	1.08	1.3	2.71	---	----
Sabine, TX	3.1	0.42	1.7	0.88	---	----
Galveston, TX	---	---	2.6	1.03	---	----
Port Aransas, TX	---	---	2.1	0.74	---	----
WEST COAST						
Los Angeles, CA	4.0	0.42	1.4	1.19	---	----
San Francisco, CA			2.0	1.23	---	----
Seattle, WA	2.9	0.52	---	---	---	----

9. EQUIPMENT LEVELS

The site selection procedure in the preceding section gives only the locations of the sites, but does not indicate how much equipment is to be stored at each site. In this section the distribution of recovery capability among the sites of a given configuration will be explored. A method will be applied to yield capability levels at the sites based on the expected number and volume distribution of spills within the area covered by each site. Attention will be restricted to capability levels for non-massive spills. The site configurations 5, 5a and 5b derived in the preceding Section will be assumed. Requirements for open water recovery capability will be derived separately from those for harbors. The objective of this Section is to assign both relative and absolute levels of the two types of capability to each site in the selected configurations.

This analysis is followed in Section 10 by an examination of the effectiveness of the postulated deployment relative to each of the massive spill scenarios. Finally, in Section 11, the possibility of reducing the derived equipment levels is analysed on the basis of three additional assumptions:

1. The open water response equipment is available for both harbor and open water spills.
2. The same inventory of equipment can be used for either overland or waterborne responses.
3. Assistance is available from adjacent sites.

9.1 METHOD

The initial approach taken to the question of equipment levels was to attempt to assign to each site adequate equipment to handle the largest non-massive spill expected within its coverage area (region). This approach was found to be unsatisfactory. Historic spill data from 1974-77 (Section 3) are inadequate to yield volume distributions for separate ports or regions. Although the

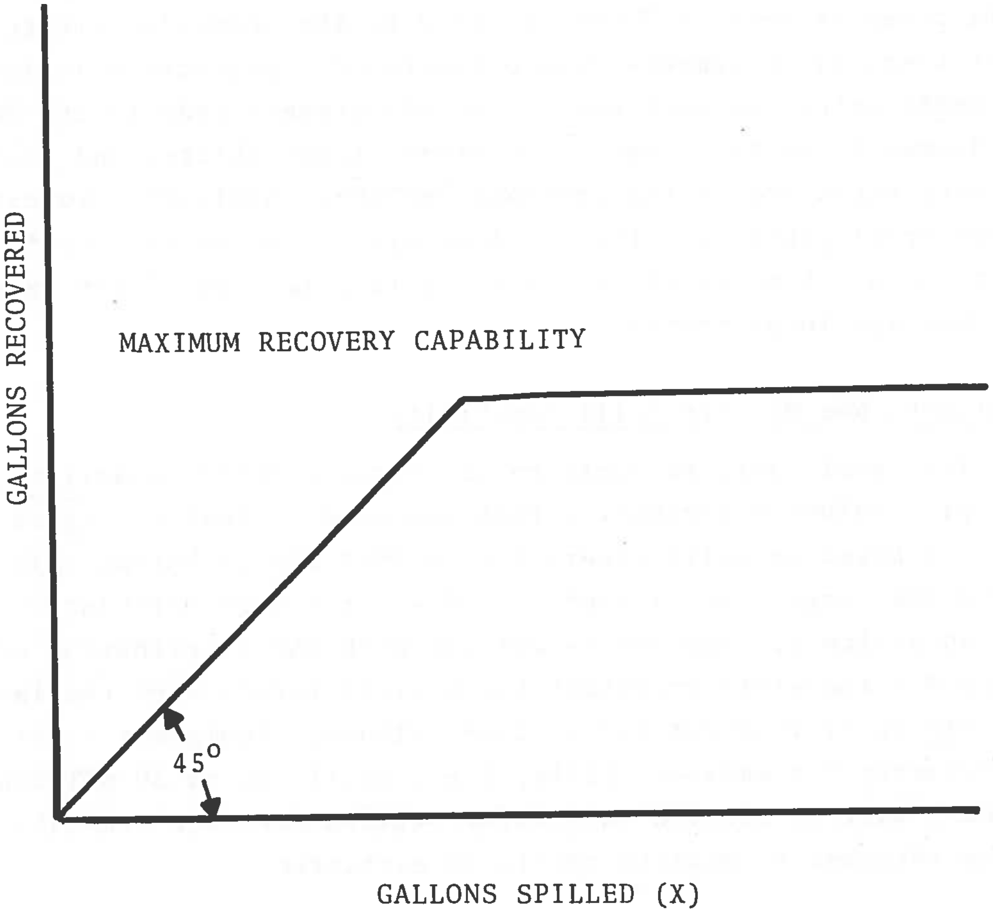


FIGURE 9-1. RECOVERY CAPABILITY MODEL

9.2 RELATIVE CAPABILITY LEVELS

The distribution of capability among the sites of a configuration depends on the total response capability of the configuration. Since the total response capability will be discussed in the following subsections, the relative distributions will be given here for several nominal total capability levels. They are shown for Configurations 5, 5a, and 5b in Table 9-1 through 9-6. The data in these tables were obtained from the allocation model described.

Some of the salient features on Tables 9-1 - 9-6 should be noted. First, it is seen that Philadelphia is assigned the greatest share of resources, as expected, in all cases. This share is greatest for low capability levels, dropping off as the national capability increases to 60 million gallons. The reason for this is that at low levels of total capability, resources are inadequate to cover the average spill volume. In the event of a spill in any region, the equipment at the site would be fully utilized. Therefore the resources are concentrated at those sites that expect the greatest <u>number</u> of spills, i.e., Philadelphia. As total resources increase, the Philadelphia capability begins to reach, and then exceed, the average spill size. As that occurs it becomes more profitable to invest capability in sites that are still unable to meet the average spill size and are more likely than Philadelphia to utilize all their resources in the event of a spill. These imbalances are adjusted for by the allotment algorithm as the total capability increases from 10 to 60 million gallons, as can be seen by the continuous decline in the relative capability assigned to Philadelphia.

Next it is seen by comparing Tables 9-2 and 9-1 that the open-water recovery capabilities are distributed similarly to the harbor capabilities. It should be realized, however, that the open-water recovery capability shown merely reflects the open-water traffic that <u>originates</u> or <u>terminates</u> in the associated port. The actual spill threat will be spread throughout the approaches to the port and along the adjacent coast. This should be taken account of in the final location of the equipment storage sites.

TABLE 9-2. RELATIVE EQUIPMENT LEVELS, PERCENT
- OPEN WATER CAPABILITY, CONFIGURATION - 5

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	0.9	0.7	0.7	0.7	0.6
Philadelphia PA	W	36.7	27.9	21.6	16.7	11.8
New Orleans LA	L	3.7	2.6	2.9	4.4	5.2
New Orleans LA	W	4.7	7.8	8.4	8.5	8.5
New York NY	L	1.6	1.6	1.3	1.0	1.3
New York NY	W	6.9	10.6	10.3	10.6	9.4
San Francisco CA	W	4.4	5.4	7.2	6.8	7.8
Galveston TX	W	4.0	3.7	5.3	5.8	6.7
Los Angeles CA	L	2.0	1.8	1.4	1.1	1.9
Los Angeles CA	W	4.7	7.9	8.4	8.6	8.6
Pascagoula MS	W	3.9	3.5	4.7	5.5	6.4
Sabine TX	L	0.5	0.3	0.3	0.2	0.3
Sabine TX	W	3.9	3.4	4.6	5.4	6.3
Port Aransas TX	W	3.8	2.9	3.5	4.8	5.6
Boston MA	L	7.1	10.8	10.7	10.8	9.4
Portsmouth VA	L	1.6	1.6	1.3	1.0	1.3
Portsmouth VA	W	1.5	1.5	1.3	1.0	1.1
Seattle WA	L	1.6	1.6	1.3	1.1	1.3
Clearwater FL	L	3.7	2.3	2.8	3.9	4.7
Chicago IL	L	0.8	0.5	0.5	0.5	0.6
Barbers Pt. HI	W	1.2	1.2	1.1	0.9	0.7
San Juan PR	W	0.8	0.5	0.5	0.5	0.6
Totals	100%					

TABLE 9-4. RELATIVE EQUIPMENT LEVELS, PERCENT

- OPEN WATER CAPABILITY, CONFIGURATION 5a -

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	0.9	0.6	0.7	0.7	0.6
Philadelphia PA	W	37.0	27.8	21.2	16.6	11.6
New Orleans LA	L	3.8	2.6	2.9	4.3	5.1
New Orleans LA	W	4.7	7.7	8.2	8.4	8.4
New York NY	L	1.4	1.5	1.2	1.0	1.1
New York NY	W	1.0	10.5	10.2	10.5	9.2
San Francisco CA	W	4.4	5.4	7.1	6.7	7.7
Galveston TX	W	4.0	3.7	5.2	5.7	6.6
Los Angeles CA	L	2.0	1.8	1.3	1.1	1.9
Los Angeles CA	W	4.7	7.9	8.3	8.5	8.5
Pascagoula MS	W	4.0	3.4	4.5	5.3	6.2
Sabine TX	L	0.5	0.3	0.3	0.2	0.2
Sabine TX	W	4.0	3.4	4.5	5.3	6.2
Port Aransas TX	W	3.8	2.8	3.2	4.6	5.4
Boston MA	L	7.2	10.8	10.5	10.7	9.3
Portsmouth VA	L	0.5	0.4	0.4	0.3	0.4
Portsmouth VA	W	1.5	1.5	1.2	1.0	1.1
Seattle WA	L	1.6	1.6	1.3	1.0	1.3
Clearwater FL	L	0.5	0.4	0.4	0.3	0.4
Clearwater FL	A	4.1	3.8	5.5	5.9	6.8
Chicago IL	L	0.5	0.4	0.4	0.4	0.5
Barbers Pt. HI	W	1.2	1.2	1.1	0.9	0.7
San Juan PR	W	0.8	0.5	0.5	0.5	0.6
Totals	100%					

TABLE 9-6. RELATIVE EQUIPMENT LEVELS, PERCENT

- OPEN WATER CAPABILITY, CONFIGURATION 5b -

SITE	TYPE	TOTAL U.S. CAPABILITY, MILLIONS OF GALLONS				
		10	20	30	40	60
Philadelphia PA	L	0.9	0.6	0.7	0.7	0.6
Philadelphia PA	W	37.1	27.8	21.2	16.5	11.6
New Orleans LA	L	3.8	2.6	2.9	4.3	5.1
New Orleans LA	W	4.7	7.7	8.2	8.4	8.4
New York NY	L	1.4	1.5	1.2	1.0	1.1
New York NY	W	7.0	10.5	10.1	10.5	9.2
San Francisco CA	W	4.4	5.4	7.1	6.7	7.7
Galveston TX	W	4.0	3.7	5.2	5.7	6.6
Los Angeles CA	L	2.9	1.8	1.3	1.1	1.8
Los Angeles CA	W	4.8	7.9	8.3	8.5	8.5
Pascagoula MS	W	4.0	3.5	4.7	5.4	6.3
Sabine TX	L	0.5	0.3	0.3	0.2	0.2
Sabine TX	W	4.0	3.4	4.5	5.3	6.2
Port Aransas TX	W	3.8	2.8	3.2	4.6	5.4
Boston MA	L	6.9	10.4	10.0	10.4	9.2
Elizabeth City NC	A	4.2	4.1	6.1	6.2	7.2
Portsmouth VA	L	0.0	0.0	0.0	0.0	0.0
Portsmouth VA	W	1.5	1.5	1.2	1.0	1.1
Seattle WA	L	1.6	1.6	1.3	1.0	1.3
Clearwater FL	L	0.8	0.6	0.6	0.6	0.6
Chicago IL	L	0.5	0.4	0.4	0.3	0.4
Barbers Pt. HI	W	1.2	1.2	1.1	0.9	0.7
San Juan PR	W	0.8	0.5	0.5	0.5	0.6

Totals 100%

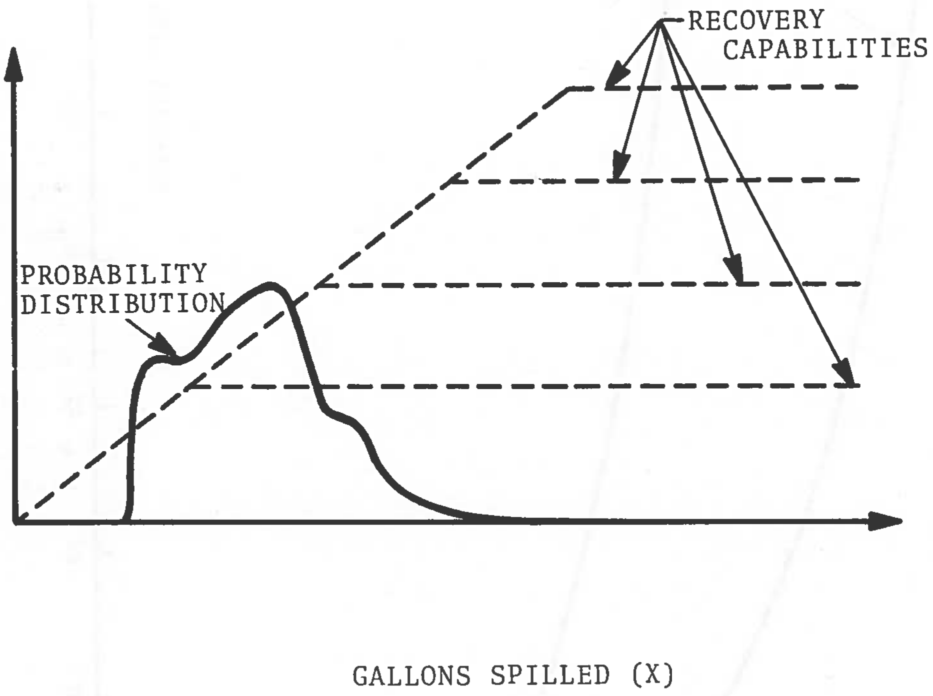


FIGURE 9-2. SPILL PROBABILITY AND SPILL RECOVERY VS SPILL SIZE

to harbor capability and recovery; the lower curve applies to open water. It can be seen that the expected amount recovered rises rapidly at first and then more slowly as the total capability exceeds the 10 million gallon range. Harbor recovery appears to approach about 6.4 million gallons asymptotically, while open water recovery appears to approach about 4.2 million gallons. The curves for Configurations 5a and 5b are almost identical and are not shown for that reason.

An absolute level of capability may be selected from Figure 9-3 by setting a lowest acceptable limit to the ratio of incremental total recovery to incremental total capability. A lowest value of 0.1 was tried first, that is, the total capability K was set at a value such that the slope of the curve is 0.1 (1/10 gallon recovered per gallon increase in capability,

$$\Delta\overline{R}/\Delta K = 0.1).$$

For the harbor recovery capability this criterion gives K = 10 million gallons and $\overline{R}$ = 3.6 million gallons/year; for open water recovery the criterion gives K = 8 million gallons, and $\overline{R}$ = 2.3 million gallons/year. In both cases the resulting annual recovery $\overline{R}$ is about 55% of its asymptotic value.

An alternate approach to selecting a total capability K is to select a recovery goal as a percentage of maximum possible recovery. Such a goal might place $\overline{R}$ at, say, 80% of its asymptotic value, and yield K = 42 million gallons of harbor capability, and K = 30 millions of open water capability. Some possible recovery goals, and corresponding total capabilities are listed:

Recovery Goal	Harbor Capability	Open Water Capability
95%	>100 million gals	80 million gals
90%	66	56
80%	42	30
65%	18	14
50%	6.5	5.5

of the recovery equipment available outside of the US Coast Guard. The details of the data extracted from the inventory are given in Appendix M, as are the assumptions employed to convert the numbers of pumps, barriers, skimmers, barges, etc., to gallons of recovery capability.

The results of comparing the external capability for each region to the capability requirements previously derived are shown in Table 9-7 for harbors and in Tables 9-8 for open water. From these tables several results emerge:

(1) Non-USCG pumping capability is, in general far greater than the required total capability at almost every site. Since these pumps are often employed for offloading and transferral in the normal course of business at major ports, and a large supply exists.

(2) The non-USCG storage capability shown is highly variable from site to site. This is due to gaps in the data. In particular, the barge availability in Texas is probably greater than shown. Also, for many ports, the number of units was reported, but not the total capacity.

(3) Harbor skimmers from non-USCG sources generally have less capability than called for at the sites. According to the data, the external open-water capability is greater than the harbor capability. However, the classification of a skimmer as "harbor" or "open water" in the inventory seems rather arbitrary, and many of those listed under "open water" may in fact be unable to operate effectively in more than 3 ft. waves. A better approximation to non-USCG capability may be to assign all skimming capability to harbors.

