Chapter 8
Urban Stormwater and Sedimentation

- Introduction to Volunteer Water Quality Monitoring Training Notebook -

Introduction

Sedimentation (inorganic particles < 2mm) is an important variable influencing the physical and biological characteristics of stream systems. Geology, climate and terrestrial characteristics of a stream's watershed determine the level of deposited and suspended sediments in each stream (Leopold et al. 1964, Estep and Beschta 1985, Allan and Johnson 1997). Sediment aids in shaping streams and are important in developing each stream's biotic communities. Undisturbed streams contain a natural level of sediment delivered from soil erosion and runoff from the surrounding watershed. However, a change in sedimentation is often influenced by human activities which can degrade stream condition and have negative impacts on aquatic life within a stream. The pictures on the right show examples of excessive sedimentation as a result of channelization and riparian degradation. Human input of sediment comes in many forms and has been noted as a major pollutant in the waters of the United States. Because appropriate levels of sediment are critical to stream health, and human activities are known to alter sediment inputs, it is important that stream monitoring include an evaluation of stream sedimentation.

Photos by: Andy Turner

Invertebrate and fish species require specific water quality and habitat characteristics for survival. When those requirements are altered, a species can become scarce or even disappear. Invertebrate communities are the most sensitive to degradation and changes in their populations can be the first sign a stream is being degraded by sedimentation. These organisms serve an important role in the food web of a stream (Figure 1) and reductions in their populations can be detrimental to the entire biotic community.

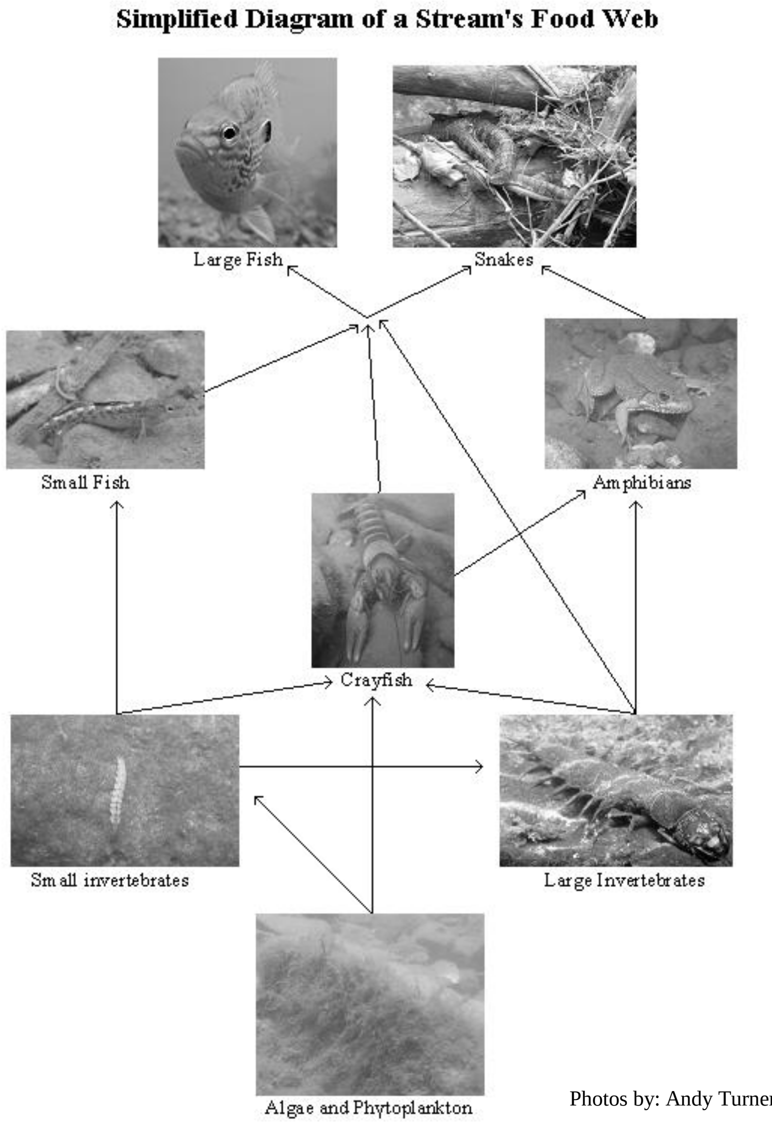


Figure 1. A simplified schematic of a streams food web showing the important role invertebrate communities play in stream systems.

