II. BASIC CONCEPTS

2.1 Physical Processes Governing Sediment Yield from Small Areas

The four sediment control design procedures presented in this manual are all based on known physical processes which cause erosion. Figure 2.1 illustrates four dominant physical processes which control the production of sediment. The first source of sediment supply is raindrop impact, which detaches soil from the soil surface and makes it available for transport by overland flow. The amount of soil detached by raindrop impact depends on the energy of the rainfall; as rainfall intensity increases, the amount of soil detachment increases.

The second dominant physical process is the transport of the sediment supply by overland flow. The sediment transport capacity of overland flow depends on its velocity and depth. These two hydraulic conditions, velocity and flow depth, depend on the amount of rainfall excess (i.e., the amount of the rainfall which has not infiltrated, been intercepted by vegetation, or been caught in depressions), the overland slope, and the slope roughness. The roughness of a slope will depend on erodibility of the soil and the ground cover on the slope. Rills and gullies easily form on erodible soils, thereby reducing the slope roughness. Ground cover increases slope roughness by adding roughness elements to the slope such as leaves, roots and small branches. Ground cover will also decrease the amount of rainfall excess by increasing the amount of infiltration and interception. If the sediment transport capacity of a flow exceeds the supply of sediment from raindrop detachment, then overland flow will attempt to erode additional sediments from the soil surface.

The third dominant physical process is overland flow detachment. If the sediment transport capacity of the overland flow exceeds the supply of sediment, then it is possible for an additional sediment supply to be derived from flow detachment of the soil surface. Some soils are bound together by cohesive forces (dominant in the clay particle sizes), such soils resist detachment. For soils that are very cohesive flow detachment will be small. Conversely, noncohesive soil will erode easily and will provide an additional sediment supply which approaches the transport capacity of the overland flow.

If the supply of sediment from raindrop detachment and overland flow detachment remains below the transport capacity of the flow, then sediment

