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Processes and Principles of Erosion and Sedimentation

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When land is disturbed at a construction site, the erosion rate accelerates dramatically. Since ground cover on an undisturbed site protects the surface, removal of that cover increases the site's susceptibility to erosion. Disturbed land may have an erosion rate 1,000 times greater than the pre-construction rate. Even though construction requires that land be disturbed and left bare for periods of time, proper planning and use of control measures can reduce the impact of man-induced accelerated erosion.

The major problem associated with erosion on a construction site is the movement of soil off the site and its impact on water quality. Millions of tons of sediment are generated annually by the construction industry in the United States. The rate of erosion on a construction site varies with site conditions and soil types but is typically 100 to 200 tons per acre and may be as high as 500 tons per acre. In N.C., 15% to 32% of eroded soil is transported to valuable water resources (SCS, 1977).

Identifying erosion problems at the planning stage and noting highly erodible areas, helps in selecting effective erosion control practices and estimating storage volumes for sediment traps and basins. This manual focuses primarily on the prevention of sedimentation problems associated with water-generated soil erosion.

THE EROSION AND SEDIMENTATION PROCESS

Types of Erosion

Erosion is a natural process by which soil and rock material is loosened and removed. Erosion by the action of water, wind, and ice has produced some of the most spectacular landscapes we know. Natural erosion occurs primarily on a geologic time scale, but when man's activities alter the landscape, the erosion process can be greatly accelerated. Construction-site erosion causes serious and costly problems, both on-site and off-site.

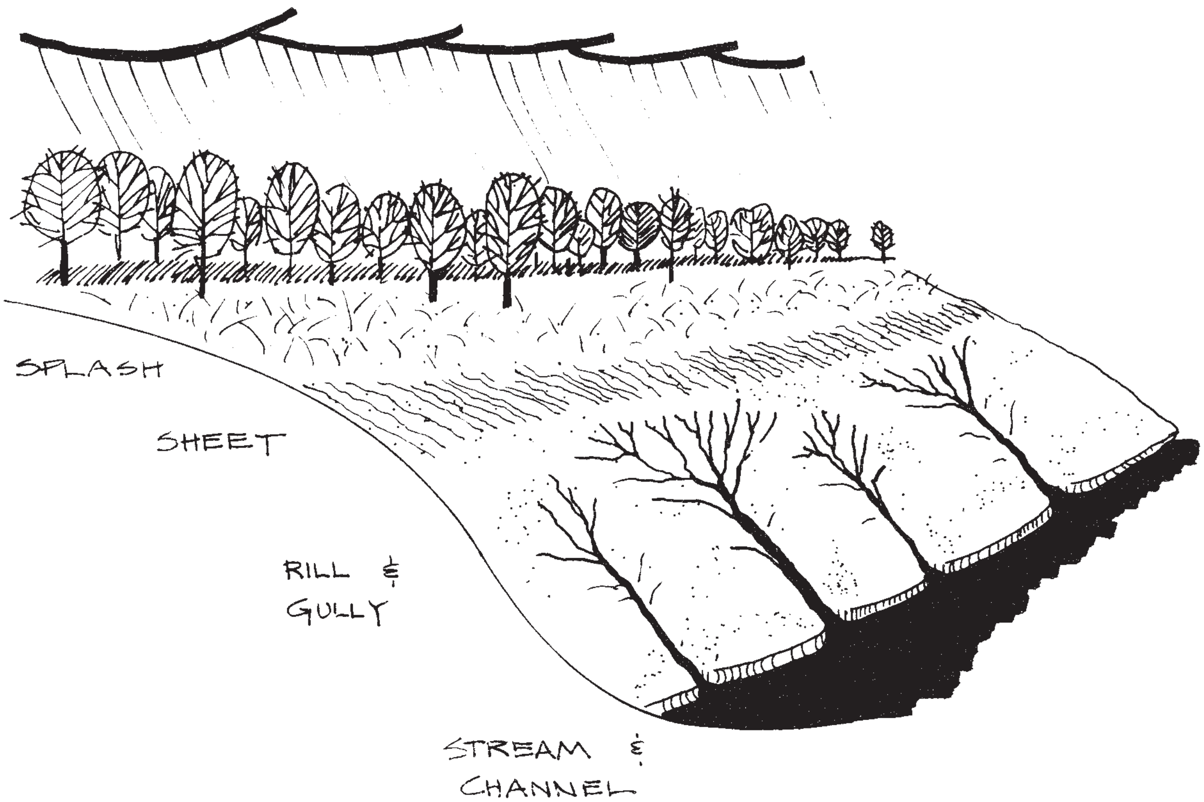


Figure 2.1 The four types of soil erosion on an exposed slope.

