CE440
Erosion and Sedimentation
Lecture Notes on Chapter 5

Text Reading: pp. 205-242

Important terms:

Erosion - Removal of granular material (sediment). The major mechanisms include water, wind, ice, and gravity. A geologist might prefer the narrower definition that refers to the breaking of the bond between sediment grain and the underlying material (formation of the grain itself).

Sedimentation - Deposition of sediment. "Sedimentation" is often used to describe both erosion and deposition.

Denudation

Geomorphology

Aggradation / Degradation

Sheet erosion, rill erosion, gully erosion

Washload, bed material load

Suspended load, bedload

Delivery ratio

Enrichment ratio

Shear stress

Dimensionless shear stress

Erosion and sedimentation requires:
- Gravity
- Fluid - we focus exclusively on water
- Topography
- Erodible material

Two fundamental controls:
- the transport capacity of the flow
- the availability of material to transport

Variables that influence quantity and quality of sediment vs. variables that influence capacity:

Quantity and quality of sediment
- geology
- topography
- watershed / network characteristics
- magnitude, intensity, duration, distribution, and season rainfall
- soil type / condition
- vegetation
- land uses such as agriculture, urbanization, grazing etc.
- surface erosion
- bank cutting and channel erosion
- others?

Capacity:
- fluid properties
- slope
- roughness
- depth or hydraulic radius
- discharge
- velocity
- velocity distribution
- turbulence
- tractive force (shear)
- size and gradation of the sediment
- others?

Two primary sources of sediment:

- material from the watershed and stream banks; and
- bed material that makes up the stream bed.

Sources of sediment and practices resulting in excessive erosion—see pages 213-215.

Impacts of erosion and sedimentation—why do we care?

Eutrophication—why?
Habitat loss—examples?
Transport of pesticides, PCB’s and other organics to receiving waters
Reduced recreation
Reduced reservoir life
Loss of productivity from <u>lack</u> of sediment—example?
Channel scour from lack of sediment—example?
Aquatic life / ecological integrity
Others?

USDA soil textural triangle – be sure you know how to get % sand, silt, and clay for different soil types

Estimating sediment yield for a watershed, pages 218-235

- Measurements – event oriented
- Bed material load—difficult to sample
- Wash load
- Reservoir sediment surveys
- "Representative" storms
- Used to develop rating curves

- Models
  - Most highly empirical
    - Rating curves, see figure 5.10 on page 252.
    - USLE and delivery ratio
  - Some more physically based

Estimating Erosion using the **Universal Soil Loss Equation**

A = RK(LS)CP

A = annual soil loss in metric tons/acre
R = rainfall energy factor
K = soil erodibility factor
LS = slope length factor
C = crop management factor
P = erosion control practice factor

Rainfall erosivity factor

- Annual values in Fig 5.12
- Single storm values, equation 5.3 on page 220

Modification of USLE for soil detachment by overland flow, equation 5.5.

Dimensionsless Adjustment Factors

Soil Erodibility Factor, K, found in Figure 5.14 or Table 5.3, pages 223-224.

Slope Length Factor, LS, adjusts for length and steepness

- LS = 1 for 22m length and 9% slope
- Equation 5.6 and Figure 5.15 on pages 224-225

Crop Management Factor, C

- C = 1 for continuous fallow
- Values in Tables 5.4-5.5 on pages 225-227
- Table 5.5 has C values for construction sites and mulch practices

Erosion Control Practice Factor, P

Tables 5.6 and 5.7 on pages 228-229 and handouts

Work through Boxes 5.2 and 5.3 on pages 230-232

Modifications of the USLE: MUSLE, RUSLE, WEPP

Sediment Delivery Ratio

Definition

Rough annual values may be obtained from Figure 5.16, based on watershed area. However, site-specific values will vary greatly. Note the quote from Wolman near the top of page 234.

Some computer models include sediment routing capability which considers the sediment carrying capacity of overland and/or stream flow and accounts for deposition of sediment in excess of this capacity.

Enrichment Ratio

Definition from Chapter 2

Enrichment by clay, see equation 5.24 on page 288

> Relationship to delivery ratio, see figure 5.25 and equation 5.25 on page 290. If 5.25 holds, then the net result is pretty much a wash for clay. This implies that if a chemical is largely adsorbed on clay, then most of what is eroded would be delivered to the outlet of the watershed. (Obviously, the mass of clay delivered to the outlet of the watershed must be the same or less than the amount eroded, and the total amount of any chemical adsorbed on the clay that is delivered to the outlet must be the same or less than the total amount eroded.)

Enrichment by organic matter -we do not have a good relationship with delivery ratio for OM.

The overall enrichment is really a combination of the two enrichment ratios.

For **annual loads**, a rule-of-thumb type number to use for overall enrichment is ER = 2.

Sediment Transport in Streams

Sediment is transported by rolling, sliding or skipping on the bed (bed load or contact load) or by suspension via the turbulence of the stream.

Three ways to classify modes of sediment transport:
1. Where and how it moves (bed load vs. suspended load)
2. Where it came from (bed material load vs. wash load)
3. Whether it's measured on not (measured vs. unmeasured)

Total Load = Bedload + Suspended Load = Bed Material Load + Washload = Measured Load + Unmeasured Load

Sand and coarser material may move as **bedload**. For practical purposes, gravel and coarser sediments are only transported as bedload (exceptions in the case of gravel might occur in mega events). As a general approximation, particles coarser than about 1 mm almost always move as bedload, particles smaller than 0.1 mm predominately move as suspended load, and particles from 0.1-1 mm are frequently transported in both modes.

Washload is not transported at the capacity of the stream and is not functionally related to measurable hydraulic variables. Instead, washload depends on the supply of fine sediments. There is no sharp demarcation between washload discharge and bed sediment discharge. Washload is often assumed to be silt and clay fractions (d <0.0625 mm) or sizes less than the d_{10} of the bed material.

Dimensional Analysis

- Shear stress, dimensionless shear stress
- Shields diagram

More on Sediment Measurement

Varies tremendously in time and space

Measurement accuracy and precision are affected by:
- discharge
- antecedent conditions
- pulse / stochastic phenomena
- hydrograph hysteresis (rising vs. falling limb)
- sampler design (efficiency, effects on flow)

Bedload
- Helley-Smith sampler
- traps
- bags

Suspended
- point-integrated
- depth-integrated
- siphon bottles
- grab samples
- pump samplers (e.g. ISCO)

Even after many years of observation, estimates of suspended load and bedload typically involve 25-50% and 50-100% uncertainty, respectively (even for the same location and discharge)

If G = 2.65, then 1 mg/liter of sediment corresponds to roughly:

- 90 particles of very fine sand
- 90,000 particles of medium silt
- 90,000,000 particles of fine clay

Implications for turbidity and aquatic biota?

At the sediment concentrations commonly found in many rivers (<10,000 ppm), 1 ppm is equivalent to 1 mg/l for practical purposes (per Homework 2).

Sediment rating curves

Often a relationship of the form Q_s=aQ^b or q_s=aq^b

Logarithmic transformation of data induces systematic error, there are many correction techniques