

Erosion characteristics and horizontal variability for small erosion depths in the Sacramento – San Joaquin River Delta, California, USA

Schoellhamer David H.¹ and Andrew J. Manning^{2,3,4}

¹ United States Geological Survey, 2130 SW 5th Avenue, Portland, OR 97201, USA
E-mail: dschoell@usgs.gov

² HR Wallingford, Howbery Park, Wallingford, Oxfordshire, OX10 8BA, UK

³ Department of Geography, Environment and Earth Sciences, University of Hull, Kingston Upon Hull, Humberside, HU6 7RX, UK

⁴ School of Marine Science and Engineering, Plymouth University, Drake Circus, Plymouth, Devon, PL4 8AA, UK

Cohesive sediment transport in the Sacramento – San Joaquin River Delta landward from San Francisco Bay affects habitat for pelagic organisms, contaminant transport, and marsh accretion, restoration, and sustainability. Several numerical models of sediment transport are being developed and applied to address these issues. Erosion algorithms are determined by calibrating model output to measured suspended-sediment concentration (SSC). To better inform and constrain numerical model development, an erosion microcosm has been used to quantify erosion and develop a conceptual model of erosion in the Delta.

Field methods for applying the microcosm are similar to those described by Dickhudt *et al.* (2011). Two sediment cores are collected from a study site with a gravity Gomex (The use of firm, trade and brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.) corer lowered to the bed from a small boat. After raising the corer back onto the boat, a 10-cm-diameter tube is immediately pushed into the top of each core to collect a sample. Samples are disturbed as little as possible. The top 1cm is also sampled for grain size and water content. A piston inserted into the bottom of the tube is used to push the sediment surface up to 10cm from the top of the tube. The subsampled core is eroded using a dual core University of Maryland Center for Environmental Science - Gust Erosion Microcosm System. A disk rotates at the water surface at the top of the tube and water is pumped through the water column in the tube at predetermined rates that provide nearly uniform and known shear stresses at the sediment/water interface (Gust and Mueller, 1997). Turbidimeters continuously monitor the effluent. A 0.01 Pa shear stress is initially applied to flush and stabilize the system. Applied shear stress

about 3 hours. Water samples are collected during each step to calibrate turbidity to SSC. The time series of erosion rate (kg/m²/s) is calculated and the erosion model of Sanford and Maa (2001) is used to calculate erosion parameters. The erosion rate E for an experiment as a function of mass eroded (m) and time (t) is

$$E(m,t) = M(m) [\tau_b(t) - \tau_c(m)] \quad (1)$$

Critical shear stress τ_c is calculated at the end of each step and is assumed to increase with m which in turn increases with erosion depth. The erosion rate constant $M(m)$ is assumed to be a constant for each step.

A total of thirty cores from four sites in the Delta were analyzed from November 2011 to July 2014. Erosion parameters showed no seasonal signal. Erosion rate constant $M(m)$ generally increased with eroded mass or depth. The mass eroded where the bed critical shear stress equals 0.4 Pa and the mean value of $M(m)$ between the surface and where τ_c equals 0.4 Pa increased with water content.

Initial critical shear stress as a function of solids volume of the mud matrix concurs with other empirical data presented by Dickhudt *et al.* (2011). It is noteworthy that initial critical shear stress for one particular site in South San Francisco Bay was smaller than expected. SSC at this site (typically 100-200 mg/l) is 1-2 orders of magnitude greater than in the Delta, so it is possible that suspended sediment in the corer settles and creates a fluid mud or that the top 1cm sample is not representative of water content or grain size because a thin fluid mud actually exists.

During a tidal cycle, observed changes of SSC in the Delta indicate that about 0.05 to 0.20kg/m² are eroded from the bed. This corresponds to an erosion depth of about 30 to 150 microns if erosion is uniform horizontally, about the diameter of a typical suspended floc. We believe that these small erosion depths and visual observation of horizontally varying biota and texture at the surface of the

□b is increased

sediment cores indicate that a conceptual model of erosion depending on horizontally varying properties (van Prooijen and Winterwerp, 2010) may be more appropriate than assuming horizontally homogeneous erosive properties. In addition, observed erosion rate constant $M(m)$ increases with depth, contrary to expectations for a consolidating bed, possibly because the eroding surface area increases as applied shear stress increases.

To test this hypothesis, we collected five cores at Franks Tract in the Delta and measured the horizontal variability of shear strength within each core in the top 5.08cm with a shear vane. Small tubes built by a freshwater worm and macroalgae were observed on the surface of all cores. Measurements were made near the four corners and edge midpoints of the Gomex corer because the shear vane is too large to insert in the 10-cm-diameter subsampling tube. The shear vane was inserted into the sediment until the top of the vane was at the top of the sediment, torque was applied to the vane until the sediment failed and the vane rotated, and the corresponding dial reading in Nm was recorded. In a typical application, the vane is inserted further into the sediment and the dial reading is divided by a constant to get the vane shear strength in kPa. Here we assume that the dial reading is proportional to the surface strength. The midpoints had greater strength than the corners. Standard deviations were 35% and 26% of the mean for corner and midpoint readings respectively. Thus an approximation is that the horizontal standard deviation of the critical shear stress is 30% of the mean. The shear vane test provides some empirical evidence that surface strength of the bed does appreciably vary horizontally. A numerical experiment is conducted to determine the observed SSC for a sediment core in the erosion microcosm with horizontally varying erosion properties.

References

- Dickhudt P.J., C.T. Friedrichs and L.P. Sanford. 2011. Mud matrix solids fraction and bed erodibility in the York River estuary, USA, and other muddy environments. *Continental Shelf Research* 31:S3-S13.
- Gust G. and V. Mueller. 1997. Interfacial hydrodynamics and entrainment functions of currently used erosion devices. p.149-174. In: Burt N., R. Parker, J. Watts (Eds). *Cohesive sediments*. Wallingford, UK.
- Sanford L.P. and J.P.-Y. Maa. 2001. A unified erosion formulation for fine sediments. *Marine Geology* 179:9-23.
- van Prooijen B.C. and J.C. Winterwerp. 2010. A stochastic formulation for erosion of cohesive sediments: *Journal of Geophysical Research*, v. 115, C01005, doi:10.1029/2008JC005189.