The soil erosion process begins by water falling as raindrops and flowing on the soil surface. Figure 2.1 illustrates the four types of soil erosion on exposed terrain: **splash, sheet, rill, and gully**, and **stream and channel**. Splash erosion results when the force of raindrops falling on bare or sparsely vegetated soil detaches soil particles. Sheet erosion occurs when these soil particles are easily transported in a thin layer, or sheet, by water flowing. If this sheet runoff is allowed to concentrate and gain velocity, it cuts rills and gullies as it detaches more soil particles. As the erosive force of flowing water increases with slope length and gradient, gullies become deep channels and gorges. The greater the distance and slope, the more difficult it is to control the increasing volume and velocity of runoff and the greater the resultant damage.

Sedimentation

Sedimentation is the deposition of soil particles that have been transported by water and wind. The quantity and size of the material transported increases with the velocity of the runoff. Sedimentation occurs when the water in which the soil particles are carried is sufficiently slowed for a long enough period of time to allow particles to settle out. Heavier particles, such as gravel and sand, settle out sooner than do finer particles, such as clay. The length of time a particle stays in suspension increases as the particle size decreases. The colloidal clays stay in suspension for very long periods and contribute significantly to water turbidity.

Factors that Influence Erosion

The potential for an area to erode is determined by four principal factors: soils, surface cover, topography, and climate. These factors are interrelated in their effect on erosion potential. The variability in North Carolina's terrain, soils, and vegetation makes erosion control unique to each development.

Understanding the factors that effect the erosion process enables us to make useful predictions about the extent and consequences of on-site erosion. An empirical model developed for agricultural applications, the Universal Soil Loss Equation (USLE), predicts soil loss resulting from sheet and rill erosion. It considers both the effects of erosion control practices and the factors that influence erosion, so it is useful for evaluating erosion problems and potential solutions. The factors that influence erosion are soil characteristics, surface cover, topography, and climate.

Soils

A soil is a product of its environment. The vulnerability of a soil to erosion, known as its erodibility, is a result of a number of soil characteristics, which can be divided into two groups: those influencing infiltration, the movement of water into the ground; and those affecting the resistance to detachment and transport by rainfall and runoff. The soil erodibility factor (K) is a measure of a soil's susceptibility to erosion by water. Key factors that affect erodibility are soil texture, content of organic matter, soil structure, and soil permeability.

Soil texture is described by the proportions of sand, silt, and clay in the soil. High sand content gives a coarse texture, which allows water to infiltrate readily, reducing runoff. A relatively high infiltration rate coupled with resistance to transport by runoff results in a low erosion potential. Soils containing high proportions of silt and very fine sand are most erodible. Clay acts to bind particles and tends to limit erodibility; however, when clay erodes, the particles settle out very slowly.

Because **organic matter**, such as plant material, humus, or manure, improves soil structure, increases water-holding capacity, and may increase the infiltration rate, it reduces erodibility and the amount of runoff.

Soil structure is determined by the shape and arrangement of soil particles (Figure 2.2). A stable, sharp, granular structure absorbs water readily, resists erosion by surface flow, and promotes plant growth. Clay soils or compacted soils have slow infiltration capacities that increase runoff rate and create severe erosion problems.

Soil permeability refers to a soil's ability to transmit air and water. Soils that are least subject to erosion from rainfall and shallow surface runoff are those with high permeability rates, such as well-graded gravels and gravel-sand mixtures. Loose, granular soils reduce runoff by absorbing water and by providing a favorable environment for plant growth.

Surface Cover

Vegetation is the most effective means of stabilizing soils and controlling erosion. It shields the soil surface from the impact of falling rain, reduces flow velocity, and disperses flow. Vegetation provides a rough surface that slows the runoff velocity and promotes infiltration and deposition of sediment.