TABLE 9-8 NON-USCG OPEN WATER CAPABILITY
(THOUSANDS OF GALLONS)

	TOTAL REQ'D CAPABILITY	NON-USCG CAPABILITY(1)			
		PUMPS	STORAGE	SKIMMING	CONTNMNT
Philadelphia PA	6690	69,000	27,300	32	0
New Orleans LA	3390	754,700	10	190	0
New York NY	3480	39,600	100	32	0
San Francisco CA	2160	106,600	400	880	0
Galveston TX	1590	7,300	0	0	0
Los Angeles CA	2940	13,800	1,400	260	0
Pascagoula MS	1410	6,000	150	100	0
Sabine TX	1470	81,900	20	130	0
Port Aransas TX	1050	0	0	160	0
Boston MA	3210	104,700	1,600	960	32
Portsmouth VA	780	16,400	600	980	0
Seattle WA	390	52,100	300	320	0
Clearwater FL	840	14,800	1,500	230	0
Chicago IL	150	359,400	6,200	0	0

(1) Adjusted. See Appendix M

TABLE 9-9 REQUIRED USCG HARBOR CAPABILITY (THOUSANDS OF GALLONS)

	TOTAL REQ'D CAPABILITY (1)	REQUIRED USCG CAPABILITY			
		PUMPS (2)	STORAGE (3)	SKIMMING (4)	CONTNMNT
Philadelphia PA	7160	0	820/1800	7120	0
New Orleans LA	7800	0	900/1980	7550	0
New York NY	4520	0	520/1145	4480	0
San Francisco CA	2600	0	300/660	1400	0
Galveston TX	2160	0	250/550	2160	2000
Los Angeles CA	2920	0	330/740	2600	0
Pascagoula MS	2440	0	280/620	2340	0
Sabine TX	2240	0	250/560	2000	0
Port Aransas TX	1240	1240	140/314	1040	0
Boston MA	3040	0	350/770	2740	0
Portsmouth VA	960	0	100/230	0	0
Seattle WA	640	0	70/160	240	0
Clearwater FL	1520	0	170/390	1220	0
Chicago IL	320	0	40/80	320	0
	39560*	1240	4520/10000	35210	2000

(1) Total of land-based and water-based capability for configuration 5 (Table 9-1) for total U.S. capability of 40 million gallons.

(2) Based on immediate availability of non-USCG pumping capability

(3) Offloading/Skimming; temporary storage requirement based on 8 hr start time and 96 hours of operation with storage required up to 18th hour only.
Skimmer recovery efficiency 45%

(4) Based on non-USCG skimming capability shown in Table 9-7.

* 40 Million gallons, less Hawaiian and Puerto Rican capabilities.

TABLE 9-11. REQUIRED USCG HARBOR CAPABILITY, LAND- AND WATER-BASED (THOUSANDS OF GALLONS)

SITE	TYPE	REQUIRED USCG CAPABILITY PUMPS	STORAGE (1)	SKIMMING	CONTNMNT
Philadelphia PA	L	0	46/100	398.	0
Philadelphia PA	W	0	774/1700	6722.	0
New Orleans LA	L	0	267/589	2246.	0
New Orleans LA	W	0	632/1390	5304.	0
New York NY	L	0	51/111	436.	0
New York NY	W	0	469/1034	4044.	0
San Francisco CA	W	0	300/660	1400.	0
Galveston TX	W	0	250/550	2160.	2000.
Los Angeles CA	L	0	50/112	392.	0
Los Angeles CA	W	0	280/628	2208.	0
Pascagoula MS	W	0	280/620	2340.	0
Sabine TX	L	0	50/122	400.	0
Sabine TX	W	0	200/448	1600.	0
Port Aransas TX	W	1240	140/314	1040.	0
Boston MA	L	0	350/770	2740.	0
Portsmouth VA	L	0	50/120	0.	0
Portsmouth VA	W	0	50/120	0.	0
Seattle WA	L	0	70/160	240.	0
Clearwater FL	L	0	170/390	1220.	0
Chicago IL	L	0	40/80	320.	0
Barbers Pt*HI	W	320	320/320	320.	320.
San Juan* PR	W	120	120/120	120.	120.
		1680	4960/10440	35650.	2440.

(1) Offloading/Skimming

*Non-USCG capability not allowed for.

The final step is to convert the net required USCG capabilities into numbers of baseline equipment units. These units are summarized in Section 7.1, have capabilities as follows:

ADAPTS:	Double stage pump with 300 ft. hose, prime mover, stripping pump, spare parts. 1000 gal/min nominal pumping rate.
OWORS/Barrier:	Lockheed disk skimmer with USCG 612 ft. barrier (employs type F Dracone Barge, barrier towing vessels (2) work and support vessel). 300 gallons/minute recovery rate.
OWOCRS:	USCG open water barrier with integral weir skimmers, pumps, hose, type F Dracone Barge, support vessel, two towing vessels. 300 gallons/minute recovery rate.
POHSSC:	Type OW Dracone Barge for offloading, (250,000 gallon capacity) Type F for skimming (42,000 gallons capacity)

To estimate the net capability in gallons of the baseline equipment, the assumptions of Table 9-13 were made, with the results given in the same Table. It should be noted that the POHSSC's are assumed to be replaced by barges after 18 hours of operation in harbors, and 30 in open water. In practice, since the OWORS and OWOCRS must trail their containers after them, the assumption is that the POHSSC will be emptied into a hard hull and recycled starting at the 18th or 30th hour. If this is not feasible because of lack of pumping capability, the POHSSC requirement would be as shown in parentheses, which is substantially higher. Because of the assumptions on barge availability, an amount of USCG temporary storage in the form of POHSSC units is required independently of the need for USCG pumping capability. The method of determining equipment units from Tables 9-9 through 9-13 is as follows:

ADAPTS: The number of units required is equal to the REQUIRED USCG CAPABILITY shown under

PUMPS in Tables 9-9, 9-10 or Tables 9-11, 9-12, divided by 4,356 x 10^3 for harbor and 4,950 x 10^3 for open water, rounded up to the next integer.

POHSSC, Type OW: this is the REQUIRED USCG CAPABILITY for STORAGE (number to left of slash) divided by 250,000, rounded to next largest integer.

OWORS-Barrier: The number of units required equals the REQUIRED USCG CAPABILITY for SKIMMING divided by 396,000 for harbor and 233,000 for open water, rounded to the next largest integer.

OWOCRS: The number of units required equals the REQUIRED USCG CAPABILITY for SKIMMING divided by 396,000 for harbor and 233,000 for open water, rounded to the next largest integer.

POHSSC, Type F: The harbor requirement is 1.1 times the number of OWORS-Barrier units or 2.2 times the number of OWOCRS units, rounded to the next largest integer. For open water, the requirement is 1.8 times the number of OWOCRS units, rounded to the next largest integer.

When the above procedure is applied to the total required USCG capabilities, shown at the bottom of Tables 9-11 and 9-12, the results are as shown in Table 9-14. Because of rounding the equipment requirements based on total U.S. capability is less than the sum of the units required for the separate sites. Moreover, assigning units to separate land- and water-based sites results in substantially more equipment than assigning them to combined sites, again because of rounding to whole units. The effect is most pronounced in the case of ADAPTS units, because of their high capacity relative to most site requirements, which results in upward rounding to a single unit at most sites.

TABLE 9-14. EQUIPMENT UNITS CORRESPONDING TO TOTAL CAPABILITY, CONFIGURATION 5

	Harbor	Open Water
OFFLOADING		
ADAPTS 2-Stage	1	7
POHSSC Type OW	20	22
SKIMMING		
1. OWORS-Barrier	90	129
POHSSC Type F	99	232
2. OWOCRS	90	129
POHSSC Type F	198	464

10. MASSIVE SPILL RESPONSE

In this section of the report the ability of the selected site configuration to respond to the massive spills described in Section 4 will be examined. The analysis will be based on the recovery requirements to be derived for each spill scenario in terms of offloading (Section 10.1.1) and skimming (Section 10.1.2). After these requirements have been established, three possible logistic strategies will be defined, and the response capability of each strategy will be determined for the selected configuration.

Oil storage is assumed to be accommodated by the POHSSC system for the first 30 hours. In that time each ADAPTS would have offloaded 2,880,000 gallons, and 8.3 units would have offloaded about 24 million gallons. These can be contained in about 97 of the Type OW POHSSC. Each operating ADAPTS would require about 11.7 Type OW storage containers, on the average, over the 30 hours. This implies a new storage unit every 2.5 hours. It appears, then, that a technique would be required to change the containers with a minimum of down time. A down time of 30 minutes per change seems reasonable. The time to change containers might be substantially reduced if a Y-coupling, with valves in each of the arms, were employed. This would allow one container to be removed and replaced while the other is being filled.

The filling of flexible containers in heavy onshore swells from a stranded vessel, such as is being considered here, would be exceedingly risky because of the proximity of nearby submerged rocks. It is almost imperative to moor these containers well offshore of the stranded vessel and to feed them via floating hose. (The 1600 gpm pumping rate allows for 300 feet of hose.) The Type OW POHSSC are themselves about 300 feet long. If the PACIFIC PIGEON is 1000 feet long, with only the starboard side accessible, then the 8 operating pumps would be, on the average, about 125 feet apart. (See Figure 10-1.) It appears that attaching and removing the containers would be difficult because of the confined space between the extended bags, particularly if continuous operation via a Y coupling were desired. Space must also be allowed for the moorings at both ends of the containers. The handling of these storage containers would probably be the most difficult aspect of the offloading operation.

A time-line of the offloading requirements for PACIFIC PIGEON is given in Figure 10-2.

Scenario B

Offloading cannot commence on the UNIVERSAL WONDER until the fire is extinguished, which occurs at 1000 July 2. At that time some 40,000 tons (12.3 million gallons) will have leaked from the

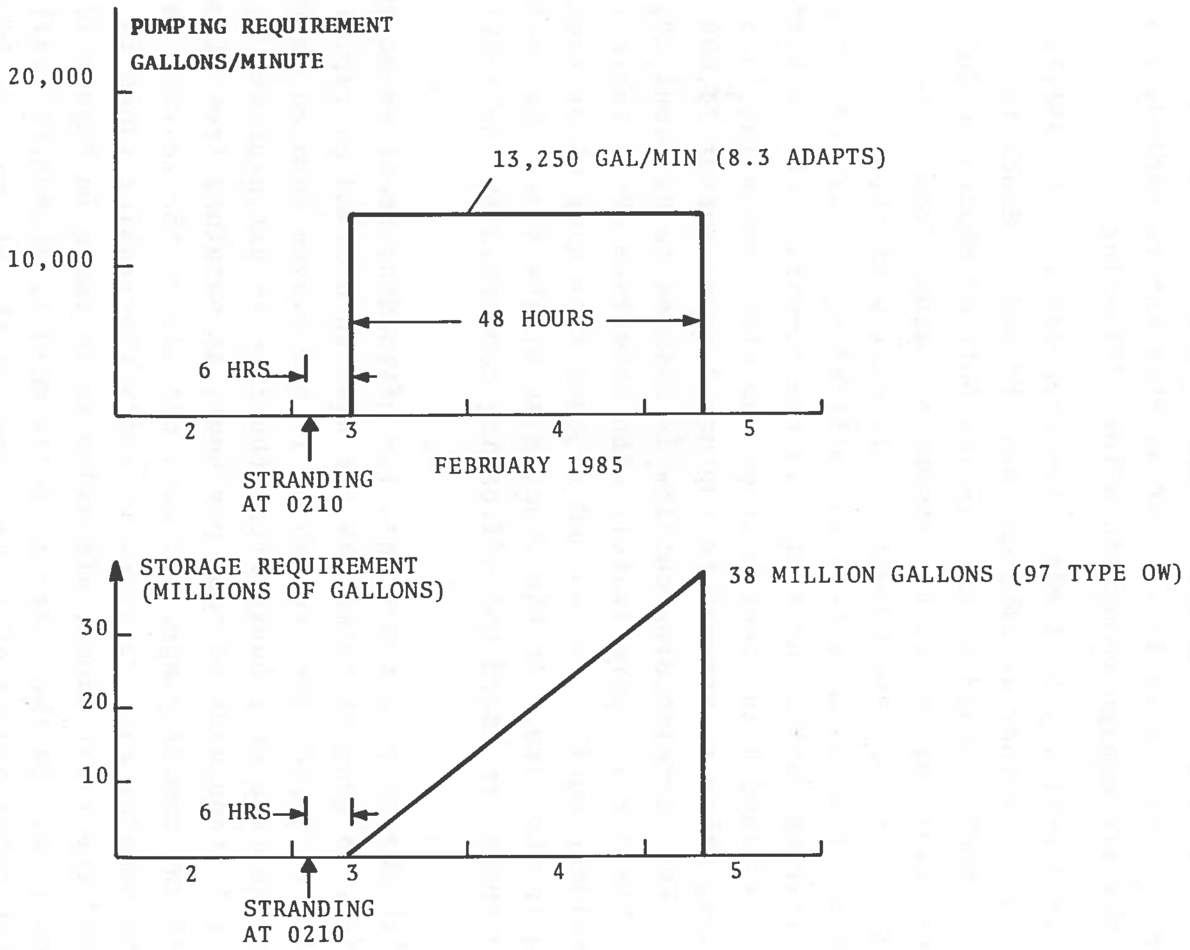


FIGURE 10-2 OFFLOADING REQUIREMENTS FOR PACIFIC PIGEON

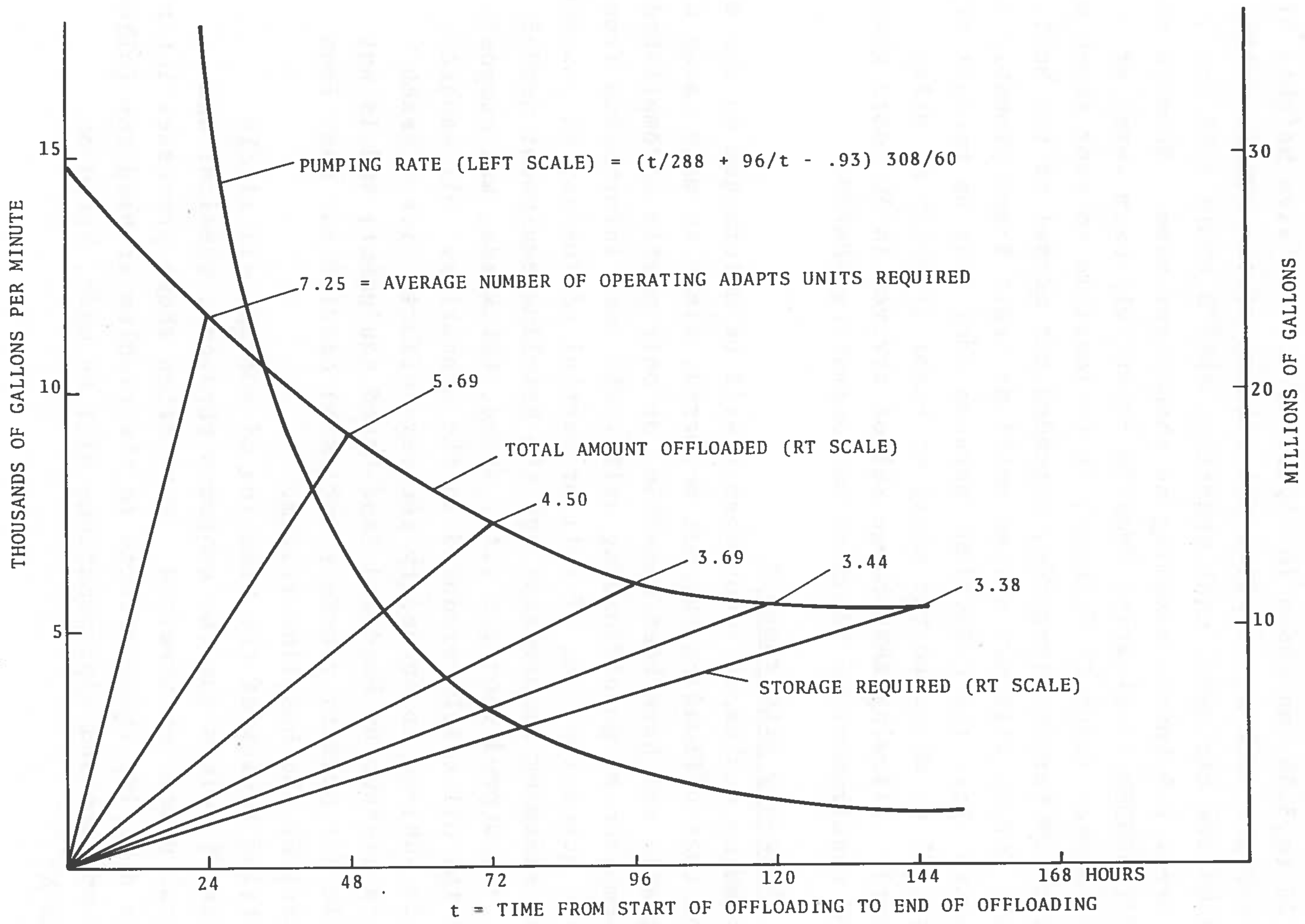


FIGURE 10-3 OFFLOADING REQUIREMENTS FOR UNIVERSAL WONDER

(1) The general motion of an oil slick is approximately equal to the vector sum of the subsurface current, plus 3% of the wind speed.

