Sediment Sources, Transport, and Impact

What is It?

Sediment is earth material. Soil and rock transported from hillslopes and other land surfaces into watercourses are the major sources of sediment in waterbodies. Sediment encompasses particles ranging in size from clay to boulders. It is the natural work of rivers to move these materials across the landscape. The rate and the mechanisms by which this happens are governed mostly by the size of sediment particles, but are also influenced by physical properties of stream and riverbeds and the hydraulic forces of flowing water.

Sediment is transported as *suspended load* (silt and clay held in the water column above the bottom by turbulence), *bedload* (sand, gravel and coarser material, like cobbles and boulders moved by rolling, sliding, and bouncing along the streambed), and *dissolved load* (products of chemical weathering of rocks carried in solution). Most sediment is transported during peak flow events when it is carried as suspended load. Usually bedload represents a smaller percent of the total sediment transported; however, it can range from a few percent in low-gradient rivers to 15 percent in mountain rivers, to as much as 60 percent in some arid watersheds.

Why is it Important?

As earth material, sediment is obviously an important material affecting the physical, chemical and biological conditions of the environment. As such, sediment is neither "bad" or "good", but simply a part of the aquatic and terrestrial environments. We tend to see it as a problem when it is affecting another part of the environment that we place value on, such as fish habitat, backyards, recreational waters, or hydroelectric turbines.

Aquatic environments can posess both *erosional* areas that supply sediment for transport, such as scoured streambanks, and *depositional* areas, which receive sediment after it has been transported, such floodplains. The natural processes that govern the spatial and temporal distribution of these environments produce some of the most dramatic events in nature, including floods and landslides, and are an important key to understanding watershed landforms.

Within a particular aquatic environment a kind of balance exists between the inputs, outputs, and storage of sediment. Natural disturbances like fire, floods and earthquakes, as well as human-caused (anthropogenic) disturbances, can disrupt this balance. However, if the natural processes that brought about this balance in the first place remain intact, the environment will begin to reestablish equilibrium.

During a period of disturbance, whether it occurs over a few weeks or several decades, sediment may have a variety of effects that are deleterious to water quality and biological communities. For example, the effects of increased levels of fine sediment in streams are felt by all biotic components of stream ecosystems from microbes to fish, and in functional components such as primary and secondary production and nutrient cycling.

Sediment can carry pathogens, pollutants and nutrients downstream and excessively high sediment loads can be problematic. Gravel and cobble-sized sediments are very important as habitat for benthic macroinvertebrates, and as spawning habitat for salmon and trout. Where these types of sediment are not available, such as may occur downstream of a dam, the impact to these organisms is substantial. On the other hand, too much sediment can cause problems also. For example, sand and finer grained sediment, including silts and clays, can degrade gravel and cobble habitats under some conditions, especially when introduced to the channel at low flows, when it may accumulate on the bed of the watercourse.

Unlike coarser sediments, silt and clay are cohesive, their grains held together by chemical attractions, increasing their resistance to erosion. Often they will form aggregates and act like larger particles as they move through the watershed. But when they are not in aggregate form, they may remain in *colloidal* suspension for longer periods affecting water quality differently than if they were to settle out onto the bottom of the watercourse or its floodplain through the process of *sedimentation*. Suspended particles diffuse sunlight and absorb heat. This can increase temperature and reduce light available for algal photosynthesis.

How is It Measured?

Sediment studies are often complex and costly and require a longterm commitment in order to produce information from which conclusive findings can be made. Probably the biggest challenge in these studies is to sort out the *background* levels from those caused by a human-caused disturbance. Before initiating a sediment monitoring program, citizen monitors should seek to understand as much as they can about the natural variability, the history of disturbance (both anthropogenic and natural), and the aquatic resources that may be at risk or impaired within their watershed. Knowledge of the temporal and spatial variability is necessary to efficiently develop a sampling effort. Considerations of the temporal scale range from the short-term variability of sediment *transport rates* to the variability in annual sediment *loads* within a single watershed. The spatial scale is equally important to consider and can include the variability in sediment loads within a watercourse cross-section, the variation in the amount of sediment transport along a downstream gradient, and the interbasin variability in annual sediment loads.

