Seoul National University

457.562 Special Issue on River Mechanics (Sediment Transport)
.06 Sediment Transport Basic

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1. Sediment transport

- Sediment load
  - Classification based on mechanism
    - Suspended load
    - Bed load
  - Classification based on particle size
    - Wash load
    - Bed-material (sediment) load
- Total sediment load
  - Wash load
  - Suspended load (bed material load)
  - Bed load (bed material load)

2. Sediment transport modes: bed-material load and Wash load

- While bed-material load (suspended and bed) can be quantified, wash load is hardly done.
- Wash load can deliver clay, silt (<0.062) and from the land surface erosion rather than from the channel bed.
- Also many pollutants are attached and delivered by wash load.
- But, still hard to know exact amount

2. Sediment transport modes: bed-material load and Wash load

- Energy balance equation of suspended load
- This is not accepted but…the average rate of work (pow et)

$$P_g \equiv \rho gSUH + \rho RgSCUH - \rho RgHCv_S$$

  - The first term of the right hand side is mean rate of energy input to the fluid phase
  - The second is mean rate of energy input to the mean flow t hrough solid phase
  - Mean rate of energy loss by mean flow through turbulent mixing required for maintain sediment in suspension

2. Sediment transport modes: bed-material load and Wash load

$$P_g \equiv \rho gSUH + \rho RgSCUH - \rho RgHCv_S$$

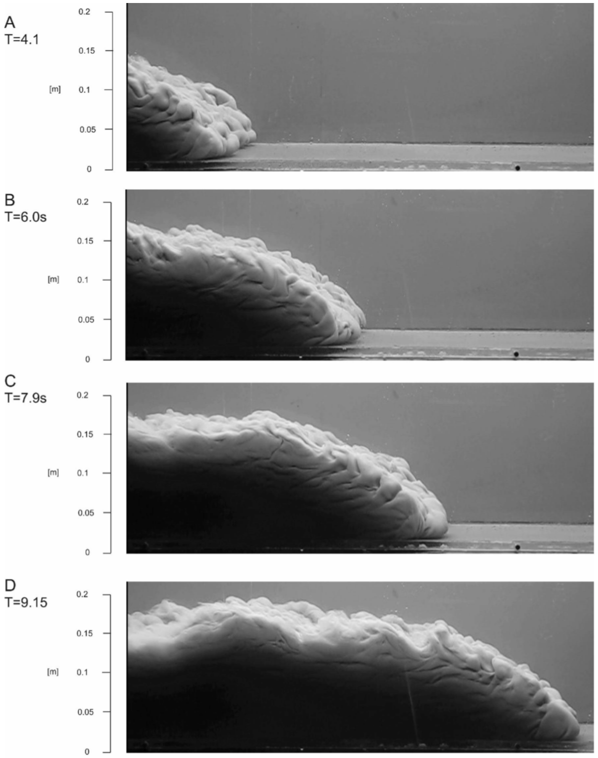
- If second term is larger than the third term, suspended lo ad contribute energy to the flow.
- In opposite condition, suspended particle depletes energi es from the flow.
- In the turbidity current, the first term (clean water) do not contribute to the current.
- Also to produce current, second term need to be larger t han the third term

