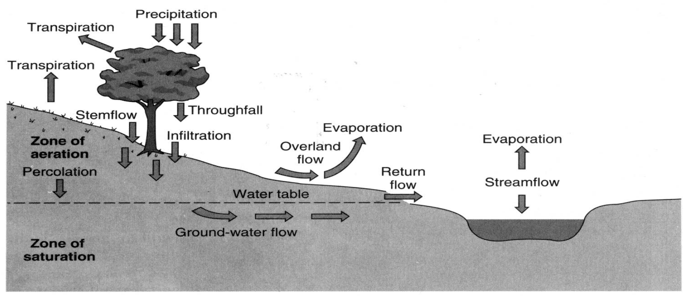
Soil Hydraulics & Stream Hydrology



- Vegetation & Soil Biota
  - Canopy (increases H_2O infiltration)
  - Plant roots & soil organisms (promotes ⇓ percolation)
- Soil Texture
  - Related to H_2O infiltration rates
  - Soil porosity = 1.00 - (bulk density)/2.66 X 100%
- Flow of Soil Water
  - Field capacity (H_2O-holding capacity)
  - Darcy's Law (flux = k*I*A)

Stream Load

- Dissolved Ions (chemical weathering)
  - Rainfall
  - Soil Solution
- Particulates (mechanical weathering)
  - Surface Erosion
    - Size range (clay colloids to large boulders)
  - Concepts of suspended load & bed load

C/N/P Biogeochemical Transformations

- Carbon in Small Streams
  - Allochthonous inputs dominate
    - Dissolved organic compounds (DOC)
      - carbohydrates/amino acids/humic acids
    - Particulate organic compounds (POC)
    - DOC & POC increase with increasing streamflow
      - ⇑ Fraction of water derived from overland flow

C/N/P Biogeochemical Transformations

- Carbon in Small Streams
  - Bear Brook (NH)
    - DOC (42%)
    - POC (57%)
    - Autochthonous Algae & Moss (~0.2%)

C/N/P Biogeochemical Transformations

- Carbon in Large Rivers
  - Autochthonous OC inputs
    - Phytoplankton & rooted plants
    - Easily assimilated by higher trophic levels
    - Transport of OC fuels large heterotrophic bacterial population
      - Most major rivers supersaturated with CO_2
  - Allochthonous OC inputs still dominate

Total Riverine Transport of Organic C

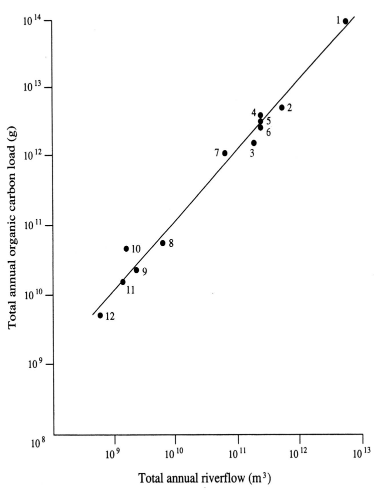


Figure 8.3 Total annual load of organic carbon shown as a logarithmic function of total annual riverflow for major rivers of the world. Rivers 1–7 are among the 50 largest: 1, Amazon; 2, Mississippi; 3, St. Lawrence; 4, MacKenzie; 5, Danube; 6, Volga; and 7, Rhine. From Schlesinger and Melack (1981), with a revision of the data for the St. Lawrence derived from Pocklington and Tan (1987).

- Small Watersheds
  - Estimate Allochthonous Inputs
  - Global summation
- Large Rivers
  - Measure OC loads near mouth
  - Compile annual flow estimates
- Estimates Differ By…
  - OC metabolized within system
  - OC deposited in floodplains/dams

<u>Global Riverine Transport of OC:</u>

0.3-0.5 X 10^{15} grams C/year

Inorganic Nitrogen & Phosphorus

- Autochthonous productivity limited by nutrients (N & P)
- Decomposition of coarse particulates decreases C/N & C/P ratios
  - Immobilization of N & P by decomposers of OM
    - Inorganic NO_3 & NH_4 converted into organically bound N
- ⇑ Fraction of stream N & P in particulate & organic forms
  - ~87% of nitrogen in organic forms
  - ~100% of phosphorus in particulate forms
    - Absorbed on sediments and suspended materials

