Modeling transport of mixed sediments on the Belgian Continental Shelf

Dries Van den Eynde[1], Michael Fettweis[1], Frederic Francken[1], Job Janssens[2], Erik Toorman[3], Vera Van Lancker[4] and Toon Verwaest[2]

1 Management Unit of the North Sea Mathematical Models (MUMM), Royal Belgian Institute of Natural Sciences, Gulledelle 100, 1200 Brussels, Belgium
2 Flanders Hydraulics Research, Berchemlei 115, 2140 Antwerpen, Belgium
3 Katholieke Universiteit Leuven, Hydraulics Laboratory, Department of Civil Engineering, Kasteelpark Arenberg 40, 3001 Heverlee, Belgium
4 Universiteit Gent, Renard Centre of Marine Geology, Krijgslaan 281, S8, 9000 Gent, Belgium

The effects of anthropogenic impacts, such as harbour extension, dredging and dumping works, deepening of navigation channels and aggregate extraction, is becoming increasingly important. A good knowledge of the natural sediment balance to allow an appropriate evaluation of these anthropogenic impacts and to develop marine policies for the development of socio-economic activities in equilibrium with marine environmental protection. In parallel with the execution of high quality measurement, *in situ* and by remote sensing, also the application of numerical models can be a very powerful tool to get information on the sediment balance.

Two sediment transport models are applied at the Belgian Continental Shelf (BCS). The mu-STM model is an advection-diffusion model, suited for the simulation of fine material in suspension. The model accounts for erosion and sedimentation and for consolidation of the sea bed. The model was already applied to model the turbidity maximum area in the Belgian coastal waters, between Oostende and the mouth of the Westerschelde (Fettweis & Van den Eynde, 2003) or for the simulation of the dispersion of tracers on the BCS (Van den Eynde, 2004). The mu-SEDIM model on the other hand simulates the transport of sand, by applying a local sand transport formulae. The model was already applied for the modeling of the kink in the Westhinder sand bank (Deleu *et al.*, 2004), for the simulation of different scenarios of sand extraction on the Kwinte Bank (Van den Eynde, *et al.*, 2008) or for the assessment of the wave influence on the sand transport on the Kwinte Bank (Giardino *et al.*, 2008).

However, it is becoming clear that the division between non-cohesive sand and cohesive mud is artificially and that in the bed, a mixture of sediments usually is found. The cohesive sediments can contain a varying amount of sand, while the sandy sediments usually contain a varying amount of mud. The mud and sand content of a sea bed influences the transition between cohesive and non-cohesive sediments, which has a major influence on the erosion behaviour and possibly on the benthic ecological properties (Flemming & Delafontaine, 2000).

For sandy, non-cohesive sediments it is possible to calculate reasonably well the critical erosion stress and the erosion rate when only grain-size and sorting is known. For cohesive sediments the erodability depends mainly upon the degree of cohesion, consolidation, aggregation and compaction, the biological community structure, the sand content of the sediment and the layering. Mixed sediments may behave as cohesive or non-cohesive sediments, depending on the mud content, *e.g.* the addition of mud increases the sediment shear strength and thus the erosion threshold of a sandy bed (Williamson & Torfs, 1996).

Furthermore, these mixed sediments do not necessarily occur as well mixed. Frequently alternation of sand and mud layers are observed. These alternations are interpreted as tidal or storm/calm weather influences. Fan *et al.* (2004) describe storm waves as random destructive factors of the sediment bed and highlight them as effective agents of sediment transport and deposition of the sand-dominated layers. This type of segregation can only occur if cohesive suspended sediment concentration is low.

Recently, some studies have been published that take into account mutual interactions between cohesive and non-cohesive sediments (Van Ledden, 2002; van Ledden *et al*., 2004; Waeles, 2005; Waeles *et al*., 2007; Sanford, 2008). It is clear that more accurate predictions of the sediment transport are possible if the mutual influence of sand-mud mixtures is incorporated in the model.

