## PDHonline Course C196 (2 PDH)

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# Stormwater Control Practices

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# CHAPTER 2

# CAUSES AND EFFECTS OF EROSION AND SEDIMENTATION, HYDROLOGIC CHANGES AND POLLUTION TRANSPORT

The major problem associated with erosion on a construction site is the movement of soil off the site and its consequent pollution of receiving rivers, streams and lakes. In Missouri, 70 to 90 percent of the eroded soil (sediment – see Glossary) that reaches any type of channel is transported to the state's water resources.

## Types of Soil Erosion

Soil erosion is a natural process that wears away the earth's surface. Soil particles are detached (eroded), transported (as sediment) and deposited (sedimentation) by wind, water, ice or gravity. On a construction site, the erosion process is accelerated because the soil is left bare and unprotected by vegetation. Water and wind erosion will be described in detail below.

### Water Erosion

There are five types of water erosion (shown in Figure 2.1) described below and ranked from least severe to most severe. Splash and sheet erosion can best be prevented by protecting the land surface with vegetation, mulch or erosion control blankets. Sheet, rill and gully erosion can be controlled by keeping runoff velocities slow.

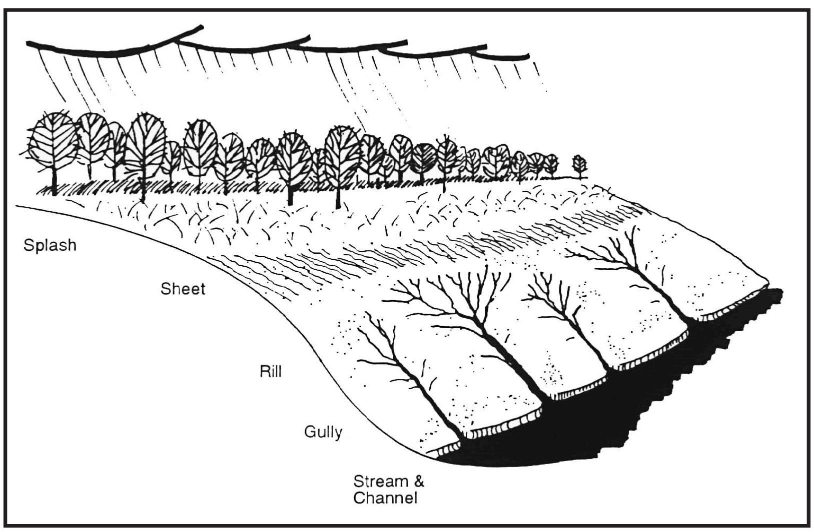


Figure 2.1 The Five Types of Soil Erosion on an Exposed Slope  Source: North Carolina DEHNR, 1993

**Splash:** Splash erosion results from the direct impact of falling drops of rain on soil particles. This impact breaks the bonds between the particles, dislodges them and splashes them into the air. The dislodged soil particles can then be easily transported by the flow of surface water runoff.

**Sheet:** Sheet erosion is the removal of a thin layer of exposed surface soil by the action of raindrop splash and runoff. The water moves in broad sheets over the land, picks up these particles and carries them along as it flows downhill.

**Rill:** As the runoff moves down a slope, it cuts small paths or rills. In rill erosion, water flowing through these paths detaches more soil from their sides and bottoms.

**Gully:** Further down the slope, water tends to concentrate in channels and pick up speed. In gully erosion, soil is removed rapidly by water gushing over the headcut or uphill end of the gully, by concentrated flow scouring the sides and bottom of the gully and by water removing soils that have slumped from the sidewalls of the gully. A nearly vertical headcut allows water falling over the surface to undermine the bank so the gully moves upslope. Large earthmoving equipment is required to reshape or control gullies.

**Stream and Channel:** Increases in the volume, velocity and time of runoff may cause erosion of the receiving stream or channel banks and bottom.

