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Preliminary Results of an Oilspill Risk Analysis for the Bombay High Region

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ABSTRACT

An Oilspill risk analysis was conducted to determine the relative environmental hazards of developing oil in different regions of the Bombay High. The likely paths of oilslicks, and locations of resources vulnerable to spilled oil were analysed, covering estimates of the time between spill occurrence and contact with resources. The combined results yielded estimates of the overall risks associated with production within the developmental area. Preliminary results of an oilspill risk analysis conducted for the Bombay High Region are presented.

INTRODUCTION

The past decade has been a period of rapid growth of the offshore petroleum industry. Oilspills are one of the major concerns associated with offshore oil development. Concern is clearly strongest among those who live in coastal areas and who depend, directly or indirectly, on coastal zone resources other than oil for a livelihood. Controversy over the risks and benefits of offshore oil development inevitably gives rise to a need for quantitative estimates of the oilspill risk involved in a particular developmental area.

An important fact that stands out when one attempts to predict oilspill damages for a developmental area is that the problem is fundamentally probabilistic [4]. A great deal of uncertainty exists with regard not only to the location, number and size of spills that will occur during the course of development, but also to the wind and current conditions that will exist when the spills occur. While some of the uncertainty reflects incomplete or imperfect data, considerable uncertainty is simply inherent in the problem.

The fate of the oil spilled over the sea surface, either by accident or due to negligence, is a complicated multiprocess phenomenon called 'weathering'.

Weathering consists of spreading, evaporation, dispersion, emulsification, auto-oxidation and microbial degradation. While these processes are occurring, there is a movement of the oil patch under the influence of wind and ocean currents. The complex nature of oil and its interaction with water during its movements make it difficult to make a comprehensive study of the problem. As a result, scattered studies have been made of the various aspects and in particular of aspects that appear dominant under certain conditions. Besides, a number of studies have been carried out after the actual oilspills, such as in the 'Torrey Canyon' and 'Santa Barbara' disasters [1].

Like any other place in the world where offshore oil is being exploited, in the Bombay High Region also, there are chances of oilspills due to the presence of tankers, drilling rigs, production platforms and submarine pipelines. Any major oilspill in the Bombay High region can affect the Indian shoreline and inshore water. Attempt to prevent such a situation requires a forecast of the movement of accidental spills from the region.

The risk analysis is conducted in two parts corresponding to different aspects of the overall problem. The first part deals with the trajectories of oilspills from potential launch points to various targets, and the estimates of the time between spill occurrence and contact with resources. The results obtained are used to give estimates of the overall oilspill, risk associated with oil and gas and production in the area.

An oilspill risk analysis was conducted to determine the relative environmental hazards of developing oil in different areas of the Bombay High region. The aim of the study was to analyse the likely paths of oilslicks and locations of resources vulnerable to spilled oil. The analysis included estimates of the time between spill occurrence and contact with resources. The combined results yielded estimates of the overall risks associated with development of the proposed lease area.

MODELLING OILSPILL MOVEMENTS

Modelling of oilspill movements could be either real time or risk analysis. In real time modelling of oilspills, we require — i) real time winds and currents, and ii) program to compute the movement based on the data. For oilspill risk analysis, we require — i) historical winds, ii) modelled or observed currents, iii) program to simulate several possible spills, and iv) program to generate the risk analysis results. We have developed a model for assessing the oilspill risks associated with petroleum development. The model has been constructed to deal with two fundamental and essentially independent factors which comprise the total oilspill risk to coastal zone resources. The risk analysis model consists of two parts:

a) *Trajectory model* — This model gives the probability of occurrence of various spill trajectories from production sites and transportation routes as a function of historical wind and current patterns for the area.

b) *Oil budget model* —The model gives the location in space and time of vulnerable resources taking into consideration the physical processes like evaporation, dispersion and spreading. This enables calculation of the possible extent of spreading on the coastline, thereby giving an idea of the extent of the coastline that would be damaged. The results of the individual parts of the analysis are combined to estimate the total oilspill risks associated with production and transportation within the developmental area.

The movement of oil on the sea is governed by two physical phenomena, viz. winds and currents. Winds are modelled by generating the wind transition matrix [3] obtaining several wind series. The cumulative probability wind transition matrix shown in Table 1 has been constructed from the historical wind record and should be used to model the Markov process, for assessing the oilspill risks associated with petroleum development. The variations in the wind is represented as a first order Markov process i.e. wind in one time-step is a random function of the wind in the previous time-step.

The individual elements of the percentage cumulative wind transition matrix are the probabilities that a particular wind velocity will be succeeded by another wind. The longer the historic data set, the better will be the resolution of the cumulative probability wind transition matrix. To generate the wind series, we have to assume a particular wind state, i.e. choose a particular number from a particular row of the cumulative probability matrix. We then generate a random number and check the corresponding value on the same row, which is closer to the random number. The corresponding column is then obtained for this new location. This value gives the wind state for the next instance, which is the first element of the wind series. The previous value obtained is used as a seed to generate the next element of the wind series. The procedure is continued to obtain other elements of the wind series [2]. An example of wind series generation is shown in Table 2. The cumulative probability wind transition matrix allows presentation of a large amount of data in a limited space and thus can be used to predict the next occurrence of the wind state to a good degree of accuracy. The source of wind data will be from the offshore drilling site. The source of current data will either be from the coastal circulation model run or from KNMI atlas.

