MODELLING 2DH COASTAL MORPHODYNAMICS INCLUDING THE SEDIMENT SUPPLY FROM RIVERS AND NATURAL STREAMS

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INTRODUCTION

The term "Watershed-Coast System" refers to the entities consisting of watersheds and the areas adjacent to their outlets, where the sediment supply from rivers and natural streams plays a key role in the evolution of coastal morphology (Samaras and Koutitas, 2014a). The study of the morphodynamics of such systems entails a large number of uncertainties and modelling limitations, thoroughly analysed in Samaras (2023). Focusing on the land-sea interface, integrated modelling approaches that have been proposed and applied to actual case studies favour the use of reduced-complexity models (typically shoreline evolution models based on the one-line theory). Even regardless of integrated approaches in the above context, though, modelling attempts of 2DH coastal morphodynamics in the vicinity of stream mouths and estuaries are limited in relevant literature.

This work investigates the capabilities of a 2DH approach in modelling coastal morphodynamics under the strong influence of the sediment supply from rivers and natural streams. Applications are performed for a coastal area in North Greece using an integrated coastal engineering model developed by the authors. Results provide useful insights regarding the use of 2DH models in this work's context and are deemed to contribute significantly to the study of Watershed-Coast Systems for management and engineering purposes (Samaras, 2023).

MODELLING APPROACH

The present work retains the viewpoint of a modular modelling approach, that of the integrated coastal engineering model of Karambas and Samaras (2017). The model consists of three main modules that simulate: linear wave propagation (i.e., WAVE_L), wave-induced circulation (i.e., WICIR), and sediment transport along with bed morphology evolution (i.e., SEDTR).

WAVE_L is based on the hyperbolic-type mild slope equation and is also valid for simulating compound wave fields near coastal structures. WICIR simulates currents in the coastal zone by solving the depth and shortwave-averaged 2D continuity and momentum equations, including a series of adaptations in order to reproduce quasi-3D effects in the nearshore and swash dynamics, as well as coastal flooding due to wave setup through the "dry bed" boundary condition (Militello et al., 2004). Since WICIR is based on the Shallow Water Equations, it has been easily adapted to simulate the open channel flow, as well as the flooding, of the estuarine estuary area. SEDTR calculates bed load and sheet flow transport based on the formulation proposed by Camenen and Larson (2007) and incorporates suspended sediment transport by solving the depth-integrated transport equation for suspended sediment (see Camenen and Larson, 2008). Extended ana-lysis and details on the integrated model can be found in Karambas and Samaras (2017).

Regarding the sediment transport in rivers and natural streams inside the computational domain, this is simulated through the same formulae (for both bed load and suspended load) used in the integrated coastal engineering model, as described above (i.e. Camenen and Larson, 2007, 2008; Karambas and Samaras, 2017), considering solely the current flow. The sediment supply from the upstream watersheds is considered as a sediment source (input boundary condition).

Finally, the integrated model also simulates the hydraulics of water flowing over eventual sand dikes at the coast or shoals in river mouths (subcritical, transcritical and supercritical flow, hydraulic jump formation, etc.), along with the accompanied erosion processes (e.g. breaching and erosion of a sand dike due to overtopping).

A CASE STUDY

This work investigates the morphodynamics of the coast of Fourka, located in the middle of the Kassandra peninsula in Northern Greece (see Figure 1). The study area comprises the sandy coast in the vicinity of a stream mouth. The case identifies as a typical Watershed-Coast System, as coastal morphology evolution has been proven to be heavily affected by the variations in the sediment supply of the upstream watershed (Samaras and Koutitas, 2014b).

Figure 1 – Geographic location and satellite image of the study area.

Samaras and Koutitas (2014a) studied coastal morphodynamics in the study area under the combined effect of waves and stream sediment supply using a shoreline evolution model. The present work expands the study to 2DH coastal morphodynamics, following the modelling approach presented in the previous section.

Model applications were designed in order to investigate the complex morphodynamics of such systems that arise from the inherent uncertainties of simulating morphology evolution under the effect of processes that do not necessarily follow the same temporal patterns (i.e. wave action and sediment delivery from rivers/streams).