### Wind Erosion

Wind erosion is a serious environmental problem. Suspension, saltation and surface creep are the three types of soil movement that occur during wind erosion (See Figure 2.2).

**Suspension:** Occurs when very fine dirt and dust particles are lifted into the wind. The particles can be thrown into the air through impact with other particles or by the wind itself. Once in the atmosphere, these particles can be carried very high and be transported over extremely long distances.

**Saltation:** Fine particles are lifted into the air by the wind and drift horizontally across the surface increasing in velocity as they go. They travel approximately four times longer in distance than in height and when they strike the surface again they either rebound back into the air or knock other particles into the air. This is the major form of soil movement due to wind.

**Creep:** The large particles that are too heavy to be lifted into the air are moved through a process called surface creep. The particles are rolled across the surface after coming in contact with the soil particles in saltation.

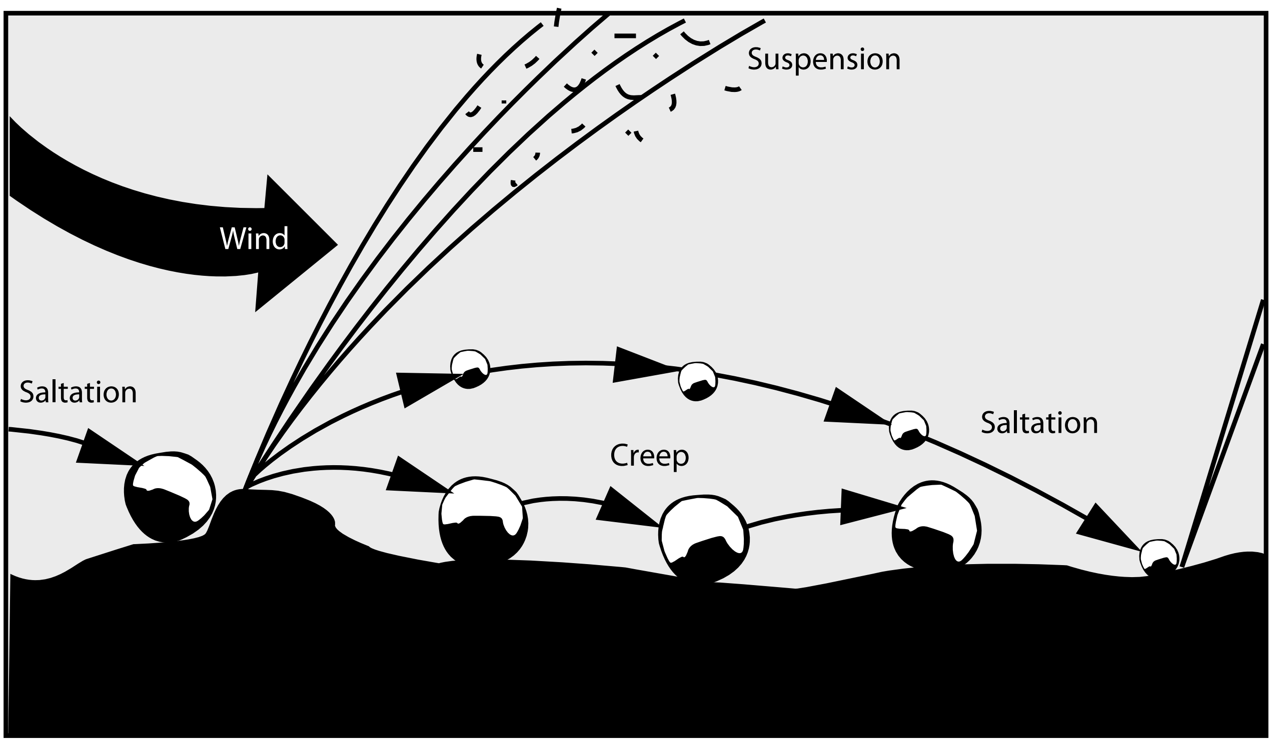


Figure 2.2 Types of Wind Erosion Source: Wind Erosion Research Unit

## Factors That Influence Water and Wind Erosion

The potential for a land area to erode is determined by several key factors: climate, rainfall, soil erodibility and the length and steepness of the slope. These factors are interrelated in their effect on the potential for erosion. The variability in terrain and soils makes erosion control unique to each development site.