Measurements of sediment include a broad array of field and laboratory methods. Field measurements that do not require collection of a sample include many of the geomorphological measurements, like stream channel cross-sections and longitudinal (thalweg) profiles. Estimates of the *total quantity of sediment* and *particle size distrib*ution are the measurements usually made on samples collected for sediment analysis.

Bedload quantity and size distribution are measured in samples collected using samplers placed on the streambed at a number of locations usually at a fixed interval. Suspended load is measured in samples collected through the entire water column (depth-integrated

samples). Dissolved load can be measured as Total Dissolved Solids (TDS) and is measured most commonly with electrical conductivity meters.

Dissolved load can also be characterized through analysis of turbidity. Turbidity refers to the amount of light that is scattered or absorbed by a fluid. It is an optical property of the fluid, and though it can be correlated with the amount of sediment in the water, it is not a measure of the amount of sediment. Turbidity in streams is usually due to the presence of silt and clay particles in suspension as well as certain dissolved constituents.

The effects of sediment transport manifest themselves in changes to stream and river bed morphology. As sediment is deposited or scoured in the bed, the dimensions and features (i.e., pools, riffles, flood plain levees, gravel bars, cutbanks) of the watercourse change. Measuring and tracking these changes over time can permit direct quantification of available habitat as well as reveal overall trends in the sediment budget (inputs and outputs) of a watershed. The methods most commonly used to measure these changes are the thalweg profile (also called a “longitudinal”, or, “long” profile) and the cross-section.

Woody debris, while not a form of sediment, plays an important role in streambed morphology by creating structures that trap sediment and add complexity to the streamcourse. Woody debris is an area of intense research in areas of California where fisheries are in decline. Methods to quantify woody debris and characterize its role in streambed sedimentation are available for certain watersheds throughout the State.

What Factors Affect It?

Natural Factors

- Algae and nutrient loading
- Suspended sediment from erosion and sediment transport
- Seasonal weather, storm events, climatic events (e.g. droughts).
- Local stream morphology will determine whether sediments are deposited or eroded

Human Factors

- Erosion due to removal of riparian vegetation, changes in stream morphology or stream flow patterns
- Excessive nutrient loading and algal growth

What are the Water Quality Objectives[1]?

Water quality objectives are included in the Regional Water Quality Control Board's Basin Plans. The water quality objectives vary from region to region in California. Therefore, you should check with the Regional Water Quality Control Board in your area. Most of the nine Regions have a broad "sediment" water quality objective, an objective for turbidity, one for suspended material and another for settleable material (Table 1). All of these objectives can be considered when designing a monitoring project. However, consult with Regional Board staff to insure that the objectives apply in the waterbodies you are interested in.
Refer to the Basin Plans for specific requirements, and exceptions to these limits. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.

[1] A water quality objective is a law or regulation that consists of: 1) the beneficial designated use or uses of a waterbody, 2) the numeric and narrative water quality criteria that are necessary to protect the uses of that particular waterbody, and 3) an antidegradation statement.

Table 1: Water Quality Objectives for Sediment [2]

Region	Sediment Objective	Turbidity Objective	Suspended Material Objective	Settleable Material Objective
1	*Objectives for inland surface waters, enclosed bays, and estuaries:* The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.	*Objectives for inland surface waters, enclosed bays, and estuaries:* Turbidity shall not increase more than 20 percent above naturally occurring background levels.	*Objectives for inland surface waters, enclosed bays, and estuaries:* Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.	*Objectives for inland surface waters, enclosed bays, and estuaries:* Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.
2	*Objectives for surface waters:* Same as above.	*Objectives for surface waters:* Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases from normal background light penetration or turbidity relatable to waste discharge shall not be greater than 10 percent in areas where natural turbidity is greater than 50 NTU.	*Objectives for surface waters:* Same as above.	*Objectives for surface waters:* Same as above.
3	*Objectives for surface waters:* Same as above.	Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increase in turbidity attributable to controllable water quality factors shall not exceed that following limits: 1. Where natural turbidity is between 0 and 50 Jackson Turbidity Units (JTU), increases shall not exceed 20 percent. 2. Where natural turbidity is between 50 and 100 JTU, increases shall not exceed 10 JTU. 3. Where natural turbidity is greater than 100 JTU, increases shall not exceed 10 percent.	*Objectives for surface waters:* Same as above.	*Objectives for surface waters:* Same as above.
4	N/A	*Objectives for selected constituents in inland surface waters:* Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increase in turbidity attributable to controllable water quality factors shall not exceed that following limits: Where natural turbidity is between 0 and 50 NTU, increases shall not exceed 20 percent. Where natural turbidity is between 50 and 100 NTU, increases shall not exceed 10%.	*Objectives for surface waters:* Same as above.	*Objectives for surface waters:* Same as above.
5	*Objectives for surface waters:* Same as Region 1.	*Objectives for inland surface water:* Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increase in turbidity attributable to controllable water quality factors shall not exceed that following limits: 1. Where natural occurring turbidity is between 0 and 5 Nephelometric Turbidity Units (NTUs), increases shall not	*Objectives for surface waters:* Same as above.	*Objectives for surface waters:* Same as above.