Fine sediment is defined as solid fragments of organic or inorganic material with a particle size of less than 2mm and includes sand, silt and clay particles. Coarse sediments are particles greater than 2mm, including gravel, cobble, and boulders. Both fine and coarse sediments play important roles in the function of aquatic ecosystems and both can have a negative or positive effect on biota depending on the life history requirements of individual species. The primary agent that may negatively affect the water quality and habitat of streams is fine sediment. Fine sediment can move freely from eroding soils during stormwater events and eventually make its way into streams. In extreme circumstances, where massive amounts of sediment are introduced into a stream system, the entire streambed may be covered. This fills interstitial spaces and eliminates habitat used by the resident aquatic life (Picture below).

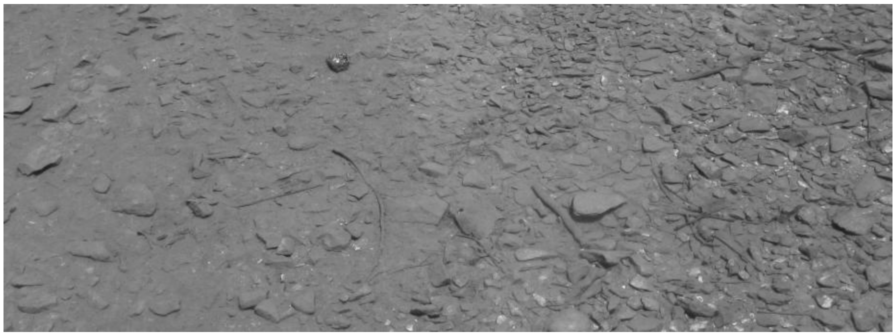


Photo by: Andy Turner

The four predominant stream ecological drainage systems in Missouri are Prairie, Ozarks, Lowland, and Big Rivers. All four ecosystems have different geology and soil types that determine the erodability of the soils in the watershed. Generally speaking, Ozark systems have shallow soils, are very rocky and may be high in clay. Prairie systems in north and west Missouri contrast Ozark systems in that soils are deep and often highly erodable. The Lowland and Big River systems have deep soils and sediments that have been deposited during high water events and floods. The amount of sediment in Prairie, Lowland and Big River systems will be, on average, naturally higher than in Ozarks systems due to soil type and geology. While the process of erosion is natural, it can be greatly accelerated by human activities (Picture below).

Photos by: Andy Turner

Characteristics of a watershed that have a natural influence on sedimentation are those that are not readily controlled by the human activities within the watershed. Rather, these characteristics have formed throughout history as a result of earth-forming processes such as glaciations, climate, geologic events and weathering. Common characteristics of a watershed that are considered natural include watershed slope, elevation, soil composition and watershed size. To varying degrees these characteristics contribute sediment to streams but their contribution is critical to the livelihood of the aquatic life that has adapted to each stream system. Alternatively, human activities in watersheds represent unnatural influences on sedimentation and can result in degradation of stream systems. Watershed characteristics that are commonly considered unnatural contributors to sedimentation include channelization, logging, road construction, gravel mining, cattle access to the stream and conversion of land covered by native vegetation to land uses associated with agriculture and urbanization.

Impacts of urbanization

Photo by: Andy Turner

Urbanization within a stream's watershed frequently adds excessive amounts of sediment to streams and is regularly encountered by Stream Teams. The impact of urbanization can have many detrimental effects on water quality and stream habitats. Some of the main contributors to degraded water quality in urbanized areas are excessive sediment input from land disturbance, increased impervious surfaces, non-point source runoff of nutrients and chemicals, and elevated bacteria levels. During development, land is often left bare during construction making it more erodable. If disturbed areas are not managed with proper Best Management Practices (BMPs), to slow erosion and trap sediment in runoff, the accumulation of sediment may become excessive and the system will be degraded.