A site specific soils analysis and the assistance of a registered design professional (see Glossary) can aid in the development of an effective erosion, sediment and stormwater control plan.

## Basic Principles of Erosion Control

Keeping soil in place when possible is the first step to erosion control. If the soil must be exposed to stormwater and wind, then it must be contained on the construction site through sediment control measures. Remember erosion controls are preventative and sediment controls are corrective.

The contractor can control erosion and sedimentation most effectively by leaving vegetation intact as long as possible, avoiding removal of streamside vegetation, leaving wetlands in place and phasing in land disturbance to minimize the amount of soil exposed at any one time. Secondly, they can protect whatever soil is exposed from the erosive force of rain, surface water runoff and, in some cases, wind. Eroded soil must be captured and retained on the construction site. In addition, it is important to keep stormwater runoff at low velocities and volumes on-site, and at or below pre-development levels going off-site. Ideally, no sediment is to leave the perimeter of the site. Reasonably, of course, some minimal amount of sediment may leave the site. The following principles will help minimize erosion on the construction site, significantly reduce soil from leaving the site and limit off-site sedimentation that result in water pollution.

Erosion from the splash of a raindrop is caused from the energy of the drop falling from the sky with a specific size and velocity. The most important part of erosion control is to design to protect the soil from the energy of the raindrop by reducing the area of bare soil at any time.  Keep as much of the existing vegetation in place as possible. For those areas that were stripped of the existing, protective vegetation, cover the bare soil with erosion control measures and reestablish permanent vegetation as quickly as possible. Remember erosion controls are preventative and sediment controls are remediation.

### Retain Existing Vegetation Wherever Feasible

Vegetation is the most effective form of erosion control. Try to integrate the existing vegetation including grass, trees and shrubs into the design to reduce the amount of land disturbance. For those areas where the vegetation must be removed, re-establish vegetative cover as soon as possible to reduce the potential for erosion in these areas. Retain all existing riparian corridor to waterways unless removal is absolutely necessary.

### Design the Development to the Site

Reduce the amount of soil cut and fill that could occur over the site. One of the best ways to minimize the risk of erosion and sedimentation problems by construction is to disturb as little of the land as possible. The better the development fits with the topography of the site, the less the grading activity occurs, thereby minimizing the amount and intensity of land disturbance. When development is tailored to the natural topography of the land, less massive earth movement is necessary and erosion potential is greatly reduced. It is also important to avoid disturbance of sensitive areas. You should try to avoid disturbance near wetlands and within the riparian (see Glossary) corridor of perennial streams.

### Reduce Surface Runoff by Increasing Infiltration

Vegetation is the most effective form of erosion control. It provides both erosion control and stormwater runoff reduction through infiltration. You can design for increased infiltration by altering the soil texture and subsoil for greater void spaces, which will increase infiltration. Try to integrate the existing vegetation including grass, trees and shrubs into the design to reduce the amount of land disturbance. Retain all existing riparian corridor to waterways unless removal is absolutely necessary. The plants dissipate the energy of the raindrop, reducing the potential for erosion and the root systems increase infiltration and decrease surface runoff.

### Protect the Land Surface

Schedule and limit grading activities to minimize bare soil areas and the time of exposure. Consider the use of erosion control blankets, mulch or other erosion control measures when appropriate. Use diversions and perimeter protection to intercept runoff and divert it away from bare soil slopes. Install these practices before clearing and grading or as soon as possible. Stabilize the construction entrance and channels immediately. Establish vegetation on graded areas as quickly as possible or whenever work is interrupted. As stated in the *Missouri State Operating General Permit for Land Disturbance*, “Where soil disturbing activities cease in an area for 14 days or more, the permittee shall construct BMPs to establish interim stabilization.”

