SLIDES, SLIPS AND ROCK FALLS

09.01 GENERAL POLICIES AND RESPONSIBILITIES

This manual is intended for internal guidance only and is not intended to create a legal or moral duty. Supervisors have discretion, based upon their expertise and the particular circumstances, to deviate from this manual and to conduct additional research or receive input from experts in other areas, as needed.

09.01.01 PREVENTATIVE MAINTENANCE

The best method of controlling unwanted movements of earth and rock is to prevent them. Before final construction plans for a highway are approved, it is highly desirable that they be reviewed by the Director of Maintenance or his representative. Maintenance Engineers and County Maintenance Superintendents have good opportunities to recognize the good features of a road and to detect deficiencies. This familiarity with local geological formations, old slide areas, topography, and drainage features can be of great value in determining where slides, slips, or rock falls are likely to occur. When a new road is being planned or an old one is relocated or improved, the advice of the Maintenance Division can be helpful to the engineers who locate and design the road.

All Maintenance Supervisors should strive to increase personal knowledge and understanding of the causes of unwanted movements of earth or rock. While performing routine duties, the Supervisor may be better able to detect conditions that are likely to cause slides, slips, or rock falls. As a result of these observations, a movement may be prevented. For instance the Supervisor may notice the need for repairing a break in a culvert pipe beneath a fill before there is a slip, or may realize that benches or scaling is needed in a rock cut before rock falls occur.

09.01.01.01 DEFINITIONS

Slides, slips and rock falls occur in practically every county in West Virginia. A "slide" is the movement of a mass of earth, or earth and rock, onto the roadway from the adjacent slope in a cut. Such a movement must be distinguished from a "slip" or "slip-out", which occurs when movement of a mass of earth and rock in a supporting embankment causes a displacement of a portion of the roadway itself. The term "slide" should be used only when the material involved is earth or a combination of earth and rock. When there is a movement of rock, shale, or boulders without any earth, the term "rock fall" is preferred.

The term "hazard" in these instructions indicates any type of obstruction to normal safe travel found on a shoulder or the traveled way. An obstruction in or behind the ditch or gutter line is not considered a hazard to the traveling public. In time, however, it will cause damage to the roadway. It will therefore be treated as a hazard and should be removed as quickly as possible.

09.01.01.02 DRAINAGE IMPORTANCE

At mention of the term slide, slip, or rock fall, the word "water" should instantly come to mind. When a slide or a slip occurs, it is almost certain that the presence of water is a contributing factor. An important factor in preventative maintenance is to locate the source of the water and either eliminate or divert it.

09.01.01.03 MOVEMENT INDICATIONS

A major and costly earth movement may often be prevented, or the damage resulting from a movement may be greatly reduced, by early detection of certain indications that movement has already started or is about to start. Examples of such indications are the following: "catspaws" on a natural slope; cracking and subsidence in a pavement or a shoulder, accompanied by "humps" in the natural ground near the toe of an embankment. Trees or saplings on a slope should be observed for abnormal leaning.

An alert maintenance employee learns to recognize the conditions that may lead to a rock fall. Sometimes the danger is evident even before any debris has fallen, but more often a warning is given when rock fragments or small amounts of shale or earth become dislodged and drop into the ditch or onto the roadway.

09.01.02 RESPONSIBILITIES

09.01.02.01 MAINTENANCE PERSONNEL

Careful inspection and prompt preliminary investigation of a slide or slip that has already occurred is an important duty of County and District maintenance forces. The need to investigate the cause of a slide or a slip at the first indication of its presence and to apply corrective measures as soon as possible cannot be over-emphasized. Ignoring the conditions will not make them better. Delay in correcting them usually only makes repairs more difficult and costly.

If a slide or slip is small and action taken soon enough, the use of hand augers by qualified maintenance personnel will often permit the collection of enough information to make possible the proper corrective action. However, where slides or slips occur frequently, it is highly desirable for the Maintenance Division to call the Materials Control, Soil and Testing Division for assistance in solving problems caused by the soil movements. That Division has equipment and personnel for conducting tests on soil with the thoroughness required, and its engineers have special knowledge needed to analyze and interpret the results of the tests. They are more able to select the most effective methods of preventing or controlling further movements of the soil.

When the travelled way or shoulder of a road is affected by a slide, two-way traffic controlled by signs or flaggers must be provided with the least possible delay.