(2) Advection of the slick by waves alone is poorly understood at present, and advection by waves and wind together even less well understood. Therefore, ad hoc assumptions must be made for each scenario.

(3) Slick spreading is assumed to occur approximately according to Figure 10-4 for the lighter components, which form a thin film of the order of $4x10^{-3}$mm; after 2 to 3 days approximately 90% of the oil is assumed to be contained in layers of several millimeters thickness,* which occupy about 10% of the visible slick area. Spreading is superimposed on the general motion.

(4) Evaporation in all three scenarios will be taken as that for "average" crude, as given in Appendix N: 25% evaporated in 8 hours, 40% in 16 hours, about 50% in 5 days; at 20°C (68°F), sea state 2. These values are plotted in Figure 10-5

(5) The formation of a water-in-oil emulsion will be assumed to proceed similar to the experiments of Reference N-6. Specifically, the following viscosity-time values will be assumed, as shown in Figure 10-6.

---

* The thickness of these "pancakes" is apparently determined by the slick thickness at the time that evaporation and emulsification have removed the volatile, spreading fractions and rendered the central portion more viscous. As seen in the Table and in Figure 10-5, these two processes take about 1-2 days. Hence pancake thickness will be taken to be slick thickness on the 2nd day after the spill commences.

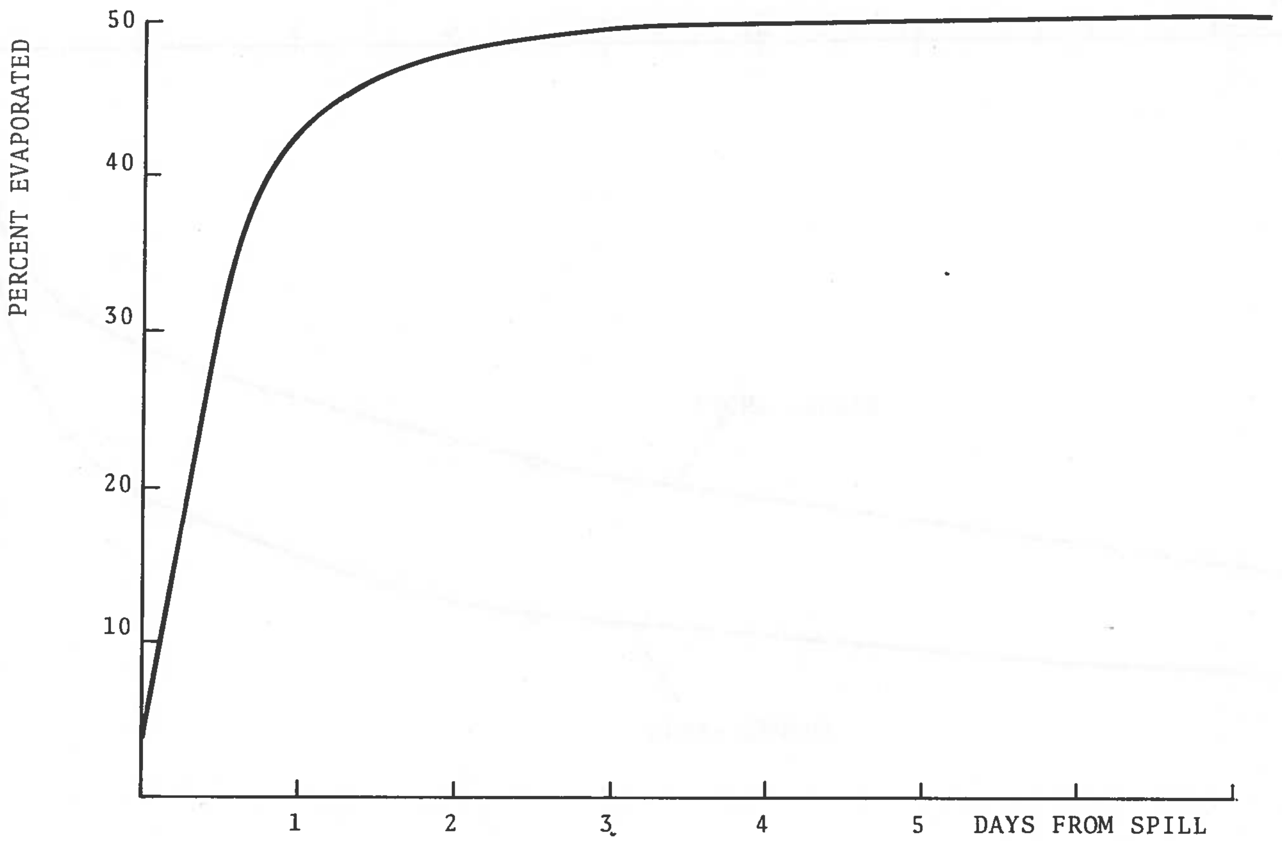


FIGURE 10-5 EVAPORATION FOR "AVERAGE" CRUDE

	Viscosity (centistokes)	
Time from Start	Heavy Crudes	Light Crudes
0	16	8
1 day	316	56
2 days	800	80
7 days	5,000	500
21 days	20,000	5,000

(6) The effects of dissolution, dispersion into the water, photo-oxidation, biodegradation and sedimentation will be ignored, as will all other effects not already mentioned.

The above assumptions provide a general framework for deriving skimming requirements. The three scenarios now will be treated in detail.

Scenario A - Skimming Conditions

Stranding occurs at the point of Cape Flattery, at 0210 Feb. 3, with seas 6-8 ft and onshore winds of 40 knots, gusting to 60. The outflow rate from time of stranding until breakup at 1000 Feb. 6, is taken from Figure 4-1 as 800 tons/hour, on the average.

At 0800 Feb. 3 about 4800 tons have been released and the slick is assumed to be one half mile long. From Figure 10-4, the slick area is approximately 5 x $10^6 m^2$ or 1.46 (n.mi.)^2, which gives a "width" of 3 n. miles and an average slick thickness of .044 inches. The gravity-inertia phase of spreading must prevail in the vicinity of the vessel, while the gravity-viscosity phase probably prevails for the major part of the slick area. The winds average about 28 knots onshore during this 6 hour period (0210 to 0800 Feb. 3), giving a net slick motion of about 5 n. miles, more than enough to drive the slick 1 1/2 n. miles from Duntze rock to the tip of Cape Flattery.

At 0600 Feb. 18, 364 hours from the start, essentially all of the 154,000 tons of oil has been released. The slick area, from Figure 10-4, is about $3.5 \times 10^9 m^2$, or 1022 sq. n. miles. Again it is assumed that half of the oil and one-third the total slick area lies along the coast, and the other half of the oil and two-thirds of the total slick is in the Straits of Juan de Fuca. The coastal slick is 2 n. miles wide, 128 n. miles long, and.004 inches thick, on the average. Only the portion greater than 1/2 n. mi. from the coast is assumed to be accessible for skimming, where the average thickness is assumed to be .002 inches. The slick in the Straits is 512 sq. n. miles, 8 n. miles wide by 64 n. miles long, with an average thickness of .002inches. Evaporation and pancaking have progressed extensively in the Straits.

During the entirety of Scenario A, the effects of evaporation, pancaking, and emulsification must be taken into account. Evaporation will reduce the volumes given above, and this is assumed to affect the slick thickness, but not the slick dimensions. The "pancaking" phenomenon described in Appendix N is assumed to occur in the Straits of Juan de Fuca, but not in the Pacific coast slick. Emulsification is assumed to occur in both slicks, but more in the one on the Pacific coast.

The results of allowing for the above three effects are shown in Table 10-1. In this Table, Q is the quantity of oil spilled, and Q' is the quantity remaining after evaporation is allowed for; h' is the slick thickness after evaporation is allowed for and measured (a) 1/2 the slick width from the shore, in the coastal slick, or (b) at the center of the pancakes in the Straits. The time, T', is hours from the time PACIFIC PIGEON arrived at Duntze rock.

The time employed to calculate evaporation loss is (T/2) while oil is still issuing from the vessel. Pancakes begin to form, by assumption, on the 2nd day as shown by the values of h' in the Straits of Juan de Fuca for hour 48 and after.

The wave heights of Figure 4-1 apply to the coastal area. Waves under 5 ft. persist from 0600 Feb. 4 to 0000 Feb. 15, and from about 0600 Feb. 18 onward. Wave heights in the Straits of Juan de Fuca are assumed to be less than 5 feet from 0600 Feb. 4 onward.

Scenario A - Skimming Requirements

The quantities of oil available for skimming are plotted in Figure 10-7, while viscosities are shown in Table 10-1. Skimming rates are determined for the two baseline equipments under the conditions just obtained (Table 10-1 and Figure 10-7).

OWORS: The range of viscosities shown in Table 10-1 spans the operating range of the OWORS. If a slick thickness of 4" is maintained by the OWOCS then recovery rates would be in the 500-1,000 gallons per minute range, per unit, according to the data of Section 6. To keep pace with the leakage rate, minus evaporation rate, (dashed line in Figure 10-7) a total skimming capability of 70,840 gallons per hour must be achieved for each slick in the first 100 hours, and an average of about 20,500 gallons per hour for the next 300 hours. If a fixed rate is maintained for the entire 400 hours, then that rate must be about 30,800 gallons per hour per slick. After 360 hours the viscosity of the water-in-oil emulsion has reached 11,220 cs in the Pacific and the OWORS efficiency drops rapidly beyond that point. Hence the Pacific Ocean slick must be skimmed in about 400 hours.

The 30,800 gallons per hour per slick will be taken as the operating requirement for Scenario A for the OWORS. In order to maintain a rate of 500 gallons per minute (30,000 gallons per hour) the OWORS requires a slick thickness of at least 1 inch. This is not available in either slick without the sweeping barrier (OWOCS) of the baseline system. However, the OWOCS cannot collect more than 300 gallons per minute in a .012 inch slick, such as would exist in pancake form in the Straits of Juan de Fuca. If pancakes do not form as on the coast, the slick would be 1/2 to 1/5 that of the Straits, with a corresponding drop in the barrier collection rate. Hence the limit of the OWORS is neither oil viscosity or slick depth at the disks, but the OWOCS collection rate. The latter is directly proportional to open water slick thickness, reaching 250 gallons per minute at .01 inch slick thickness, at a 1 knot sweep speed.

Given a peak rate of 300 gallons of oil per minute for the OWORS, operating inside a sweeping barrier, allowance must be made for (a) operating hours per day, (b) maneuvering efficiency. If one assumes (a) is 12/24, and (b) is 50%, it follows that in order to collect 30,800 gallons per hour, one requires

$$\frac{30,800}{300 \times 60 \times (12/24) \times .50} = 6.8 \text{ units}$$

per slick, plus spares. If the 6.8 units is rounded to 7, and 1 spare is adequate, then 8 units are required for the slick in the Straits of Juan de Fuca.

A note must be added regarding maneuvering efficiency. Suppose the slick reaches an area of 120 sq. n. miles, and that 90% of the oil is in pancakes of .01 inches thickness. Then the pancakes will cover about 60 sq. n. miles, or half of the total slick area. Hence a sweep will yield about 50% efficiency, even without maneuvering. If the pancakes are large, maneuvering can increase the efficiency above 50%. Whether these theoretical efficiencies can be achieved in practice is not known.

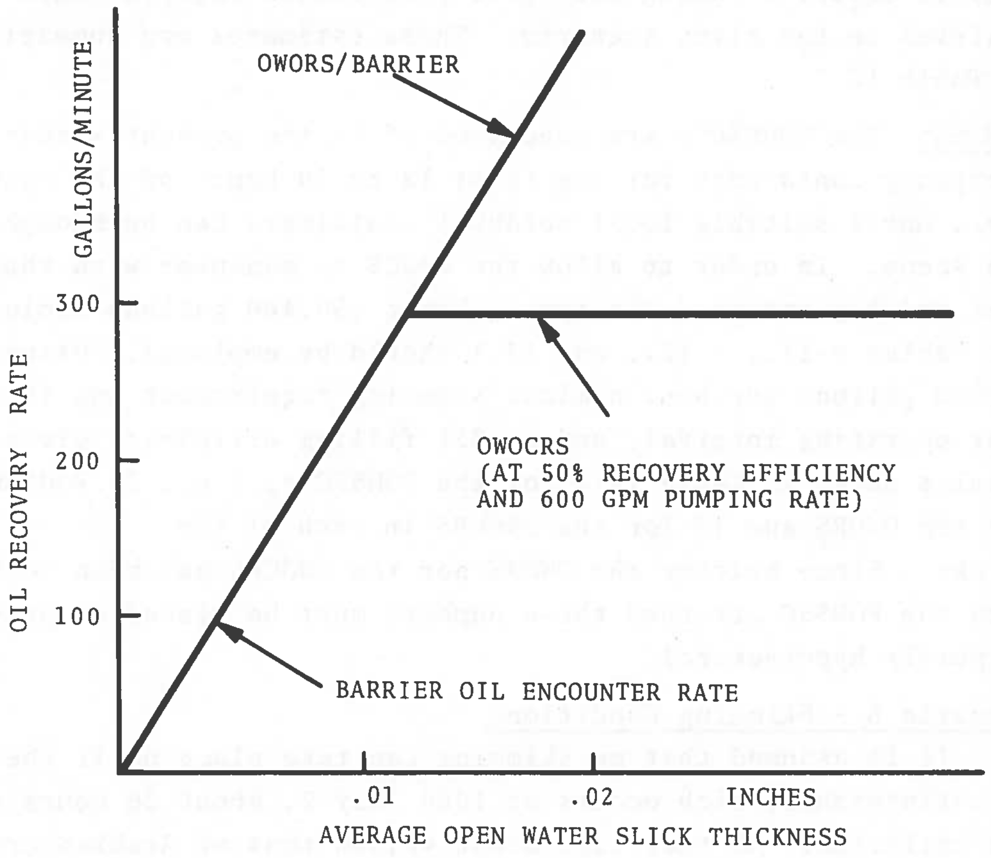


FIGURE 10-7b. OIL RECOVERY RATE VS SLICK THICKNESS

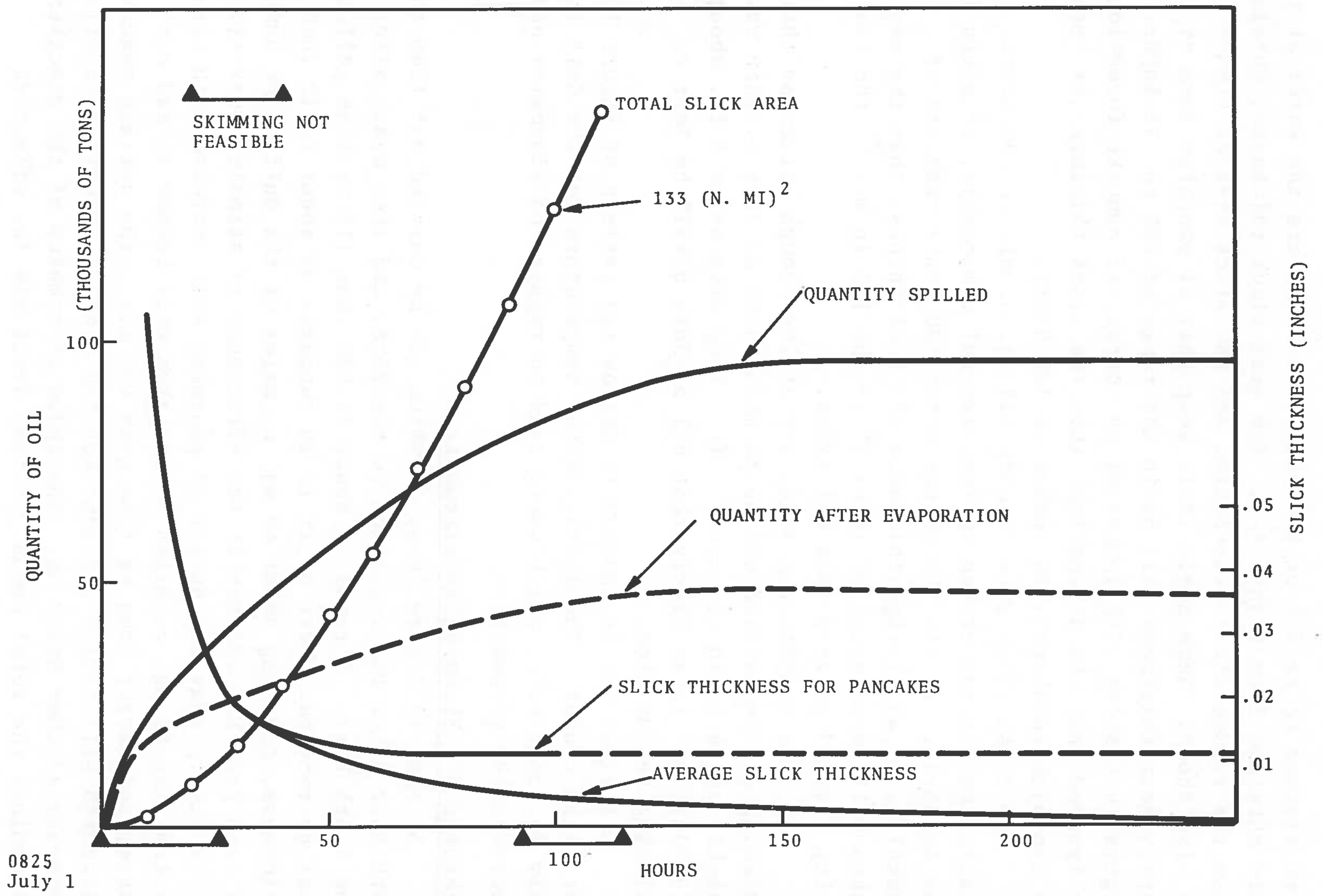


FIGURE 10-8. SLICK HISTORY FOR SCENARIO B

skimming . It is assumed that large pancake areas will be available until the storm of July 5, after which they will have been largely dispersed. Therefore, the time from the 26th hour to the 93rd hour is the prime skimming time. To skim all 48,000 tons in these 67 hours requires an average recovery rate of 220,000 gallons per hour. This must be acquired while the slick area goes from about 15 $(\text{n.mi.})^2$ to about 110 $(\text{n.mi.})^2$, with about 60 square n. miles of .012 inch pancakes breaking away after about thirty hours. The average slick thickness drops from about .022 inches at hour 26 to about. 006 inches at hour 93.