### Keep Runoff Velocities Low

Preserve natural vegetation where possible; mulch and vegetate exposed areas immediately after grading to allow infiltration and slow surface runoff. Use practices that shorten or “break” the slopes to reduce flow volumes and velocities, such as terraces or wattles. Convey stormwater runoff away from steep slopes to stable outlets and detain water in holding ponds before leaving the site.

### Capture Sediment on the Site

Sediment traps, basins and barriers are designed to reduce runoff velocity, not filter it; allowing the water to pool and the sediment to settle out. Several sediment traps or barriers located at the border of a graded area are more effective than a single large sediment basin near the site boundary. These practices also reduce the volume and velocity of stormwater runoff.

### Schedule Land Grading

The contractor can control erosion and sedimentation most effectively by coordinating the grading sequence and the installation of erosion and sediment control practices. Install key sediment control practices before site grading begins. Schedule or limit grading to small areas. Install the permanent stormwater drains early in the construction and protect all inlets from sedimentation.

### Design, Install. Operate and Maintain Practices Properly

Proper design, installation, operation, inspection and maintenance are vital to the success of erosion and sediment control practices. These elements will be covered in Chapter 5. Choosing the wrong practice, improper installation, improper operation and lack of maintenance are the cause of most failures. Failures of installed practices can deliver large amounts of polluted water runoff into streams and lakes. A large structure that fails, such as a detention basin, may be hazardous or damaging to people and property; just as low points in a dike can cause major gullies to form on a fill slope. Ensure the appropriate practice is selected. Also, assign an individual to be responsible for routine checks, operation oversight, repairs and maintenance of erosion, sediment and stormwater control practices.

Figure 2.3 The improperly installed check dam created significant bank erosion. Source: *ABC's of BMP's LLC*

## Hydrologic Changes

Land development in urban areas causes drastic changes in the local and watershed hydrology. As land is covered with roads, buildings and parking lots, the amount of rainfall that can infiltrate into the soil is reduced. Figure 2.4 shows the reduction in rainfall infiltration into the soil as paved surface and building cover increases. Table 1.1 shows a range of runoff coefficients for different land uses. The runoff coefficient, or "C" value in the Rational Method of determining runoff, is the percentage of rainfall runoff in the watershed.

This is one reason why construction practices must work hand-in-hand with post-construction runoff controls. It is a relationship that must be well understood. Post-construction controls are designed for the long-term additional runoff from the developed areas to reduce stormwater quantity while improving stormwater quality (See *Missouri Guide to Green Infrastructure: Integrating Water Quality into Municipal Stormwater Management*).

The first line of defense in protecting urban water quality is to assess the entire development site for water quality protection opportunities before ever designing where roads and structures are to be located. The initial stage of site design should work to preserve and enhance the existing features.

