NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

Land Reclamation, Landslide Treatment
(No. And Acre)
No. 453

Definition

Treating inplace material, mine spoil (excavated overburden), mine waste, or overburden to reduce downslope movement.

Purpose

To prevent or stabilize landslides to: protect life and property; prevent excessive erosion and sedimentation; improve water quality and landscape resource quality; and to create a condition conducive to establishing surface protection and beneficial land use.

Conditions Where Practice Applies

To areas where inplace material, mine spoil, waste, or overburden is unstable, moving, or judged to have potential of moving downslope in a manner that will cause damage to life, property, or the environment and produce excessive sediment and debris. Land reconstruction is normally associated with this practice.

This practice does not apply where a landslide or potential landslide threatens cultural developments such as houses, utilities, roads, and structures.

Federal, State, and Local Laws[1]

Design and construction activities shall comply with all federal, state, and local laws, rules, and regulations governing pollution abatement, health, and safety. The owner or operator shall be responsible for securing all required permits or approvals and for performing in accordance with such laws and regulations. NRCS employees are not to assume responsibility for procuring these permits, rights, or approvals, or for enforcing laws and regulations. NRCS may provide the landowner or operator with technical information needed to obtain the required rights or approvals to construct, operate, and maintain the practice.

Permits may be required from the following agencies:

1. West Virginia Department of Health

2. West Virginia Department of Agriculture

Planning Considerations

Water Quantity

1. Effect on the discharge capacity of water courses affected by the landslide.

2. Water budget effect on volumes and rates of runoff, evaporation, deep percolation, and ground water recharge.

3. Potential for a change in plant growth and transpiration because of changes in the amount of soil moisture in the vicinity of the structure.

Water Quality

1. Potential to reduce erosion and related movement of sediment or sediment-attached substances.

2. Short-term and construction-related effects on downstream water courses.

3. Potential to alter the discharge of toxic materials to ground or surface waters.

4. Effects on the visual quality of water resources.

Conservation practice standards are reviewed periodically, and updated if needed. To obtain the current version of this standard, contact the Natural Resources Conservation Service.

Design Considerations

1. Geology of the area and associated subsurface conditions.
2. Type and amount of spoil or waste.
3. Topography of the slide and adjacent areas, including known or estimated pre-mine, preconstruction, or pre-slide conditions.
4. Surface drainage and runoff patterns.
5. Ground-water profiles, seepage patterns, and sources of subsurface water.
6. Land use, dwellings, roads, structures, and water disposal system.
7. Procedures used during mining operations or construction.
8. Slide potential during investigation and construction.
9. Rainfall and runoff.

Landslides result from a combination of several factors, the most important being static load, slope of the surface and slip zone, the soil characteristics in the slip zone, and the presence of water. The key to control is to bring about a favorable balance between the load that creates the tendency to move and the resisting forces that restrain movement. This can be done by reducing the load, reducing the slope, increasing internal strength, and providing external restraining forces. A good reference on landslides is the publication "Landslides: Analysis and Control," 1978. Transportation Research Board, National Academy of Sciences, Special Report 176, 234 p.

Investigations are to be made to determine:

1. Surface profiles, cross sections, and topographic features.
2. Geologic profiles and cross sections showing attitude and condition of strata and details of the slip zone.
3. Soil properties, including gradation, density, strength, and physical and chemical characteristics.
4. Ground-water conditions.
5. Depth and volume of material involved.
6. Extent of problem or potential problem area.
7. Estimated pre-slide profile and subsurface conditions.
8. Conditions where slopes are stable in similar materials.

Extreme caution must be exercised and careful planning is required before permitting any drilling equipment, construction machinery, or personnel in the slide area. A slide is often active only during wet periods and may be comparatively stable during dry periods. With this in mind, heavy drilling and machinery work should be scheduled during dry periods.

Design Criteria

In most cases the unstable or potentially unstable conditions cannot be attributed to one cause. Therefore, the solution is usually a combination of treatment measures, each either increasing the internal strength or decreasing the external load to the point where required stability is obtained.

Slope stability. Measures developed to prevent or stabilize slides shall be based on engineering analysis and judgement made by an engineer trained and experienced in soil mechanics. Slides are the most complex of geotechnical problems requiring analysis. The best available expertise in soil engineering is needed and expert consultants should be hired, if necessary.

Slope stability analysis shall account for all critical soil and loading conditions. The strength parameters of natural soil and rock or of waste materials shall be based on the appropriate conditions for each slide. Long-term strength parameters (c=0 and internal friction based on residual shear) are often required. The methods of slope stability analysis are to be appropriate for the loading conditions and for the location and shape of sliding or potential failure surfaces. Appropriate safety factors shall be provided based on the degree of uncertainty in the soil strength values used, the soil and water conditions assumed, and the detail of the analysis used.