The requirements for the baseline equipment in Scenario B, presented in Table 10-3, are now discussed.

OWORS/Barrier: The oil viscosity can be expected to increase from about 56 cs to 400 cs in the skimming time. The OWORS reaches peak efficiency at about 1000 cs. Nevertheless the recovery rate is limited by slick thickness, rather than viscosity, and as in Scenario A, the OWORS must be operated within a barrier. The oil encounter rate of the barrier is the limiting factor in OWORS operation, as in Scenario A. In fact it is seen that the average slick thickness, pancake thickness, and slick area are similar to that in the Straits of Juan de Fuca in Scenario A. The ratio of pancake area to total slick area reaches about 0.5 at about the 100th hour, suggesting that a maneuvering efficiency of 50% is achievable, which percentage will be assumed. A utilization factor of 12 hours per day will again be employed. The maneuvering efficiency and utilization may be optimistic considering the frequency of bag changes that will be seen to be required.

OWOCRS: The recovery rate for this equipment is essentially the same as for the OWORS operating within a similar barrier, since the barrier collection rate is the limiting factor in both cases. One major difference that emerges is in the number of POHSSC's required: the assumed 50% recovery efficiency of the OWOCRS means that it fills the POHSSC twice as fast as the OWORS.

if x percent of the required equipment were deployed before the storm then 1 - x/100 of the oil would remain to be recovered after the storm. Moreover the recovery rate per unit would be, on the average, only about 1/6 of that before the storm, due to spreading. Thus it would take at least Tr hours,

$Tr = 67 + 67\ (1-x/100)/(1/6\ \frac{x}{100})$, for the complete recovery.

Number of Units	x	Tr
54 units	100%	67 hours
40	75	201
27	50	469
13	25	1273
5	10	3685

The above serve as a lower limit on the actual time required to recover the oil because they do not allow for thinning of the slick due to the recovery effort itself.

Scenario C - Skimming Conditions

The 3.5 million gallon spill postulated in Scenario C differs from the previous two in that the volume of oil released is much less and the release time much greater than at Cape Flattery or in the Straits of Florida. Once again it is assumed that an "average" crude is spilled, consisting of 50% volatile compounds, which evaporate according to a simple first-order process with a 1/2 day time constant.

The slick area as a function of time given in Figure 10-4 is a rough estimate, having only one set of samples in the lower volumes (100 tons, Reference 3, Jeffrey, 1972). It is likely that the low discharge rates of the wells (13.6 tons per hour) will produce a smaller slick area at a given time than a sudden discharge of the entire 10,700 tons (the amount that comes from the wells over the 30-day period). Hence the slick area as a function of time given in Figure 10-4 is reduced by 1/2 for the purposes of this scenario.

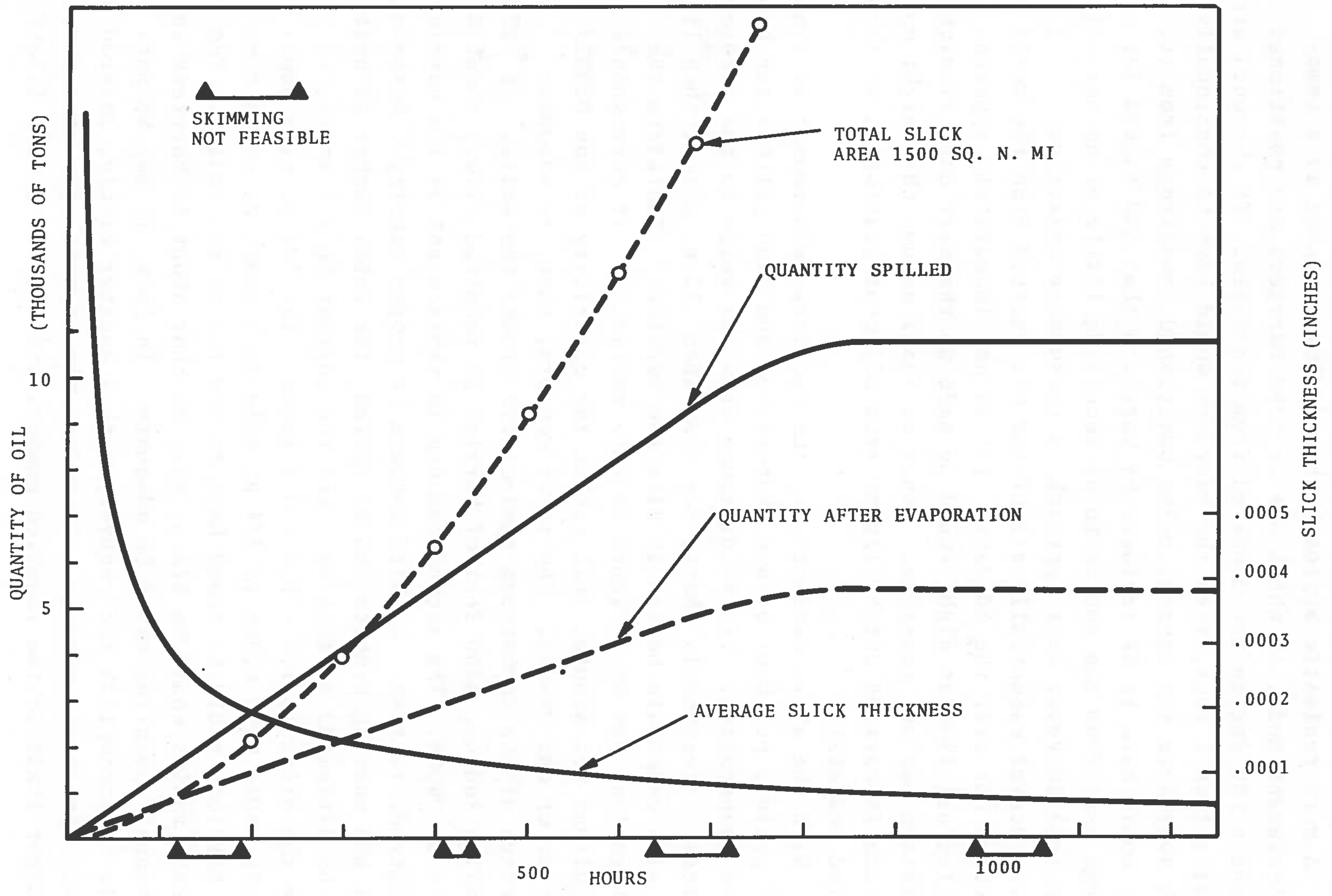


FIGURE 10-9. SLICK HISTORY FOR SCENARIO C

figure, even if currents are 1.5 knots. If the current is below the critical speed, then 4 to 8 OWORS/Barriers or OWOCRS would be adequate.

The POHSSC requirement is obtained for this Scenario by dividing the outflow rate, 4200 gallons/hr., by the type F capacity, 42,800 gallons, to obtain .11 POHSSC per hour, for the OWORS/ Barrier (90% recovery efficiency) and .19 POHSSC per hour for the OWOCRS. Over 30 hours, a total of 3.3 (i.e. 4) POHSSC would be required for the OWORS and 5.7 (i.e. 6) for the OWOCRS.

The skimming requirements for Scenario C are summarized in Table 10-4. A semi-circle of 1/4 n.mi. is assumed, current less than 1 knot. The recovery would be suspended during periods of adverse weather, a total of 22% of the time.

Observations: If currents remain less than the critical value then this Scenario presents relatively few uncertainties, aside from the possibility of fire or explosion. On the other hand, if currents exceed the critical value for the barrier, then, although the equipment requirements are still reasonable, the operational difficulties are greater than in either of the other two scenarios. In particular, a method must yet be worked out and tested that would allow 8 barriers, sixteen tow boats, 8 pump floats, 8 attendant boats, 8 flexible containers and all the connecting hose to operate in synchronism with the current in a semi-circular area of about one square mile. At the present level of planning and experimentation this operation must be considered impractical.

It should also be noted that the well outflow rate may be increased by a factor of thirty (30) to 3,000 BBL per hour, (400 tons/hr.) before the recovery rate of either OWORS or OWOCRS is exceeded, in the stationary semi-circular configuration.

TABLE 10-2 (Concluded)

	Straits of Juan de Fuca	Coast	Units
Recovery Efficiency	50	50	Percent
Mixture Collection Rate/Unit	150	50	Gal./Min.
POHSSC Capacity (Type F)	42,800	42,800	Gallons
POHSSC per Day per Unit	5.0	1.68	POHSSC's
POHSSC per Day, all Units	34.3	34.3	POHSSC's
POHSSC for 30 Hours, all Units	42.9	42.9	POHSSC's

* Evaporation allowed for.

** A "Unit" refers to one complete skimming apparatus.

TABLE 10-4 SCENARIO C SKIMMING REQUIREMENTS

	OWORS/ Barrier	OWOCRS	UNITS
Total to be Recovered*	3,500,000	3,500,000	Gallons
Recovery Period	850	850	Hours
Average Recovery Rate Req'd.	4,200	4,200	Gal./Hr.
Oil Encounter Rate, Avg. Per Unit**	8.75	8.75	Gal./Min.
Maneuvering Efficiency	100	100	Percent
Utilization	24	24	Hrs./Day
Average Recovery Rate/Unit	8.75	8.75	Gal./Min.
Average Number of Units in Operation over Recovery Period	8	8	Units
Number of Units on Scene	10	10	Units
Recovery Efficiency	90	100	Percent
Mixture Collection Rate/Unit	9.7	17.5	Gal./Min.
POHSSC Capacity (Type F)	42,800	42,800	Gallons
POHSSC per Day per Unit	.33	.59	POHSSC's
POHSSC per Day, all Units	2.6	4.7	POHSSC's
POHSSC for 30 Hrs, all Units	2.9	5.9	POHSSC's

* Without evaporation.

** A "Unit" refers to one complete skimming apparatus.

TABLE 10-5 BASELINE EQUIPMENT REQUIRED FOR SCENARIOS A, B, C

	SCENARIO		
	A (1)	B (2)	C (3)
Offloading			
ADAPTS	12	5 to 9	-
POHSSC Type OW	97	42 to 90	-
Skimming			
OWORS/Barrier	8+23	54	10
OWOCRS	8+23	54	10
POHSSC Type F:			
for OWORS/Barrier	24+24	171	3
for OWOCRS	43+43	308	6

Notes:

(1) The two components given for skimming under Scenario A apply to the Straits of Juan de Fuca and the Pacific Coast, respectively.

(2) The lower figure for offloading in Scenario B achieves 34% offloading from the leaking vessel and the upper figure achieves 75% offloading.

(3) Offloading does not apply to Scenario C.

TABLE 10-6 (concl.)

SCENARIO C

Offloading	10^3lbs.	Cu. ft.	10^3dollars
ADAPTS	—	—	—
POHSSC (Type OW)	—	—	—
Recovery (OWORS)			
OWORS/Barrier	332	20,700	9,040
POHSSC(Type F)	26	1,030	270
Recovery (OWOCRS)			
OWOCRS	190	11,000	1,750
POHSSC(Type F)	53	2,050	540

10.2.1 General Assumptions

It is assumed that all available land-based and air-based equipment will be delivered to the massive spill site, but that 20% of the water-based equipment will be retained for multiple spill coverage. The probability of two concurrent massive spills is low enough (about .01, as calculated in Appendix L) that only a fraction of the total response capability need be reserved. This fraction would serve primarily to allow for the possibility of a simultaneous non-massive spill occurring before the main portion of the equipment is returned from the massive spill debarkation site. Since only integral numbers of pumps, containers, and skimmers may be shipped, some arbitrary assignments were made for the equipment to be left behind. At the outset configuration capability levels were assumed from Tables 9-11 and 9-12. They were converted to units of equipment, using the baseline per unit capabilities of Table 9-13. When the reserve of water-based equipment is allowed for, the amounts available are as shown in Table 10-7 (only sites in the 48 states are considered to respond to the scenarios). Either the OWOCRS or OWORS/Barrier would be stored and employed in Configuration 5 at any one site. The weights corresponding to the equipment shown in Table 10-7 are given in Table 10-8.

It is assumed that the offloading equipment is delivered first, followed by the skimming equipment. In the most demanding scenarios, A and B, of Table 10-6, the OWORS/Barrier weight is approximately the same as the OWOCRS, when the POHSSC weight is included. In practice only one of the two systems will be deployed. From the standpoint of logistics, no substantial difference could be seen in the present study when the complete systems (including POHSSC) were considered. For delivery calculations, the OWORS/Barrier was employed.

For strategies 2 and 3 it is necessary to make assumptions regarding the number of aircraft available for pollution response duty. Since a spill of the order of 100,000 tons of oil in U.S. coastal water is likely to be a regional emergency, it is assumed that all USCG C130 aircraft, except a minimum required for search and rescue, would be made available. Based on 1977 deployments,

TABLE 10-8 WEIGHTS OF EQUIPMENT AVAILABLE FOR MASSIVE SPILL RESPONSE (1)

(THOUSANDS OF LBS)

		ADAPTS 2 Stage	POHSSC Type O	OWORS Barrier	POHSSC Type F	OWOCRS (2)	POHSSC (2) Type F
Philadelphia PA	L	6	13.7	33.2	8.8	19.0	8.8
Philadelphia PA	W	0	68.5	1228.4	501.6	703.0	1003.2
New Orleans LA	L	6	27.4	398.4	149.6	228.0	290.4
New Orleans LA	W	0	41.4	630.8	228.8	361.0	466.4
New York NY	L	6	13.7	166.0	44.0	95.0	88.0
New York NY	W	6	27.4	863.2	246.4	494.0	484.0
San Francisco CA	W	6	54.8	365.2	149.6	209.0	299.2
Galveston TX	W	6	41.4	199.2	132.0	114.0	264.0
Los Angeles CA	L	6	13.7	66.4	52.8	38.0	96.8
Los Angeles CA	W	0	41.4	199.2	176.0	114.0	352.0
Pascagoula MS	W	6	54.8	199.2	123.2	114.0	246.4
Sabine TX	L	6	13.7	66.4	26.4	38.0	44.0
Sabine TX	W	6	27.4	298.8	105.6	171.0	211.2
Port Aransas TX	W	6	27.4	199.2	88.0	114.0	158.4
Boston NA	L	6	68.5	697.2	290.4	399.0	580.8
Portsmouth VA	L	6	13.7	66.4	35.2	38.0	61.6
Portsmouth VA	W	6	13.7	33.2	17.6	19.0	44.0
Seattle WA	L	6	27.4	99.6	44.0	57.0	79.2
Clearwater FL	L	6	27.4	265.8	96.8	152.0	176.0
Chicago IL	L	6	27.4	66.4	26.4	38.0	44.0
		102	643.9	6142.0	2543.2	3515.0	4998.0

(1) See Note (1), Table 10-7

(2) See Note (2), Table 10-7

CARGO DENSITIES	
ADAPTS	30 lbs/cu.ft.
POHSSC	
Type OW	18
Type F	26
OWORS	16
OWOCRS	16

MAX. PAYLOAD DENSITIES	
C130B	
1600 n.mi.	4.4 lbs/cu. ft.
500	5.5
C130H	
1500 n.mi.	10.3
1000	11.1
C141A	
2000 n.mi.	13.2
3000	11.3

The cargo densities should be reduced by about .8 to allow for packing density. This gives a minimum density of 12.8 lbs/cu.ft. for the OWORS, which is barely below the maximum achieveable aircraft load density. Hence in almost all cases air transport will be limited by weight rather than volume.

