Entrainment of Sediment Into Suspension

A number of different formulations exist. Like boundary layer formulations, a level is sought where deposition balances entrainment.

Most formulations are tied to the idea of estimating *E* in the formula

$$Flux = w_s\left(E - \overline{C}_b\right) \tag{11}$$

where the *Flux* is the vertical flux of sediment at some height above the bed. $\overline{C}_b$ is the volumetric concentration at that height. This often serves as the bed-boundary condition for suspended load calculations (discussed next lecture).

The dimensionless entrainment coefficient *E* will necessarily be a ratio of the ability to move sediment (turbulence) and the settling velocity of the sediment. Because it equates with a near bed concentration, sometimes it will be referred to as the "reference concentration."

One possibility is $u_* \sim w_s$ for entrainment (Garcia and Parker, 1991)

Therefore we create the ratio u_*/w_s and estimate

$$E = \frac{AZ_u^5}{1 + \frac{A}{0.3} Z_u^5} \tag{12a}$$

where

$$A = 1.3 \times 10^{-7};\ Z_u = \frac{u_*}{w_s} Re_p^{\ 0.6};\ Re_p = \frac{D\sqrt{RgD}}{\nu} \tag{12b}$$

This formulation was derived for sandy flows and does not require any coefficients to be measured *in situ*. It works remarkably well for sandy flows, but cannot easily incorporate fine-grained effects.

Many alternatives exist. One of the most successful models based upon standard open-channel flow experiments is that of Smith and McLean (1977), where –

$$E = 0.65 \frac{\gamma\left(\tau_s^* / \tau_c^* - 1\right)}{1 + \gamma\left(\tau_s^* / \tau_c^* - 1\right)} \tag{13}$$

where $\gamma = 0.0024$ and τ_c^* is the critical shear stress. An advantage of the Smith and McLean model is that they provide a method to estimate the height of the reference concentration, when used in sandy environments –

$$b = 26.3D\left(\tau_s^* / \tau_c * -1\right) + k_s \tag{14}$$

The form of Smith-McLean is similar to ‘Lickian’ entrainment relations (named for Wilbert Lick, UCSB) that take the general form –

$$E = \alpha\left(\tau_s^* / \tau_c^* - 1\right)^\gamma \tag{15}$$

where α and γ are empirical constants.

The problem with Lickian relations is that a τ_c^* needs to be assumed. τ_c^* is dependent on both sediment and flow characteristics, therefore it is extremely difficult apply these laboratory-derived relations to the field.