Theoretical calculations of the distributions of dissolved, particulate and bed-sediment concentrations of a contaminant within a muddy estuary are presented for the case of strong partitioning between dissolved and particulate phases ($K_d = 200 \text{ m}^3 \text{ kg}^{-1}$,$200 \text{ I g}^{-1}$)). Results for both continuous fluvial and marine contaminant inputs are averaged over winter and summer periods and are plotted as contaminant-salinity mixing diagrams. Water-column concentrations (contaminant mass per unit volume of water) are dominated by particulate-contaminant levels. For a fluvial input of contaminant there is a marked enhancement of dissolved levels above conservative values at higher salinity, although maximum water column (dissolved plus particulate) concentrations occur in the turbidity maximum region. For a marine input of contaminant, maximum water-column concentrations during summer also occur in the turbidity maximum region and are roughly twice those in coastal waters, contrary to intuition.

INTRODUCTION

The turbidity maximum within some macrotidal estuaries migrates axially in response to changing river flows (Allen et al. 1977, 1980). There is an accompanying shift in the sediment pattern, which consists of sediment accumulation in the upper estuary during summer and in the lower estuary in winter and spring (Bale et al. 1985). Theoretical studies of these sediment transport processes and their consequences for the transport of a contaminant which partitions between dissolved and particulate forms have been given by Uncles et al. (1987, 1988). A typical value of the partition coefficient, $K_d$, considered was $5 \text{ m}^3 \text{ kg}^{-1}$ ($5 \text{ I g}^{-1}$), which is similar to that measured for several trace metals within the estuarine environment (zinc, caesium and cadmium; IMER, 1986/1987; Salomons, 1980).

The objective of this paper is to investigate the seasonal transport and behaviour of a contaminant which has the much higher partition coefficient of $200 \text{ m}^3 \text{ kg}^{-1}$ (typical of, say, Cobalt in the coastal zone; IAEA, 1985). The chemistry of the contaminant is not taken into account. We are concerned only with physical transport.
processes in a macrotidal estuary. The model estuary is topographically similar to the Tamar, UK. Chemical transformations within the sediment are excluded. Speciation is not treated explicitly. Total dissolved and total particulate states only are considered, and equilibrium exists everywhere between these states, with \( C_p = K_d C_d \), where \( C_p \) is the particulate concentration (kg kg\(^{-1}\)), \( C_d \) is the dissolved concentration (kg m\(^{-3}\)) and \( K_d = 200 \text{ m}^3 \text{ kg}^{-1} \).

**BASIC MODEL AND RESULTS**

Details of the model are given in Uncles et al. (1987, 1988) and Harris et al. (1984). Currents, tidal elevations and sediment transport are determined from a one-dimensional, hydrodynamical model of the Tamar Estuary. A tidally-averaged, one-dimensional model is used to compute the dispersal of a contaminant (Harris et al. 1984). Tidally-averaged, longitudinal and vertical fluxes of sediment are used. Within-tide resuspension and deposition are treated as a vertical mixing process superimposed on a tidally-averaged vertical transport.

We consider two types of contaminant input to the estuary. First, a continuous fluvial input at the head, where the dissolved contaminant concentration (\( C_d \)) is constant at \( 10^{-6} \text{ kg m}^{-3} \) (1 \( \mu \text{g l}^{-1} \)). The coastal value is zero when salinity reaches 34 ppt. Second, a continuous marine input of contaminant through the mouth, where the dissolved contaminant concentration (\( C_d \)) is \( 10^{-6} \text{ kg m}^{-3} \) (1 \( \mu \text{g l}^{-1} \)) when the salinity reaches 34 ppt. The fluvial concentration (zero salinity) is zero.

**Dissolved Concentrations**

Figure 1(A) shows the steady-state, conservative (zero partitioning, \( K_d = 0 \)) mixing line (\( C_d \) against salinity, line(1)) for a fluvial input of contaminant. A typical summer, spring-tide distribution of suspended particulate matter (SPM) concentration is shown as line (2) in Figure 1(A), on a normalized scale of 0 - 1 (corresponding to 0 - 0.34 kg m\(^{-3}\)). The turbidity maximum is a very pronounced feature of the SPM concentrations at low salinity. If the partitioning is now 'switched-on', with \( K_d = 200 \text{ m}^3 \text{ kg}^{-1} \), then the dissolved concentration, \( C_d \), is immediately reduced to the low levels shown in line (3) of Figure 1(A). Almost complete removal of dissolved contaminant occurs in the turbidity maximum region at very low salinity.

The dynamical situation for a fluvial input, depicted in Figure 1(B), is very different. Averaging winter (line 2) and summer (line 3) periods over a four-year simulation period shows that dissolved levels exceed conservative values for most of the salinity range, but that depletion still occurs in the turbidity maximum region.