

Cooperating Parties Group

**LOWER PASSAIC RIVER RI/FS
NEWARK, NEW JERSEY**

APPENDIX M - ATTACHMENT D

**GUST MICROCOSM DATA AND
COMPARISON TO ENTRAINMENT
RATE**

Prepared by:



D.1 Introduction

The Gust microcosm study (CBA, 2006) involved erosion experiments on sediment cores from the LPRSA in 2005. The Gust Microcosm measures the erodibility of a relatively thin veneer of surficial sediments (on the order of millimeters) located at the sediment-water interface. This is in contrast to the depth intervals measured by Sedflume (described in Attachment E) which typically extends to deeper strata. Even the surficial depth-intervals measured in the Sedflume experiments typically extend over a few centimeters. Since the CPG's sediment transport model application involved the parameterization of the erodibility of a surface layer of easily erodible sediments (the fluff layer, parameterized using an analysis of PWCM data described in Attachment C) overlying more consolidated sediments (parameterized using Sedflume data as described in Attachment E), model inputs developed for the fluff layer were compared to the Gust Microcosm data as an independent verification of the model parameterization.

D.2 Core Locations and Experimental Setup

The sampling program consisted of cores collected from six locations (with duplicate cores at each location) in the LPRSA in 2005. Figure 1 shows the core locations (Site 13 was located at approximately RM 13). The cores were relatively short (~10cm), with some cores taken from locations in the shallows and some within the former navigation channel. With the exception of one core at RM 11, the remainder were within the lower 8 miles.

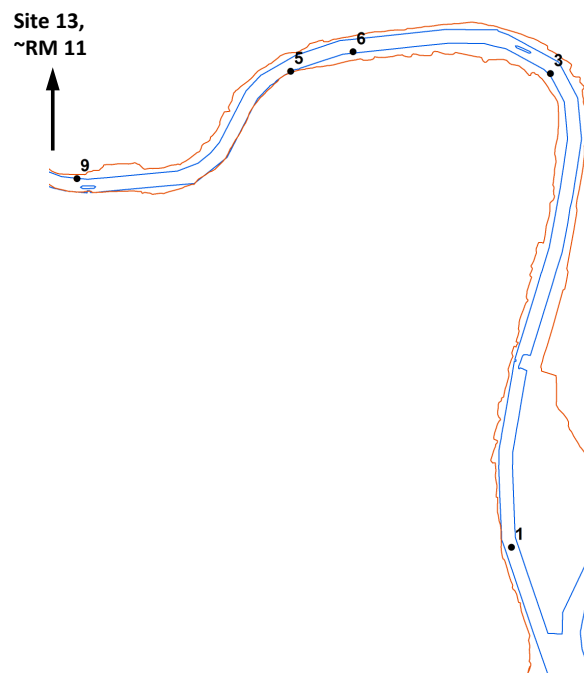


Figure 1. Core locations sampled for the Gust microcosm experiments.

The cores were subject to erosion measurements using a Gust Microcosm. Figure 2 shows a typical setup for erosion tests using the Gust Microcosm. The experimental setup consists of a rotating disc within the core tube, with a layer of continually refreshed water separating the disc from the sediment-water interface. The rotation speed of the disc is used to impose varying shear stresses, with a suction pipe located at center of the disc to extract the water containing eroded sediments. The experiment consists of seven 20 minute intervals, with increasing shear stress (0.01, 0.05, 0.1, 0.15, 0.2, 0.3, and 0.45 Pa). The turbidity of the extracted water is measured, converted to SS concentration, and in combination with the pumping rate, gives the eroded mass corresponding to the given shear stress.



Figure 2. Gust microcosm experimental setup (adapted from CBA, 2006).

