

The impact of sea level rise on tidal mudflats: modelling decadal time scale mudflat morphodynamics in South San Francisco Bay

van der Wegen Mick^{1,2}, Bruce Jaffe³, Amy Foxgrover³, Edwin Elias⁴ and Dano Roelvink^{1,2,5}

¹ UNESCO-IHE, PO Box 3015, 2601 DA, Delft, the Netherlands
E-mail: m.vanderwegen@unesco-ihe.org

² Deltares, PO Box 177, 2601 DA, Delft, the Netherlands

³ Pacific Coastal and Marine Science Center, USGS, 400 Natural Bridges Drive, Santa Cruz, CA 95060, USA

⁴ Deltares USA, 8070 Georgia Ave, Silver Spring, MD 20910, USA

⁵ CITG TU Delft, PO Box 5048, 2600 GA, Delft, the Netherlands

Introduction

Estuarine tidal flats are rich habitats that change at seasonal and decadal time scales. Their shape and width is determined by the interplay of wind waves, tides, sediment availability and biotic dynamics (Friedrichs, 2012). Variable forcing conditions shape the profile (Bearman *et al.*, 2010) but changing forcing conditions will disturb possible equilibrium conditions.

It is important to gain understanding in the morphodynamic adaptation rates of mudflats as the result of decadal and centennial forcing variations in order to assess the conditions of mudflats and associated ecological parameters due to sea level rise.

Earlier mudflat modelling studies focussed on sediment transport dynamics on a fixed bed (e.g. Van Maren and Winterwerp, 2013), equilibrium profiles by development towards shear stress conditions below a critical erosion threshold (e.g. Roberts *et al.*, 2000; Pritchard *et al.*, 2002) or the effect of sediment grain sorting [e.g. Zhou *et al.*, (in prep.)].

Objective

The objective of this work is to explore the processes governing tidal mud flat evolution of tidal flat channel system at Dumbarton Bridge in South San Francisco Bay and the impact of sea level rise. This study will improve assessment of possible impacts of restoration and sea level rise on tidal flats and their ecosystems.

Methodology

We use a combination of observations and 1D process based modelling (Delft3D). A series of bathymetric surveys collected approximately every 30 years from 1858 to 2005 shows that the average tidal flat height varied from -2 to 0 MSL. Width is correlated with net deposition/erosion patterns in the entire South Bay. Tidal flats widen during periods of net sediment import and narrow during net sediment export from South Bay.

The 1D model describes a 800m long and 100m wide mudflat stretch bordered by a closed boundary at the landward side and a channel at the seaward side. Mud transport is modelled by the well-known Krone-Parteniades formulation (Ariathurai, 1974). First aim of this model is to reproduce the current mudflat profile. In order to understand the governing factors that shaped the profile we subsequently conducted extensive sensitivity analysis on model input parameters related to sediment characteristics, wind wave forcing and tidal dynamics. Finally, we assessed the impact of sea level rise on profile development.

Model results

Model runs with constant sediment supply and wave and tide forcing show slow development from a flat bed towards the current profile within 50 years (see Fig. 1). This profile consists of similar erosion and deposition rates, maintaining locally high sediment concentrations above the tidal flat. Still, small developments continue and suggest that the profile will further steepen under current conditions. This behaviour is qualitatively independent of reasonable variations in sediment characteristics and forcing conditions. However, adaptation time scales may differ considerably (10-80 years). For example, low sediment concentrations at the boundary show slower adaptation rates but will eventually lead to the same profile. Calculations reflecting sea level rise impact are currently running.

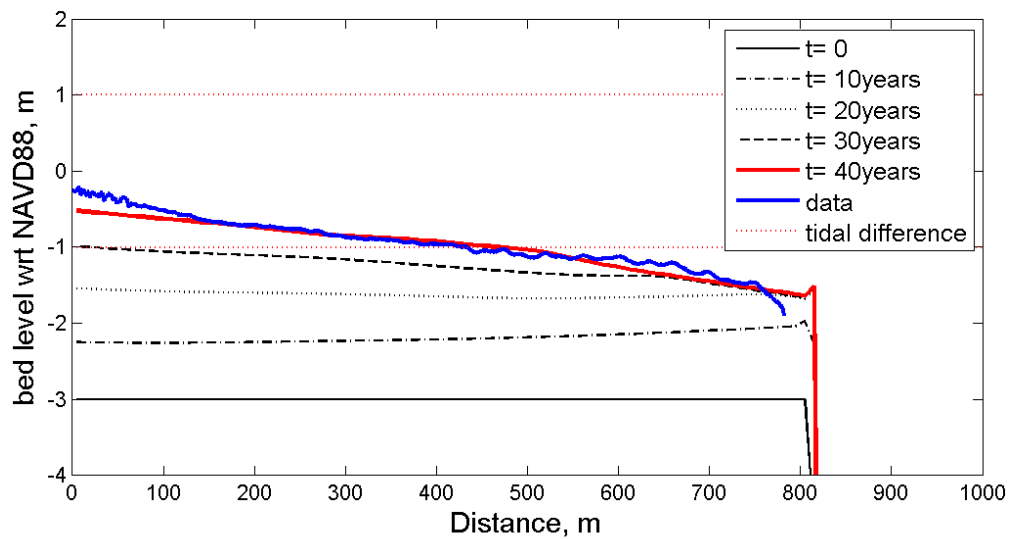


Fig. 10. Profile development towards measured bathymetry of Dumbarton mudflat.

Conclusions

Measured mudflat profiles over the past 150 years on Dumbarton mudflat show that considerable profile development occurred as the result of changing sediment supply. Our modelling effort reproduces the current mudflat profile, but also suggests that development continues over coming decades. Model results are sensitive to uncertain model parameters only in a quantitative manner. Formal equilibrium is not present due to prevailing high sediment concentrations above the mudflat, both in our model as well as reflected by measurements. We can assess the impact of sea level rise on mudflat dynamics.

References

- Ariathurai C.R. 1974. A finite element model for sediment transport in estuaries, Ph.D. thesis. Univ. of Calif. Davis, Davis.
- Bearman J.A., C.T. Friedrichs, B.E. Jaffe and A.C. Foxgrover. 2010. Spatial trends in tidal flat shape and associated environmental parameters in South San Francisco Bay. *Journal of Coastal Research* 26(2):342-349.
- Friedrichs C.T. 2012. Tidal flat morphodynamics: a synthesis. p.137-170. In: *Treatise on Estuarine and Coastal Science, Vol. 3, Estuarine and Coastal Geology and Geomorphology*. Hansom J.D. and B.W. Flemming (Eds).
- Pritchard D., A.J. Hogg and W. Roberts. 2002. Morphological modelling of intertidal mudflats: the role of cross-shore tidal currents. *Continental Shelf Research* 22:1887-1895.
- Roberts W., P. Le Hir and R.J.S. Whitehouse. 2000. Investigation using simple mathematical models of the effect of tidal currents and waves on the profile shape of intertidal mudflats. *Continental Shelf Research* 20:1079-1097.
- Van Maren D.S. and J.C. Winterwerp. 2013. The role of flow asymmetry and mud properties on tidal flat sedimentation. *Continental Shelf Research* 60S:S71-S84.