09.01.02.02 COUNTY MAINTENANCE SUPERINTENDENT

When the County Maintenance Superintendent is notified that a hazard exists, a qualified person shall be sent to inspect the conditions. Only after such an inspection has been made will equipment and personnel be dispatched to the site to remove the hazard. This procedure will be followed whenever a report of a slide, slip or rock fall

is received. When responding to such reports, the investigating person must remember to carry the necessary warning signs and lights or have them sent ahead.

Where signs and lights must be left in place for an extended period of time, personnel will be designated to check and service them.

09.02 SLIDES AND SLIPS

09.02.01 TYPICAL CONDITIONS

09.02.01.01 SATURATION SLIDES

Ordinarily, when the slope above the roadway is in shale or soil and is dry, there is little likelihood of a slide. When water infiltrates these materials, equilibrium is sometimes disturbed and movement begins. A great number of small hillside slides are the result of saturation. There have been places where rain falling directly on a slope has saturated the material to the extent that it became almost a liquid and literally flowed across a four-lane highway. In case of a saturation slide, initial movement is caused by a combination of lubrication, reduction of cohesion, and increased weight. Typical conditions that may lead to a slide near the bottom of a cliff, or at the foot of a rocky hill with a steep slope are shown in Figure 09-1.

09.02.01.02 SLIDE PLANE SLIDES

Very often, a layer of pervious soil lies directly over a slanting layer of impervious material such as rock, fire clay or hard shale. The slanting surface of this impervious material is a potential slide plane. Typical conditions are shown in Figure 09-2. When the soil is dry, the frictional resistance between the pervious and impervious materials is great enough to keep the upper layer from moving downward to the roadway. If rainwater soaks downward through the overlying pervious material to the impervious layer, or if water from a spring or a water-bearing layer of soil seeps along the top of the impervious layer, as indicated in Figure 09-3 or Figure 09-4, the resulting lubrication overcomes the frictional resistance and movement begins. Cracks then form in the earth mass and additional water flowing to the slide plane accelerates the movement.

09.02.01.03 CLAY SLIDES

In other locations, the conditions causing slides may be more complex. For example, subsurface water may act on a layer of clay. Such material is quite hard and stable when dry, but it becomes very plastic and even grease-like when damp.

09.02.01.09 SLIPS

A slip may be caused by any one of the following conditions: accumulation of water at the foot or toe of a fill, as indicated in Figure 09-5; seepage of water into the lower portion of a fill, as in Figure 09-6; subsurface water in the natural ground beneath the fill seeping along the top of an impervious layer as indicated in Figures 09-7 or 09-8; or subsurface water reaching an unstable sloping layer of clay. Of course, a slip may be the result of faulty construction methods. For example, the side of a hill may not have been properly benched before the fill was placed, or the layers of fill material may not have been properly compacted. In a rare case, a slip may occur

because the natural soil did not have sufficient strength to support the overburden and loads from traffic. Such a condition is indicated in Figure 09-9. Excavations of soil below the roadway, as for driveways or buildings, can reduce lateral support and allow the roadway to slip. A slip may also be created by placing earth or rock on the shoulder or dumping it over the fill slope. This action increases the load on the slope and may result in a slope failure.

09.02.02 CORRECTIVE MEASURES

09.02.02.01 GENERAL PROCEDURES

In most cases the primary underlying natural cause of earth movement is the presence of water. It is logical that the general procedure for correcting a slide or slip consists in finding the source of the water and then intercepting and diverting it. The actual corrective measures to be taken will depend on the results of the investigation made to determine the cause of the earth movement. The best measures for each of the conditions shown in Figures 09-1 to 09-9 are indicated on the illustrations. County maintenance crews must often apply prompt emergency measures, such as the digging of diversion ditches to channel water from the slide area in an attempt to halt further progress of a slide or slip.

09.02.02.02 TALUS SLIDE

Where a talus slide occurs or may occur near the bottom of a cliff or at the foot of a rocky hill, the best corrective treatment is to divert surface water and intercept ground water as indicated in Figure 09-1. The preferred position of the diversion ditch is at the top of the talus and the interceptor drain is at the shoulder of the roadway. In the investigation for locating the source of the water, test holes must be drilled a few feet apart from the toe of the slope of the embankment to the upper limit of the break.

The use of piling generally is not effective for correcting a slide under the conditions shown in Figure 09-1. The effect of placing a retaining wall or other barrier at the toe of the hill would be uncertain unless proper provision is made for draining the water. If a drainage system is installed a barrier may not be needed.