Nutrient Spiraling

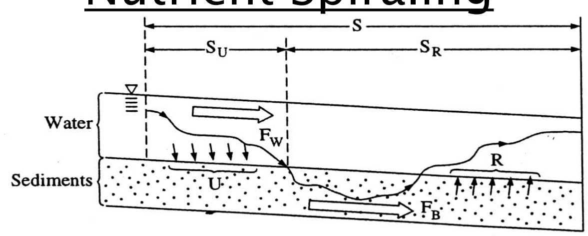


Figure 8.4 Nutrient spiraling in a two-compartment stream. Spiraling length, *S*, is the sum of the uptake length, S_U, and the remineralization length, S_R. F_w is the downstream flux of dissolved nutrients in the water compartment and F_b is the downward flux in the particulate compartment. Modified from Newbold et al. (1982).

- Cycle between organic & inorganic forms
  - Occurs most rapidly when biotic activity is highest
  - Spiral length = inverse index of stream metabolism
    - Estimate turnover using isotopic tracers (^{15}N & ^{32}P)
- Tennessee stream:
  - Phosphorus downstream velocity = 10.4 m/day
  - Cycles once every 18.4 days
  - Spiral length = ~190 meters ($S_U + S_R$)

Other Dissolved Constituents
($Ca/Mg/Na/Si/Cl/SO_4/HCO_3$)

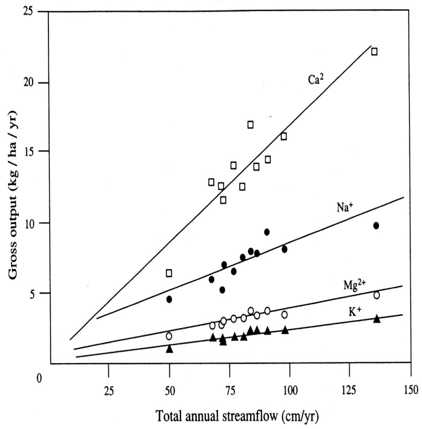


Figure 8.5 Annual streamwater loss of major cations as a function of annual stream discharge in the Hubbard Brook Forest, New Hampshire. From Likens and Bormann (1995).

<u>'Simple Geochemical Model'</u>

⇑ Concentrations at low flow

- Soil Water (equilibrium)

⇓ Concentrations at high flow

- Precipitation & surface runoff

<u>'Real World'</u>

⇑ Flow dominates over dilution

Total Transport is Greater in Rivers with High Discharge

Other Dissolved Constituents
(Gibbs 1970)

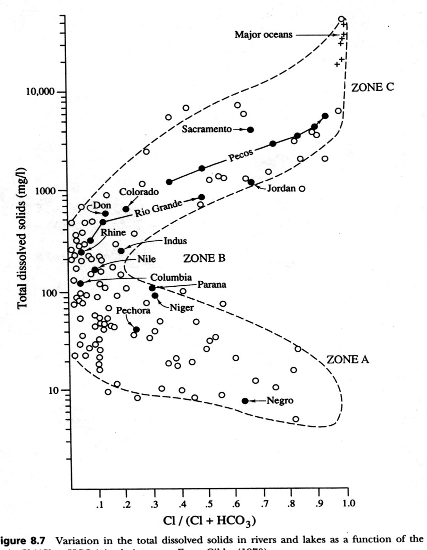


Figure 8.7 Variation in the total dissolved solids in rivers and lakes as a function of the ratio $Cl/(Cl + HCO_3)$ in their waters. From Gibbs (1970).

A-Precipitation

- High $Cl/Cl{+}HCO_3$ ratios
- ⇓ Dissolved ion concentrations

B-Chemical Weathering

- Low $Cl/Cl{+}HCO_3$ ratios
- ⇑ Dissolved ion concentrations

C-Arid Region Rivers

- High $Cl/Cl{+}HCO_3$ ratios
  - $CaCO_3$ Precipitation = ⇓ HCO_3
- ⇑ Dissolved ion concentrations
  - Evaporation

