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AN OILSPILL RISK ANALYSIS FOR THE MID-ATLANTIC OUTER CONTINENTAL SHELF LEASE AREA

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OUTER CONTINENTAL SHELF LEASE AREA

BY

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ABSTRACT

An oilspill risk analysis was conducted to determine relative environmental impacts of developing oil in different regions of the Mid-Atlantic Outer Continental Shelf lease area. The study analyzed probability of spills, likely path of pollutants from spills, and locations in space and time of recreational and biological resources likely to be vulnerable. These results are combined to yield estimates of the overall oilspill risk associated with development of the lease area.

INTRODUCTION

The Federal Government has proposed to lease 876,750 acres of Outer Continental Shelf (OCS) lands lying off the coast of New Jersey and Delaware for oil and gas development. Estimated recoverable petroleum resources for the proposed 154 tract sale area range from 0.4 to 1.4 billion barrels. Contingent upon actual discovery of this quantity of oil, production is expected to span a period of about 25 years (U.S. Department of the Interior, 1976).

Oilspills clearly represent one of the major concerns associated with offshore oil and gas development. Accordingly, much of the information contained in the environmental statement for the Mid-Atlantic lease sale bears on various aspects of the oilspill hazard. An important fact that stands out when one attempts to evaluate the significance of accidental oil spillage for this, or any proposed lease area, is that the problem is fundamentally probabilistic. A great deal of uncertainty exists, for example, concerning the number and size of spills that might occur during the course of development, as well as the wind and current conditions that would exist and give direction to the oil slick at the specific

times spills do occur. While some of the uncertainty reflects incomplete and imperfect data, considerable uncertainty is simply inherent in the problem.

In view of the inability to predict with certainty future oilspill impacts, it is important to consider the range of possible impacts that could accompany oil and gas development, paying particular attention to "worst case" conditions. It is equally important, however, in attempting to maintain perspective on the problem, to associate these potential impacts with quantitative estimates of the probability of their occurrence.

This report summarizes results of an oilspill risk analysis we conducted for the Mid-Atlantic OCS lease sale. The study had the objective of determining relative risks associated with oil and gas development in different regions of the proposed lease area and was undertaken to facilitate final selection of tracts to be offered for lease. The analysis was conducted in three more or less independent parts corresponding to different aspects of the overall problem. The first part dealt with the probability of spill occurrence, the second with likely spill trajectories for the times and places spills might occur, and the third part with the spatial and temporal location of specific biological and recreational resources thought to be vulnerable to oil spills. Results of the individual parts of the analysis were then combined to give estimates of the over oilspill risk associated with oil and gas development in the lease area.

Much of the data and information used in the analysis were compiled by the Bureau of Land Management in the course of preparing the environmental statement for the Mid-Atlantic sale. These results, then, represent synthesis and analysis of existing information rather than presentation of new material.

We would like to express special appreciation to Thomas S. Cooke of the Bureau of Land Management for his assistance in gathering the necessary data and information for the study.

Methods

A detailed mathematical description of the models used in this analysis is given in a forthcoming Geological Survey Circular (Smith, and others 1976). The present discussion focuses on the conceptual framework of the models, and on data sources and limiting assumptions.

Spill Frequency Estimates

Statistical distributions for estimating probabilities of oilspill occurrence were taken from Devanney and Stewart (1974). In addition to the fundamental assumption that meaningful estimates of future spill frequency can be based on past OCS experience, use of these distributions requires the further, specific assumptions that spills occur independently of each other (i.e. a poisson process), and that accident rate is dependent on volume of oil produced and handled.

Spill frequency estimates were calculated separately for four subdivisions of the proposed lease area (fig. 1) based on the mean of estimated petroleum resources for individual prospects within those areas (U.S. Geological Survey, proprietary data). Use of the Devanney and Stewart distributions permitted separate estimates of platform, pipeline, and tanker spill frequency which could then be combined to compare the two alternative modes of transport of crude to shore. Spill frequency estimates were further catagorized for spills between 50 and 1,000 bbls, and greater than 1,000 bbls in size. The size grouping is somewhat arbitrary but, as discussed below, is very important in considering the significance of weathering in reducing oilspill impacts.