Figure 2 presents the wave setup, coastal flooding and velocity field due to the combined action of open channel flow (from the stream) and breaking wave-induced currents (results for NW waves of H = 1.2 m and T = 5 s). Figure 3 presents the evolution of coastal morphology solely due to upstream sediment supply and stream flow, while Figure 4 presents the respective evolution due to waves and wave-induced currents (combined effect of NW, W and SW waves). Results clearly show the deposition of sediment at the estuary (estuary shoal), as well as the subsequent accretion southwards of the stream mouth.

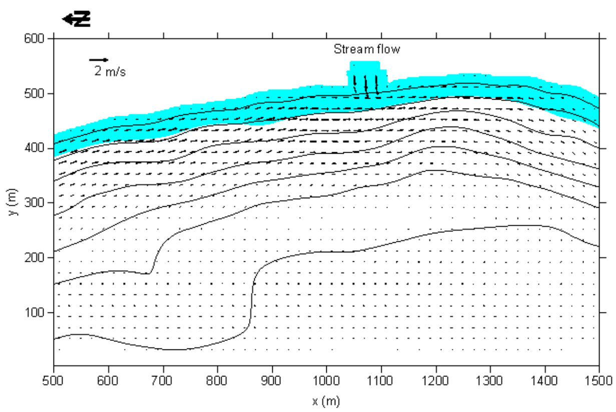

Figure 2 - Bathymetry (solid lines), wave setup (cyan fill), coastal flooding (cyan fill) and velocity field (stream flow and wave-induced currents under NW waves of H =1.2 m and T = 5 s).

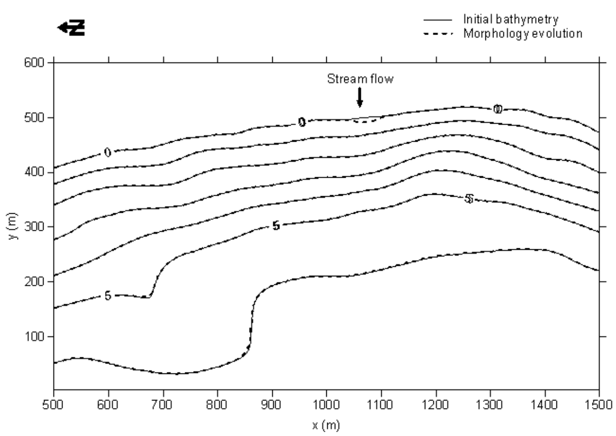

Figure 3 - Morphology evolution solely due to upstream sediment supply and stream flow.

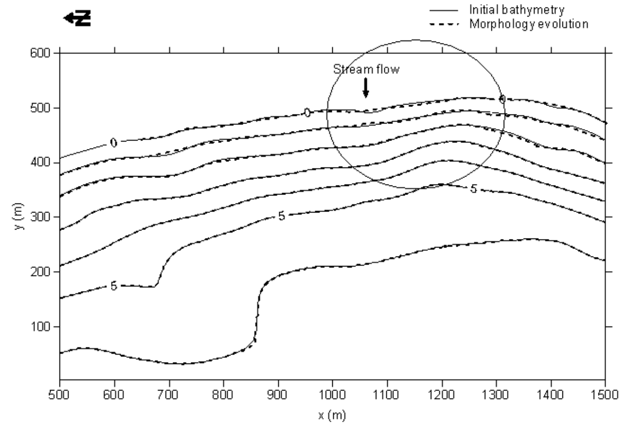

Figure 4 - Morphology evolution dues to waves and wave-induced currents (combined effect of NW, W and SW waves).

CONCLUSIONS

All in all, the adaptation of the integrated 2DH coastal engineering model presented in this work yielded promising results regarding the simulation of coastal morphodynamics in Watershed-Coast Systems. The introduction of sediment supply from a natural stream through open channel flow to the action of waves and wave-induced currents, represented in a satisfactory way both flooding in the estuarine area and accretive trends under the combined effect of all the aforementioned forcings.

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