With this simplification, it is possible to determine the number of aircraft loads required to deliver each of the items required for a massive spill. This is done in Table 10-9a. This Table also includes truckloads required, based on a 40 ft. flat bed tractor and semi-trailer of 80,000 lbs. gross weight and 50,000 lbs. payload. The volume that can be carried is roughly 8 x 40 x 9 or 2880 cu. ft., which comes to about 17.4 lbs per cu. ft. Therefore, truck loads are limited by volume in the case of the OWORS, the OWOCRS and the Type OW barge. Otherwise they are limited by weight. For simplicity it will be assumed that all aircraft loads are weight-limited, and that enough tractor-trailers are available to transport equipment without limit on load or volume.

In order to determine offloading capability delivered to the debarkation point, it was assumed that the total offloading equipment delivered consists of 14% by weight of ADAPTS and 86% by weight of POHSSC type OW. These percentages correspond to the total weights shown in Table 10-8. The number of ADAPTS and POHSSC Type O delivered is then obtained by dividing the delivered weights by 6,000 lbs per ADAPTS and 13,700 lbs per POHSSC, and multiplying by 1000 gal/min for ADAPTS and 250,000 gal for POHSSC.

In order to determine the skimming capability delivered, the same procedure was followed. The percentage breakdown for off-loading is 71% OWORS/Barrier and 29% POHSSC Type F. The weights were taken as 33,200 lbs and 8,800 lbs respectively. The capabilities were taken as 300 gal/min and 40,000 gal.

10.2.3 Delivery Profiles

Strategy 1, All Land

The truck-loaded equipment responds according to the estimates made in Section 7, i.e., 105 minutes plus travel time at 33.33 knots. Water-based equipment must be retrieved from its vessel (whether on a launch ramp or in the water) and loaded on to semi-trailers. It is assumed that these will be commercially available tractor semi-trailers, leased or rented as required. The intervals for waterborne equipment delivery then are carried out in parallel with those for land delivery, and are as follows:

(a)	Alert time	15 min.
(b)	Assembly of personnel	45
(c)	Briefing	15
(d)	Equipment retrieval	60
(e)	Tractor Semitrailer availability and delivery; acquire loaders	120
(f)	Load	160
(g)	Road Time equals Response Range/33.33 knots	

Activities (d) and (e) are simultaneous and are sequential with the others. The net result is a response time of 255 minutes plus road time at 33.33 knots. Response time is calculated to the time of arrival of the trucks at the debarkation point, and does not include unloading or delivery to the spill. The response times to each of the three debarkation points are shown in Table 10-10. Since it is assumed that adequate land transport is available, the recovery capabilities listed in Table 10-7 will arrive at the three debarkation points without regard to weight or volume. The total offload capability at the debarkation point at anytime is taken to be the cumulative ADAPTS capability in

TABLE 10-10 RESPONSE TO MASSIVE SPILLS - STRATEGY NO. 1
(HOURS) (1)

		TIME TO PORT ANGELES	TIME TO KEY WEST	TIME TO ATLANTIC CITY
Philadelphia PA	L	66.0	31.3	3.2
Philadelphia PA	W	68.5	33.8	5.7
New Orleans LA	L	58.7	18.1	30.4
New Orleans LA	W	61.2	20.6	32.9
New York NY	L	66.7	33.1	4.2
New York NY	W	69.2	35.6	6.7
San Francisco CA	W	25.3	72.5	68.6
Galveston TX	W	57.0	27.7	35.9
Los Angeles CA	L	28.6	61.4	65.9
Los Angeles CA	W	31.1	63.9	68.4
Pascaqoula MS	W	63.7	17.7	24.4
Sabine TX	L	54.8	23.2	35.4
Sabine TX	W	57.2	25.7	37.9
Port Aransas TX	W	57.0	30.0	42.2
Boston MA	L	69.0	37.6	8.8
Portsmouth VA	L	67.5	25.5	7.0
Portsmouth VA	W	60.0	28.0	9.5
Seattle WA	L	3.4	73.8	66.1
Clearwater FL	L	70.0	8.0	25.8
Chicago IL	L	48.7	34.1	20.3

(1) Measured form time of receipt of OSC requests.

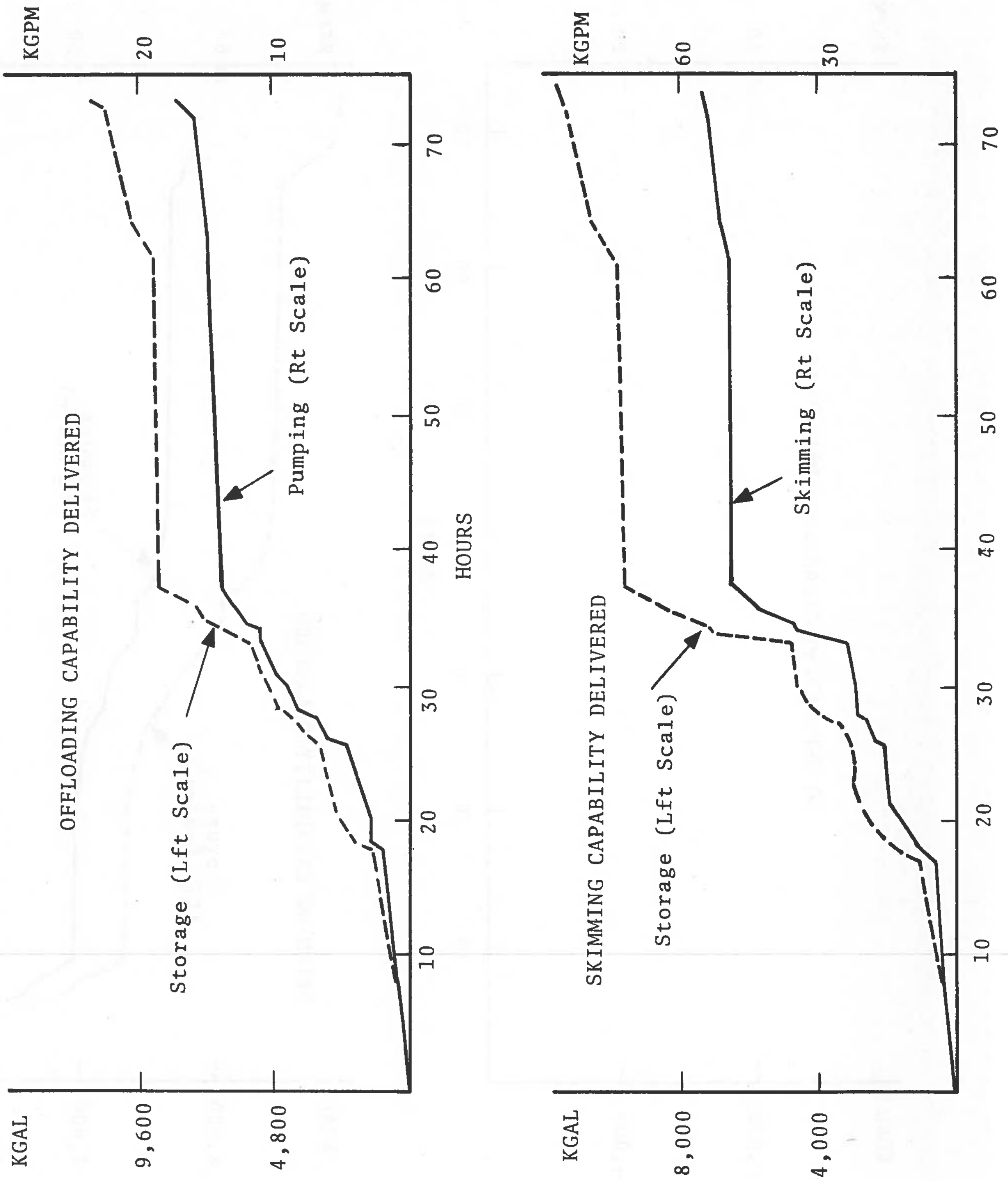


FIGURE 10-10b. STRATEGY 1, SCENARIO B

TABLE 10-11 AIRPORTS EMPLOYED FOR STRATEGIES 2 & 3

		AIRPORT FOR STRATEGY 2	AIRPORT FOR STRATEGY 3
Philadelphia PA	L	McGuire AFB	McGuire AFB
Phialdelphia PA	W	McGuire AFB	MCGuire AFB
New Orleans LA	L	Belle Chase CGAS	Belle Chasse CGAS
New Orleans LA	W	Belle Chase CGAS	Belle Chasse CGAS
New York NY	L	McGuire AFB	J F Kennedy (1)
New York NY	W	McGuire AFB	J F Kennedy (1)
San Francisco CA	W	San Francisco CGAS	San Francisco CGAS
Galveston TX	W	Belle Chasse CGAS	Ellington AFB
Los Angeles CA	L	Los Angeles CGAS (2)	Los Angeles CGAS (2)
Los Angeles CA	W	Los Angeles CGAS (2)	Los Angeles CGAS (2)
Pascaqoula MS	W	Belle Chasse CGAS	Belle Chasse CGAS
Sabine TX	L	Belle Chasse CGAS	Ellington AFB
Sabine TX	W	Belle Chasse CGAS	Ellington AFB
Port Aransas TX	W	Belle Chasse CGAS	Corpus Christi CGAS (3)
Boston MA	L	Otis AFB	Otis AFB
Portsmouth VA	L	Elizabeth City CGAS	Elizabeth City CGAS
Portsmouth VA	W	Elizabeth City CGAS	Elizabeth City CGAS
Seattle WA	L	Seattle CGAS (4)	Seattle CGAS (4)
Clearwater FL	L	Clearwater CGAS	Clearwater CGAS
Chicago IL	L	Clearview CGAS	Clearview CGAS (5)

(1) Alternate: McGuire AFB, Wrightstown, N.J.

(2) Alternate: March AFB, Riverside, CA

(3) Alternate: Kelley AFB, San Antonio TX

(4) Alternate: McChord AFB, Tacoma WA

TABLE 10-13 AIR/LAND TRANSPORT TIME FOR THREE MASSIVE SPILL SCENARIOS

(MINUTES)

FROM ORIGINATING AIRPORT	TO PORT ANGELES		KEY WEST		ATLANTIC CITY	
	C130	C141	C130	C141	C130	C141
Belle Chasse	570	414	298	252	379	300
McGuire AFB	620	444	388	306	-	-
San Francisco	218	204	680	480	580	420
Elizabeth City	640	456	338	276	228	210
Clearwater	650	462	228	210	348	282
Los Angeles	368	284	590	426	620	444
Otis AFB	650	462	429	330	228	210
Seattle	-	-	670	474	620	444
Glenview IL	499	372	409	318	308	258
New York City	630	450	499	312	197	192
Ellington AFB	539	396	348	282	429	330
Corpus Christi	539	396	348	282	479	360

NOTES:

1. Transport time for C130 is 184 minutes plus air time from orginating airport to debarkation point at 295 n.miles per hour.
2. Transport time for C141 is 184 minutes plus air time from originating airport to debarkation point at 495 n.miles per hour.

Figures 10-2 and 10-3 for offloading and 10-7, 10-8 and 10-9 for skimming.

Scenario A - PACIFIC PIGEON

Scenario A calls for 13,250 gallons/minute pumping capability from hour 6 through hour 54. This can not be achieved by strategy 1; strategy 2 meets the need at about hour 13, as does strategy 3. Similarly, while none of the strategies provide the 38 million gallons of storage called for, nevertheless, strategies 2 and 3 do provide between 8 and 10 million gallons of Type OW storage between the 10th and 20th hour, and over 12 million gallons by the 30th hour.

The skimming requirements for Scenario A are given in Figure 10-7. About 15 million gallons should be skimmed by the 100th hour, and about 22 million by the 200th hour. Strategy 1 provides about 10,000 gpm (600,000 gallons/hr) from hour 20 to hour 57, yielding about 22 million gallons up to that time. This is more than required at the 100th hour, but the buildup in the first 20 hours is somewhat less than required. It must be concluded, then, that strategy 1 would provide most but not all of the skimming requirement of Scenario A. Strategies 2 and 3 provide well over twice as much equipment as strategy 1 and hence would more than meet the skimming needs of PACIFIC PIGEON in terms of equipment delivery.

Scenario B - UNIVERSAL WONDER

Offloading requirements for UNIVERSAL WONDER are not as unambiguous as those for PACIFIC PIGION. As seen in Figure 10-3, they depend on the time spent offloading. Strategy 1 builds up to about 13,000 gallons/minute in 38 hours. If the pumps were all operating at the 38th hour, the cargo remaining would be offloaded in about 28 hours. When allowance is made for (1) use of the pumps arriving before the 38th hour, and (2) leakage during pumping, it appears that the leaking tanks would be emptied by about the 48th hour by strategy 1. The picture for strategies 2 and 3 is even more encouraging, since essentially 16-17,000 gallons per minute capability is delivered by the 20th hour (strategy 2) or 17th hour (strategy 3). It must be concluded, a larger blowout would take longer to cut off. The rate of discharge, then, must be met for a longer period of time by the skimming equipment. The capability available, however, is over 800 times the requirement of the initially assumed discharge rate (1.8 million gal/hr vs 2,125 gal/hr) and hence is more than 250 times the trebled requirement.

Summary

The comparison of requirements and delivered capability presented above may be summarized qualitatively as follows:

	Scenario(1)					
	AO	AS	BO	BS	CO	CS
Strategy 1	Poor	Marginal	Good	Marginal	-	Excellent
2	Marginal	Very Good	Excellent	Marginal	-	Excellent
3	Marginal	Very Good	Excellent	Marginal	-	Excellent

(1) First letter indicates Scenario, second letter indicates Offloading or Skimming. Thus, AO indicates Scenario A offloading.