Oilspill Trajectory Simulations

An oilspill trajectory model was constructed and used to analyze movements of hypothetical oil slicks on a digital map of the Mid-Atlantic Bight between 37°N and 41°N latitude and 71°W longitude and the Atlantic Coast. The coordinate system for this area was established with a grid size of 1 nautical mile (nmi). Seasonal surface current velocity fields were provided by Bureau of Land Management staff and were based on results of a 10-year drift bottle study (Bumpus, 1973). Short-term patterns in wind variability were characterized with a probability matrix for successive 6-hour velocity transitions (first order Markov process). Wind transition matrices were evaluated from U.S. Weather Service records from the Barnegat Light Ship (7-year record) and were established separately for four seasons.

Figure 1.--Map of the Mid-Atlantic Outer Continental Shelf showing subdivision of the lease area.

Trajectories of 100 hypothetical oilspills were simulated in Monte Carlo fashion for each of seven representative spills sites within the lease area and under wind and current conditions for the four seasons -- a total of 2,800 trajectories. Surface transport of the oil slick for each spill was simulated as a series of straight-line displacements of a point in space, each representing the joint influence of wind and current vectors on the slick for a 6-hour period. Wind transition probability matrices were randomly sampled each period for a new wind speed and direction, and the current velocity was updated as the spill changed location in the velocity field. The wind drift factor was taken to be 0.034 with a drift angle of 20°.

In summary, the final product of trajectory model runs consisted of a large number of possible oilspill trajectories or pathways which collectively reflect both the general trend and variability of winds and currents (see figs. 4 through 7), and which can be described in statistical terms. It should be emphasized that these trajectories represent only hypothetical pathways for the transport of oilslicks and do not involve any consideration of dispersion or weathering processes which would determine the quantity and quality of oil that may eventually come in contact with biological populations or other important resources. The significance of this and other limitations of the modeling effort are discussed in more detail below.

Locations of Biological and Recreational Resources

The locations of 10 categories of biological and recreational resources were digitized in the same coordinate system as that used in trajectory simulations. The seasonal sensitivity of these resources (e.g. spawning period or migration period) was also recorded. Resource groups were as follows:

- Group 1. Endangered birds -- The known and suspected coastal habitats of the American Peregrine Falcon, Southern Bald Eagle, and Osprey were identified as sensitive in all seasons.
- Group 2. Migratory waterbirds -- Wildlife management areas, refuges, and parts of Cape May were identified as having significant concentrations of migratory birds during the winter, spring, and fall seasons.

- Group 3. Shell fisheries -- Areas along the shore were identified as beds for surf clams, bay scallops, northern hard clam, and oyster. Both commercial and sports harvesting areas for these species were included in all seasons.
- Group 4. Coastal finfish -- A 25-mile strip of coastal waters along the entire length of shore was identified as critical during the summer and fall seasons with respect to the egg and ichthyoplanktonic stages of the scup, porgy, and menhaden.
- Group 5. Estuarine finfish -- Estuarine areas and sounds were identified as important areas for Weakfish, Sea Trout, Whiting, and Striped Bass during the spring, summer, and fall seasons.
- Group 6. Wetlands -- All marsh areas were identified as sensitive in all seasons.
- Group 7. Wildlife refuges and management areas -- All national wildlife refuges, wildlife management areas, wildlife areas, and natural areas were identified as critical in all seasons.
- Group 8. Beaches with high-intensity use -- Gateway National Recreation Area including adjacent state and municipal beaches, Atlantic City and New Jersey boardwalk and adjacent Atlantic County and New Jersey beaches, Cape May and New Jersey beaches, Rehobeth Beach area, Cape Henlopen State Park, Delaware Seashore State Park, Ocean City and adjacent Assateague Island State Park and National Seashore were all identified as areas of high-intensity usage in all seasons.
- Group 9. Parks and recreation areas -- The locations of all state parks and national recreation areas were recorded as important in all seasons.
- Group 10. Offshore dumpsites -- The locations of offshore sewage dumpsites were recorded (all seasons).

It was further recognized that the lease area itself exists within the habitat of a number of coastal finfish species including bluefish, Atlantic mackerel, butterfish, red hake, and flounder and that any oilspills occurring on the Outer Continental Shelf must, at least in a conceptual sense, be thought of as impacting these populations. An additional limitation of the model, therefore, is that it does not predict concentrations of hydrocarbons in the water column, information which would be important in assessing the significance of spills in the offshore environment.