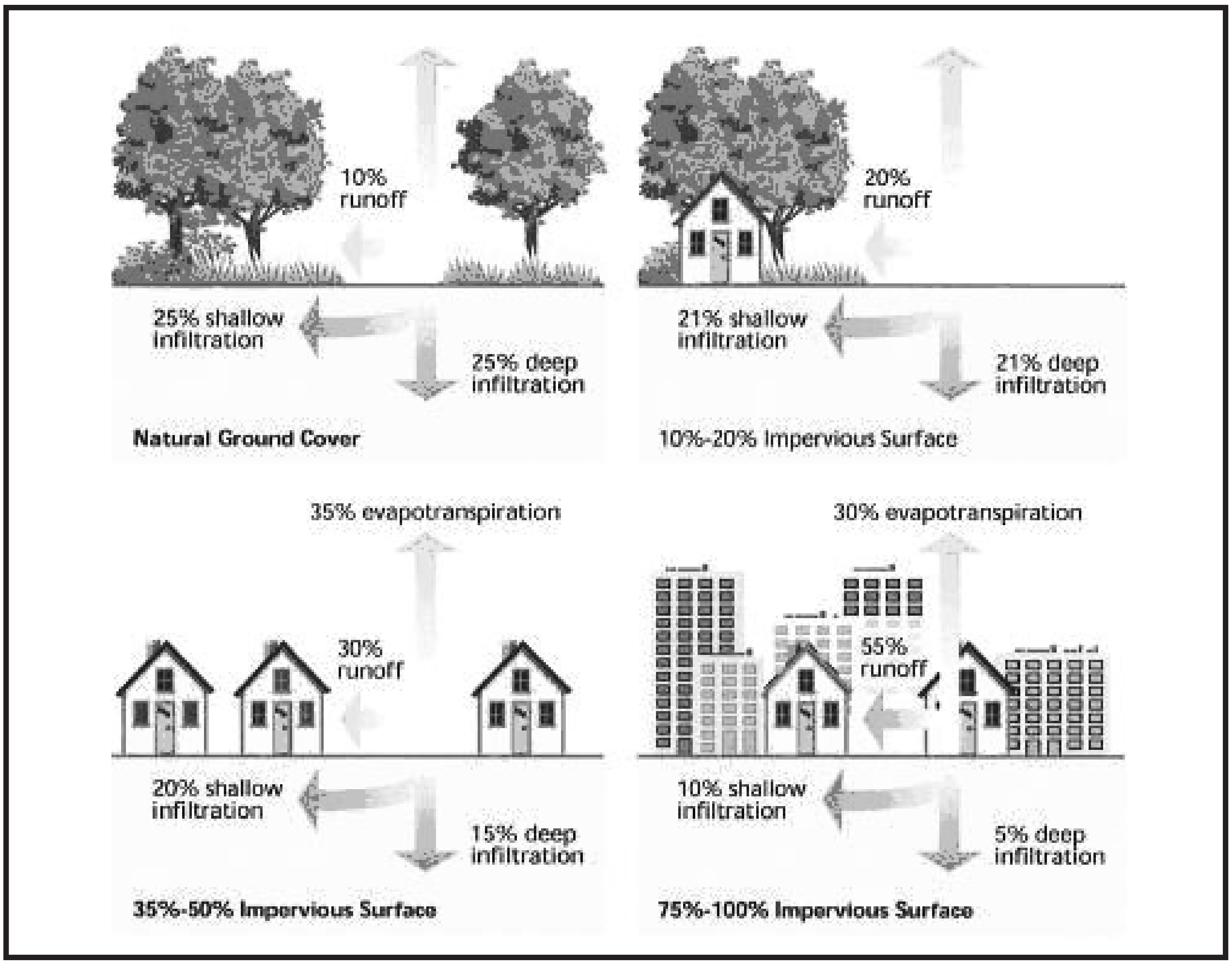


Figure 2.4 Typical changes in runoff flows resulting from paved surfaces
Source: USDA, NRCS, Stream Corridor Restoration, 2001

| Land Use | Runoff Coefficient | Land Use | Runoff Coefficient |
|---|---|---|---|
| Business | | Lawns | |
| Downtown | 0.70 – 0.90 | Sandy soil | 0.05 – 0.20 |
| Neighborhood | 0.50 – 0.70 | Heavy soils | 0.13 – 0.35 |
| Residential | | Agricultural Lands | |
| Single Family | 0.30 – 0.50 | Bare packed soils | 0.30 – 0.50 |
| Multiunits, detached | 0.40 – 0.60 | Cultivated rows | 0.30 – 0.60 |
| Multiunits, attached | 0.60 – 0.75 | Pasture | |
| Residential, suburban | 0.25 – 0.40 | Heavy soils | 0.15 – 0.45 |
| Apartment | 0.50 – 0.70 | Sandy soils | 0.10 – 0.25 |
| Industrial | | Barren slopes | |
| Light | 0.50 – 0.80 | Smooth, impervious | 0.70 – 0.90 |
| Heavy | 0.60 – 0.90 | Rough | 0.50 – 0.70 |
| Parks, cemeteries | 0.10 – 0.25 | Woodlands | 0.05 – 0.25 |
| Playgrounds | 0.20 – 0.35 | | |
| Railroad yard | 0.20 – 0.40 | | |
| Unimproved | 0.10 – 0.30 | | |

