SEDIMENT TRANSPORT MODELLING

Method Indicator		
Bottom-Up	Hybrid	Top-Down
YES		

Summary of key issues

Issue	**Description**
Description	Process based modelling of bed load and suspended sand and/or mud movement, with relationships to determine the rates of erosion and deposition.
Temporal Applicability	Typically applied to the short to medium-term (single tide up to several months)
Spatial Applicability	Typically estuary wide
Links with Other Tools	Most often dynamically linked to hydrodynamic models thus allowing for a change in the hydrodynamic taking account of the change in bed elevations over the simulation time period. Can be linked to sediment budget analysis, expert geomorphological analysis, sediment quality and water quality, for example.
Data Sources	Model set up Sediment characteristics: • Grain type and size; • Settling velocity; • Sediment density; • Critical shear stress; • Shear strength. Sediment distributions: • Initial sediment thickness; • Mixing coefficients. Boundary conditions: • Seaward and riverine suspended sediment concentrations; • Location of sediment inputs. Calibration and verification data: • Suspended sediment concentrations; • Historic bathymetric data.
Necessary Software Tools / Skills	Hydrodynamic modelling system linked with a sediment transport module.
Typical Analyses	Mass balance equation uses predictions of current velocity and various sediment characteristics to output calculations of sediment concentrations. The effect of turbulence is included by applying a well-known Reynolds procedure. Momentum balance for the fluid-sediment mixture is solved to represent the modification of transport of particles resulting from the presence of other particles in suspension (Brownian motion).
Limitations	Correct sediment distributions are only produced if salinity is well reproduced as well as correct river discharges, tidal flow, topography and, intertidally, the occurrence of vegetation. Different equations are needed to deal with the differences between transports of cohesive or non-cohesive material, Hence different models are often used when modelling sand and mud sediment.

Introduction

Sediment transport modelling methods are aimed at providing information regarding the movement of sediment within hydrodynamic systems, such as estuaries. Outputs from a sediment transport model include estimates of suspended sediment concentrations, rates of sediment erosion and deposition and sediment transport pathways.

The majority of sediment transport models are based on either outputs from hydrodynamic models or solve both hydrodynamic and sediment related equations at each time step of the model simulation. In both cases predictions of water levels and currents, driven by tidal, discharge, wave and meteorological forcing are used in the numerical solving of the equations describing sediment movements.

Because of the variety of sediment types, sizes and transport mechanisms occurring within an estuary a range of mathematical equations are required to simulate the sedimentary processes occurring in estuarine systems (Fredsøe & Deigaard, 1992; van Rijn, 1993; Soulsby, 1994; Whitehouse *et al*. 2000). In different models, varying formats and types of sediment transport equations are solved. Different equations are needed to deal with the differences between transports of cohesive or non-cohesive material. Hence different models are often used when modelling sand and mud sediment.

In the majority of sediment transport models the basic equations solved numerically include (van Rijn, 1993):

- A mass-balance equation, which uses predictions of current velocity and various sediment characteristics to output calculations of sediment concentrations. The effect of turbulence is included by applying a well-known Reynolds procedure;
- A momentum balance for the fluid-sediment mixture is solved to represent the modification of transport of particles resulting from the presence of other particles in suspension (Brownian motion);
- Sediment particles are carried (advected) by the mean flow in both horizontal and vertical directions, while simultaneously moved by turbulent eddy motions. Particles are also carried downwards by gravitational forces (settling). Horizontal and vertical mixing terms are included in equations to simulate mixing processes.

Before any of these equations can be numerically solved, a whole range of sediment characteristics (grain size, particle density, critical shear stress, shear strength of the bed, settling velocity,) must be defined (WL|delft hydraulics, 2001).

A number of sediment transport modelling studies have shown that correct sediment distributions are only produced if salinity is well reproduced as well as correct river discharges, tidal flow, topography and, intertidally, the occurrence of vegetation. Consequently the estuarine circulation pattern is particularly important in determining sediment movement. It is important that circulation patterns within a specific estuary are careful considered to ensure the correct processes are being represented in the sediment model (STOWA-RIZA guide, 1999).

Within an estuary the processes of erosion or accretion are likely to have feedback effects on the hydrodynamics within the system. Large amounts of deposition may cause the tidal flow in that area to considerably increase or shifted into different channels. For this reason sediment transport models should only be used to compute sediment transport rates over relatively short time scales, (one to two tidal cycles.) If sediment transport rates in an estuary are particularly small the model could be used to predict transport over longer periods (EMPHASYS Consortium, 2000). In very dynamic estuarine systems it is important that morphological bed-updating models are used, as these take into account feedback affects by updating the estuary bed.

Data requirements

In addition to the data requirements outlined for the hydrodynamic modelling a large number of measurements are required to ensure the set-up, calibration and validation of a reasonable sediment transport model. The data requirements are listed below.

Model Set-up

Inclusion of the following parameters needs considering in the model setup:

- Sediment Characteristics;
- Grain type and size;
- Settling velocity;
- Sediment density;
- Critical shear stress;
- Shear strength;
- Sediment distributions;
- Initial sediment thickness;
- Mixing coefficients.

Boundary conditions

- Seaward and riverine suspended sediment concentrations;
- Location of sediment inputs.

Calibration and verification data

- Suspended sediment concentrations;
- Historic bathymetric data.

Conclusion

Sediment transport modelling methods provide information about sediment movement within estuarine systems, including suspended sediment concentrations, rates of sediment erosion and deposition and sediment transport pathways. Numerical models are aided by predictions of water levels and currents, driven by tidal, discharge, wave and meteorological forcing are used in the numerical solving of the equations describing sediment movements. A range of mathematical equations are required to simulate the sedimentary processes occurring in estuarine systems. These differ according to the cohesiveness of the sediment, resulting in a range of complex sediment models.

References

EMPHASYS Consortium, 2000, Modelling estuary morphology and process. Estuary Research Programme, Phase 1, MAFF Contract CSA 4938, Final Report, HR Wallingford TR 111, 222pp.

Fredsøe, J. and Deigaard, R., 1992, *Mechanics of coastal sediment transport*. World Scientific Publishing Co Ltd, Singapore.

Soulsby, R.L., 1994, *Manual of Marine Sands*. Thomas Telford, London, 1-70.

STOWA/RIZA, 1999, *Smooth modelling in water management: Good modelling practice handbook.* Dutch Department of Public Works, Institute of Inland Water Management and Waste Water Treatment, Den Haag, Netherlands, Report No: STOWA report 99-05, 167pp.

van Rijn, L.C., 1993, *Principles of sediment transport in rivers, estuaries and coastal seas*. Aqua Publications, The Netherlands.

Whitehouse, R., Soulsby, R.L., Roberts, W. and Mitchener, H., 2000, *Dynamics of estuarine muds*. Thomas Telford, London.