Results and Discussion

Spill Frequency Estimates

The probability distribution on the frequency of oilspills greater than 1,000 bbls in size during the production life of the proposed lease area is given in figure 2. Probabilities apply to the total of production platform spills and pipeline spills assuming transport of the total product to shore via pipeline. Although transport by pipeline is the preferred method, tanker or barge transport is considered a possibility (U.S. Department of the Interior, 1976) and the corresponding frequency distribution for the total of platform and tanker spills is presented in figure 3 for comparison. Means of the distributions in figures 2 and 3 are indicated with arrows.

One of the advantages of making predictions about oilspill frequency in the form of a probability distribution is that such data give not only an estimate of the most likely number of spills that would be expected to occur but some measure of the uncertainty that exists about that prediction. Figure 3, for example, indicates that the expected number of spills greater than 1,000 bbls is about 5 spills (mean of 4.8), but that there is only about an 18-percent probability that the number would be exactly 5 spills and a 70-percent chance there would be from 2 to 7 spills (obtained by summing the probabilities over that range). Noting that the probability of zero oilspills greater than 1,000 bbls is only about 1 percent, one can conclude that the probability of at least one such spill (i.e., sum of the probabilities for one and greater) is about 99 percent. Again, these probabilities apply to the sum of platform and pipeline spills over the field life of the entire proposed lease area. A breakdown so these data for platform, pipeline, and tanker spills appears in table 1A.

Figure 2.--Spill frequency distribution for platform and pipeline spills greater than 1,000 bbls during the production life of the lease area.

Figure 3.--Spill frequency distribution for platform and tanker spills greater than 1,000 bbls during the production life of the lease area.

Table 1 (A and B). -- Oil Spill Frequency Statistics
by Potential Source

	Expected number of spills during the production life of the lease area ¹	Probability of at least one spill occurrence
A. Spills greater than 1,000 bbls in size		
Platforms	2.3	.90
Pipelines	2.5	.92
Tankers	3.3	.96
Platforms and Pipelines	4.8	.99
Platforms and Tankers	5.6	.99
B. Spills 50 to 1,000 bbls in size		
Platforms and Pipelines	17.8	.99
Platforms and Tankers	Not available	

¹ Mean of spill frequency distribution.

Expected frequencies for spills in the size range 50-1,000 bbls over the production life of the total area are given in Table 1B.

All of the above figures are subject, of course, to the validity of earlier stated assumptions, the most important of these being that accident rates per unit production of future Mid-Atlantic fields would be the same as those observed to date in other areas. One might strongly debate this assumption either from the point of view that safety records tend to improve with time, or from the standpoint that accident rates are not transferrable to a newly opened OCS area.

Oilspill Trajectories

The results of trajectory model runs consist of a large number (2,800) of hypothetical oilspill trajectories which collectively reflect both the general trend and variability of winds and currents and which can be described in statistical terms. Ten trajectories based on wind and current conditions for each of the four seasons have been randomly selected as examples from a total of 400 trajectories released from the northwest corner of the lease area and are shown in figures 4-7. It can be seen that the predominant trend of surface transport is toward the southwest and that the large majority of spill trajectories pass from the boundaries of the map without coming ashore. This trend is consistent with the results of model runs for the other six representative spill sites within the lease area. Averaging results over the four seasons and over the seven spill sites, the probability of coming ashore for a spill occurring in the lease areas is about 10 percent with a considerably greater likelihood of spills eventually reaching the New Jersey and Delaware beaches in the summer than in any other season. It appears that the chance of spills being carried north from the lease area and impacting the long Island shoreline is small.

Oilspill Trajectories in Relation to Biological Resources and Recreation Areas

Oilspill trajectory simulations were conducted keeping track of the frequency with which trajectories intersected the locations of biological and recreational resources. Trajectories originating in a given season were recorded as impacting a resource only in cases where the resource was listed as being vulnerable to oilspills in that season. Table 2 gives the probability of impact on each of the 10 categories of biological resources and recreation areas for a spill originating at a randomly selected time and place within the lease area. As one would expect, the likelihood

Figure 4.--Example oilspill trajectory results for a spill site in the northwest subdivision of the proposed lease area: winter conditions. Number on trajectory reaching the coast gives time to land in days.

Figure 5.--Example oilspill trajectory results for a spill site in the northwest subdivision of the proposed lease area: spring conditions. Numbers on trajectories reaching the coast give time to land in days.

Figure 6.--Example oilspill trajectory results for a spill site in the northwest subdivision of the proposed lease area: summer conditions. Numbers on trajectories reaching the coast give time to land in days.