A major issue related to urbanization is the conversion of vegetated land that allows rainfall to be soaked into the soil, to impervious surfaces (streets and parking lots) that quickly diverts rainfall to the stream (Figure 2). The volume and velocity of runoff is dramatically increased with the addition of impervious cover. This speeds up the process of runoff making streams “flashy,” meaning that the flow during storm events rises very quickly and then drops very quickly. These intense flows have more erosive power and can scour habitat from streams and erode stream banks. A comparison of runoff volume from impervious and unimpervious surfaces can be shown by the measurements in Table 1.

Photo by: Andy Turner

Figure 2. Runoff from storm drains will eventually enter streams at a much greater rate than runoff in an un-urbanized area of the watershed. In this photo sediment can be seen entering the storm drain which directly enters a stream.

Look at the peak discharge rates of the parking lot compared to the meadow (Table 1). The runoff from the parking lot has increased 3 to 4-fold depending on the intensity of the storm. Why is this important? These “flashy” streams have increased runoff from impervious surfaces. This causes stream flows with short duration but high intensity and can scour the stream channels and erode banks. In many instances, it may also scour the stream bottom making it incised or “down cut.” Urban streams that are flashy generally do not have stable habitat and degradation of these streams can often be correlated to impervious cover. Streams with populations of sensitive species have been shown to have <10% impervious cover, impacted streams 11-25% impervious cover, and non-supporting streams having >26% impervious cover.

Table 1. Example of real world data showing how impervious surfaces associated with urbanization compare to a naturally vegetated area.

Comparison of One Acre of Parking Lot vs. One Acre of Meadow in Good Condition

Runoff or Water Quality Parameter	Parking Lot	Meadow
Curve number (CN)	98	58
Runoff coefficient	0.95	0.06
Time of concentration	4.8	14.4
Peak discharge rate (cfs), 2 yr., 24 hr. storm	**4.3**	**0.4**
Peak discharge rate (cfs), 100 yr. storm	**12.6**	**3.1**
Runoff volume from one-inch storm (cubic feet)	**3450**	**218**
Runoff velocity @ 2 yr. storm (feet. second)	8	1.8
Annual phosphorous load (lbs/ac./yr.)	2	0.50
Annual nitrogen load (lbs/ac./yr.)	15.4	2.0
Annual zinc load (lbs/ac./yr.)	0.30	ND

Key Assumptions:

Parking lot is 100% impervious with 3% slope, 200 foot flow length,
Type 2 Storm, 2 yr. 24 hr. storm = 3.1 inches, 100 yr. storm = 8.9 inches
Hydraulic radius = 0.3, concrete channel, and suburban Washington 'C' values.

Meadow is 1% impervious with 3% slope, 200 foot flow length, good vegetative condition, B soils, and earthen channel.

Schueler, Holland, Practice of Watershed Protection, 2000

Impacts on Aquatic Life

An unnatural increase in sediment within a stream can lead to various negative effects on the aquatic community. These effects can exert both direct short term and chronic long term impacts on biotic populations. During storm events when suspended sediments are at their greatest levels, the input of excess sediment in the system can be great enough to suffocate and kill sensitive invertebrate and fish species. When the stream returns to baseflow and these excessive sediments are deposited, chronic population reductions can occur by making it more difficult for organisms to feed and reproduce. Suspended (Bruton 1985) and deposited (Rabeni and Smale 1995) sediments can have similar and/or separate effects on biota including:

- Reduced visibility
- Clogging gills
- Reduced feeding
- Hindered reproduction
- Reduced growth rates
- Smothering the streambed
- Limited egg survival
- Reduction of sensitive species