Table 1.1 Typical Runoff Coefficients as Percentages Source: *Goldman, Erosion and Sediment Control Handbook*, 1986

As land areas are developed, natural drainage patterns are modified when runoff is channeled into road gutters, storm sewers and paved surfaces. These changes concentrate the volume of runoff in drainageways and increase the speed of flow. This results in higher peak discharges and shorter times to reach peak discharge. Figure 2.5 shows typical pre-development and post-development discharge rates versus elapsed time for a site being developed for urban land use. The area under the curves represents the volume discharged. The increased volume and discharge rate shows how the discharge from the site is increased. The rapid rise and fall of runoff is often presented as dangerous flash flood events. Major flooding or soil erosion problems also occur often after an area has been developed.

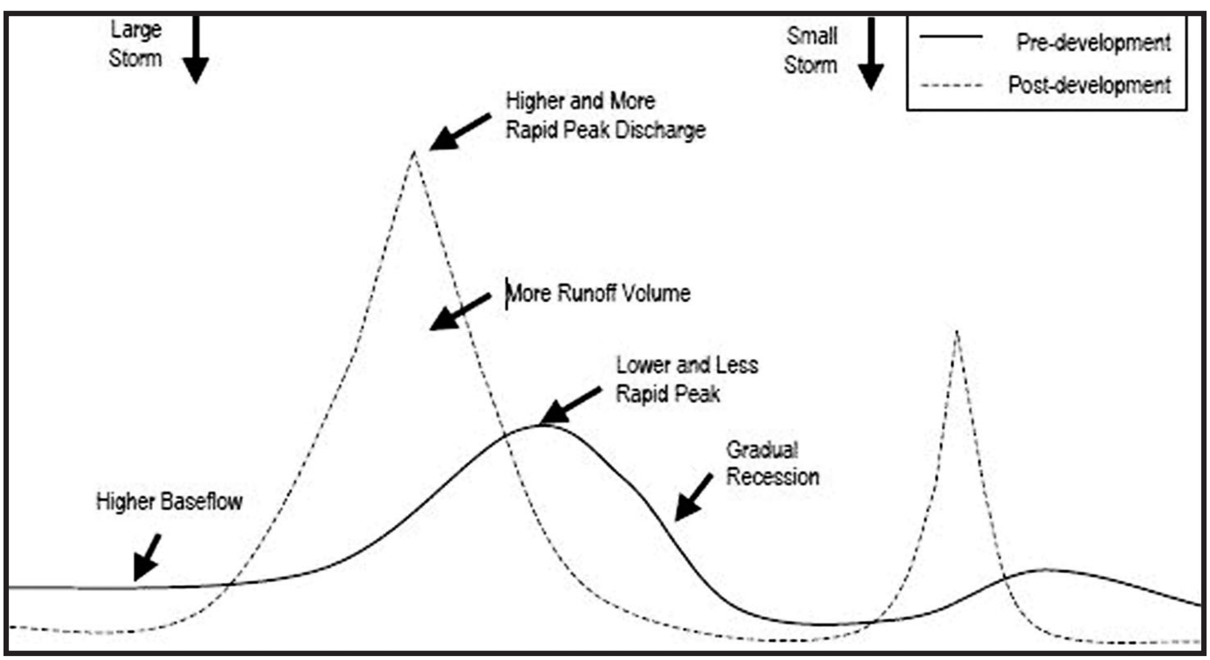


Figure 2.5 Consequences of Development to Urban Streams Source: EPA 841-B-05-004, November, 2005

Another hydrologic effect of urbanization is reduced stream flow during periods of low rainfall. This occurs because paved surfaces do not allow infiltration or retain the water in the soil that would naturally feed the streams. The result is deterioration of the aquatic ecosystem because of high pollutant loadings and low flow during periods of low rainfall.