Figure 7.--Example oilspill trajectory results for a spill site in the northwest subdivision of the proposed lease area: autumn conditions. Numbers on trajectories reaching the coast give time to land in days.

Table 2. -- Probabilities that an oil spill occurring in the
Mid-Atlantic lease area would impact
important biological resources and recreation areas

	<u>P (percent)</u>
Probability ashore	10
<u>Wildlife habitat</u>	
Endangered species	1.5
Migratory birds	4
Shell fisheries	1
Coastal finfish	7
Estuarine and Anadromous fish	1
Wetlands	
Wildlife refuges and management areas	3
Resort beaches	2
Parks and recreation areas	5

that a given spill trajectory would beach at the location of a specific resource onshore during critical seasons is smaller than the 10 percent probability of coming ashore anywhere. The relatively high 12 percent probability a given trajectory will pass through the location of an offshore sewage dumpsite results from the fact that one such site lies just to the southwest of the lease area.

Again, it must be emphasized that these trajectories represent only pathways for the transport of surface oil by winds and currents and do not involve any consideration of dispersion or weathering processes which would progressively reduce the quantity of oil contained in the slick as it traveled towards shore. The trajectories shown in figures 4-7, therefore, represent a worst-case analysis in the sense that a large fraction of the spills occurring more than 50 miles off shore in the lease area can be expected to deteriorate to the point of insignificance before reaching land. Included in the list of factors which would determine the potency of spills at the time of impact would be spill size, of course, as well as the quality or composition of the oil since lighter weight crudes evaporate at a much more rapid rate than those with a large proportion of high molecular weight hydrocarbons. This latter factor being hard to predict in advance, the significance of weathering is very difficult to quantify despite its obvious importance in interpreting these results. Some information on Mid-Atlantic oil quality may be contained in test well results from Sable Island in the North Atlantic; oil sample gravities ranged from 36° to 41° API, indicating a medium to light weight crude (Smith, 1975).

One important factor determining the significance of weathering in reducing oilspill impacts is the time required for spills to reach land. Times to land for simulated trajectories, in fact, covered a very wide range, and it is therefore particularly important to consider this factor in interpreting results of the spill trajectory analysis. Figure 8 shows the distribution of days at sea for those trajectories which reached the coast within 61 days and prior to crossing the map boundaries.

The mean time to land under winter, spring, and autumn conditions was about 16 days as opposed to about 25 days under summer conditions. Thus, while summer spill trajectories, on the basis of wind and current direction, appear to be more likely to eventually come ashore than spills occurring in other seasons (see above), the considerably longer times required to make the trip suggest that perhaps summer spills are actually of less concern. Minimum times to land were as brief as 3 to 5 days but such short transit times were observed

only very rarely (3 percent of spills landing). Perhaps one meaningful way to summarize figure 8 is to note that of those trajectories which eventually came ashore, 37 percent did so within 14 days. Thus the earlier stated 10-percent probability of a given spill coming ashore can be qualified to state that there is a 3.7 percent chance that a spill originating in the lease area will come ashore within 2 weeks. One conclusion that can be reached from results of trajectory model runs is that, at least with respect to important resources on shore, attention should be focused on spills greater than 1,000 bbls in size. The apparent long times to land in combination with the possibility of spill containment in the event of an accident, indicate that spills less than this size pose a relatively small risk.

Combined Analysis: Spill Frequency Estimates and Oilspill Trajectories

With respect to the overall objective of the present study, the data presented in table 2 represent only a partial solution to the problem of assessing oilspill risks to important resources. The overall oilspill risk posed by oil and gas development in the proposed sale area must be assessed as a joint function of the probability that spills will occur in the course of development as well as the likelihood that spills will follow certain trajectories. Thus, the data in table 2 must be combined with the spill frequency estimates presented in figures 2 and 3 above to obtain a total probability distribution for impacts on specific resources.

Despite the intuitive logic of simply multiplying the probabilities in figure 2 by those in table 2, the correct computation of the overall or "total" probability is in fact somewhat more complicated. This results from the fact that the probabilities presented in table 2 are actually conditional probabilities and refer to the probabilities of impacts on resources "conditioned" on the chance of spills occurring in the first place. The overall probability that oilspills will impact a particular resource exactly k times during the production life of the area, $P(k)$, is given by

$$P(k) = \sum_{n=k}^{\infty} P(k|n) P(n) \quad (1)$$

Figure 8.--Distribution of days at sea for oilspill trajectories coming ashore within 61 days.

where $P(k|n)$ is the probability of k impacts on the resource given the occurrence of n spills, and $P(n)$ is the probability of n spills occurring. The conditional probability $P(k|n)$ can be assumed to be distributed binomially and is given by

$$P(k|n) = \binom{n}{k} p^k (1-p)^{n-k} \quad (2)$$

where p is the probability of impact on the resource given the occurrence of a spill (table 2).