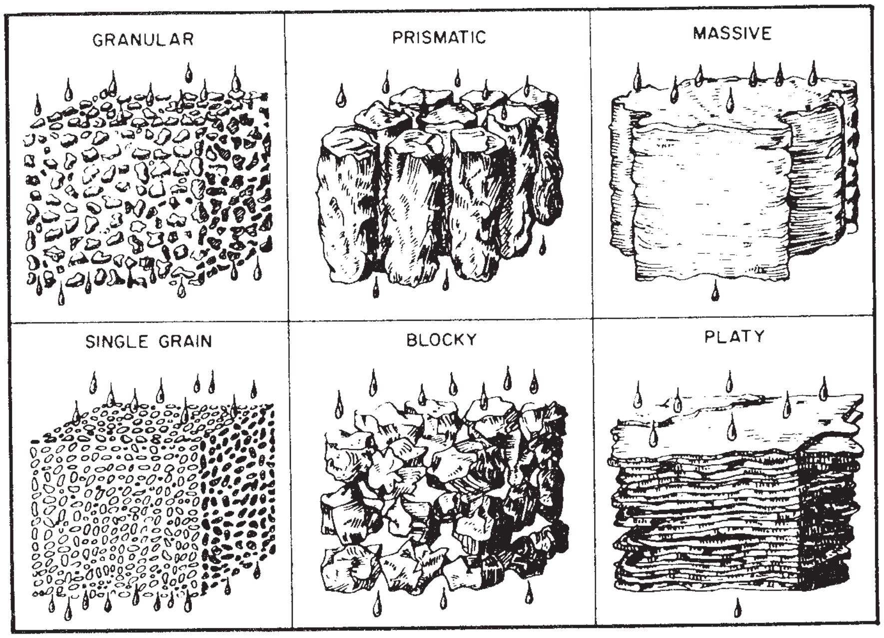


Figure 2.2 Soil structure influences the infiltration rate and movement of water in a soil. (Source: USDA and U.S. Department of the Interior, Agr. Inf. Bul. No. 199, 1959)

Plants remove water from the soil and thus increase the soil's capacity to absorb water. Plant leaves and stems protect the soil surface from the impact of raindrops, and the roots help maintain the soil structure.

The type and condition of ground cover influence the rate and volume of runoff. Although impervious surfaces protect the area covered, they prevent infiltration and thereby decrease the time of concentration for runoff. The result is high peak flow and increased potential for stream and channel erosion (Figure 2.3).

Nonvegetative covers such as mulches, paving, and stone aggregates also protect soils from erosion.

Topography

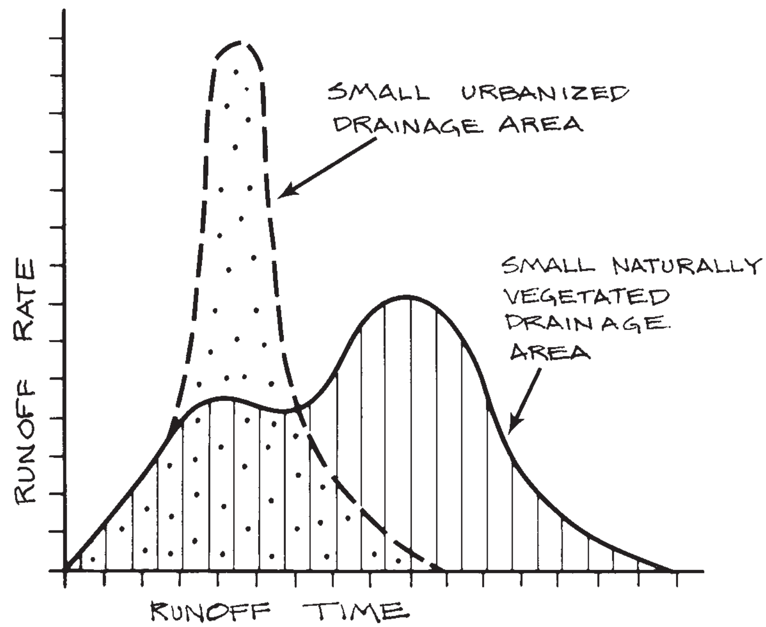
Topographic features distinctly influence erosion potential. Watershed size and shape, for example, affect runoff rates and volumes. Long, steep slopes increase runoff flow velocity. Swales and channels concentrate surface flow, which results in higher velocities. Exposed south-facing soils are hotter and drier, which makes vegetation more difficult to establish.

Climate

North Carolina has considerable diversity of climate. A hurricane season along the coastal region and snow and ice in the mountains are examples of the extremes in weather. High-intensity storms that are common in North Carolina produce far more erosion than low-intensity, long-duration storms with the same runoff volume.

The frequency, intensity, and duration of rainfall and the size of the area on which the rain falls are fundamental factors in determining the amount of runoff produced. Seasonal temperature changes also define periods of high erosion risk. For example, precipitation as snow creates no erosion, but repeated freezing and thawing breaks up soil aggregates, which can be transported readily in runoff from snowmelt.

Figure 2.3 Comparison of runoff in natural and urbanized drainage areas.