$$\rho RgSCUH > \rho RgHCv_S$$

$$\frac{US}{v_s} > 1 \quad \text{(Bagnold criterion for turbidity currents)}$$

2. Sediment transport modes: bed-material load and Wash load

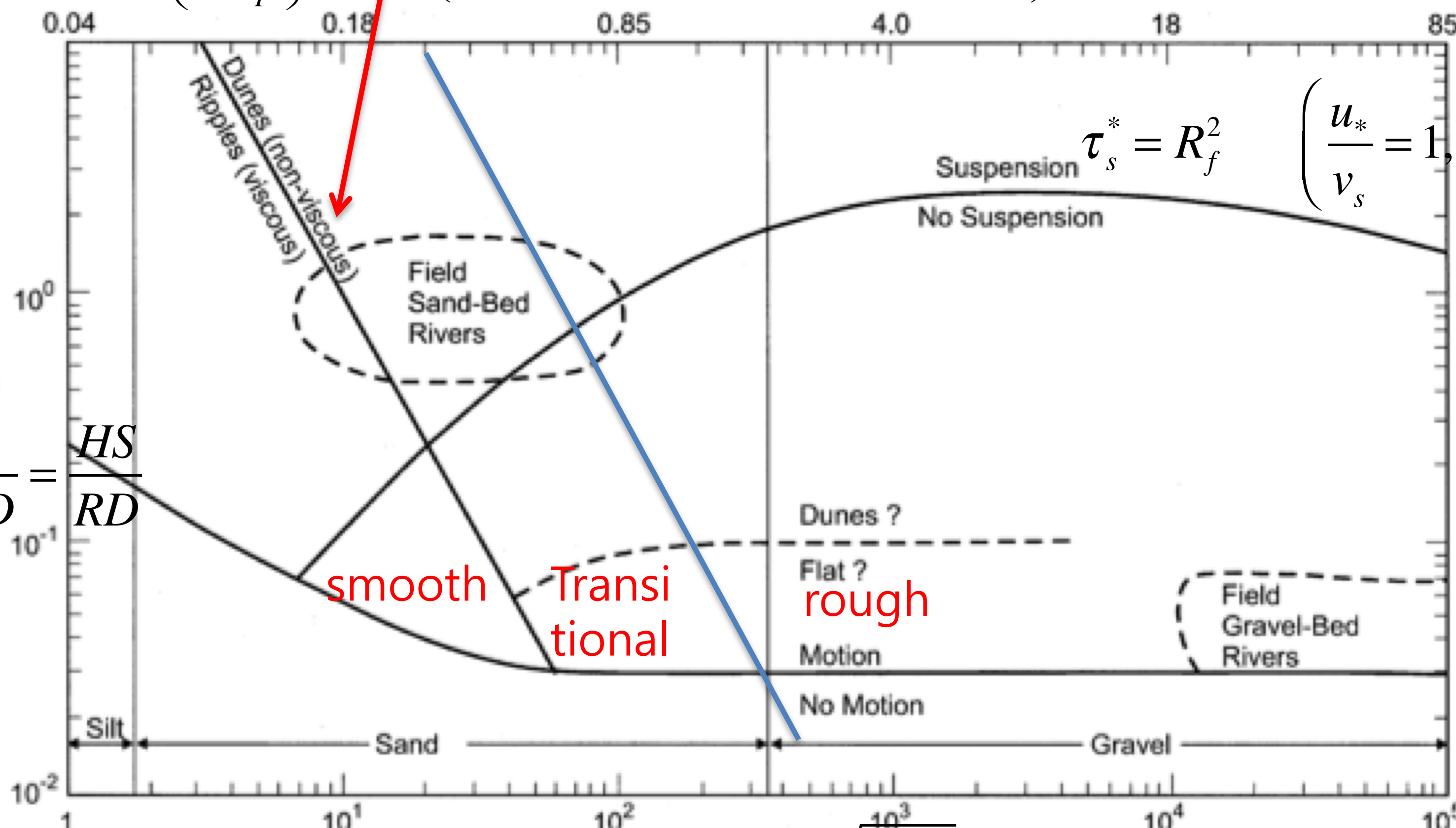
- Bagnold criterion for turbidity current ensures that the sediment supplies more energy than it consumes.
- It must be satisfied if a self-sustaining turbidity current is to occurs.
- As in the reading material, there are several criterion on the suspended load, but not any thing can tell the quantity of the suspended load.
- But still it needs to be understood for the morphological variability



3. Shields-Parker River Sedimentation Diagram

$$\tau_v^* = \left(\frac{11.6}{\mathrm{Re}_P}\right)^2 \qquad \left(\frac{u_* D}{\nu} = 11.6,\ viscous\ sublayer\right)$$

$$\tau_s^* = R_f^2 \qquad \left(\frac{u_*}{v_s} = 1,\ \tau_s^* = \frac{u_*^2}{gRD}\right)$$



$$\tau^* = \frac{\tau_b}{\rho g R D} = \frac{HS}{RD}$$

$$R_{ep} = \frac{\sqrt{gRD}\,D}{\nu}$$

4. Bedload Transport Function

- The transport occurs tangential to the bed.
- All of the transport is directed in the streamwise, or s dire ction.
- The volume bedload transport rate per unit width (n-direc tion) is given by usually q. And q is function of boundary shear stress and other parameters;

$$q = q\left(\tau_b, \text{ other parameters}\right)$$

5. Erosion into and deposition from, suspendion

- The volume rate of erosion of bed material into suspension per unit bed area denoted a *E*.
- A dimensionless sediment entrainment rate E can thus be defined in terms of the sediment fall velocity v_s.

$$E = v_s \mathrm{E}$$

- In general, E can be expected to be a function of boundary shear stress and other parameters.
- Erosion into suspension can be taken to be directed upward normal, i.e., in the positive z, direction (parallel to e_3)

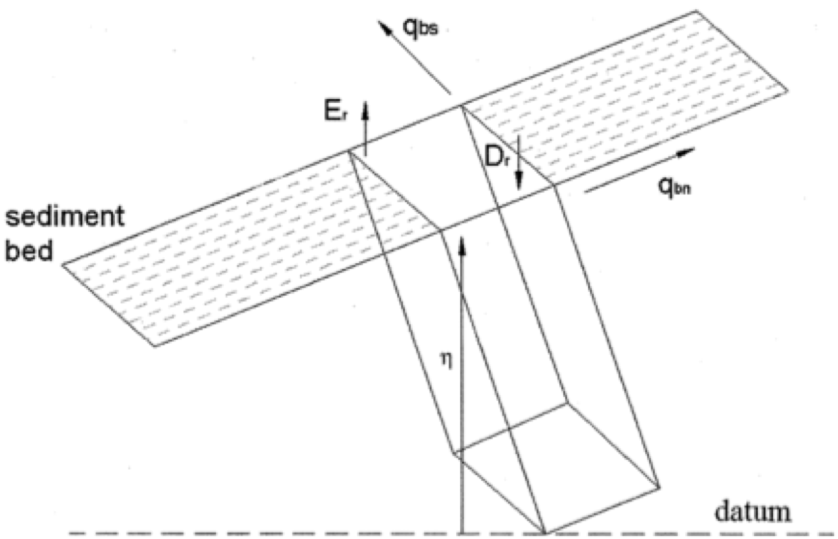
5. Erosion into and deposition from, suspension