It is generally agreed that regardless of the physical properties of oil and water, the size of the oilspill and its spreading tendency, the movement of an oilspill [3] on the sea surface is gives by

$$V=(KIUw)Kw+(k2Uc)Kc \quad \dots(4)$$

where V is the oilspill drift velocity, and Uw is wind speed at 10 m above the sea surface; Uc is current speed near the surface; Kw is Unit Vector in the direction of wind drift (inclined at an angle alpha to the wind direction due to the earth's rotation), and Kc is unit vector in the direction of the current. Although there is no general agreement on the direction of the oil drift induced by the wind, a good working value for alpha is 25° to the right of the wind direction in the northern

Table 2 — An Example of Wind Series Generation during April

Starting dir. = 0 deg
 Starting speed = .00 m/sec

Wind series no = 1
 Seed 1 = 48483
 Random 1 = .5169182

Seed 2	r n2	wspd	wdir
51691	.8216248	1.50	135
280644288	.6074033	1.50	90
-1095536679	.5990019	1.50	90
861088518	.9878345	1.50	270
1925160023	.9598522	1.50	315
2038347548	.0442986	1.50	360
-1941869851	.5039682	4.00	360
1733304450	.0501723	1.50	360
-163472637	.3921776	1.50	360
1565297848	.1386952	.20	-1
-1738248143	.9830618	1.50	135
906005186	.0490642	.20	-1
-964587025	.3759251	.20	-1
-1177811052	.9037766	1.50	135
870116285	.6100130	1.50	90
-602700486	.7672248	1.50	90
704154907	.2699814	1.50	45
336110512	.7355390	1.50	90
-617117303	.2476149	1.50	45
-255333258	.7076816	4.00	360

... Contd.

Table 2 — An Example of Wind Series Generation during April — *Contd.*

Wind series no = 2
 Seed 1 = .263228056
 Random 1 = .3554158

Seed 2	r n2	wspd	wdir
35541	.0133295	.20	-1
192965938	.3724914	.20	-1
-359928973	.2621956	.20	-1
155739112	.4664464	.20	-1
-600904415	.3441076	.20	-1
1865089774	.1669154	.20	-1
-1960487073	.1904011	.20	-1
-555345980	.6940522	.20	-1
93730221	.0161028	.20	-1
2055242730	.4286551	.20	-1
-412239989	.1753998	.20	-1
-372925216	.2520108	.20	-1
-1681387399	.1733580	.20	-1
-1446671322	.1669879	.20	-1
1516591095	.5838909	.20	-1
120762172	.9503808	1.50	135
-1512150651	.6239786	1.50	90
-1783367774	.5865035	1.50	90
-1047346013	.1341362	1.50	360
495209176	.2320333	1.50	360

hemisphere. Thus, to predict the course of movement of an oil patch, knowledge of the following parameters is necessary:

- i) Time of occurrence
- ii) Place of occurrence
- iii) Predicted winds
- iv) Currents

The region where an oilspill is likely to occur has been taken as a circular patch consisting of a large number of finite oil particles with its centre at $19^{\circ} 30'N$, $71^{\circ} 30'E$. The area is bounded by lat. 14° to $22^{\circ} N$ and long. 68° to $76^{\circ}E$, and divided into $5' \times 5'$ grids. Hence, a 1° grid will be divided into $12 \times 12 = 144$ smaller grides. The oil drift vector for each $5'$ grid was computed using Eq. (1). Assuming a sufficiently small time step, we make model runs with each wind series generated and observed currents to determine landfall and time to landfall.

This is repeated for all the oil particles with different wind series generated from the transition matrix. The process was continued till the trajectory crosses long. $68^{\circ} E$, lat. $14^{\circ} N$ or meets the coastline. From these statistics, we can arrive at the probabilities of oil hitting different land portions and the average time for the oil to hit that land portion. The trajectory model run will give the following results.

Conditional probability — Conditional probability is the probability that if an oilspill occurs at a given launch point, it will, within a specified period of time, contacts a target. Since the model records a target as "hit" only if contact occurs during a month in which it is vulnerable to oilspill damage, the conditional probabilities automatically reflect the seasonal variability. This probability refers to the target as a whole and implies nothing about the distribution of risk among any subdivisions of that target. For example, the target "Sandy beaches" may extend for several hundred kilometres of coastline and risks to particular beaches may differ.

Estimates of travel times — The model gives estimates of the time between spill occurrence and contact with resources. The travel time for spills contacting different targets obtained by the trajectory model are used to calculate the possible extent of spreading of oil on the coastline, considering the weathering processes like evaporation, dispersion and spreading of oil on water. The oil budget model is run for the different travel times obtained earlier to calculate the size of coastline that would be damaged if the spill had occurred at the particular point.

CONCLUSION

The trajectory model gives the conditional probabilities of contacting predetermined targets. It also gives estimates of the travel times for spills contacting the targets. The oil budget model is run for different travel times to calculate the size

of the coastline that would be damaged, taking into account the weathering processes like evaporation, spreading and dispersion.

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