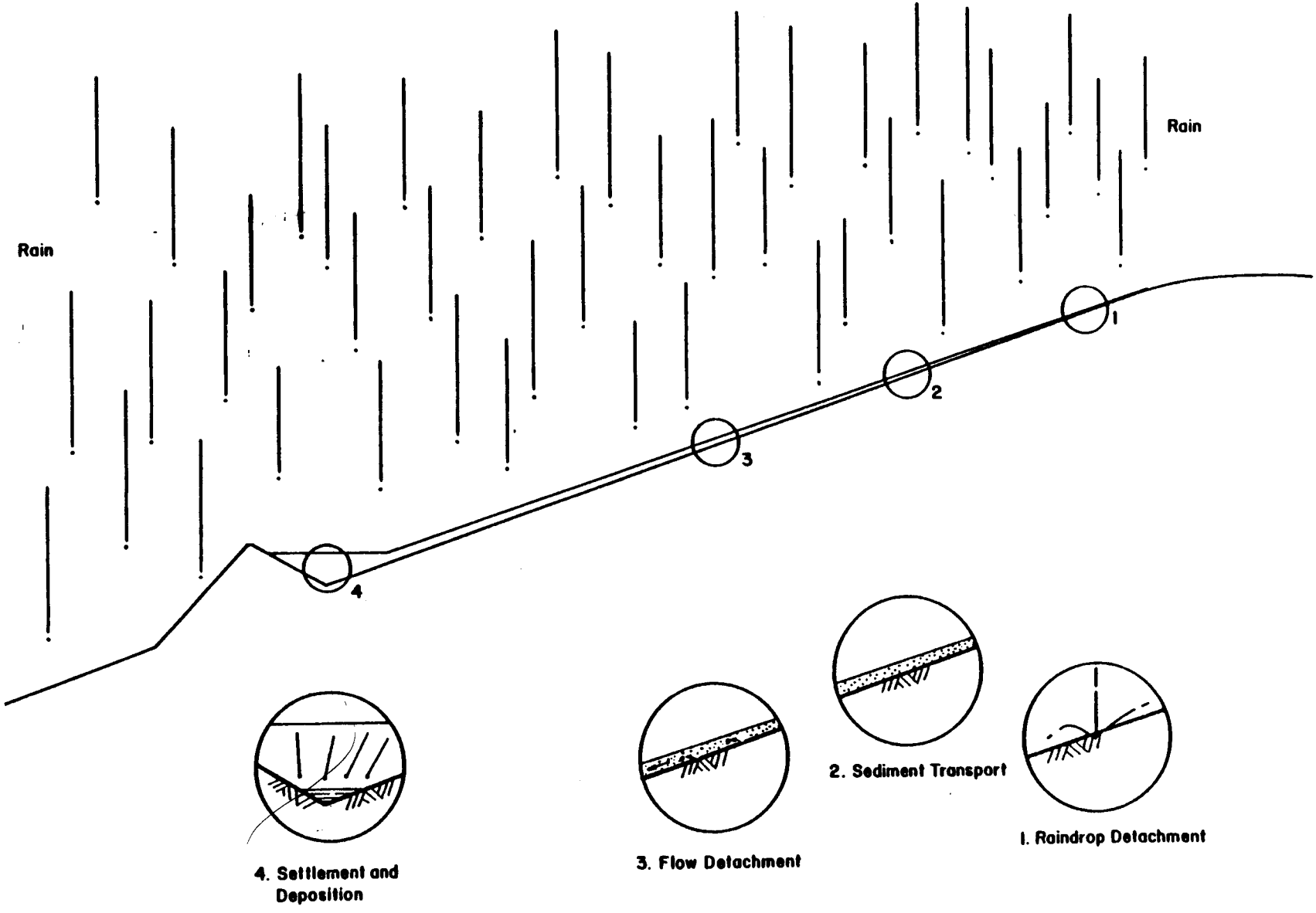

Figure 2.1. Physical processes governing sediment yield.

supply will control the sediment yield. This sediment yield condition is termed "supply controlled." Nonerosive soils such as those with a high clay content are often supply controlled. If the supply of sediment exceeds the transport capacity of the flow, the sediment yield will be controlled by the transport capacity of the flow and is termed "transport controlled." During high intensity rainfall periods or for very erosive soils, sediment yield is often transport controlled.

The fourth dominant physical process is settlement and deposition of sediment. Deposition of sediment occurs when the transport capacity of the flow is reduced. This can occur in properly designed detention ponds or diversion channels. Sediment particles will settle out dependent on their own weight and hydraulic conditions; larger sizes will settle rapidly and smaller sizes will require a much longer settling time. Sediment particles in the clay size range require very long settling times and for most practical considerations are essentially non-settleable. When sediment particles are settling in moving water, they must also overcome the effect of turbulence in the flow as well as the viscosity of the water. It is important to note that for detention structures designed to pass flow through them, the pond behind the structure must be long enough to allow most particles to settle before the flow leaves the structure.

Each of the four structure groups in this manual affects one or a number of the physical processes just discussed. The following discussion of each structure type shows how the physical processes are affected by these structures and how this modifies the sediment yield.

2.2 Surface Protection Measures

Surface protection measures include utilization of various types of mulches, vegetation, and erosion control products such as netting. These measures interact with the erosion process in a number of ways. First and most directly, they reduce the amount of bare soil area and therefore the amount of soil which can be detached by raindrop impact. The amount of raindrop detachment will decrease in direct proportion to the amount or cover provided by the surface protection measure. For example, if a straw mulch is applied to the soil surface which provides 50 percent cover, then the amount of soil detached by raindrop impact will also be reduced by 50 percent. In

this manual, cover ratios have been established for a variety of surface treatment measures.

Also, surface protection measures increase the surface roughness of a catchment area. This decreases the overland flow velocity, and therefore the sediment transport capacity of the flow. Surface protection measures increase roughness by both reducing the rilling potential of the surface and by adding small scale roughness elements to the surface.

Finally, surface protection measures increase the soil infiltration rate, provide additional retention storage for rainfall, and intercept rainfall before it reaches the soil surface. These effects work in combination to reduce the amount of rainfall excess (runoff) which in turn reduces the sediment transport capacity of the runoff.

Protection measures are among the most effective erosion control methods, since they can help halt soil erosion at the source. This group is also one of the least expensive treatments to implement, making it very cost effective.

2.3 Mechanical Treatment

Mechanical treatment measures are accomplished with the aid of heavy equipment and are used to add surface roughness and detain runoff. Individual treatment types included in this manual are contour furrowing, land imprinting, pitting and ripping. These treatment types are discussed in detail in Chapter V and a number of illustrations are given for each type.

Mechanical treatments control erosion by creating small detention volumes in the soil surface which reduce rainfall runoff. Additionally, a secondary effect is a reduction in overland flow velocities, thereby reducing the sediment transport capacity of the flow. Because of these two effects, infiltration is improved and rainfall runoff is further reduced. The depressions created by mechanically manipulating the surface provide a protected seedbed and improved soil moisture for plant germination and growth.

Equipment used for mechanical treatment of the soil usually has seeding devices attached. When vegetative cover is combined with mechanical treatment, the roughened surface lasts longer because it is protected from raindrop erosion.

