Evaluation of Intra-Site and Inter-Site Variability of Cohesive Sediment Erosion Properties

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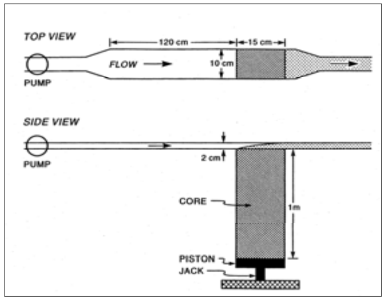
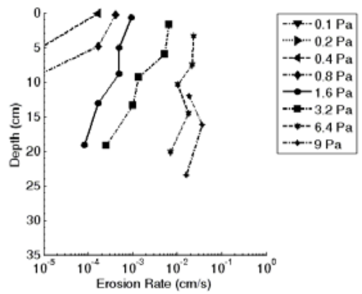
Abstract

Erosion rate data has been collected during Sedflume studies at a large number of contaminated sediment sites during the last 10 years. These data are useful for conducting modeling studies to investigate sediment stability during rare storms and net sedimentation processes over multi-year periods. The non-linear relationship between erosion rate and bed shear stress has made it difficult to quantify variability in the erodibility of cohesive sediment within a specific site and, also, between different sites. To solve this problem, a method has been developed to quantify differences in the erosion properties of cohesive sediment using Sedflume core data. This method accounts for the non-linear relationship between erosion rate and bed shear stress; it produces a single number for a particular Sedflume data series that represents the erodibility of that sample (i.e., erosion rate ratio). The erosion rate ratio may be used to make direct comparisons between Sedflume samples: 1) within a single core; 2) between cores at a specific site; and 3) between cores collected at different sites. Examples of all three types of comparisons will be used to demonstrate the utility of this method at sites in rivers, lakes, and estuaries.

Measurement of Sediment Erosion Rates





Sedflume (far left) directly measures erosion rate as a function of depth and hydrodynamic shear stress from field collected cores. It provides site specific quantification of erosion rates. The availability of measured erosion rates provides critical information for sediment transport analysis and modeling.

The figure to the left shows a series of erosion rates (x axis) as a function of depth (y axis) and shear stress (legend) for a laboratory reconstructed core of 20 micron cohesive sediment. The profile shows a general decline in erosion rate with depth due to consolidation of the material.

Erosion Rate Comparison

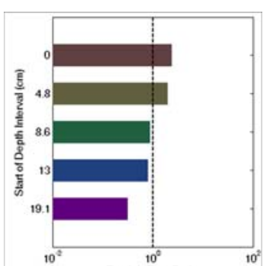
A useful method of analyzing sediment characteristics at a specific site is to compare the inter-core and intra-core Sedflume erosion rates. This method provides a means to quantify the erosion susceptibility within each core as well as the general erosion susceptibility of the coring site. In this analysis, each core has been sub-sampled into separate depth intervals. Following the methods of Roberts et al (1998), the erosion rate for each interval can be approximated by a power law function of sediment density and applied shear stress. The variation of erosion rate with density cannot be typically determined in the field due to natural variation in other sediment properties (e.g. mineralogy and particle size); therefore, the density term for a particular depth interval in a field core is parameterized. For each depth interval, the measured Sedflume erosion rates (E) and applied shear stresses (τ) can be used to develop the following equation.

$$E = A\tau^n$$

where E is the erosion rate (cm/s), τ is the shear stress (N/m²). The A parameter and n exponent are determined using a log-linear regression analysis.

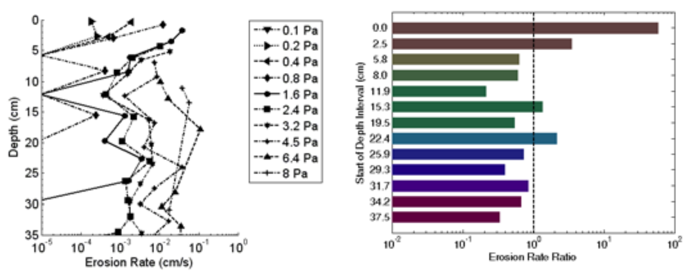
From this analysis an average erosion rate for a core can also be determined, and the erosion rate at each depth interval can then be directly compared to this average. The result is an erosion rate ratio which provides an estimation of the erosion susceptibility of each depth interval relative to the core average. In addition, a site-wide erosion rate average can be estimated that incorporates the data from all sampled cores. The erosion rate for each depth interval within a core is compared to the site-wide average and a graph of the erosion rate ratios for all of the cores is created.

