SEDIMENT: SIMPLE CONCEPTUAL MODEL NARRATIVE

S.M. Cormier; 7/30/2007

Excessive sediments (suspended or deposited and bedded) and insufficient sediments both can adversely affect aquatic biota and lead to biological impairment. Although sediments are a natural component of stream ecosystems, human activities have greatly altered sediment budgets (i.e., the supply, movement and retention of mineral and organic particles of all sizes) in many watersheds. Overland flow and in-stream flow move sediments. When the volume, discharge, and pattern of water movement are altered, increased force of moving water transports sediments; when the force lessens, sediments are deposited.

Sources of sediments are soils and topsoil from land in the watershed or sediment from the channel and streambanks. Some soils are more susceptible to movement, such as volcanic ash. Generally, smaller, lighter particles move more readily and stay in suspension longer. Slope, stream gradient, channel morphology, and other natural factors affect water velocity and discharge, and therefore the ability of water to move soil and sediments. Types of and changes in watershed land cover may increase watershed erosion by increasing overland flow and the susceptibility of soil to movement. For example, during construction, vegetation is removed and soils are compacted, reducing permeability and increasing overland flow that then carries disturbed soils from uncompacted areas.

In this conceptual model, sediments are the direct cause of biological impairments, but the behavior of sediments can be understood only in context with the hydrology, geology, and geomorphology of the system. Keep in mind that the relationship between suspended and deposited and bedded sediments is dynamic, and the relative importance of each "type" within a given system will vary with factors such as soil types, stream gradient, and water velocity or discharge (e.g., silt covering and embedding gravels under low flow conditions may become suspended during high stormflows).

Many types of channel alteration (e.g., channel straightening, separating from a floodplain) cause increased water velocity and discharge that forcefully mobilize streambed sediments, resulting in stream channels that lack stable geometries and leading to increased bank erosion. Flow can be so strong that a stream is stripped of all small and moderately sized particles, as the increased water velocity mobilizes bank and channel sediment. During storms, flows increase and the force of the water is stronger when it is restricted to a channel rather than dissipated over a floodplain. Also, the full burden of sediments is carried rather than being deposited on land in the floodplain. This situation is exacerbated when riparian areas devoid of

vegetation or lacking well-developed root structures cannot retain soil and stabilize streambanks. The increased supply of sediments moves with the flowing water as suspended sediments, or is pushed across the streambed creating an unstable habitat, which can scour the bed. When the flow lessens sediments are deposited, changing the type of substrate, filling interstitial spaces, and covering plants, animals, and substrate with material.

Decreased slopes dissipate the force of water. Water withdrawals for irrigation or trans-basin export also reduce flow and increase deposition because the force of the water can no longer mobilize sediments. Also, impounded areas reduce water velocity, leading to increased deposition of sediments behind the dam. These deposited and bedded sediments change the habitat making it unsuitable for the original inhabitants. Furthermore, dam failures and intentional releases of water from dams can release sediments and suspended, fine organic particles such as algal cells or leaf fragments to downstream areas. Organic particles also are directly discharged into waterbodies especially during storms from combined sewer overflows. Other direct inputs include deposition of mining spoils or soil during construction.

High suspended sediment concentrations can adversely affect aquatic biota by four main pathways: (1) impairment of filter feeding, by filter clogging or reduction of food quality; (2) reduction of light penetration and visibility in the stream, which may alter interactions between visually-cued predators and prey, as well as reduce photosynthesis and growth by submerged aquatic plants, phytoplankton, and periphyton; (3) physical abrasion by sediments, which may scour food sources (e.g., algae) or directly abrade exposed surfaces (e.g., gills) of fishes and invertebrates; and (4) increased heat absorption, leading to increased water temperatures.

Deposited and bedded sediments may lead to biological impairment by three main pathways: (1) increased coverage by fine particles, which can alter benthic habitats (e.g., increasing fine substrate habitats favored by burrowing insects and tolerated by nest cleaning fishes, or reducing deeper pool habitats) and bury relatively sessile taxa and life stages (e.g., fish eggs); (2) clogging of interstitial spaces, leading to reduced interstitial flows and habitats; and (3) reduction of substrate size, leading to reduced substrate diversity and stability. Deposited sediments can have indirect effects by reducing oxygen levels either with restricted flow through streambed substrates or by oxygen consumption by bacterial respiration, especially when sediments contain a high concentration of organic matter.

Insufficient sediment also can affect aquatic biota. When sediment export exceeds sediment deposition, streams can erode to bedrock or boulders, which may not be suitable habitat for most organisms. Sediments trapped behind large dams reduce the sediment supply and high velocity discharges erode the stream bed.