HYDRODYNAMIC MODELLING

Hydrodynamic modelling is the base on which advection-diffusion, sediment transport, particle tracking and morphological bed updating modelling is undertaken. Outputs of hydrodynamic modelling are predictions in water levels, tidal currents and waves that result from tidal, meteorological and density forcing.

All hydrodynamic models solve one form or other of the same governing equations for oceanic motions (Abbott & Basco, 1989). These equations are written in the coordinate frame of reference fixed to the rotating earth. These equations are essentially the Navier-Stokes equations or more appropriately Reynolds-average equations, since the flow is invariably turbulent. The Navier-Stokes equation, otherwise known as the momentum equations is derived from Newton's second law of motion applied to a fluid particle. The forces due to gravitation buoyancy (Archimedean force due to density stratification) and the Coriolis (accelerations generated due to the non-inertial nature of the rotating coordinate frame) are included in the equations. An additional equation, known as the continuity equation is required to insure that mass is conserved (Clayson & Kantha, 2000).

In an estuarine system it is important that flow and transport resulting from meteorological forcing is simulated in the hydrodynamic modelling. Changing atmospheric pressure conditions and strong winds can significantly alter tidal patterns in the relatively shallow estuary environments. Additional terms in the main equations are included to take into account the changes that are likely to results from wind and pressure fields.

Hydrodynamic models are driven by tidal, discharge, wave and meteorological forcing. At the offshore or seaward boundary, tidal forcing drives the model. This boundary tide is usually specified by a water level time series, a velocity time series or a set of tidal harmonics, derived from a set of water level measurements. An advantage of using tidal harmonics is that the model can be run over any period of time. Using a time series to drive the model restricts the running of the simulations to that period over which the water level or current velocity measurements were made. Most hydrodynamic models also allow a constant or varying salinity to be determined at the boundaries. Including salinity in the models can often be important in estuaries as salinity changes in the form of density differences can drive water movement.

In estuary hydrodynamic modelling it is also important to consider discharges of water, in particular freshwater flow from rivers. In the majority of hydrodynamic models these can be inputted as either constant values or varying time series. In the same manner salinity is also expressed at these boundaries.

Meteorological forcing in most hydrodynamic models is carried out by defining wind stress and/or pressure fields. These can be included in the model as being constant in time and space or varying in time and space. The changes in water levels that result from these additional forcing terms can then be predicted.

The simulation of waves is usually done by coupling the model with specific wave simulating models. Generally, wave models are used to predict estimates of wave radiation stress due to waves propagating from offshore that have travel inshore and locally generated wind waves. These stresses can then be included as an additional forcing term in the hydrodynamic model to include the influence of waves on water levels and currents (WL|delft hydraulics, 2001).

When using hydrodynamic models to simulate estuarine systems it is important that the processes occurring with the system are modelled. In sheltered estuaries for example the affect of offshore waves can be ignored. But, in estuaries with large mouths that are open to offshore waves, it is important that the forcing due to waves is included in the model, to obtain accurate water levels, currents and density structures.

Results from hydrodynamic models can be used in two mains ways (Dyke, 1966). Predictions of currents for example can be used to assist interpretation of sediment transport rates and pathways. Calculations of bed-shear stress can be made from the model results of current and can be used to assess potential areas of erosion and accretion. Alternatively, results from the hydrodynamic model can be used by other models (sediment transport or advection diffusion models) to estimate the sediment transport rates and pathways directly.

Data Requirements

Various data inputs are required in order to set-up, calibrate and validate a hydrodynamic numerical model. A brief list of the requirements is given below:

- **Model set-up**
    - Land boundary (xy format).
    - Bathymetric data.
    - Wind and atmospheric pressure data
    - Measurements of bed friction or roughness
- **Boundary conditions**
    - Seaward tidal boundary conditions
    - Freshwater discharge information.
    - Salinity boundary conditions
    - Offshore wave climate
- **Calibration and verification data**
    - Water levels (along the length of the estuary).
    - Flow speeds and directions (or vector format u, v).
    - Salinity measurements
    - Wave measurements or statistics

References

Abbott MB, Basco DR, 1989, Computational fluid dynamics: an introduction for engineers, Longman Scientific & Technical, Harlow.

Clayson CA, Kantha LH, 2000, Numerical Models of Ocean and Oceanic Processes, Academic Press, London.

Dyke P, 1966, Modelling Marine Processes, Prentice Hall.

WL|delft hydraulics, 2001, User Manual Delft3D-FLOW, Delft3D-WAQ and Delft3D-PART, WL|delft hydraulics, Delft.