2.4 Diversion and Conveyance Structures

Diversion and conveyance structures are widely used in surface mining to control runoff and erosion. The structures are small channels of various geometries used to collect overland flow before it concentrates to form unstable gullies. When the length and slope of these structures are correctly chosen, they will also trap sediment and therefore reduce sediment yield.

A diversion structure must have a low sediment transport capacity to effectively trap sediment. This means that the velocity of flow in the diversion should be low. The slope of the diversion should therefore be as flat as possible and have a wide cross section. The velocity of flow in a diversion can also be reduced if rough channel linings are selected. Stone and grass linings are often used. When a diversion channel is properly constructed, the transport capacity of the channel will be lower than the supply of sediment to the channel. Under this condition sediment will be deposited in the channel with the coarse sediment sizes settling out quickly and the finer sediment sizes settling out slowly. It should be noted that since settling times are quite long for small sediment sizes, diversion channels must be either very long or velocities very low for small particles to settle. Often these conditions cannot be attained in a diversion channel. Thus even though the transport capacity of small sediment sizes is less than the quantity of sediment supplied to the channel, deposition may not occur. Unless the settling time of a sediment particle is less than the travel time of the particle through the diversion channel, only partial settling will occur.

Conveyance channels which link diversion channels together (see Figures 6.1 and 6.2) are designed to remove water and sediment from an area without causing any further erosion. Therefore, deposition of sediments is usually only possible in the diversion channels. While conveyance channels are not designed to trap sediment, they do serve the important purpose of controlling any further erosion from the site.

Conveyance channels are often overlooked in erosion control designs, but they are crucial to the effective performance of all sediment control measures. Removal of sediment from water does little good if this water is discharged to an unstable erodible channel. An unstable channel can easily resupply sediment to the flow by erosion of the bank and bed of the channel.

2.5 Detention and Filtering Structures

Detention and filtering structures use two basic physical processes to remove sediment from runoff. First, these structures provide a local reduction in the sediment transport capacity by reducing the velocity of flow. Reductions in flow velocity can be achieved by ponding water (behind small check dams) or by roughening the overland flow surface (vegetative buffer strips). Second, if the structure is permeable, sediment can be trapped in the pore openings as water passes through the structure (hay bale or fabric structures). Since the permeability of the structure is low, water will also pool behind these structures and the trapped sediment will begin to settle out.

The performance of these structures (trapping efficiency) will vary with the size of sediment which is supplied. Large sediment which settles quickly or is easily caught in the pore openings of permeable structures is effectively controlled by these structures. In contrast to this, finer sediment can easily pass through the pore openings of most permeable structures. These sediments will settle only if long detention times are achieved in the pool behind the structure.

2.6 Guide to Selection of a Sediment Control Structure Type

The designer of sediment control measures and structures is faced with selecting a design which has a high rate of sediment removal and a reasonable cost. Obviously, evaluating the performance and cost of every possible treatment for a site is not practical. It can be seen from the previous discussion that some structures control certain physical processes while other measures control other processes. By understanding the importance of different physical processes, a guide to selecting sediment control treatments can be developed.

First, the largest source of sediment supply in small areas results from raindrop detachment. Only one erosion control group acts to control this supply, and that is the surface protection measures (i.e. mulches, revegetation). These measures control both the supply of large and fine sediments, whereas the other control measures have limited ability to control fine sediment. If a soil contains a large amount of fine material (specifically silt and very fine sand), surface protection measures will be the most effective means of controlling sediment.

Second, methods which reduce the amount of runoff (surface protection and mechanical treatment) will control the transport of sediment from the slope. These methods will reduce the volume of erosion. When combined with a method which protects the soil surface from raindrop detachment, a very effective sediment control system is developed.

Third, methods which rely primarily on settling of sediment (e.g. diversions, detention structures) will be most effective on larger sediment sizes (specifically fine through coarse sand). Usually adequate detention times can not be developed behind structures of this type to reduce the amount of finer sediment particles.

Fourth, any effective sediment control system for a small (or large) area will require a stable conveyance system. A concentrated flow of water can cause significant damage if it is not confined to a stable conveyance channel.

Once the erosion control groups are selected, the designer must then select the most appropriate and cost effective individual design type within each group. Many erosion control types can be eliminated simply on the basis of (1) availability of material or equipment, (2) specific climate conditions, or (3) nature of the mining operation. This type of review and selection of structures or measures should reduce the number of alternatives to a reasonable number. These can then be evaluated in a more detailed manner.

In summary, a physical process approach to sediment control allows a designer to quickly identify which structures or measures will be most effective. Trial and error selection of erosion control groups can be eliminated by utilizing the concepts of this approach. As a designer gains experience with the design procedures presented in the following chapters, he will gain a working knowledge of important physical processes for a mine site and the proper use of treatments to control sediment.

2.7 References

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