D.3 Gust Microcosm Data

Using this data, and fitting the erosion rate as a linear function of the excess shear stress (Equation 1, where E = erosion rate, M = erosion rate parameter, τ = shear stress, and τ_{Cr} = critical shear stress for erosion), CBA (2006) reports the cumulative eroded mass, which is a surrogate for the depth of erosion, τ_{Cr} , and M .

$$E = M(\tau - \tau_{Cr}) \quad (1)$$

Figure 3 shows the measured depth profile of the critical shear stress for erosion from the Gust Microcosm experiments, with log scales used on both axes. Figure 4 shows the same information with arithmetic scales on both axes. Each panel in both figures includes results for the duplicate cores taken at each location. The measurements of cumulative eroded mass for each core were converted to an equivalent depth in the bed assuming a dry density of 327 kg/m^3 , which is the parameterization for surface dry density in the bed consolidation module. In addition to the shear stress profile measured in the Gust Microcosm

experiments, the shear stresses used in the model parameterization are also included in each panel. These correspond to the fluff layer (the top 1 mm of the sediment bed; critical shear stress = 0.25 dynes/cm²), the transition layer (sediments in the depth interval between 1-2 mm; critical shear stress = 2 dynes/cm²), and the surficial parent/deposited layer (sediments in the depth interval between 2-27 mm; critical shear stress = 4 dynes/cm²).