Impacts of Erosion and Sedimentation

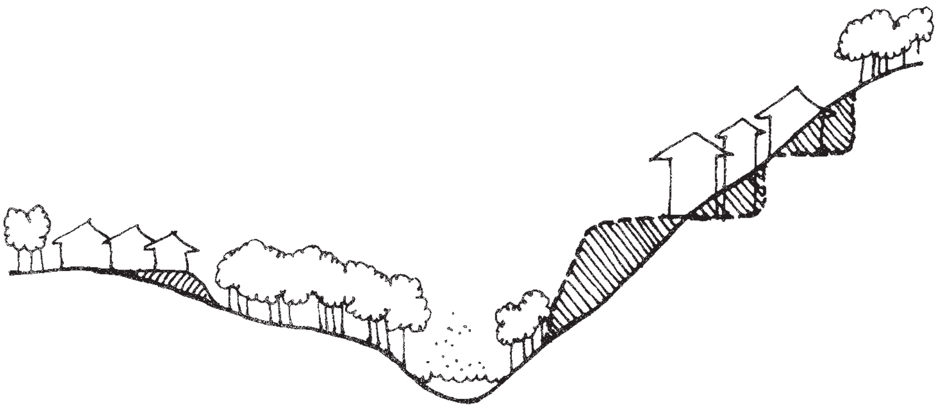
Damage from sedimentation is expensive both economically and environmentally. Sediment deposition destroys fish spawning beds, reduces the useful storage volume in reservoirs, clogs streams, may carry toxic chemicals, and requires costly filtration for municipal water supplies. Suspended sediment can reduce in-stream photosynthesis and alter a stream's ecology. Many environmental impacts from sediment are additive, and the ultimate results and costs may not be evident for years. The consequences of off-site sedimentation can be severe and should not be considered as just a problem to those immediately affected.

On-site erosion and sedimentation can cause costly site damage and construction delays. Lack of maintenance often results in failure of control practices and expensive cleanup and repairs.

PRINCIPLES OF EROSION AND SEDIMENTATION CONTROL

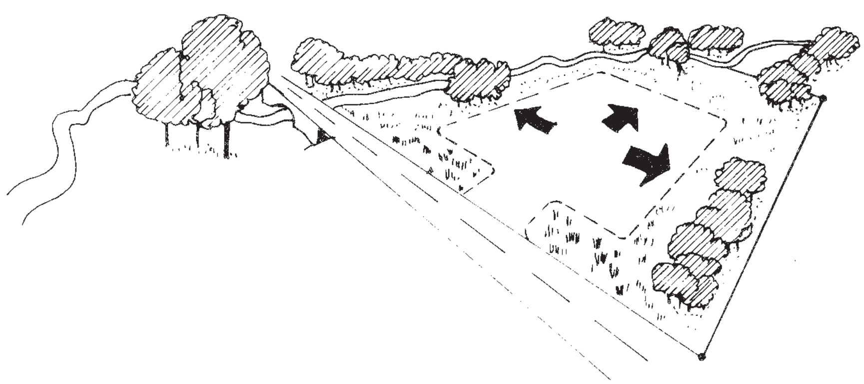
Effective erosion and sedimentation control requires first that the soil surface be protected from the erosive forces of wind, rain, and runoff, and second that eroded soil be capture on-site. The following principles are not complex but are effective. They should be integrated into a system of control measures and management techniques to control erosion and prevent off-site sedimentation.

Fit the Development to Existing Site Conditions



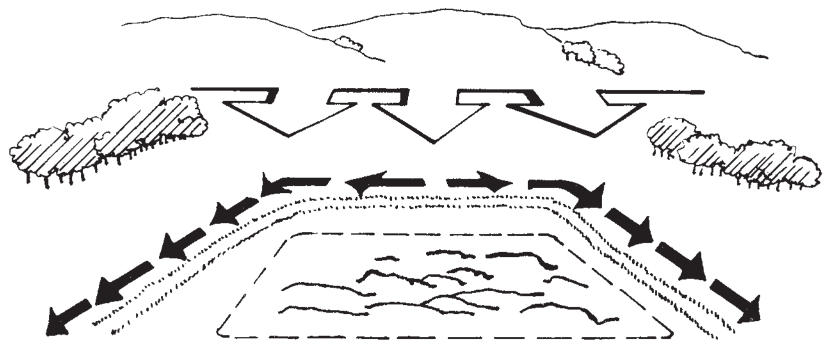
Review and consider all existing conditions in the initial site selection for the project. Select a site that is suitable rather than force the terrain to conform to development needs. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding, and highly erodible soils severely limit a site's use, while level, well-drained areas offer few restrictions. **Any modifications of a site's drainage features or topography requires protection from erosion and sedimentation.**

Minimize the Extent and Duration of Exposure



Scheduling can be a very effective means of reducing the hazards of erosion. Schedule construction activities to minimize the exposed area and the duration of exposure. In scheduling, take into account the season and the weather forecast. Stabilize disturbed areas as quickly as possible.