It should be noted that the descriptors in the above table refer only to the ability of the three logistic strategies to deliver the required equipment. The effectiveness of the equipment in actually recovering the oil is much more difficult to assess, and the discussions given in the preceding subsections provide only an outline of some of the problems. The intent of those discussions, and of the present comparative assessment has been to determine whether the quantities and locations of response

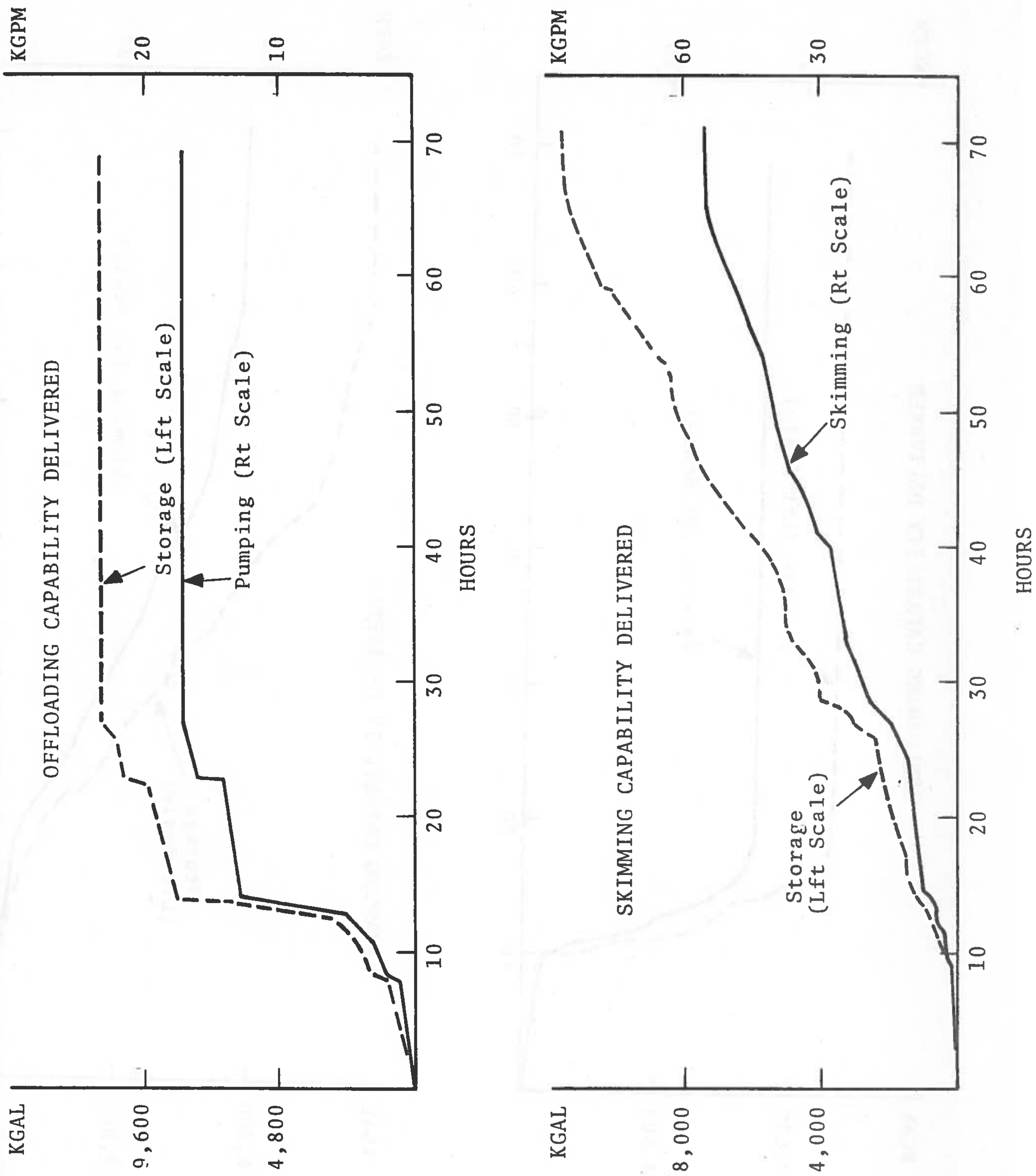


FIGURE 10-11a: STRATEGY 2, SCENARIO A

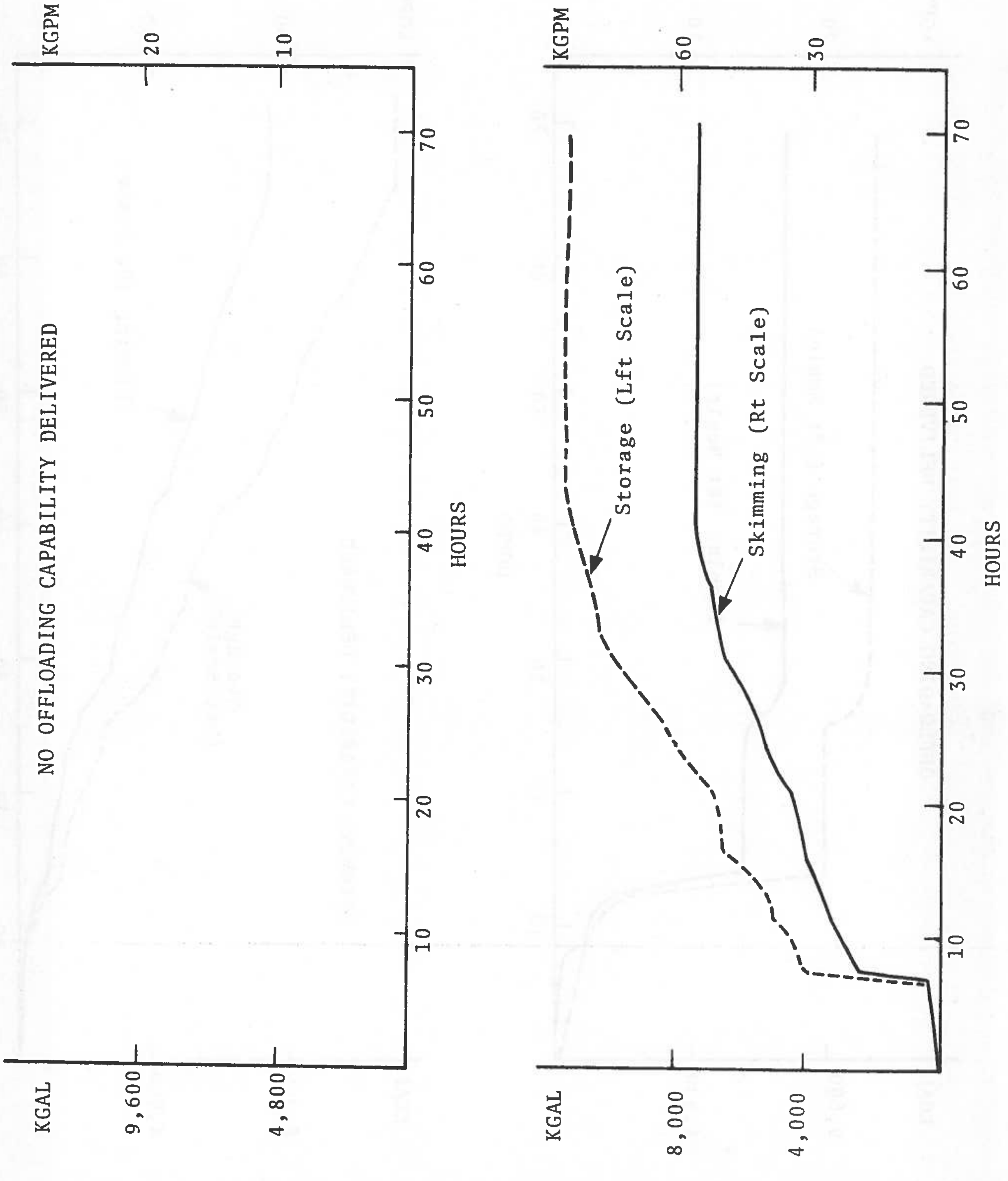


FIGURE 10-11c. STRATEGY 2, SCENARIO C

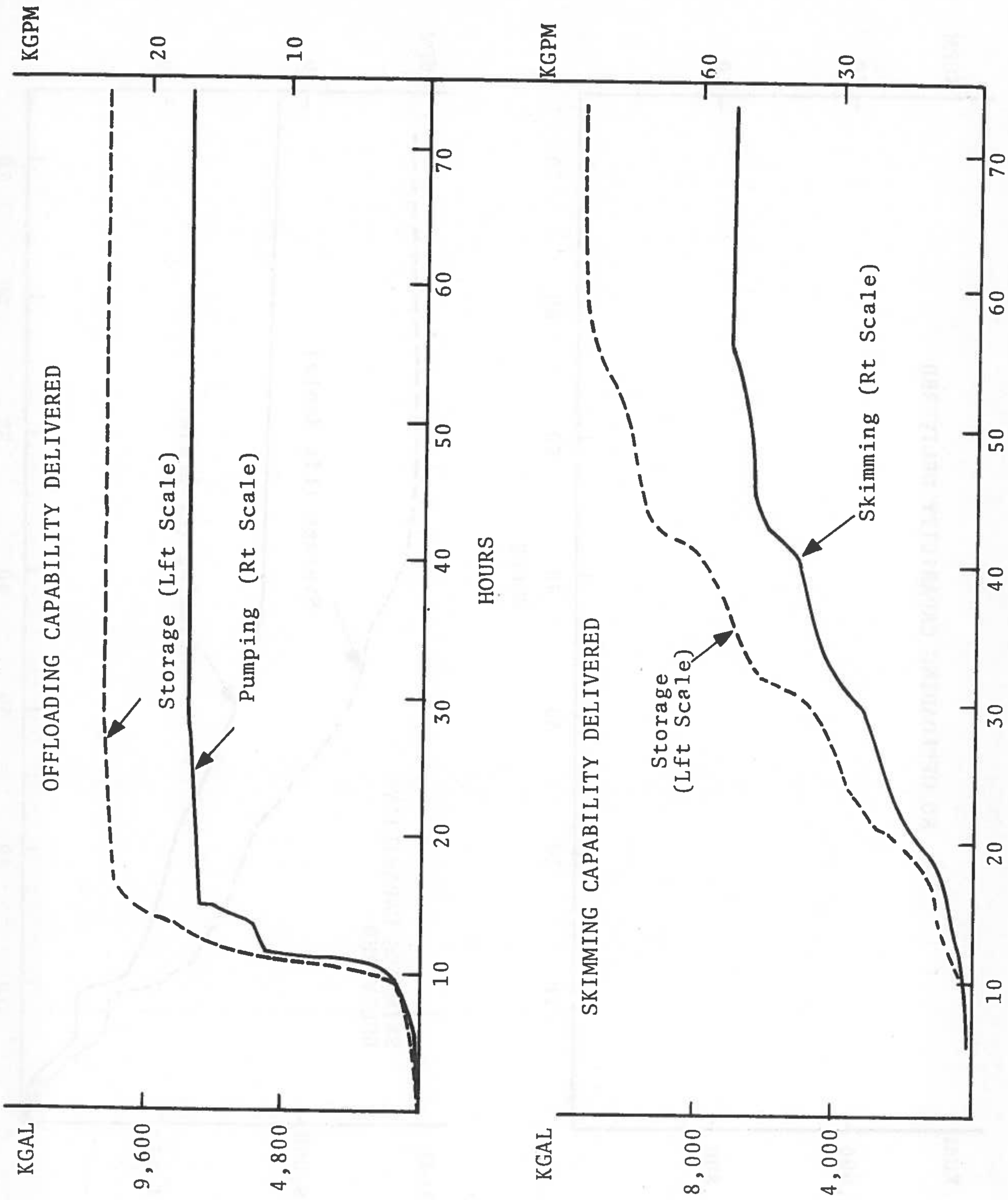


FIGURE 10-12b: STRATEGY 3, SCENARIO B

REFERENCES FOR SECTION 10

10-1. Kimon, P.M., R.K. Kiss, and J.D. Porricelli, "Segregated Ballast VLCCS: An Economic and Pollution Abatement Analysis," Marine Technology, October 1973, pp.334ff

10-2. Stolzenback, K.D., et al.: A Review and Evaluation of Basic Techniques for Predicting the Behavior of Surface Oil Slicks," Report No. MITSG 77-8, MIT Sea Grant Program, Massachusetts Institute of Technology, Cambridge MA 02139, March 1977.

10-2. Jeffrey, P.G., "Large-Scale Experiments on the Spreading of Oil at Sea and its Disappearance by Natural Factors," 1973 Proceedings of the Joint Conference on Prevention and Control of Oil Spills, Washington, D. C.

11.1 COMBINING OPEN WATER AND HARBOR REQUIREMENTS

The baseline unit requirements for harbor and for open water are given in Tables 9-11 and 9-12. These requirements were derived on the assumption that 40 million gallons of recovery capability would be allotted to cope with harbor spills and 30 million gallons to cope with open-water spills. If the same equipment can be employed for both types of spill, then it is not necessary to deploy 70 million gallons of recovery capability. Rather, it would be necessary to deploy only the larger of the two called for at each site. Since different amounts of non-USCG capability for harbor and open-water recovery were allowed for at each site, the required USCG capability at some sites is greater for open water than for harbor, despite the fact that the harbor spill potential is always greater than the open-water spill potential. Therefore each site must be examined to determine which is the larger requirement, as well as whether the two types of equipment are indeed interchangeable at the site.

Using the larger of the entries in Tables 9-11 and 9-12 we obtain the result shown in Table 11-1. Harbor requirements are noted by an asterisk, while the remaining entries are open-water requirements.

There are four sites at which harbor and open-water capability may not be interchangeable because of geographic constraints:

<u>Philadelphia</u> The open-water capability assigned to Philadelphia must serve all the Delaware Bay and the adjacent New Jersey - Delaware coast. The harbor capability, on the other hand, must cover Camden, Marcus Hook, and Newark, NJ. It may be advisable to locate the open-water capability in the lower part of Delaware Bay and to place the harbor capability at Glocester City. In this case, combining harbor and open-water capability would not be practical.

<u>New Orleans</u> The harbor capability at New Orleans must serve Baton Rouge as well as the Mississippi River to the Passes. The open-water requirement must serve the Gulf beyond the

Passes. It is difficult for the same site to serve both functions effectively, so that combining the capabilities is not effective at New Orleans. Since the Pascagoula site can serve the Chandeleur, Mississippi and Breton Sound waters, the New Orleans open-water capability should be located on the southwest coast of the delta where it can serve the offshore drilling and LOOP activities.

Sabine, TX While Sabine is ideally situated for open-water response, it must also serve the Lake Charles harbor area via the Sabine and Calcasieu Rivers and the connecting intracoastal waterway, via land, or via the Gulf Coast and Lake Calcasieu. The response time by any of these routes may be excessively long compared to what may be achieved by locating the Sabine harbor capability farther inland, at, say, Orange or Lake Charles. The desirability of an inland harbor capability in this area must be determined by an examination of the response times from Sabine to the inland ports by truck and water.

Seattle In the Puget Sound area the distance from Seattle to Cape Flattery is substantial by land or by water. It may be desirable, when the Alaskan crude influx increases, to station the capability required for open-water at Bellingham and that required for harbor spills at Seattle.

The baseline USCG equipment complement of section 6 does not include different designs for harbor and open water recovery operations. To a great extent the baseline equipment is suitable for harbor as well as for the open water operation for which it is primarily intended. The major exception is the open water containment boom (OWOCS) which is bulkier and more expensive than required for most harbor containment purposes. Even in this case, however, one must weigh the advantages of a less expensive, more easily deployed harbor barrier against the elimination of duplicate equipment and the simpler training, logistics and maintenance required by a single type of equipment. One of the major advantages of using the OWOCRS equipment for harbor spills is the

TABLE 11-2. LAND AND WATER BASED CAPABILITY AT SIX LOCATIONS - CONFIGURATION 5.

		Spills Per Yr.	Response Time (hrs)	Capability Mill Gals
Philadelphia	L	0.30	4.4	0.40
Philadelphia	W	5.07	1.4	6.76
New York	L	0.40	4.8	0.44
New York	W	1.79	1.3	4.08
Portsmouth	L	0.43	7.1	0.48
Portsmouth	W	0.41	1.9	0.44
New Orleans	L	1.08	3.6	2.32
New Orleans	W	2.71	1.3	5.48
Sabine	L	0.42	3.1	0.44
Sabine	W	0.88	1.7	1.76
Los Angeles	L	0.42	4.0	0.44
Los Angeles	W	1.19	1.4	2.44

Another consideration is the availability of land or water storage space. The allocations of Configuration 5 (Table 11-2) call for a preponderance of water-based equipment at five of the six sites in question. (Philadelphia, New Orleans, New York, Los Angeles, Sabine) with about an equal land/water division for the sixth site (Portsmouth-Norfolk). In practice, however, it may prove difficult to provide water-based storage. Wherever this is the case, transfer water-borne storage is the preferred approach since storage on land entails a response time penalty for a majority of the spills served by all ports except Portsmouth - Norfolk.

Effect on Equipment Levels and Recovery Percentage

When land- and water-based capabilities at the six sites in question are combined, different equipment levels from those shown in Tables 9-1 and 9-2 result from the allocation model of Appendix K. The 22 sites of Configuration 5 are reduced to the 16 sites of a new configuration, designated 5W. The levels are shown in Table 11-3. This table is for open water spill response only, since it was found in the previous subsection that the USCG harbor requirements are almost all less than the open water requirements, because of the non-USCG equipment available for harbors. A comparison of Configuration 5 with 5W shows that the percentage levels allocated to the combined water and land sites in Table 11-3 are not very different from the sum of the corresponding land- and water-based allocations of Table 9-1.

In addition to the percentage of allocations, the recovery fraction as a function of total U.S. capability also changes when land- and water-based sites are combined. The effect is shown in Figure 11-1 for open water spills, assuming optimum equipment allocation. It can be seen that for a given total capability the recovery for the combined configuration exceeds that for the separate configuration by 2% to 5%. Although this effect appears small, it takes on greater significance when viewed as a reduction in the capability required to achieve a given recovery percentage.