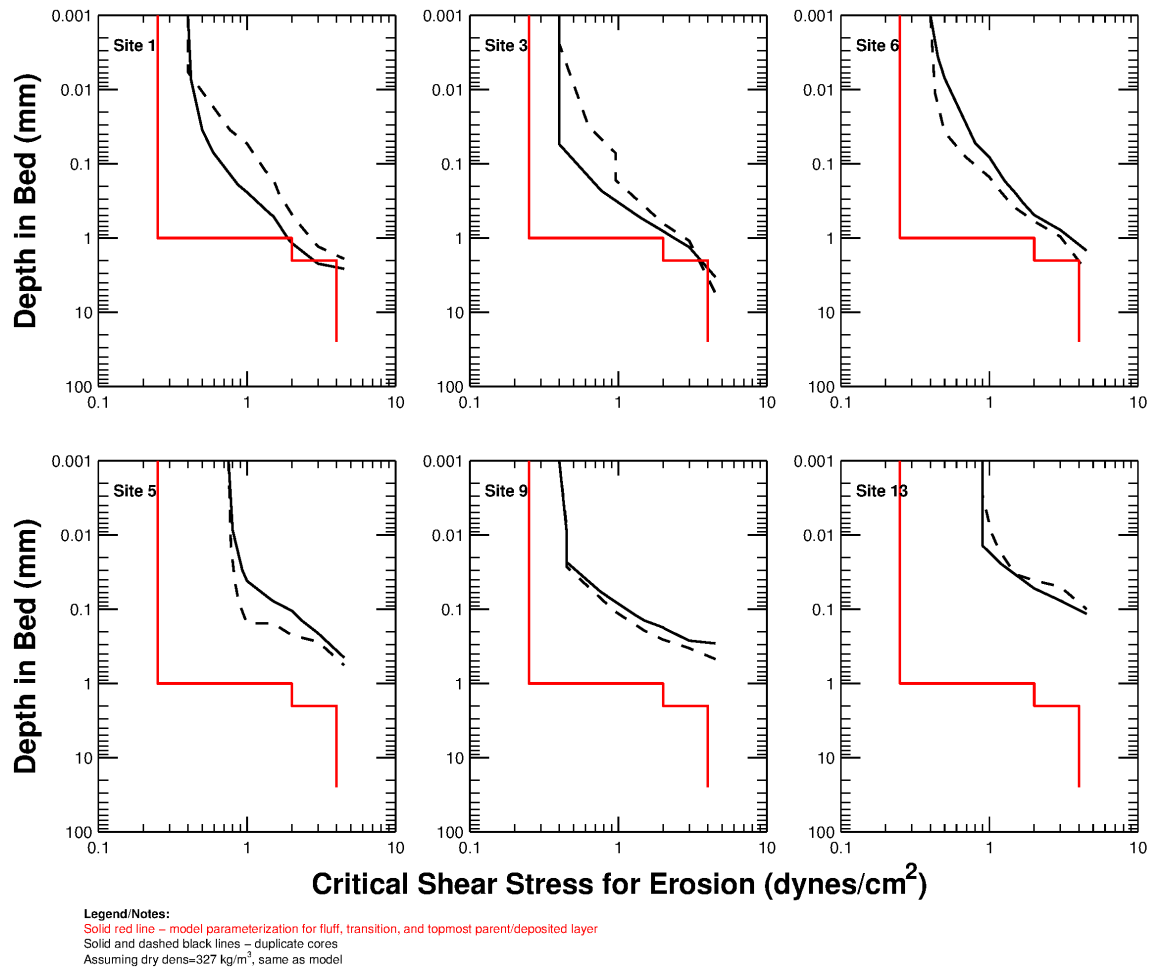


Figure 3. Depth-profile of critical shear stress measured in Gust Microcosm experiments (log-log axes).

The depth-interval sampled by the Gust Microcosm is seen to range only up to ~2 mm indicating the shallow pool of sediments eroded during the experiments. The main feature apparent in the data is an order of magnitude increase in the strength of the bed, or the critical shear stress for erosion, within the top 1-2 mm of the cores. This supports the CPG's ST model bed schematization, with a fluff layer (characterized by a relatively low critical shear stress for erosion) overlying less erodible layers (characterized by relatively high critical shear stress for erosion). The key point in the comparisons presented in Figure 3 and Figure 4 is the order of magnitude increase in critical shear stress from the fluff layer

to the surficial parent/deposited layer as parameterized in the model is similar to that noted for several of the cores sampled in the Gust Microcosm experiments.

