SEDIMENTATION, RESUSPENSION AND TRANSPORT OF PARTICULATES

SCCWRP efforts to relate changes in the physical and chemical properties of the sediments around an outfall, and the associated changes in the biological communities, continued under a grant from the U.S. Environmental Protection Agency (EPA). Recent studies include measurements of the near-bottom currents and resuspension rates (using sediment traps), the refinements of existing simulation models and development of new numerical simulation models of particulate settling, resuspension and transport.

REFINEMENT OF THE SEDIMENTATION MODEL "SEDF2D"

SEDF2D is a numerical simulation model of effluent particle settling for coastal areas with "reasonable" variations in water depth in both the longshore and cross-shore directions. The conceptual approach is described in Hendricks (1983). The model has been recently refined to include: first, a provision to incorporate current meter data collected simultaneously at up to eight moorings; second, an improved means of dealing with the properties of flow near a coastal boundary; and third, continuous up-dating of the depth of the effective coastline to reflect the sinking of settling particles. The latter two changes correct the previous apparent bias of the model to overestimate inshore deposition and underestimate offshore deposition.

DEVELOPMENT OF A SIMPLIFIED SEDIMENTATION MODEL

Because SEDF2D simulations require considerable setup and execution time, a new sedimentation flux model, SFFT, was developed to provide a quicker estimate of sedimentation patterns and rates. This model may be appropriate for outfalls with relatively small mass emission rates of particulates. The computational approach requires that the water depth remain constant (no coastal boundary), but approximation techniques can be used to modify the results to estimate sedimentation in areas with relatively simple bathymetry.

As in SEDF2D, a time series of current measurements is used to estimate the dispersion of effluent particles in the simulation area. It is assumed that the average longshore (or cross-shore) distribution of discharged particles can be described by a "similarity" probability distribution function characterized by a single parameter (e.g. "normal" or "top-hat" profiles characterized by their variance). A single variance is computed for each axis as a function of the elapsed time since the particles were discharged from the outfall.

This variance represents the sum of the variances associated with three types of processes: (1) the dispersion associated with eddy diffusion, (2) additional "eddy diffusion-like" dispersion associated with current fluctuations characterized by time scales shorter than the elapsed time since discharge, and (3) variations in the mean currents (i.e. for the set of "net" currents obtained by averaging over times equal to the elapsed time). The time scales characterizing the current fluctuations are determined by transforming the time series of current measurements from "time-space" to "frequency-space" using a discrete Fourier transform.

The computed variance is combined with the probability distribution function, the mass distribution of particulate settling speeds, the settling distance from the wastefield to the ocean bottom, and the elapsed time to estimate the deposition in a grid of cells. This statistical approach generally reduces the computational time required for a simulation to less than two percent of the time required by SEDF2D. Strictly speaking, however, the approach is only valid for areas characterized by a constant water depth. Various methods can be used to modify these results to areas with a sloping bottom, but artifacts may be introduced into the cross-shore distributions.

A MODEL OF PARTICLE AGGREGATION ("COAG")

Both SEDF2D and SFFT require information on the mass distribution of effluent particle settling speeds. Generally this information has been obtained from laboratory-based measurements using settling columns. The results from these columns have been criticized on the basis that they will not adequately simulate possible aggregation among particles.

Recent studies (Hunt, 1982; Farley and Morel, 1986) suggest that the rate of sedimentation of a collection of single-size particles in a homogeneously mixed column is approximately proportional to the square of the particle concentration. In order to explore the possible effects of particle aggregation on sedimentation rates, we adapted these homogeneously-mixed column results to the stratified (wastewater, receiving water) conditions that exist following discharge (Hendricks and Harding, 1971). The ocean water column was subdivided into a vertical set of cells.

Concentrations are assumed to be uniform within each cell, but can vary from cell to cell, and the set of cells moves with the ocean currents (i.e. a Lagrangian reference system).

Processes incorporated into the model include: (1) aggregation and settling, (2) decay of the non-refractory fraction of the organic material, and (3) modification of the vertical distribution of natural particles as a result of the entrainment of receiving water into the wastewater plume. Effluent-effluent, effluent-natural, and natural-natural particle aggregation are considered.

Simulations carried out with this model suggest that this simplified representation of aggregation, which neglects an initial distribution of particle sizes and "latency" in developing an equilibrium state of aggregation, does not provide an adequate representation of effluent particle settling speeds in an ocean environment. They do suggest, however, that aggregation between effluent and natural particles may be an important process — particularly in near-bottom waters, where high concentrations of particles may exist as a result of sediment resuspension.

