4. Prediction of the Spread of Oil in Tokyo Bay

4.1 Introduction

The scale of oil transport by tankers is rapidly increasing to meet demand, and there is growing concern about possible large-scale environmental damage occurring due to tanker accidents. This concern is, in part, well founded because most of the tankers have single bottom plates; only a few have double bottom plates. Also, the size of new individual tankers is continually increasing. Thus, the potential damage associated with the accidental loss of a tanker is escalating.

On 2 June 1997, a tanker, the Diamond Grace, containing 38 000 tonnes of crude oil produced in Umshaiff, UAE, was stranded on Nakano-se shoal in Tokyo Bay (at 1005 in the morning). The tanker was immediately anchored but crude oil was spilled from cracks (later it was reported that about 1550 kl of crude oil was spilled). At 1754 the tanker was towed off the shoal and arrived at Kawasaki sea berth at 2000.

Tokyo Bay is an enclosed water body and the coastal zone is heavily industrialized. In the event of an oil spill, there is an immediate need to determine how rapidly spilled oil will spread and where it will go in a given time. Knowledge of where the oil goes after it is spilled and the area that will be covered by the oil thus forms a basis for decisions concerning the best method of oil treatment. Here we present a method of predicting the spread of oil in Tokyo Bay.

4.2 Model Description

The spread of an oil slick may be approximately viewed as composed of two parts, the first consisting of convection by winds and currents, and the second of the increase in area covered by oil due to gravitational spreading in calm water. Since tidal currents are dominant in Tokyo Bay, the drift due to wind and tidal currents was investigated. The center of mass of the oil is given by Hoult (1972) as follows:

$$\frac{dx}{dt} = U_{current} + 0.035U_{wind} \tag{38}$$

where x is the coordinate of the center of the mass of oil, $U_{current}$ is the tidal current and U_{wind} is the wind velocity.

The properties of the oil vary with time; the most important loss process is evaporation of the lighter components into the air. Other causes are dissolution of the soluble components into seawater and the changes wrought by biological degradation. These changes all tend to make the oil denser and more viscous. In this model, such effects were not considered. Crude oil is a mixture of a very large number of components, each with its own properties. As the different components generally have quite different spreading coefficients, a bulk model may be only a first approximation of the details of the flow.

A 3-dimensional circulation model was used to calculate $U_{current}$ in eq. (38). The circulation model that describes velocities (u, v, w) and salinity (S) was originally developed by Blumberg and Mellor (1983). The second-order turbulence closure scheme of Mellor and Yamada (1982) was used in order to express the variation in vertical mixing due to wind and surface cooling.

The major sources of freshwater inputs are the 5 rivers mentioned earlier, and the computational domain included waters up to 10-km upstream. Daily averaged freshwater discharges from these rivers (River Flow Table, Ministry of Construction) were used. Tidal forcing was given from harmonic constants obtained at the Jogashima and Iwaibukuro tide-gauge stations. Daily averaged air temperature, solar radiation, cloud cover and relative