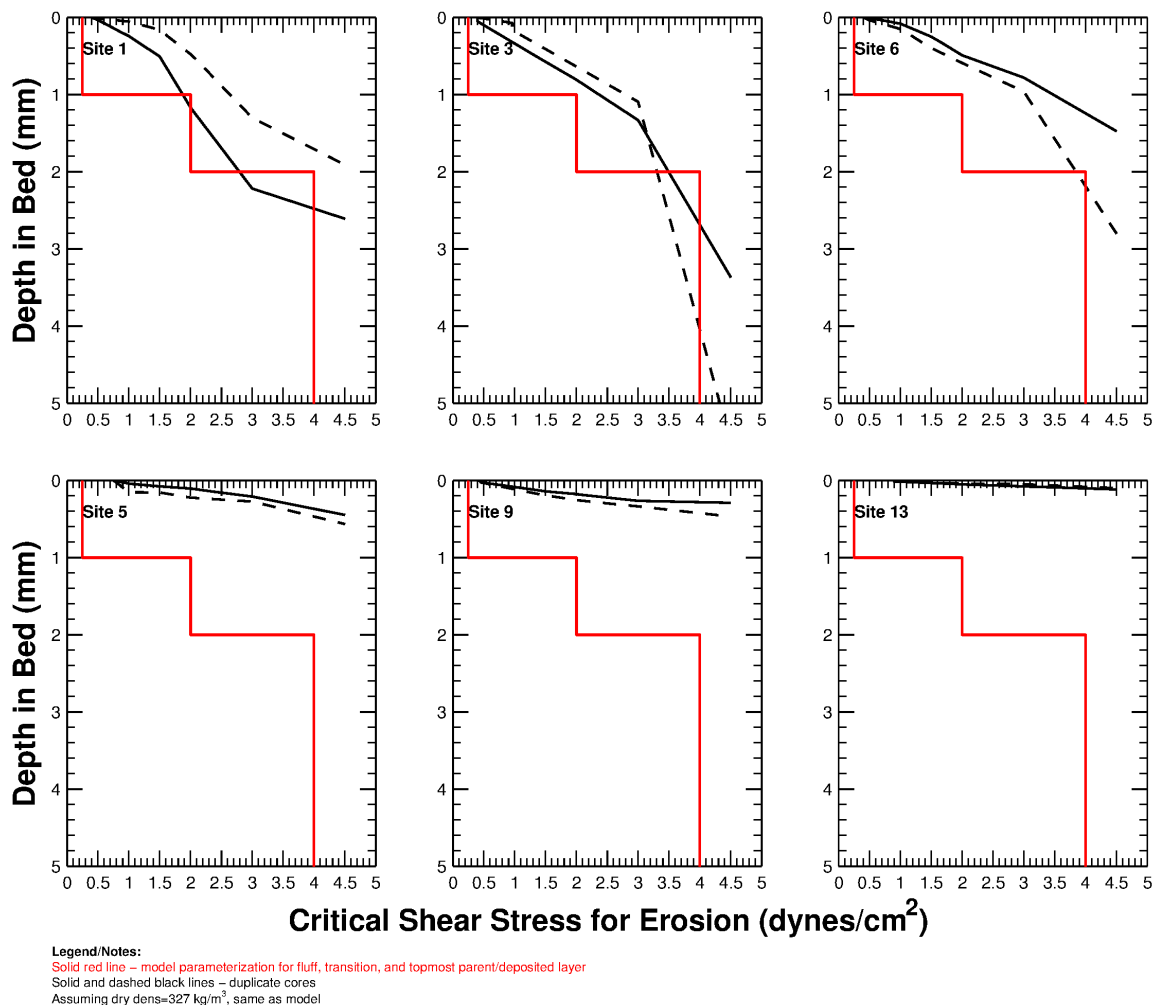


Figure 4. Depth-profile of critical shear stress measured in Gust Microcosm experiments (arithmetic scales on both axes).

It should be noted that a comparison between the model parameterization and the data in absolute terms, such as for the critical shear stress for the fluff layer, is confounded by a number of factors as listed below:

- The data represent the results of highly controlled experiments in a laboratory setting, with the imposed shear stresses calibrated and verified at fine spatial scales. However, the model parameterization reflects the fact that this is an application of a large-scale hydrodynamic model, subject to various model artifacts and limitations such as grid resolution, bathymetry, etc. that can affect the calculated currents and therefore shear stresses.

- The model parameterization is sensitive to features such as the Nikuradse roughness height, calculated in the LPRSA ST model as $2 \cdot D_{50}$. Soulsby (1997) gives an overview of this term, with alternatives ranging from $1.25 \cdot D_{35}$ to $3 \cdot D_{90}$, where D_{35} , D_{50} , and D_{90} refer to the 35th percentile, the 50th percentile, and the 90th percentile of the sediment grain size distribution curve. Thus, there is substantial disagreement about the value of the Nikuradse roughness height, which in turn implies uncertainty in the shear stress computed by the model.
- Different measurement methods do not result in the same parameter values (see Tolhurst et al., 2000), which also implies some uncertainty in the data.