- Let $\overline{c}(x_i, t)$ denote the volume concentration of suspended sediment, averaged over turbulence.
- The streamwise volume transport of sediment per unit width is given by

$$q_s = \int_0^H \overline{cu}\, dz$$

- In a two-dimensional case, two components q_{Ss} and q_{Sn} result, where

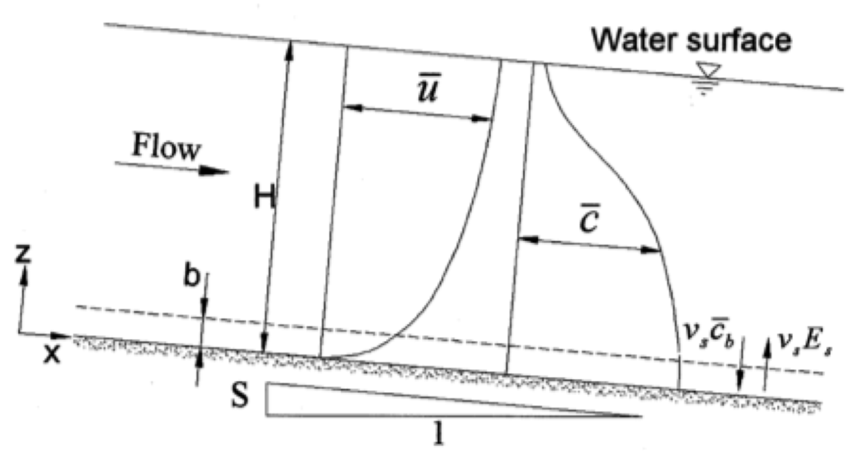
$$q_{Ss} = \int_0^H \overline{cu}\, dz; \qquad q_{Sn} = \int_0^H \overline{cv}\, dz$$



5. Erosion into and deposition from, suspension

- Deposition onto the bed is by means of settling. The rate at which material is fluxed vertically downward onto the bed is given by $v_s \bar{c}_b$ where $\bar{c}_b$ is a near bed value of $\bar{c}$.
- The deposition rate D realized at the bed is obtained by computing the component of this flux that is actually directed normal to the bed:

$$D = v_s \bar{c}_b \vec{k} \cdot \vec{e}_3$$



5. The Exner (founder of morphodynamics) equation

- Exner equation of sediment mass continuity uniform mat erial
- The bed material is taken to have a (constant) porosity λ_p
- Mass balance of sediment requires that the following equ ation be satisfied

$$\frac{\partial}{\partial t}\left[\text{mass of bed material}\right] = \text{net mass bedload inflow rate}$$

$$+ \text{net mass rate of deposition from suspension}$$

- The time rate of change of bed position is given by

$$\dot{z}_b \equiv \frac{\partial z_b}{\partial t}$$

5. The Exner equation

- The equation translates to

$$\rho_s \left(1-\lambda_p\right)\frac{\partial}{\partial t} z_b dsdn =$$

$$\rho_s \left(q_s\big|_s - q_s\big|_{s+ds} \right) dn + \rho_s \left(q_n\big|_n - q_n\big|_{n+dn} \right) ds + \rho_s \left(D - E \right) dsdn$$

- It reduces to

$$\left(1-\lambda_p\right)\dot{z}_b = -\frac{\partial q_s}{\partial s} - \frac{\partial q_n}{\partial n} + v_s \left(\bar{c}_b \vec{k} \cdot \vec{e}_3 - \mathrm{E} \right)$$

- If the bed is horizontal (or nearly horizontal), so that z is directed upward vertical, $\dot{z}_b = \partial \eta / \partial t$ and $\vec{k} \cdot \vec{e}_3 = 1$

$$\left(1-\lambda_p\right)\frac{\partial \eta}{\partial t} = -\frac{\partial q_s}{\partial s} - \frac{\partial q_n}{\partial n} + v_s \left(\bar{c}_b - \mathrm{E} \right)$$

5. The Exner equation

- Bed level changes with time t due to bed load transport, sediment entrainment into suspension, and sediment deposition onto the bed can be predicted by Exner's equation.
- To solve this equation, it is necessary to have relations to compute bed load transport, near-bed suspended sediment concentration and sediment entrainment into suspension.