[2] Refer to the Basin Plans for specific requirements, and exceptions to these limits. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.

		exceed 1 NTU. 2. Where natural occurring turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent. 3. Where natural occurring turbidity is between 50 and 100 NTUs, increases shall not exceed 10 NTUs. 4. Where natural occurring turbidity is greater than 100 NTUs, increases shall not exceed 10 percent. In determining compliance with the above limits, appropriate averaging periods may be applied provided that beneficial uses will be fully protected.		
6	*Objectives for surface waters:* Same as Region 1.	*Objectives which apply to all surface waters:* Waters shall be free of changes in turbidity that cause nuisance or adversely affect the water for beneficial uses. Increases in turbidity shall not exceed natural levels by 10 percent.	*Objectives for surface waters:* Same as above. For natural high quality waters, the concentration of total suspended materials shall not be altered to the extent that such alterations are discernible at the 10 percent significance level.	*Objectives for surface waters:* Same as above. For natural high quality waters, the concentration of settable materials shall not be raised by more that 0.1 milliliter per liter.
7	*Objectives for surface waters:* Same as Region 1.	Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses.	See Basin Plan.	*Objectives for surface waters:* Same as Reg. 1.
8	*N/A*	*Objectives are for inland surface waters:* All inland surface waters of the region shall be free of changes in turbidity which adversely affect beneficial uses. Increases in turbidity which result from controllable water quality factors shall comply with the following: 1. Where natural turbidity is between 0 and 50 NTUs, increases shall not exceed 20 percent. 2. Where natural turbidity is between 50 and 100 NTU, increases shall not exceed 10 NTU. 3. Where natural turbidity is greater than 100 NTU, increases shall not exceed 10 percent.	*Objectives for surface waters:* Same as Region 1.	*Objectives for surface waters:* Same as Region 1.
9	*Inland surface waters, enclosed bays and estuaries, coastal lagoons and ground waters*: Same as Region 1.	*Inland surface waters, enclosed bays and estuaries, coastal lagoons and ground waters:* Waters shall be free of changes in turbidity which adversely affect beneficial uses. With two exceptions (see Basin Plan), increases in turbidity attributable to controllable water quality factors shall not exceed the following limits: 1. Where natural turbidity is between 0 and 50 NTUs, increases shall not exceed 20 percent. 2. Where natural turbidity is between 50 and 100 NTU, increases shall not exceed 10 NTU. 3. Where natural turbidity is greater than 100 NTU, increases shall not exceed 10 percent.	*Inland surface waters, enclosed bays and estuaries, coastal lagoons and ground waters:* Same as Region 1.	*Objectives for surface waters:* Same as Region 1.

Sources and Resources

This Fact Sheet is implemented by the Clean Water Team (CWT), the Citizen Monitoring Program of the California State Water Resources Control Board. This Fact Sheet has been authored by Dominic Roques, former State Coordinator for Citizen Monitoring and a member of the Sediment work-group of the 2000-2001 Technical Advisory Council for Citizen Monitoring. The original fact sheet is presented, without any revisions.

Please contact your Regional CWT Coordinator for further information and technical support. For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit our website at www.swrcb.ca.gov/nps/volunteer.html

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