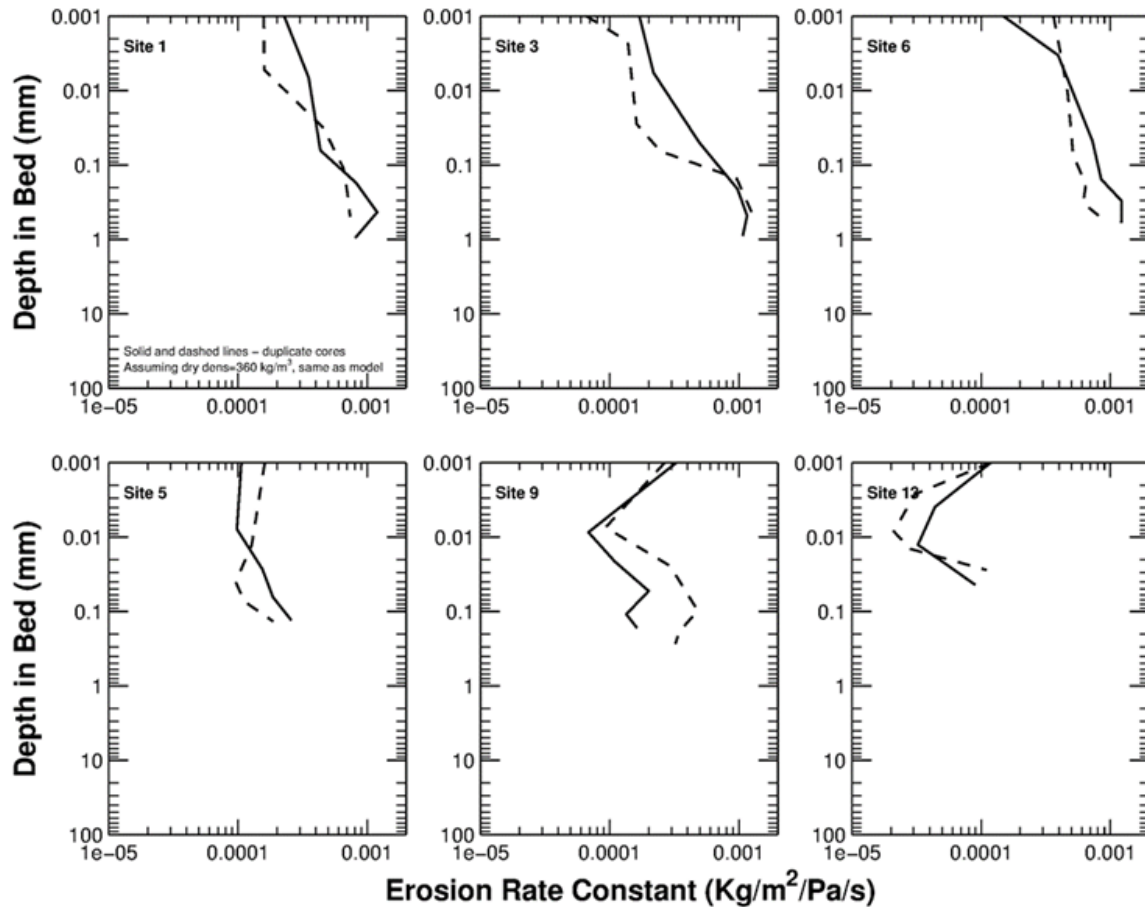


Figure 5. Depth-profile of erosion rate parameter M measured in Gust Microcosm experiments.

These sources of uncertainty influence the comparison of absolute values for the two datasets. Nonetheless, comparison of the relative trends seen in the data (the order of magnitude increase in critical shear stress within the top 1-2 mm of the bed) and that used in the model are still valid.

The depth profile of the erosion rate parameter M was also examined in a similar fashion as the critical shear stress for erosion as shown in Figure 5. However, no clear and consistent patterns are apparent in this case.

D.4 Comparison to Entrainment Rate Data

The measured erosion rate parameter M was also compared to the equivalent model inputs for a direct assessment of the model parameterization. As described in Attachment C, the equivalent model input which is the coefficient A in the ECOM-SEDZLJS erosion formulation (Equation 2, where A = erosion rate coefficient, and n = power term), was derived from an analysis of the entrainment rates measured in the Fall 2009 PWCM data.