During periods of high rainfall, the increased discharge rate and downstream flow often cause channel and streambank erosion in the receiving stream. Due to development and increase in impervious surfaces, there is less infiltration of surface water to groundwater and therefore more water arriving in stream channels and at a faster rate. This results in destabilization of streambanks and scouring of stream channels.

Removal of vegetation prior to construction activity is a major contributor to sediment moving off-site and entering nearby streams and lakes. Bare soil is highly vulnerable to erosion. Sediment movement from construction sites can range up to 35-45 tons/acre/year (ASCE and WFF, 1992). Vegetative cover is the most effective control of erosion and sediment loadings.

## Pollution Transport

Water pollutants that are commonly transported by stormwater from construction sites in urban settings include sediments, nutrients, petroleum products, chemicals, metals, pesticides, fertilizers and other potentially toxic chemicals (*After the Storm*, EPA Fact Sheet 833-B-03-002, January 2003).

### Sediment

Sediment, often incorrectly referred to as silt, (see Appendix A) from soil erosion is made up of soil particles and gravel washed into rivers, lakes and streams. It is the major pollutant in surface waters. Excessive sediment in waterbodies impairs aquatic ecosystems, reduces public water storage and increases drinking water treatment costs. These sediment particles are also a vehicle to transport other pollutants including nutrients, metals, petroleum products and bacteria to surface waters.

Runoff from construction sites is the major source of sediment in urban areas under development. Typical sediment loading rates from construction sites vary from 100 to 200 tons/acre/year (North Carolina DEHNR, 1993). Another major source of sediment is off-site streambank erosion, which is increased by the higher peak runoff flow rates and volumes previously discussed.

### Nutrients

Phosphorus and nitrogen are the primary forms of nutrients that can cause water pollution. Lawn fertilizers used to establish and maintain vegetation can be significant sources of phosphorus. Nitrogen comes from fertilizer, too, but is also found in animal wastes, grass clippings and effluent from leaking septic systems.

Phosphorus and nitrogen are sources of food for the algae and bacteria that live in lakes, streams and rivers. Waters polluted with these nutrients develop large numbers of algae and bacteria that use up oxygen, causing fish and other beneficial organisms to die. Nitrates in drinking water are responsible for the “blue baby syndrome” that has caused illness and deaths in infants and have been linked to certain forms of cancer in adults (*Health and Environment Digest*, 1988).

Nutrient pollution can be prevented by composting grass clippings and animal wastes, and repairing leaking septic systems. Nutrient pollution from construction sites can be minimized by applying fertilizer at the rate recommended by a soil test.

### Petroleum Products

Petroleum products float on water and are visible.  The hydrocarbons in petroleum have a strong characteristic for attaching to sediment particles. Hydrocarbons are known to be toxic to aquatic organisms.  Common sources of petroleum products at the construction site are oil storage, fuel facilities, leaks from crankcases and improper disposal of drain oil.

### Chemicals

Paints, solvents, sealants, cleaning agents and caulks may be found on construction sites.  These chemicals along with chemically composed or treated construction materials may enter the runoff water. Water quality is degraded and removal during water treatment processes may be very expensive.

### Metals

Trace metals including lead, zinc, copper, chromium, cadmium and nickel are found on construction sites.  In high concentration these metals are toxic to aquatic life.  They originate from building materials, vehicle emissions and road sand or salt.  Studies have shown that trace metals bioaccumulate in plants and aquatic life in areas where they are contained in sediment.