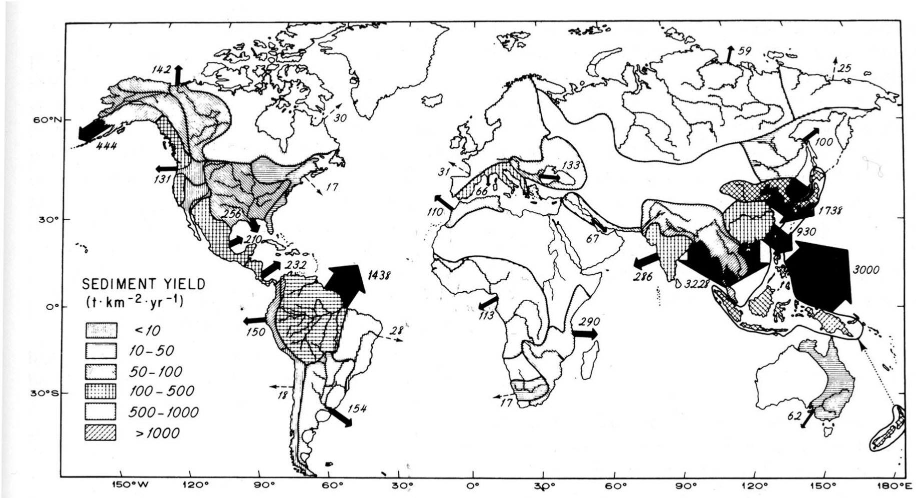
Other Dissolved Constituents

- 2/3 HCO_3^- derived from atmosphere
  - ⇑ Fraction of Na/Cl/SO_4 derived from marine aerosols
- Some Na from silicate & evaporite weathering
- Ca/Mg/K derived from rock weathering
  - Ca from carbonate weathering
  - Mg/K from silicate weathering
- Dissolved Fe/Al transport depends on organic acids
  - Transported at concentrations ⇑ than solubility of $Fe/Al(OH)_x$
  - Example of influence of biota on geochemical processes
- Dependent upon local conditions & human activities

Suspended Load

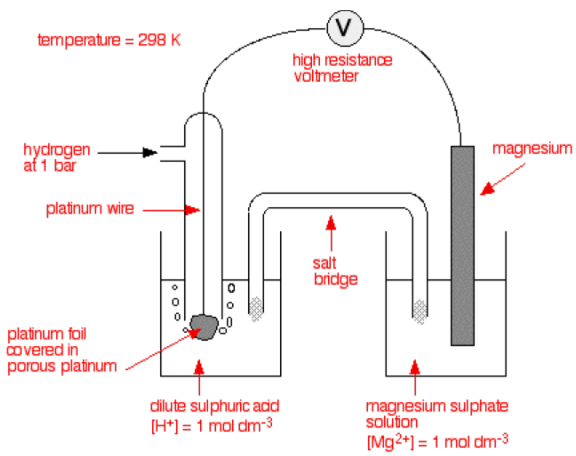
- Increases exponentially with streamflow
  - Low flows dominated by organic materials
    - OM declines as sediment load increases with high flows
- Elevation/Topographic Relief/Runoff
- ⇑ Fraction of sediments deposited in channels & floodplains
  - Sediment yield declines with increasing watershed area
  - ~10% of global suspended load reaches oceans
- Dependent upon local conditions & human activities
  - Vegetation removal/agricultural land clearing/construction

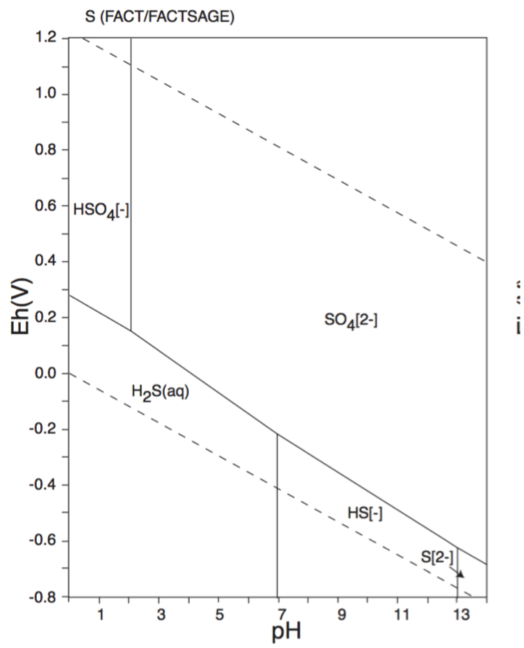
Suspended Load



- South/East Asian rivers = ~70% of global suspended load
- Amazon = ~9% of global suspended load

Electrochemistry and the long-term preservation of organic carbon




S (FACT/FACTSAGE)
Eh(V)
pH
HSO4[-]
SO4[2-]
H2S(aq)
HS[-]
S[2-]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
1
3
5
7
9
11
13