RESUSPENSION RATES

Hendricks (1984) previously developed a model of sediment quality (SEDQ). The representation of resuspension processes used in this model was based on SCCWRP's *in situ* observations of threshold resuspension speeds for sediments around outfalls. Simulations carried out with this model suggested that a constant mass of particles might be resuspended during each resuspension event, and that the thickness of this resuspended layer might be too thin to observe with SCCWRP's *in situ* resuspension water tunnel. Other complicating factors included relating near-bottom (elevation = 2 meters) current speeds to the speeds occurring in the tunnel.

In order to obtain some direct estimates of resuspension rates occurring in discharge areas, we have been carrying out a number of measurements of "total sedimentation" (resuspension plus water column) rates using sediment traps located in the lower five meters of the water column.

Total sedimentation rates are quite variable, but the average resuspension rates are remarkably independent of water depth for the depths characteristic of outfall diffusers (Table 1). Typical rates are on the order of 1800-3600 mg/cm²/yr, which are substantially higher than the net deposition of natural sediments (10 to 30 mg/cm²/yr), or estimated rates of deposition of effluent particles (0 to 200 mg/cm²/yr, depending on location). This suggests that resuspension of sediment material is the primary source of the collected material and that most of the particles are resuspended and redeposited many times before becoming a part of the "permanent" sediments.

A typical characteristic thickness of the layer of resuspended material in the water column is on the order of two to three meters. The thickness of the surficial layer of dynamically-active material deposited on top of the "permanent" sediments is estimated to be a few tenths of a millimeter. Measurements of the organic content of the material collected in the (unpoisoned) traps show that it is greater than in the upper two centimeters of the sediments. This suggests the material may still be undergoing active decay and, perhaps, that this layer is not being sampled by conventional methods.

A NEW MODEL OF SEDIMENT QUALITY (SEDP)

The sediment trap studies cast some doubt on the validity of SCCWRP's representation of resuspension processes in the previous model of sediment quality (SEDQ). Two other defects of the model were: (1) an unacceptable sensitivity of the transport rates to normal uncertainty in near-bottom current measurements, and (2) the predictions would not approach natural sedimentation rates as the outfall discharge was "turned off."
Because of these deficiencies, Hendricks decided to develop a new model of sediment quality. The approach used in this model is based on the sediment trap data and near-bottom measurements of the currents.

It is assumed that some threshold speed is required to resuspend the layer of "dynamically-active" surface sediments, and that redeposition of this material will not occur until the current speeds decline below some lesser value. Both the resuspension and deposition processes are assumed to occur "instantaneously." The statistically-averaged dispersion of resuspended particles associated with one "resuspension event" is computed from the time series of near-bottom current measurements using progressive vector diagrams. Although the threshold resuspension and deposition speeds are not known, simulations indicate that the transport is only moderately sensitive to the choice of these speeds, provided that they are not near the extreme ends of the distribution (i.e. near the lowest or highest recorded speeds). The mass of particulates resuspended during each event is based on the sediment trap results.

The concentration of a specific material within a cell in the simulation grid is dependent on the rate of input of that material into the cell, the rate of transport out of the cell, the rate of "decay" or transformation, and the rate of mixing of the deposited material with the underlying sediments.

Location	Water Depth (M)	Season[1] Summer	Winter
Encina	25	1475	3845*
White Point	30	2800 (±1000)	-
Newport Beach	30	2475 (±725)	1925
San Diego	30	475 (±125)	-
San Diego	35	-	1225
30-35 M AVERAGE		1925 (±1250)	1575 (±500)
Encina	46	2270	4170
White Point	60	2475 (±725)	4400
Newport Beach	55	1625 (±375)	1574 (±175)
55-60 AVERAGE		2050 (±600)	2975 (±2000)
OVERALL AVERAGE		1950 (±800)	2850 (±1425)

[1] Summer is calendar days 91-300; winter is calendar days 1-90 and 301-365.

* An annual rate equal to 105,000 averaged over two weeks and observed during peak swell of the year 2/15-16/86.

Table 1. Sedimentation Trap Fluxes (mg/cm²/yr) Through 11/86

Sources include the transport of resuspended material from surrounding cells and the sedimentation of natural and effluent particulates from the water column. Since a perturbation type computational scheme is used, the method guarantees that natural sedimentation and accumulation rates will occur when there is no outfall discharge.

Simulations carried out with this model generally yield predictions of concentrations of organic material in the surface sediments (0 to 2 centimeters) that are compatible with the values measured in grab samples collected in the simulated area. The primary exception to this is the sediment field around the White Point outfall(s), where the observed concentrations are substantially higher. Predicted concentrations comparable with the observed levels can be obtained by assuming that the introduction of effluent particles increases the fraction of the particles that are deposited into the "permanent" sediments during each resuspension event; however, the validity of this hypothesis is untested, and the difference between the White Point area and other outfall areas is not known at this time.

References

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