The combined probability distribution calculated in the above manner for spills coming ashore is presented in figure 9. The distribution is based on spill frequency estimates from figure 2 and therefore refers to impacts from all spills originating as 1,000 bbls or greater during the production life of the total lease area and assumes pipeline transport to shore. Figure 9 indicates that there is a 61 percent probability that no oil spills greater than 1,000 bbls will occur and come ashore in the course of oil production in the proposed lease area. One can immediately conclude, therefore, the chances are 39 percent that at least one such spill would occur and come ashore during the production life of the area (sum of the probabilities of 1 and greater).

Probability distributions similar to figure 9 can be developed and likewise interpreted for each of the 10 categories of biological resources and recreation areas. Probabilities of one or more spills greater than 1,000 bbls occurring and impacting the various resource groups are given in table 3. The data have been calculated separately for each of the four subdivisions of the lease area and then combined for the total area. Impact probabilities are considerably higher for the northwest block of tracts than for other regions of the lease area, reflecting both the relative proximity of that area to shore as well as a higher anticipated level of production.

It is important that the distinction between the probabilities given in table 2 and those in table 3 be very clear. The data given in table 2 refer only to the likelihood that spills would follow certain trajectories and have nothing to do with the chances that spills would occur in the first place. The probabilities in table 3, by contrast, reflect both the expected frequency of spill occurrence as well as the likelihood of certain trajectories.

Figure 9.--Probability distribution on frequency of landings for oil spills greater than 1,000 bbls over the production life of the Mid-Atlantic lease area.

Table 3. -- Probabilities of spills greater than 1,000 bbls occurring and impacting biological resources and recreational areas in the Mid-Atlantic area over the production life of the lease area.

Probability (percent)

	Sub-area				Entire Proposed Area
	I	II	III	IV	
PROBABILITY OF COMING ASHORE	20	6	7	13	39
<u>Resource</u>					
1. Endangered birds	5	1	1	1	8
2. Migratory waterbirds	8	2	2	7	18
3. Shellfisheries	2	1	1	1	5
4. Coastal finfish	14	4	4	9	29
5. Estuarine finfish	*	*	*	*	1
6. Wetlands	7	3	2	4	14
7. Wildlife refuges and Management areas	12	4	4	10	27
8. Beaches with high-intensity use	5	1	1	2	8
9. Parks and recreation areas	10	2	3	8	23
10. Mid-Atlantic Bight dumpsites	17	8	13	15	44

* Less than 0.5 percent.

Further Considerations

A number of limitations of the present analysis which stem from the nature of the models employed and their limiting assumptions have been discussed above. Some further limitations of the overall analysis relate to assumptions concerning the plan or scenario for development of the lease area.

Separate probability distributions on spill frequency were presented for platform spills in combination with pipeline and tanker spills so as to give a comparison of risks associated with the two methods of transport of crude oil from the lease area. In combining these data with trajectory probabilities from table 2 the tacit assumption is made that pipeline (or tanker) spills would originate within the lease area. This assumption was made in the absence of good information on future pipeline routes. It should be understood that pipeline or tanker spills occurring closer to shore than the lease area would likely reach land sooner and more often than indicated by the results of the spill trajectory analysis.

Finally, some account should be taken of the question of net oilspill risks associated with development of the Mid-Atlantic OCS area. Unless additional refinery capacity is developed to handle increased quantities of crude oil, production from Mid-Atlantic fields would tend to merely replace existing sources currently carried by tankers to Mid-Atlantic terminals. Thus some oilspill risk exists independent of decisions on leasing and development of the area. Table 1 gives a value of 3.3 for the number of spills greater than 1,000 bbls that are expected to occur in the course of tanker transport of a volume of oil equivalent to that anticipated from Mid-Atlantic fields. The estimate of 3.3 spills is not entirely comparable to the 4.8 spills predicted for production and pipeline transport of the oil from the lease area since some of the 3.3 would undoubtedly occur elsewhere on the tanker routes. The comparison, nevertheless, illustrates the importance of considering net oilspill risks.

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