Protect Areas to be Disturbed from Stormwater Runoff

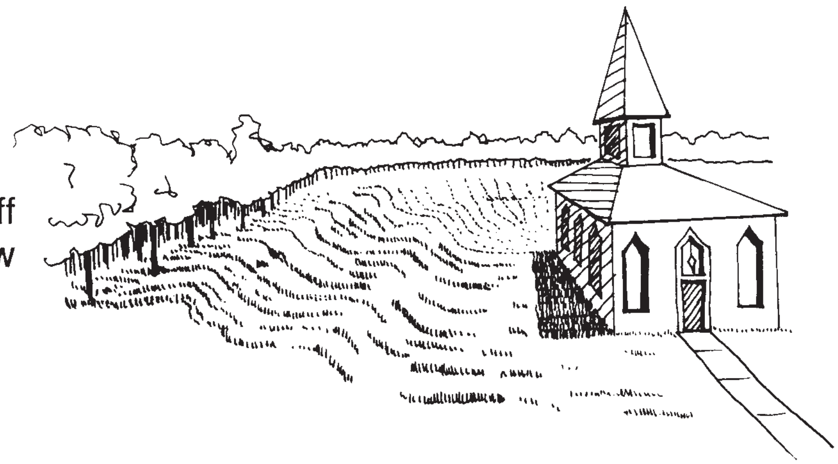


Use dikes, diversions, and waterways to intercept runoff and divert it away from cut-and-fill slopes or other disturbed areas. To reduce on-site erosion, install these measures before clearing and grading.

Stabilize Disturbed Areas

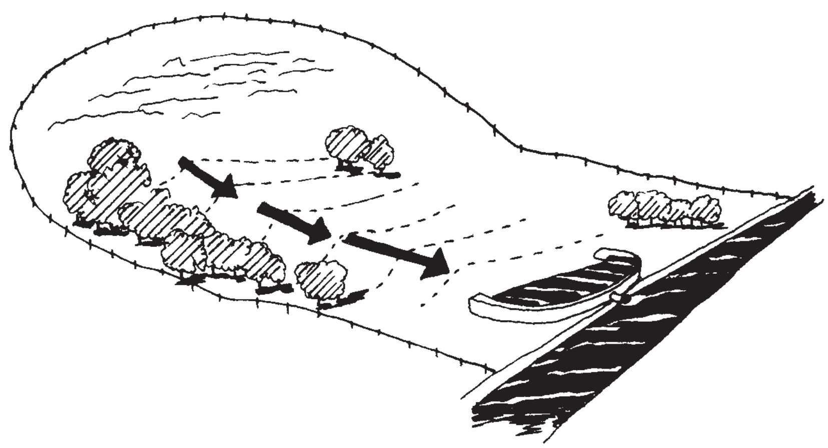
Removing the vegetative cover and altering the soil structure by clearing, grading, and compacting the surface increases an area's susceptibility to erosion. Apply stabilizing measures as soon as possible after the land is disturbed. Plan and implement temporary or permanent vegetation, mulches, or other protective practices to correspond with construction activities. Protect channels from erosive forces by using protective linings and the appropriate channel design. Consider possible future repairs and maintenance of these practices in the design.

Keep Runoff Velocities Low



Clearing existing vegetation reduces the surface roughness and infiltration rate and thereby increases runoff velocities and volumes. Use measures that break the slopes to reduce the problems associated with concentrated flow volumes and runoff velocities. Practical ways to reduce velocities include conveying stormwater runoff away from steep slopes to stabilized outlets, preserving natural vegetation where possible, and mulching and vegetating exposed areas immediately after construction.

Retain Sediment on the Site



Even with careful planning some erosion is unavoidable. The resulting sediment must be trapped on the site. Plan the location where sediment deposition will occur and maintain access for cleanout. Protect low points below disturbed areas by building barriers to reduce sediment loss. **Whenever possible, plan and construct sediment traps and basins before other land-disturbing activities.**

Inspect and Maintain Control Measures

Inspection and maintenance is vital to the performance of erosion and sedimentation control measures. If not properly maintained, some practices may cause more damage than they prevent. Always evaluate the consequences of a measure failing when considering which control measure to use, since failure of a practice may be hazardous or damaging to both people and property. For example, a large sediment basin failure can have disastrous results; low points in dikes can cause major gullies to form on a fill slope. It is essential to inspect all practices to determine that they are working properly and to ensure that problems are corrected as soon as they develop. Assign an individual responsibility for routine checks of operating erosion and sedimentation control practices.