$$E = A\tau^n \quad (2)$$

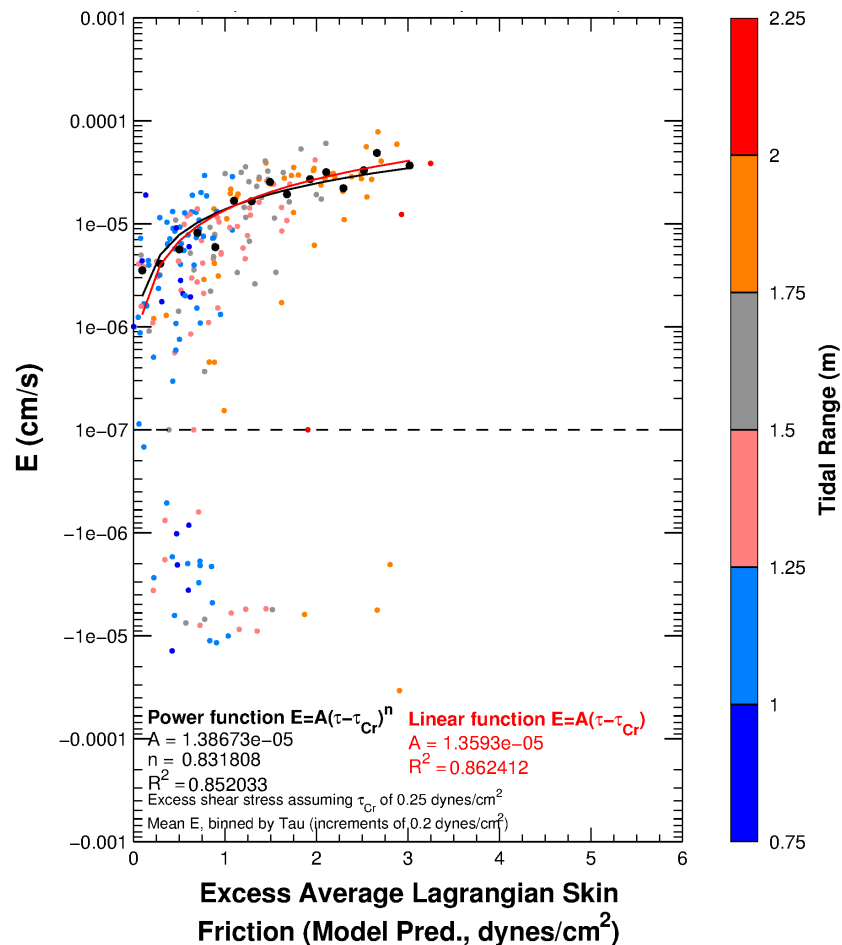


Figure 6. Entrainment rate (on Y-axis, in cm/s) from PWCM data plotted versus excess shear stress assuming critical shear stress of 0.25 dynes/cm²

However, as seen from the comparison to Equation 1, the two formulations are somewhat different. Therefore, for comparison to the Gust Microcosm measurements, the PWCM

data was reanalyzed and the entrainment rate (equivalent to erosion rate for purposes of this discussion) was plotted against the excess shear stress assuming $\tau_{Cr} = 0.25 \text{ dynes/cm}^2$ (same as the model parameterization for the fluff layer). Figure 6 shows the resulting relationship, with the trend best characterized by a power function (Equation 3; shown with black line in Figure 6) with coefficient $A = 1.39 \times 10^{-5} \text{ cm/s}/(\text{dynes/cm}^2)^n$, and $n = 0.83$.