TABLE 11-3. RELATIVE EQUIPMENT LEVELS, PERCENT - OPEN WATER CAPABILITY, CONFIGURATION 5W

		TOTAL US CAPABILITY, MILLIONS OF GALLONS				
SITE	TYPE	2	6	10	20	30
Philadelphia	LW	20.9	35.3	36.7	28.0	21.1
New Orleans	LW	13.0	7.5	9.9	12.9	13.5
New York	LW	11.7	7.3	8.4	12.2	12.5
San Francisco	W	6.3	5.9	4.3	4.7	6.8
Galveston	W	5.3	5.3	3.9	3.5	5.0
Los Angeles	LW	9.9	6.8	7.2	10.9	10.6
Pascagoula	W	5.1	5.1	3.9	3.2	4.4
Sabine	LW	5.3	5.3	3.9	3.5	4.9
Port Aransas	W	4.7	4.7	3.7	2.7	3.1
Boston	L	9.5	6.7	6.9	10.4	10.1
Portsmouth	LW	4.0	3.2	3.3	2.1	2.0
Seattle	L	0.0	1.7	1.6	1.6	1.3
Clearwater	L	4.4	4.0	3.6	2.2	2.6
Chicago	L	0.0	0.0	0.8	0.5	.5
Barbers Pt	W	0.0	1.4	1.2	1.1	1.1
San Juan	W	0.0	0.0	0.8	.5	.5

no oil, so that an assistance coefficient of zero is justified. If the equipment arrives at an intermediate time the assistance coefficient can be set between 0.0 and 1.0, in proportion to the fraction of the recovery period remaining.

The above rationale for setting the assistance coefficients is an attempt to represent the reduced effectiveness of equipment arriving later than six hours. If the six-hour response time is an end in itself, a different approach must be used. One possibility is to assign a value close to unity if the storage sites are within the six-hour response time, and zero otherwise.

In either of these two approaches, sites within the six-hour zone may be thought of as a single site. [Note that for simplicity response time is calculated from site to site, rather than from site to spill.] Any equipment assigned to one site is largely available at the other, and vice-versa. If the mutual assistance coefficients are set identically to 1.0 for the two sites, then there are an infinite number of capability allocations to the two sites that result in the same recovery level. Hence, the optimum produced by the allocation program will not be unique.

Before discussing the results obtained with non-zero assistance coefficients, the values assigned to them for each of the two approaches will be presented below.

11.3.1 Local Assistance

In this approach, adjacent sites within 6 hours response time are assigned coefficients of 1.0. Adjacent sites between 6 and 10 hours away are assigned coefficients between .90 and .99, depending on the distance between the sites. Beyond 10 truck hours the coefficients are assigned the value, zero, which leaves Clearwater, Seattle, Barber's Point, Chicago and San Juan unassisted. The coefficients assigned by this scheme are given in Table 11-4 for Configuration 5W.

11.3.2 Coastal Assistance

For this method, the coefficients for Configuration 5W were calculated by the following rules:

(1) Sites greater than 747 n. miles apart (about 860 statute miles) were assigned 0.0 assistance coefficients. This effectively isolated the sites to the three coastal areas: Atlantic, Gulf and Pacific.

(2) Sites less than 6 hours apart were assigned coefficients of 1.0

(3) Sites separated by more than 6 hours, but less than 78 hours were assigned assistance coefficients a_{ij} calculated as:

$$a_{ij} = 1.0 - (t_{ij}-6)/(78-6)$$

where t_{ij} is the response time in hours from site j to site i.

(4) Sites separated by more than 78 hours response time were assigned 0.0 assistance coefficients.

The results of applying these rules are shown in Table 11-5. The East Coast group includes New York, Philadelphia, Portsmouth/Norfolk, Boston, and Chicago, except that Chicago and Boston do not exchange assistance. The Gulf Coast group includes Clearwater, Pascagoula, New Orleans, Sabine, Galveston and Port Aransas, except that assistance is not exchanged between Clearwater and Galveston or between Clearwater and Port Aransas. On the West Coast, San Francisco and Los Angeles form a pair, and Seattle and San Francisco form a pair, but Seattle and Los Angeles do not exchange assistance. Finally, the Hawaii and Puerto Rico sites do not interact with any other sites.

11.3.3 Results

The two sets of assistance coefficients were applied to Configuration 5W. In the case of sites mutually linked by assistance coefficients of unity, the relative allotment of capability between the two sites is arbitrary, so only the total of the two allotments is meaningful. The percent recovery as a function of the total capability, K, is shown in Figure 11-2 for Configuration 5W. The three curves show recovery percentages for (a) no assistance, (b) local assistance, and (c) coastal assistance. The vertical dashed lines indicate the total capabilities that correspond to an 80% recovery level, which is achieved in Configuration 5 by a 30 million gallon open-water capability. For Configuration 5W, the following requirements can be read from the graph:

(a) No assistance - 23.5 million gallons

(b) Local assistance - 10.0 million gallons

(c) Coastal assistance - 8.0 million gallons

The relative equipment levels for these three cases are shown in Table 11-6. The brackets serve to group those sites with mutual assistance coefficients of 1.0. It can be seen that, in case (b), New York and Philadelphia together command 51.4% of the total capability, which in theory can be located at either site. Boston and Portsmouth/Norfolk, however, are assigned no capability of their own, since they have access, respectively, to .99 and .98, of the New York/Philadelphia capability. The Pascagoula/New Orleans group was allotted about the same capability level (14%) as the Sabine/Galveston/Port Aransas group, and the San Francisco/Los Angeles group. It should be noted, however, that San Francisco and Los Angeles have been made into a group even though their assistance coefficients are .93 rather than 1.0.

In order to test the sensitivity of the allotment levels to the assignment of assistance coefficients, case (b) was run with the value 0.5 for all local assistance coefficients. The results are shown in Figure 11-3 and Table 11-7, along with the original case (b) results for comparison.

It is seen from the Table that changing the assistance coefficients to 0.5 does not materially change the levels except that about 6% of the national capability is shifted from the Texas Coast to the Louisiana Coast. The percentage allocations for the

TABLE 11-6. RELATIVE EQUIPMENT LEVELS, PERCENT - OPEN WATER CAPABILITY, CONFIGURATION 5W

SITE	TYPE	TOTAL U.S. CAPABILITY* MILLIONS OF GALLONS		
		CASE(a)	CASE(b)	CASE(c)
		23.5	10.0	8.0
Boston	L	10.4	0.0	0.0
New York	LW	12.8	51.4	54.5
Philadelphia	LW	25.8		
Portsmouth/Norfolk	LW	1.9	0.0	0.0
Chicago	L	.5	.7	0.0
Clearwater	L	2.5	3.2	0.0
Pascagoula	W	3.4	13.9	27.8
New Orleans	LW	13.3		
Sabine	LW	3.8	14.7	6.3
Galveston	W	3.7		
Port Aransas	W	3.0		
Los Angeles	LW	9.5	13.3	10.5
San Francisco	W	6.1		
Seattle	L	1.5	1.3	0.0
Barbers Point	W	1.1	1.0	1.0
San Juan	W	0.5	.6	0.0

*Total of individual capabilities deployed to sites.

TABLE 11-7. SENSITIVITY OF EQUIPMENT LEVELS, PERCENT,(1) TO LOCAL ASSISTANCE COEFFICIENTS

CASE	LOCAL ASSISTANCE COEFFICIENTS CASE(b)	CASE(b1)
a_{ij} range	0.9 to 1.0	0.5
Boston	0.0	0.0
New York	51.4	49.0
Philadelphia		
Portsmouth/Norfolk	0.0	0.0
Chicago	0.7	0.6
Clearwater	3.2	2.6
Pascagoula	13.9	20.0
New Orleans		
Sabine	14.7	8.8
Galveston		
Port Aransas		
Los Angeles	13.3	16.0
San Francisco		
Seattle	1.3	1.4
Barbers Point	1.0	0.9
San Juan	0.6	0.6

(1) Calculated for Configuration 5W, Open Water capability, Total U.S. recovery capability of 10.0 million gallons in Case (b), and 15.0 million gallons in Case (b1).

air site can assist, say, all 10 East and Gulf coastal sites then its effectiveness is about 4.5 times that of an equal amount of equipment elsewhere. The large amount of equipment called for at the air site was found to be far greater than the present or planned Coast Guard air lift capability.

For the above reason an air site must be assigned very low or zero assistance coefficients compared to other sites. The assistance coefficient from the air site to a collocated land site, however, may be assigned the value 1.0, as before.

When the Clearwater air site of Configuration 5a is appended to the combined land- and water-based sites of Configuration 5W, a new configuration (5Wa) results. With an assistance coefficient of 1.0 assigned between Clearwater land-based and Clearwater air-based sites, and zero coefficients to other sites from Clearwater by air, then the levels allocated and percent recovered are only slightly different from those obtained without the air site, as shown in Table 11-8, and Figure 11-4. The difference is due to those spills in the Great Lakes and Northern Maine that are serviced from the air site rather than from one of the land sites in the northeast. But servicing these spills from Clearwater produces a marked reduction in the percent of responses greater than six hours, as discussed in Section 8.4 and shown in Figure 8-14. Hence the addition of an air site should be viewed as a trade-off between the percentage of oil recovered and the percentage of responses within six hours. Figure 11-4 shows that adding one air site at Clearwater, FL causes a slight reduction of the recovery percentage for Configuration 5W, with local assistance. The reduction takes place because, for a fixed total capability, the addition of another site (of any type) reduces the capability available to all other sites, and the average effectiveness [oil recovered/recovery capability] is reduced. This is the same phenomenon as described in Section 11.3 with regard to combining land- and water-based sites. It appears that the small reductions in recovery percentage of Figure 11-3 can be sustained in order to obtain the substantial improvement in 6 hour response that are shown in Figure 8-14.

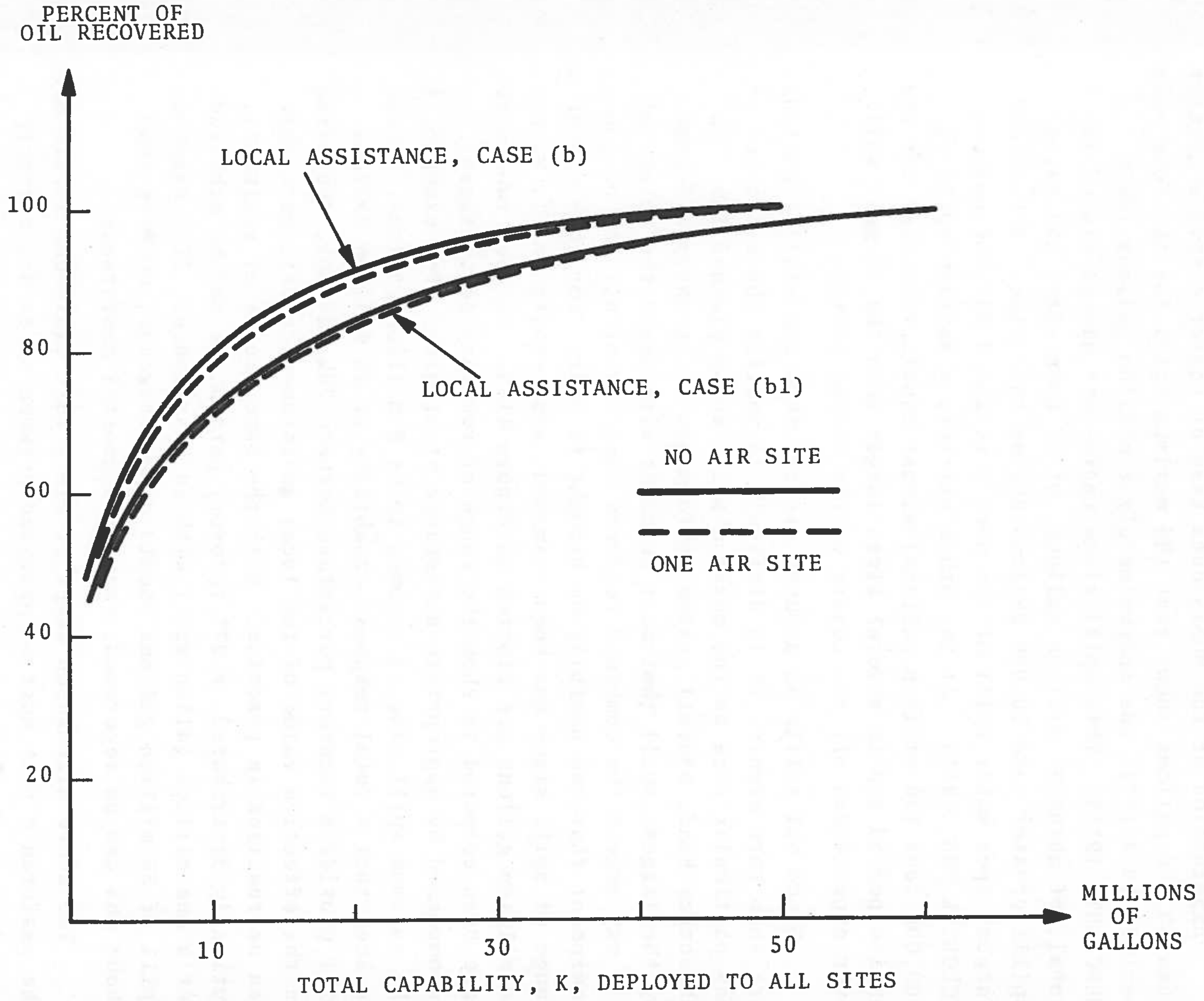


FIGURE 11-4. EFFECT OF THE ADDITION OF ONE AIR SITE TO CONFIGURATION 5W

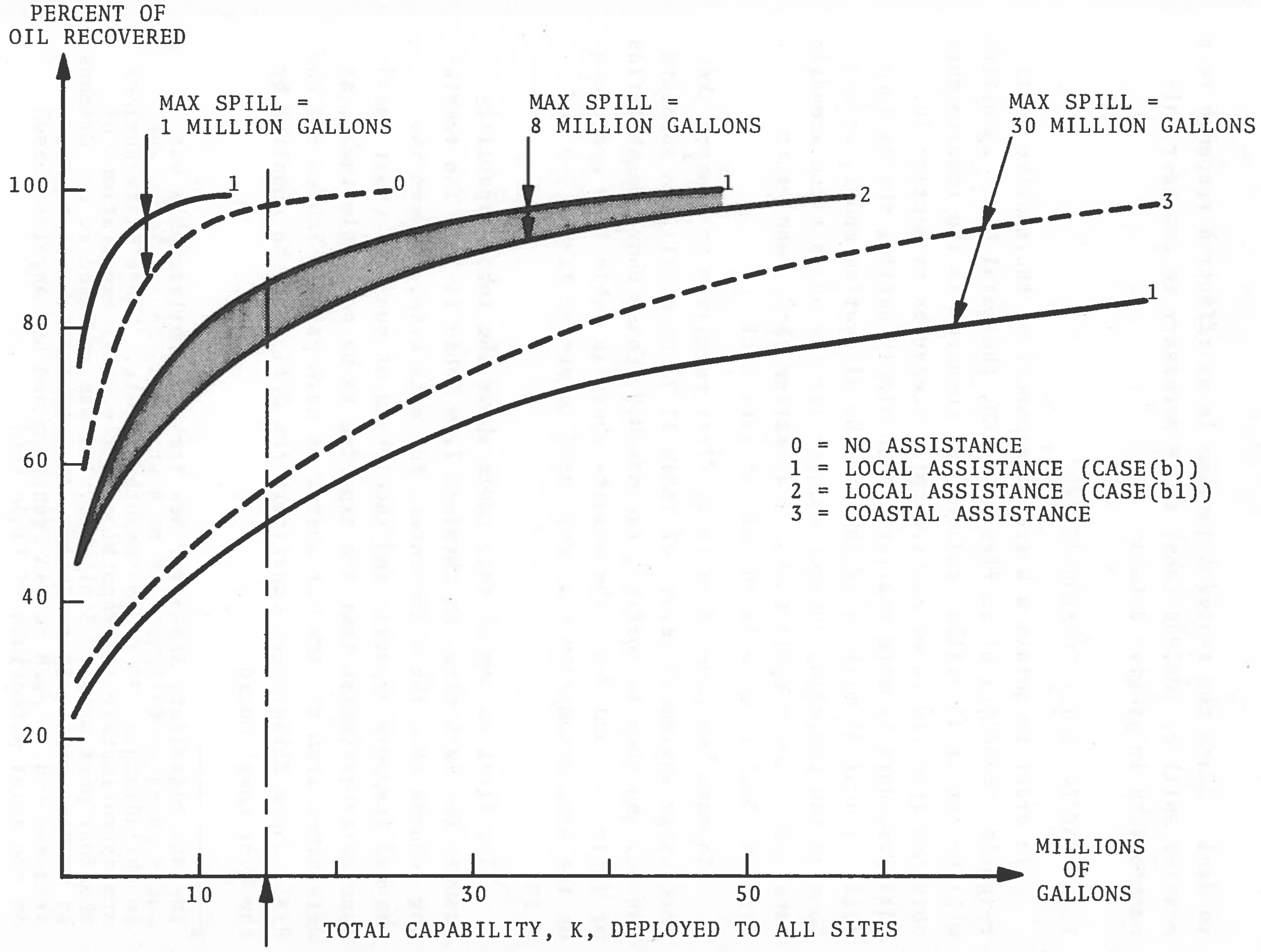


FIGURE 11-5. EFFECT ON RECOVERY PERCENTAGE OF MAXIMUM POSSIBLE SPILL SIZE

TABLE 11-9. RECOVERY CAPABILITIES OF CONFIGURATION 5W
(Thousands of Gallons)

	TOTAL ASSUMED	REQUIRED USCG CAPABILITY			
		PUMPING	STORAGE (1)	SKIMMING	CONT'MNT
Boston	450.	450.	74/320	450.	450.
New York	2100.	2100.	348/1492	2100.	2100.
Philadelphia	4350.	4350.	720/3090	4350.	4350
Portsmouth	450.	450.	74/320	450.	450
Chicago	90.	90.	15/64	90.	90.
Clearwater	390.	390.	65/277	390.	390.
Pascagoula	750.	750.	124/532	750.	750.
New Orleans	2250.	2250.	372/1600	2250.	2250.
Sabine	450.	450.	74/320.	450.	450.
Galveston	450.	450.	74/320	450.	450.
Port Aransas	450.	450.	74/320	450.	450.
Los Angeles	1200.	1200.	200/853	1200.	1200.
San Francisco	1200.	1200.	200/853	1200.	1200.
Seattle	210.	210.	35/149	210.	210.
	14790.*	14790.	2449/10,510	14790.	14790.

