Development of Estuary Morphological Models

Technical Summary: FD2107

Joint Defra / EA Flood and Coastal Erosion Risk Management R&D programme

Background to R&D project

Estuaries and associated flood risks, sediment regimes and morphology impact local populations and economic activity. Management to minimise flood risk and threats to habitats (from various human activities and climate change scenarios, for example), needs to be informed by robust, well-founded and credible tools. Outcomes depend on hydrodynamics and on sediments. However, sediment dynamics, and especially longer-term changes in morphology, are challenging to predict; well-validated predictive models have been lacking.

The UK Estuaries Research Programme (ERP) was formulated to develop techniques to predict large scale, long term morphological changes and resulting sediment related impacts in estuaries (including water quality aspects), and assess their consequences for estuarine management. ERP Phase 1 (1998-2000) included a critical analysis of process-based "bottom-up" (B-U) model limitations alongside a review of "top-down" (T-D) models. ERP Phase 2 recognised the need to use both approaches and gave priority to developing Hybrid models combining B-U and T-D elements. Project FD2115 provided an updated vision for ERP Phase 2, comprising: (i) uptake of Phase 1, (ii) improved data, (iii) enhanced hybrid models, (iv) process studies (ESTPROC), (v) enhanced T-D models, (vi) morphological systems – and dissemination and management.

This project FD2107 addressed mainly (iii), developing Hybrid models for (50-year) morphological prediction (combining advantages of T-D and B-U approaches). Several models were applied for different intervention and climate change scenarios to identify the impacts on the levels and form of eight varied UK estuaries. This model inter-comparison improved confidence in the models and provided inferences for flood risk, defences and habitats. It links with ERP2 aspects (ii), (iv), (v).

Results of R&D project

Particle-tracking models have been used to predict sediment movement and deposition in the Thames and Mersey, and sensitivity to sea level and sediment properties.

Historical evolution of the Humber (as in 20 bathymetry surveys, 1851-2000) can be modelled by a diffusion equation plus "source" of which 92% is in one spatial pattern with a near-constant time-factor.

In the ASMITA model, sea-level rise creates accommodation space causing the estuary to become a sink for available sediment. This matches past Thames behaviour reasonably and predicts that the Thames' overall form can keep pace with sea-level rise up to 20 mm/yr.

Various models on eight varied estuaries suggest: inter-tidal area usually decreases; sediment

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transports usually suffice for infill keeping pace with sea-level rise, but models differ in whether such infill occurs; effects of small changes in tidal range are small. More river flow (+20%) gives mostly small changes, a Hybrid Regime model predicts inter-tidal area loss (Mersey, Blackwater).

Limitations of an Analytical Emulator's schematic high- and low-water areas are overcome by Hybrid Regime and 2-D or 3-D particle-tracking models with fine-enough resolution.

Historical trend analysis can guide expectations of future trends if there are precedents. Models should be validated against historic change or by inter-comparison if data are lacking.

In case studies of effects of morphological change: the impact of dredging on flood risk may be deleterious (especially near tidal limit), small or beneficial, depending on the characteristics of the estuary; particular features may be critical; defences may become more vulnerable to wave attack.

Estuaries do not all respond to imposed changes in the same manner.

R&D Outputs and their Use

Improved capability of the pre-existing model *SandTrack* (sediment dynamics, particle-tracking), to predict estuarine morphodynamic development; the flow model is re-run as bathymetry evolves.

A Hybrid Regime model combines 1-D hydrodynamics with "regime" relations between discharge, cross-section area and width. For changed (e.g.) sea levels or engineering works, changed cross-sections are predicted allowing for Holocene and solid surface constraints. A Shell provides a user interface facilitating set-up, coupling, application, assessment and visualisation.

Prediction of bathymetry may use an "Inverse" diffusion-equation-plus-"source" model *if* (i) bathymetry data exist at frequent intervals (relative to changes in the estuary), (ii) one (or more) principal-component spatial patterns account for most the inferred "source". Prediction is limited to the auto-correlation time of the corresponding time-series and to scenarios with precedents.

An Analytical Emulator using 1-D hydrodynamics and a schematised estuary was programmed. It indicates area/volume response to water levels and tidal range (for unchanged morphology).

ASMITA, evolving the size of aggregated elements (intertidal area, channels, ebb-tidal delta; interacting through sediment exchange) has been programmed in MATLAB for wider availability.

A Realignment model predicts local changes in morphology and saltmarsh due to managed realignment, including the effects of waves and sediment trapping by vegetation.

The FutureCoast data-base has been augmented; it will be archived with BODC and should benefit the EstSim (FD2117) Simulator.

This R&D Technical Summary relates to R&D Project FD2107 and the following R&D output:

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The above outputs may be downloaded from the Defra/EA Joint R&D FCERM Programme website (www.defra.gov.uk/environ/fcd/research).

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