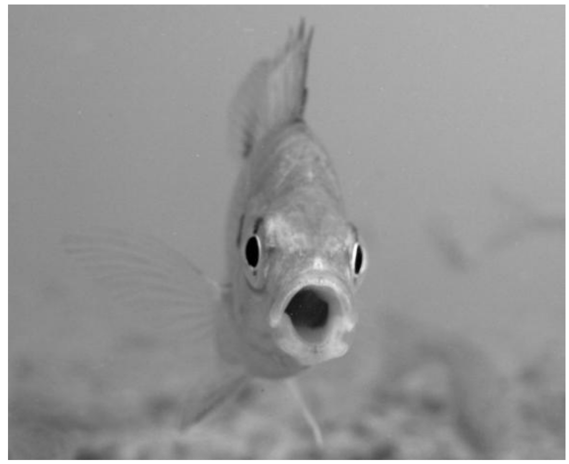
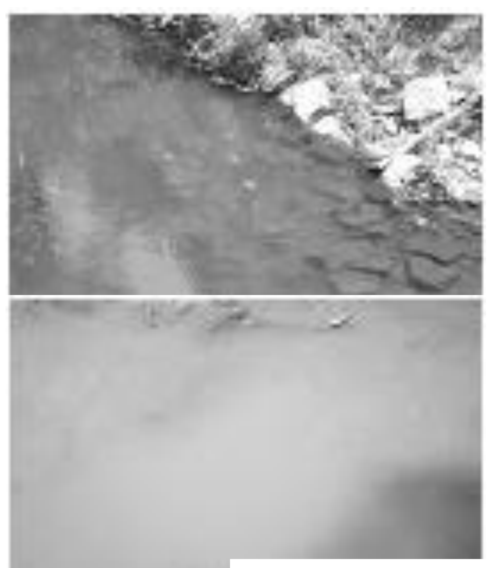


Photo by: Andy Turner

Depending on the species these effects can work independently or in conjunction to limit the ability of aquatic biota to survive inputs of excessive sedimentation. When these sediments are suspended in the water column, biota are limited by a reduction in visibility. Many aquatic species rely on eyesight and a reduction in visibility can effect feeding, reproduction, and make the organism more vulnerable to predators. A large influx of sediments can also physically clog the gills by inundating them as the organism is respirating. Dissolved oxygen is then unable to diffuse into the gills and the organism can be suffocated.

When sediments deposit on the streambed, both feeding and reproductive success can be hindered. Interstitial spaces on the streambed provide cover and food for many organisms that are specially adapted to living on the streambed. When these spaces are filled by fine sediments, species become unable to survive and the entire food web is disrupted. Deposited sediments effect reproduction two ways: 1) impacts life history requirements and 2) reduced oxygen availability. Many organisms have specific substrate



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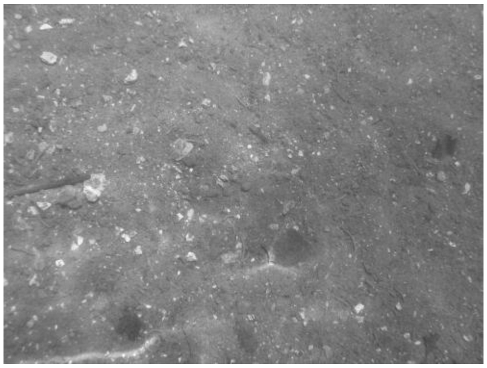

Photos by: Andy Turner

requirements for reproduction and when the streambed is covered by excessive sediments they are unable to successfully reproduce. Fine sediments are unstable and are easily suspended and re-deposited on the streambed. Eggs can then become covered by fine sediments making it difficult for oxygen to diffuse into the eggs, thus suffocating the embryos. Some organisms are more "sensitive" to excessive sediments, exaggerating these effects, and these species can be an indicator that future stream degradation is occurring.

When excessive sediment enters a stream, the effects can result in major problems to the aquatic community and subsequently to the overall health of a stream. Healthy streams provide the unique aquatic and aesthetic values throughout the state of Missouri. Sedimentation through human activity threatens these values but controlling human inputs of sediment can help limit the degradation of Missouri's aquatic resources.