$$E = A(\tau - \tau_{Cr})^n \quad (3)$$

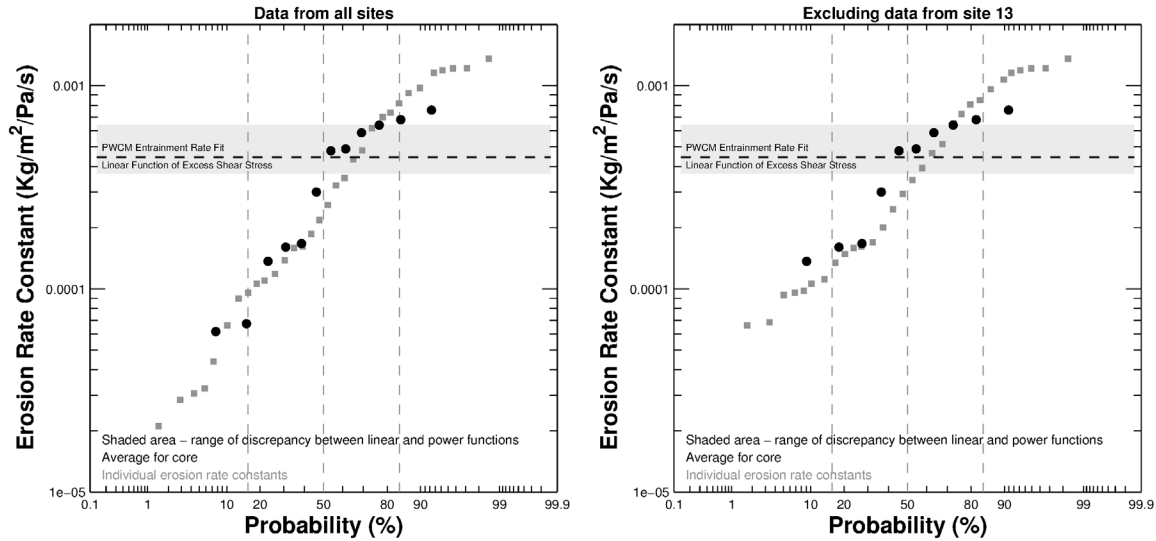


Figure 7. Probability distributions of erosion rate parameter measured in the Gust Microcosm experiments compared to the entrainment rate parameter calculated from the PWCM data.

However, $n \neq 1$, and given the objective of comparing to the erosion rate parameter from the Gust Microcosm experiments, Equation 3 has been approximated as a linear function of the excess shear stress (shown with red line in Figure 6) with $A = 1.36 \times 10^{-5} \text{ cm/s}/\text{dynes/cm}^2$ or $4.45 \times 10^{-4} \text{ kg/m}^2/\text{Pa}$ using dry density of 327 kg/m^3 . The linear and power functions are seen to be very similar in terms of the function fits, value of parameter A , and the correlation R^2 . The term A from the linear relationship is the equivalent of the erosion rate parameter M from the Gust Microcosm experiments and is compared to the full range of measured M values over the various depth intervals in each core, as well as an average M per core in Figure 7. The left panel in Figure 7 includes data from all the sites, and the right panel only includes the cores from the lower 8 miles which are characterized by predominantly fine sediments. The value of parameter A resulting from the linear approximation of Equation 3 is indicated by the horizontal dashed line and is seen to be comparable to the median of the distribution of average M for each core. Over the range $0.1\text{--}4 \text{ dynes/cm}^2$ of excess shear stress, the power function in Equation 3 calculates erosion rates that are between -20% and $+50\%$ of the erosion rate from the linear approximation of Equation 3. Incorporating this range into the value of A from the linear approximation results in the grey shaded region indicated in the probability distributions in Figure 7, with

the range of values resulting from the power function also seen to be within the range of measured M values.

D.5 Conclusions

The measurements from the Gust Microcosm experiments have been reviewed and compared to the entrainment rate analysis from the PWCM data. The measurements from the Gust Microcosm experiments support the bed schematization adopted for the LPRSA ST model. The depth-profile of critical shear stresses measured by the Gust microcosm show the presence of an easily erodible layer overlying more consolidated sediments, with approximately an order of magnitude increase in critical shear stress in the top 1-2 mm of the bed. This is similar to the bed schematization and the parameterization adopted for the ST model. Furthermore, the erosion rate parameter resulting from the entrainment rate analysis used to parameterize the fluff layer in the ST model is also seen to be within the bounds of the measured range of erosion rate parameters from the Gust Microcosm. Both these comparisons to measured erosion rate parameters provide an independent verification of the bed schematization in the ST model and the parameterization of the fluff layer.

D.6 References

Soulsby, R.L., 1997. Dynamics of marine sands—A manual for practical applications. Thomas Telford Publications, London.

Tolhurst TJ, Black KS, Paterson DM, Mitchener HJ, Termaat GR, and Shayler SA (2000) A Comparison and Measurement Standardisation of Four In Situ Devices for Determining the Erosion Shear Stress of Intertidal Sediments. Cont Shelf Res 20:1397-1418.