When there is a potential for loss of life or damage to farmsteads, residential areas, frequently traveled roads, any occupied facilities, or important public utilities, the measures shall include removal of the material subject to sliding or any other control to ensure safety.

Earthquake or seismic forces are to be considered on major high hazard sites. The criteria as contained in Technical Release No.

60 for earth dams shall apply for geologic investigations, seismic assessments, and minimum seismic coefficients associated with earthquakes.

Water control. Water creates problems in two ways. The addition of water to the material above the slip zone increases the load. It also acts as a lubricant, or increases pore pressure within the slide material and in the slip area, thereby reducing internal strength. In both cases water increases the potential for sliding.

There are three major sources of water within the slide area - surface runoff that finds its way onto the slide area, precipitation directly on the surface, and subsurface water from known or unknown sources. A combination of these sources usually contributes to the excessive water problem.

Surface runoff water. Runoff water from outside areas is to be controlled by using diversions, associated structures, and conveyance systems.

Water from direct precipitation. Infiltration can be limited and controlled by providing positive surface drainage, sealing the surface cracks and breaks on the slide and adjacent areas, and establishing vegetation. Grading and shaping may be required to provide positive surface drainage. Terraces, structures, and waterways are to be installed as needed to provide safe water disposal without erosion and with positive grade to reduce seepage. Cut and fill to a depth of 0.9 to 1.2 m (3 to 4 ft) may be required to reduce surface infiltration and seal cracks and breaks. Compaction of the material will further reduce infiltration, but care must be taken to prevent excessive compaction which would restrict vegetative establishment. Establishing a vigorous vegetative cover will increase evapotranspiration and control erosion.

Ground water. Ground water that contributes to instability is to be controlled. Many slides remain active during the reconstruction period and further movement can be expected. Therefore, drainage systems are to be designed to remain operative after limited movement. Pipes must be used with caution because of the potential of breaking and/or misalignment with further movement. Flat or nearly flat gradients should not be used for the same reasons. A properly designed filter shall be used to prevent clogging of the drains.

Earth material control. Earth material and internal water are the load factors that contribute to the unstable conditions that cause slides. Treatment consists of removing earth material to reduce the load and slope, increasing the internal strength of the earth material, and providing external restraints to movement.

Loading control. In most cases loading control consists of removing excess material to a safe location. However, in some instances the solution may be adding material to the toe of the slide area to increase the load, resisting further movement. Removal of slide debris from the toe (downhill side) of the slide usually will increase the instability and cause further slide movement.

Slope reduction. Slope can sometimes be reduced by grading and shaping to eliminate critical slopes within the slide area. It can also be reduced as a result of loading control measures.

Increasing internal strength. Reducing the internal water of the slide material, removing or replacing the slide material, incorporating any admixture needed into it, and compacting it can increase the internal strength to resist a tendency to slide.

External restraints. In some cases, buttresses, bulkheads, retaining walls, pilings, tieback anchors, and gabions can be used to restrain further slide movement. These structures may provide the only practicable solution where high-valued improvements are involved and movement must be contained in a short distance. The structures are normally very expensive and are usually not practicable otherwise. They also require complex design analyses, using the expertise of geologists, soil mechanics engineers, and structural engineers.

Component practices. All individual practices installed as a component of landslide treatment are to be designed and installed in accordance with applicable NRCS standards and specifications. If NRCS standards are not available, the practice is to be designed and installed using current engineering technology.

Environmental. All disturbed areas are to be provided with adequate water disposal systems and established to vegetative cover, or otherwise protected, to control erosion and sediment as soon as practicable. Temporary protective measures will be necessary if a long delay is anticipated in establishing permanent cover. Foot and vehicular traffic is to be controlled to protect the area.

Visual resources are to be given the same consideration as other design features during planning, design, and installation. All disturbed areas shall be reshaped and regraded to blend in with the surrounding land features.

Plans and Specifications

Plans and specifications for slide treatment shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve the intended purpose.

Specifications shall be from the National Engineering Handbook, Section 20 or the West Virginia 700 Series, as appropriate.

Operation and Maintenance

The operation and maintenance plan is to include periodic inspections because of the potential for additional movement, failure of water disposal systems, failure of vegetation, and other problems. The water disposal system, subsurface drainage system, access roads, and vegetative cover are to be maintained to accomplish their intended purposes. Necessary maintenance and repair activities are to be initiated promptly.

[1]Bold italics is information added to the National standard by West Virginia