(*) 15 million gallons, less requirements for Hawaii and Puerto Rico.

(1) Type OW/Type F. Skimming efficiency of 45% assumed for Type F Storage requirement.

POHSSC, Type OW

The number of Type OW flexible storage containers available in Configuration 5W is only about one fifth of that called for in Scenario A. That scenario called for 97 units to receive the oil from an average of 8.3 ADAPTS during the first 30 hours of offloading preceding the arrival of large-scale hard-hull storage vessels. As pointed out in Section 10.1.1, the operational problems of feeding 8 Type OW barges simultaneously from a single vessel appear at present to be formidable, and the number of Type OW barges that could be used may well be limited by the number of barges that can be moored simultaneously, and the rate at which they can be exchanged. These operations, in turn, depend on the short-term availability of suitable work vessels. Until these and other problems can be resolved by testing and investigation, the usefulness of all 97 Type OW barges is questionable. The best conclusion that can be drawn at this stage is that the requirement is for a minimum of 18 Type OW barges (based on non-massive spill response) and a maximum of 97 Type OW barges (based on the 'worst case' Scenario). Before a firmer estimate can be developed more information is needed about (1) the practicality of exchanging Type OW barges in a confined area, possibly in heavy seas and in a minimum of time, (2) the availability of work vessels and crews capable of carrying out such an exchange operation, (3) the availability time of other (hard-hull) storage, (4) alternatives to offloading, such as refloating, burning, and sinking, and (5) the production capability of the manufacturer of the Type OW barges. Until such information is developed, a tentative number of 42 Type OW barges will be chosen, corresponding to the number called for in Configuration 5. This number may be considered the maximum required to cope with non-massive spills, i.e., with spills up to 8 million gallons.

OWORS/OWOCRS

The skimming units available in Configuration 5W exceed the requirements of Scenario B, whether the OWORS/Barrier or OWOCS/Skimmer is employed. While both have the same nominal recovery is advisable at these sites, either (1), to find an intermediate location for the equipment, accessible from both harbor and ocean, or (2), to improve the mobility of the equipment. The latter course is related to the question of land- and water-based sites.

2. Consolidating land- and water-based equipment at a location would increase the average response time from 15 to 30 minutes (6% to 12%) and reduce by about 22% the amount of equipment needed to achieve a given recovery percentage. This trade-off is considered desirable. It would become even more attractive if a transfer-waterborne mode (trailer-launcher) were developed, since this would reduce the penalty in response time, as well as alleviate the difficulties in combining open water with harbor capabilities by improving the mobility of the equipment. For example, land-mobile, launchable equipment pads would allow location of open water equipment in harbor areas without an excessive time penalty paid to trailer it to open-water debarkation points. It is estimated that consolidating land- and water-based capabilities will reduce the equipment needed to achieve 80% recovery from about a 30 million gallon national capability to about 22 million gallons.

3. The effect of site-to-site assistance depends on how much equipment is sent, how many assisting sites send it, and how far they are from the spill location. While adjacent sites, such as Philadelphia and New York, may in theory provide almost all of their equipment to the other within six hours, it would be excessively risky not to allow a substantial reduction in the available assistance percentage for such contingencies as:

a. Secondary spill coverage

b. Congested or blocked highways

c. Unscheduled equipment maintenance

d. Initial underestimation of the amount of oil spilled (or to be spilled)

e. Increased coordination time.

With the above adjustments and qualifications, the total U.S. equipment levels obtained for Configuration 5W provide a satisfactory match for a "massive" spill, as depicted in the three Scenarios. It would be misleading, however, to rely exclusively on these Scenarios to obtain an estimate of what may be needed to cope with a massive spill.

In gross terms the total U.S. recovery capability of Configuration 5W is only about 50,000 tons, compared to the recovery goal of 100,000 tons. The situation seems more favorable, however, when offloading and skimming are considered separately.

In the case of offloading, the major limitation of Configuration 5W levels is in storage containers. If, however, the number of Type OW POHSSC's deployed is increased from 18 to 42 then the true offloading capability is ADAPTS-limited to about 70,000,000 gallons or 230,000 tons, well over 100,000 tons. In the case of skimming, one must assume that a 100,000 ton petroleum cargo is very likely to be crude oil, which contains a large volatile fraction. For the international standard crude this fraction is about 1/2, leaving a skimming requirement of about 50,000 tons (at the worst). This is equal to the skimming capability of the Configuration 5W levels.

Hence, one may conclude that the 15 million gallon total U.S. recovery capability level, arrived at on the basis of non-massive spills and adjusted to include 42 Type OW POHSSC units, meets both the requirements for the three massive spill scenarios, and the gross estimated demands of a nominal 100,000 ton spill.

4. The final point to be considered is that of equipment transport for a massive spill. It has been assumed up to this point that almost all the equipment in the United States would be brought to bear on a massive spill. As seen in Section 10, this can not (and need not) be done in six hours. Neither can it be accomplished, in the case of spills on the Pacific Coast, without the aid of large numbers of DOD aircraft. The same is obviously

TABLE 11-11. APPROXIMATE PURCHASE COST, SIZE AND WEIGHT OF BASELINE SYSTEM UNITS

BASELINE UNIT	NUMBER REQUIRED	THOUSANDS OF POUNDS	CUBIC FEET	THOUSANDS OF 1976 DOLLARS
ADAPTS	16	96	320	960
POHSSC Type OW	46	630	33,948	11,040
OWORS/Barrier*	75	2490	155,250	67,800
OWOCRS	75	1425	82,500	13,125
POHSSC, Type F				
for OWORS*	140	1232	47,880	12,600
for OWOCRS	280	2464	95,760	25,200
TOTALS **	-	4615	212,528	50,325

* Not recommended for deployment. Included for comparison only.

** Exclusive of OWORS/Barrier and associated Type F POHSSC

The number of tractor-trailers is estimated as the total weight of equipment divided by 50,000 lb. The number of FSD or equivalent vehicles is estimated as the total equipment weight divided by 15,000 lbs. The results are 93 tractor/semi-trailer units of 80,000 gross weight, and 50,000 payload, or 307 FSD units of 15,000 lb payload. The number of trailer-launcher units required for transfer waterborne is probably closer to the number of FSD's required.

A final element of transport cost should be noted: it is to be expected that DOD will provide C141 aircraft for massive spill response on a reimbursable basis. If such is the case, funds must be set aside, probably in the revolving contingency fund, for transfer to DOD in the event of a massive spill.

11.8.3 Support Equipment

No attempt will be made to estimate support equipment amounts or costs, but the major items will be noted. Only support equipment devoted to pollution response will be considered.

Among the major items are:

a. Barrier retrieval system
b. ADAPTS maintenance shops
c. Barrier mooring equipment
d. Aircraft loaders for C130
e. FSD launch and retrieval facilities
f. Tractor maintenance facilities
g. POHSSC inflation, retrieval and cleaning equipment
h. POHSSC repair facility
i. Trailer loading and unloading cranes
j. Loading crane for sled

A major support requirement exists for storage space for the equipment. As calculated above, space is required for about 93 tractor/semi-trailer units or 307 trailer-launcher units. If all equipment is stored on trailer-launchers, then about 300 vehicles would be required, spread over 14 sites. This comes to an average

POHSSC: Approximately 48

These trained personnel would perform routine maintenance but a number of mechanics, technicians and/or contractor personnel would be required at each site for major repairs. No attempt is made to estimate these support personnel. In addition, communications specialists and logistics supervision would be required at each site. Finally, USCG officers would be required for over-all supervision and operation.

Considering that the operation personnel may be transported much more easily than the equipment itself, it may be possible to reduce the number of operating personnel system-wide by staffing only the larger sites and performing routine maintenance at other sites on a rotating basis. The major difficulty here, however, is obtaining enough trained operating personnel to man a massive spill operation, during which virtually all available equipment would be simultaneously employed. This may be handled by training USCG personnel, normally assigned to other duties, in the operation of the ADAPTS, POHSSC or OWOCS equipment. The requirements for such an approach to staffing were not investigated in this study, but the approach appears to offer substantial cost savings.

4. In the 1974-77 data that most spills were small, but most oil was spilled in large spills, verifying the results of other studies.

Massive Spill Potential: (Section 4) In order to establish scenarios for massive oil spills in US waters, 68 world-wide spills greater than one million gallons were examined,* as were potential changes in coastal oil movement and production in the 1980-1990 decade, with the following results:

1. Spills within 50 n. miles of the shore were predominantly groundings (24%), strandings (43%)collisions (19%), mechanical and structural failures (14%). These results are consistent with other studies.
2. Average outflow rates estimated for seven of the largest spills ranged from 50 tons per hour (METULA) to 600 tons per hour (AMOCO CADIZ).
3. Data on oil well blowouts show that the largest have been in the range of 5 to 140 tons per hour, with total volumes of from 7,000 tons to 40,000 tons.
4. Based on assumptions with regard to oil imports, Alaskan oil production and distribution, possible Deepwater ports, and future oil demand, the following coastal areas were found to have a relatively high potential for massive spills, and were selected for scenarios:

   - Pacific Northwest Coast
   - Straits of Florida

   A third area was added because of potential serious consequences of a spill:

   - Baltimore Canyon Trough OCS

Environmental Factors (Section 5): National Oceanic and Atmospheric Administration data yielded the following information:

1. Wave heights in US Coastal Waters exceed 5 feet from 25% to 75% of the time in February, and from 4% to 37% in August.
2. The average duration of seas less than 6 feet on the North East US Coast ranges from 40 to 83 hours in winter and from 117 to 315 hours in summer.

---

* The spills span the period 1967-1978, from the TORREY CANYON to the AMOCO CADIZ.

It was found that (Figure 8-14):

1. With regard to the first criterion, Configurations A through D, derived on the basis of geographic coverage of debarkation points, are superior. Of these four, configuration C is to be preferred.
2. With regard to the second criterion, Configurations 1 through 4, derived by collocating the sites with port areas of greatest spill potential, achieved lower average response times. In general, the average response time improved smoothly from 4 hours to 2 hours as the number of sites increased (Figure 8-14). But these configurations have about 5% of their spill response times greater than six hours, compared to about 2% for Configurations A through D.
3. The addition of a single air based equipment site in the eastern United States (e.g. Clearwater FL or Elizabeth City NC) to Configurations 1 through 4 dramatically reduces the percent of responses greater than six hours.

Based on the above evaluations, a composite configuration, with optional addition of air sites, was developed (See Configurations 5, 5a and 5b, Section 8).

<u>Equipment Levels</u> (Section 9): The relative and absolute levels of oil recovery capability for non-massive spills were established for Configurations 5, 5a, and 5b as follows:

1. Relative capability levels of the sites were established on the basis of maximizing the average amount of oil recovered per year, using a simple model for recovery capability with the spill volume and frequency distributions obtained in the spill potential study (Section 3). The results are contained in Tables 9-1 through 9-6.
2. Absolute capability levels for the sites were established by setting the average total annual recovery level at 80% of full recovery. This point corresponds to an overall equipment utilization of 10% per year. The resulting recovery capability is 40 million gallons for harbor recovery, plus 30 million for open water recovery.
3. Based on a set of assumptions on the duration of spills and the effectiveness of various equipments, the capability was estimated for non-USCG equipment, as contained in available inventories and lists. These capabilities were subtracted from the total capabilities calculated for the sites to obtain the net

When the above factors were taken into account it was found that a slight modification of Configuration 5, with a total US recovery capability of 15 million gallons, can meet an 80% recovery percentage as well as the requirements developed for massive spill response. The capability levels for the sites are given in Table 11-9, and the total units of equipment are given in Table 11-11.

12.2 OBSERVATIONS

The following observations have to do with the critical procedures of this study. A procedure is called "critical" if it is both influential in the results and not well established. Among those contained in this study, the following deserve recognition:

1. The calculation of spill potential from (among other things) oil movement. The difficulty here is that oil movement is well recorded only for ports, channels, and other waterways. The estimation of coastal traffic and corresponding spill potential must proceed on the basis of the coastal and foreign component of port oil movements, and/or on approximate flow information, such as referenced in Sections 3 and 4. In either case little information is obtainable about the location of critical points along the coast. Knowledge of coastal traffic could alter the optimum location of sites.

2. The use of average values for response intervals. Assuming the values employed are the mean values, one still must deal with the effect on the results of the variance of these estimated means. Examples are the values employed for notification and alert time, loading times, and travel speeds (except for aircraft).

3. The use of the simplified recovery model of Appendix K, which assumes 100% oil recovery up to the limit of the site's capability. The inaccuracy arises not because 100% recovery is never achieved (a lesser percentage would not alter the results), but because recovery effectiveness varies widely with conditions other than equipment limits, such as weather, oil type and local coastal geography. In so far as these factors vary from site to

7. With regard to massive spill response, several procedures and assumptions should be noted as critical: The number and availability of C141 aircraft and loaders have not been fully established in this study. The same applies to leased tractor-trailers.

8. Performance characteristics of non-USCG equipment. The inventory information available at the time this report was prepared had not yet been checked for accuracy and completeness. In addition, the capabilities assigned or calculated for the different equipments depend upon assumptions about, rather than actual specifications for each piece of equipment. When a refined data base is available, changes in the USCG equipment requirements can be expected.

12.3 CONCLUSIONS

From the results and observations above, several conclusions may be drawn. These fall into four general categories, corresponding to the four questions posed at the beginning of the report (Section 1.2):

1. Where should pollution response equipment be located?
2. How much equipment should be stored at these sites?
3. How effectively can it deal with a massive (100,000 ton) spill?
4. What will it cost to purchase and maintain?

Location

The equipment should be sited according to Configuration 5W. This configuration allows delivery of the equipment to the spill debarkation point within six hours of receipt of the OCS' request, for over 90% of the spills anticipated in US coastal waters (Alaska excluded) in the next decade. For the most part, delivery can be effected by tractor-trailer, or towed water sled; but development of a combined trailer-launcher should be investigated. The response intervals (alert time, loading, travel, unloading, etc.) required to meet the 6-hour delivery are believed to be

1. Logistics: Transport of the total complement of equipment from the 14 sites scattered over the US to and from the Pacific Coast, Hawaii and Puerto Rico would require substantial air lift assistance. A plan for such assistance needs to be worked out.
2. Weather: The results of Section 5 show that wave heights exceed 5 ft (the operating nominal limit of the baseline boom) about 50% of the time in February, and about 20% of the time in August. Thus the chances of carrying out a successful skimming operation off the US coast at any one time may be reduced by about 20% to 50% because of weather alone.
3. Equipment State of the Art: While equipment performance is fairly well established for the ADAPTS and OWOCS, the other elements of the Baseline system are newer, and data are still being collected on their performance and operating characteristics under realistic conditions. The completion of unit testing, and, in particular, of total system integration tests of the OWOCRS/Type F barge must be awaited before its real capability in adverse weather conditions is known. Success of a massive spill recovery depends on the performance of these baseline elements, and the development of appropriate operating procedures.

Of these factors, the first is the easiest to overcome, since the required capability exists and needs only to be integrated into present contingency plans. The third factor is somewhat more difficult to mitigate, depending on continual improvements in the state of the art. The second factor, however, promises to pose formidable design difficulties for several years before the present nominal performance limits of 5 ft. waves and 20-30 knot winds can be raised significantly.

Cost

The very brief cost analysis made in Section 11.8 can serve