For the BCS, a combined model is set up, to model both the transport of the material in suspension and the transport of the non-cohesive sand. A detailed bed model will be set up, which can represent the erosion, sedimentation, consolidation and bioturbation of the mixed sediments. The bed model will take into account the detailed distribution of the sediment on the BCS, the clay content and the critical erosion stress of the bed. Newly collected measurements of grain size distribution, bulk density, critical erosion stress and erosion rate (Westrich and Jancke, 2007, 2008a, 2008b) will be incorporated.

Some first results of the model will be presented.

References

Fan, D., C. Li and P. Wang, 2004. Influences of storm erosion and deposition on rhythmites of the upper Wenchang Formation (Upper Ordovician) around Tonglu, Zhejiang province, China. Journal of Sedimentary Research, 74, 527-536.

Fettweis, M. and D. Van den Eynde, 2003. The mud deposits and the high turbidity in the Belgian-Dutch coastal zone, southern bight of the North Sea. Continental Shelf Research, 23, 669-691.

Van den Eynde, D., 2004. Interpretation of tracer experiments with fine-grained dredging material at the Belgian Continental Shelf by the use of numerical models. Journal of Marine Systems, 48, 171 - 189.

Deleu, S., V. Van Lancker, D. Van den Eynde and G. Moerkerke, 2004. Morphodynamic evolution of the kink of an offshore tidal sandbank: the Westhinder Bank (Southern North Sea). Continental Shelf Research, 24, 1587 - 1610.

Flemming, B.W. and M.T. Delafontaine, 2000. Mass physical properties of muddy intertidal sediments: some applications, misapplications and non-applications. Continental Shelf Research, 20, 1179-1197.

Giardino, A., D. Van den Eynde and J. Monbaliu, 2008. Wave effects on the morphodynamic evolution of an offshore sand bank. Accepted for publication in Journal of Coastal Research.

Van den Eynde, D., A. Giardino, J. Portilla, M. Fettweis, F. Francken and J. Monbaliu, 2008. Modelling the effects of sand extraction, on sediment transport due to tides, on the Kwintebank, Accepted for publication in Journal of Coastal Research.

Sanford, L.P., 2008. Modeling a dynamically varying mixed sediment bed with erosion, deposition, bioturbation, consolidation and armoring. Computers & Geosciences, 34, 1263-1283.

van Ledden, M., 2002. A process-based sand-mud model. In: Fine Sediment Dynamics in the Marine Environment, J.C. Winterwerp and C. Kranenburg, C. (eds.), Proceedings in Marine Science, 577-594.

van Ledden, M., Z.-B. Wang, J. Winterwerp and H.J. de Vriend, 2004. Sand-mud morphodynamics in a short tidal basin. Ocean Dynamics, 54, 385-391.

Waeles, B., 2005. Modélisation morphodynamique de l'embouchure de la Seine. Université de Caen Basse-Normandie, 225 pp.

Waeles, B., P. Le Hir, P. Lesueur, and N. Delsinne, 2007. Modelling sand/mud transport and morphodynamics in the Seine river mouth (France): an attempt using a process-based approach. Hydrobiologia, 588, 69-82.

Westrich, B. and T. Jancke, 2007. Report on erosion behaviour measurements of undisturbed sediment cores from the Belgian North Sea bed. University of Stuttgart, Institute of Hydraulic Engineering, 13 pp.

Westrich, B. and T. Jancke, 2008a. Report on erosion behaviour measurements of undisturbed sediment cores from the Belgian North Sea bed, Belgica campaign 2007/25. University of Stuttgart, Institute of Hydraulic Engineering, 15 pp.

Westrich, B. and T. Jancke, 2008b. Report on erosion behaviour measurements of undisturbed sediment cores from the Belgian North Sea bed, Belgica campaign 2008/02. University of Stuttgart, Institute of Hydraulic Engineering, 17 pp.

Williamson, H. and H. Torfs, 1996. Erosion of mud/sand mixtures. Coastal Engineering, 29, 1-25.