Best Management Practices

The Environmental Protection Agency (EPA) defines Best Management Practice (BMPs) as "schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants to waters of the United States." Therefore, BMPs are a practice or combination of practices determined to be the most effective, practicable means for protecting our natural resources. There are three purposes of BMPs with respect to stormwater: 1) to slow the rate of runoff ; 2) to reduce the amount of pollutants in the runoff and 3) to maintain the natural hydrology of the site in question. While BMPs cannot solve all of the problems associated with land disturbance such as erosion and increased runoff from impervious surfaces, they can reduce impacts to our aquatic resources.

There are many examples of BMPs and new technologies are constantly being developed. There are BMPs for many purposes during construction such as erosion control, sediment traps and filters, settling basins and storm drain protection. Some post-construction BMPs include dry and wet detention ponds, porous pavement, bio-retention, grass swales, filter strips, buffer zones and green parking. BMPs often include engineering solutions but they also include more natural means to control runoff and erosion, such as grass waterways or preserving native vegetation. If you are interested in more information regarding the use of BMPs and their purpose, there is an excellent overview on EPA's website at:

http://cfpub.epa.gov/npdes/stormwater/menuofBMPs/menu.cfm.

Of all the management options for reducing human impacts on stream systems, the best ecological option is protecting or re-establishing a natural riparian corridor along the stream. A healthy riparian corridor is a 100-foot strip of native vegetation (woody and non-woody) bordering a stream. Riparian corridors stabilize stream banks by preventing bank erosion which can lead to excessive sedimentation. A healthy riparian corridor serves to buffer and filter storm water as rainfall drains from the watershed by acting as a natural sponge to filter nutrients and sediment that might otherwise enter the stream unimpeded. It provides shade, keeping the water cooler and increases its ability to hold oxygen. It also provides the natural source of energy when the leaves fall in autumn.

Photos by: Andy Turner

Removal of the vegetation within the riparian corridor is a common practice in developing urban and agricultural areas and can have a detrimental effect on the stream system. Additionally, it should be noted that preservation of riparian corridors is usually much cheaper economically than restoration of a degraded stream system.

All across Missouri, communities are dealing with the unintentional consequences of conventional site design strategies: stressed watersheds, polluted waterways and loss of community character. Even when they comply with official stormwater policies, standard design practices often create a large “ecological footprint” because they treat hydrology as a problem and not as a natural system. The typical approach to site planning is to clear, grade and pave the entire area; then collect all the stormwater and dispose of it through a series of pipes to the nearest stream.

Low Impact Development (LID) is a comprehensive land-planning and engineering design approach with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds. LID technology provides a comprehensive approach to stormwater management. It can be used to address a wide range of Wet Weather Flow (WWF) issues:

- Combined Sewer Overflows (CSOs)
- National Pollutant Discharge Elimination System (NPDES) Stormwater Phase II permits
- Total Maximum Daily Load (TMDL) permits
- Nonpoint Source Program goals
- Other Water Quality Standards

These practices can be as simple as employing rain barrels and rain gardens to reduce residential runoff or as complex as developing permeable paver parking lots and green roofs on large commercial buildings. The LID approach improves water quality, minimizes the need for expensive pipe-and-pond stormwater systems and creates more attractive developments. As a result, aquifers are recharged, streams and rivers are cleaner and development has a more natural appearance.

Additional References

The following is a list of internet educational references that relate to stormwater and urbanization.

- Center for Watershed Protection: www.cwp.org
- Stormwater Manager's Resource Center: http://www.stormwatercenter.net/
- Environmental Protection agency:
  - http://www.epa.gov/owow/nps/urban.html
  - http://www.epa.gov/ost/stormwater/
  - http://cfpub.epa.gov/npdes/stormwater/menuofBMPs/menu.cfm
  - http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/ws_abs.html
- Low Impact Development Center: http://www.lowimpactdevelopment.org/
- Brookings Institute: http://www.brook.edu/es/urban/missouri/abstract.htm

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