Laboratory Core



The figure above shows erosion rate ratios for each depth interval in the core for a laboratory reconstructed core. The erosion rate ratios decrease from above average at the surface to below average at depth, illustrating the increasing resistance of the sediment to erosion with depth.

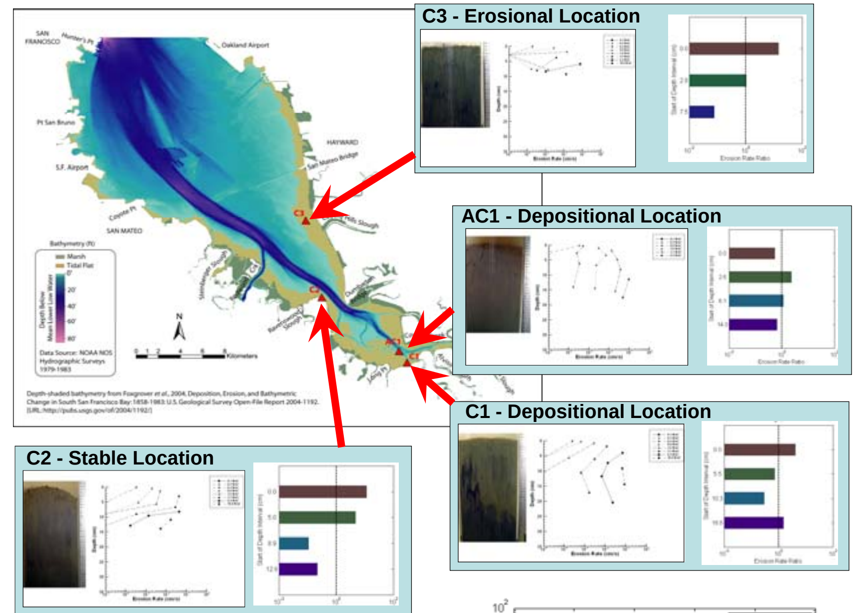
Field Core



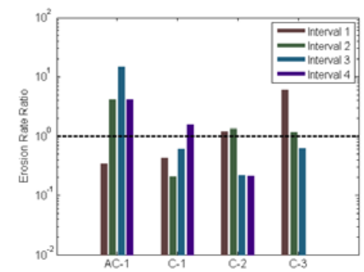
The figure above shows the measured erosion rates and resulting erosion rate ratios for a field collected core. The measured erosion rates illustrate the complexity in the raw erosion rate data. The erosion rate ratios decreases from above average at the surface to below average at depth and then again increases above the average value at approximately 15 and 22 cm. The erosion rate ratios more clearly illustrate the trends in the sediment and provide better qualitative and quantitative understanding.

Evaluation of Sediment Erosion Rates at a Site

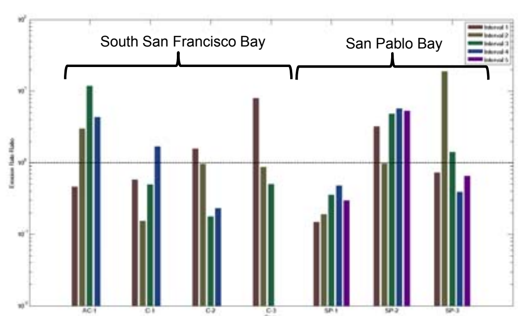
Four Sedflume cores were collected and analyzed in four different environments in South San Francisco Bay. Cores were collected at a depositional mudflat, depositional channel, a stable mudflat, and an erosional shoreline. The sediments at the four locations had marked differences, yet erosion rates alone were difficult to interpret. The use of erosion rate ratios yielded additional information about the spatial variations in sediment erodibility in the region and provided insight into subsequent conceptual model development and overall sediment transport trends.



The figure to the right shows the site-wide comparison of erosion rate ratios for the four cores above. The differences in the cores are evident in that the depositional sites have the higher erosion rate ratios at depth. The erosional site has a higher surficial erosion rate but is essentially non-erodible below the third depth interval. These trends are indicative of a physically disturbed surface on top of overconsolidated deeper sediment at the erosional site.



Evaluation of Sediment Erosion Rates at Multiple Sites



Comparison of the four cores from South San Francisco Bay with three cores from San Pablo Bay show interesting Bay wide trends where areas of greater and lesser erodibilty can be readily identified.

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