09.02.02.03 SLIDE PLANE SLIDES

Where the conditions are as shown in Figure 09-2 and a layer of pervious material slides, or is likely to slide, along the slanting surface of an impervious layer, the corrective measures are to divert the water and also to install a retaining structure. If the layer of pervious soil is shallow, the water can be diverted by digging a ditch to carry away surface water. If the pervious soil is deep, it will be necessary to install an interceptor drain. In the investigation, it will be necessary to locate the surface of the impervious layer. When the pressure exerted by the soil is not excessive, the use of piling or a retaining wall to prevent movement of the soil may be effective.

09.02.02.09 SEEPAGE CAUSED SLIDES

Whenever there is seepage of water from a spring or a water-bearing layer of soil, as indicated in Figure 09-3 or 09-4, the obvious treatment to prevent a slide is to dig a diversion ditch to carry away surface water and install an interceptor drain as close as possible to the point at which the water tends to enter the pervious soil. Where

the seepage depth is shallow, it may be possible to locate the diversion ditch to carry both surface water and underground water and eliminate the need of an interceptor drain. If seepage occurs at more than one level, an interceptor drain must be provided at each level.

Under conditions shown in Figure 09-4 at Section B-B, the use of piling instead of an under drain at the lower seepage level may not be economical because the saturated soil would exert additional pressure on such a barrier and require a much larger than normal piling size.

09.02.02.05 TREATMENT FOR SLIPS

When water accumulates at the toe of a fill, as indicated in Figure 09-5, the best way to prevent a slip is to remove the soil that would be in contact with the water and replace it with rock. Care must be taken during excavation since a steep back slope without proper shoring may result in a more extensive failure.

To correct a slip when the conditions are as shown in Figure 09-6, it is necessary to dig a diversion ditch or to install an interceptor drain on the uphill side of the road. After a slip has occurred and after the water has been intercepted, stability of the fill can be increased by cutting a bench into the impervious material at the toe of the fill and backfilling with large pieces of rock. The same care as indicated above must be taken to protect the back slope.

If a slip occurs or may occur because of seepage of water, as indicated in Figure 09-7 or Figure 09-8, the water must be diverted by an interceptor drain before it escapes into pervious material. What was said in connection with the use of piling also applies to Figure 09-7 or Figure 09-8. It is always necessary to locate the source of the water and the location of the point at which it tends to enter the pervious soil. The probable location of this point can often be determined by the examination of the exposed surface of a cut near the slip, as in Figure 09-7 at Section A-A.

In the event that the natural soil does not have sufficient strength to support the loads from traffic and fill material as indicated in Figure 09-9, one method for correction is to excavate a bench at the toe of the slope and to replace the weak material with stable material. As stated previously, care must be taken to protect the back slope during excavation.

Where the natural ground under an embankment has moved upward and outward as a result of the combination of lateral and downward movement of embankment material displaced during a slip, it is sometimes possible to prevent further movement by placing a counterweight fill over an area of the natural ground near the toe of the embankment. This will have the effect of buttressing the slip.

09.02.03 REPAIR MEASURES

09.02.03.01 CLEANING ROADWAY

The first step in repairing damage caused by slides is to remove debris. If a ditch is clogged, it should be cleaned.

The proper method of removing loosened material from the roadway is to start

at the top of the slope and to work downward. If the material at the bottom were removed first and suitable precautions were not taken, the material above would be left without support and could easily start to move again. In fact, a new slide involving additional material may be caused. In case conditions make it necessary to remove slide material by starting at the bottom, special precautions shall be taken to prevent another unwanted movement of material and to provide adequate protection of crews and equipment.

09.02.03.02 MATERIAL DISPOSAL AND REPLACEMENT

Before work is begun to clear the roadway of loose material deposited during a slide, suitable arrangements must be made for disposing of that material. Waste material should not be used for widening shoulders. In many cases this extra material could overload the existing fill slope, thereby causing a slip. An area available for the disposal of material from a slide will be selected in advance and will be clearly defined, so material will not be dumped in some unsuitable location.

If material is displaced as the result of a slip and must be replaced by new material to restore the width of the roadway or a shoulder, the use of cribbing or gabions may be helpful for holding the new material in place. These structures must be placed on a solid foundation to prevent settlement and/or failure.

09.02.03.03 SMOOTHING OPERATION

The surface of the material at a slide should be kept as smooth as possible so water will drain readily from the surface instead of soaking into cracks and fissures thereby making the conditions worse. This smoothing operation may be performed by hand tools, track equipment, or graders. The selection of equipment will depend on the steepness of the slide slope and the volume of earth involved.

09.03 ROCK FALLS

09.03.01 TYPICAL CONDITIONS

A rock fall involves the displacement of rock, shale material or boulders without soil. A rock fall may occur at any time, but the most likely time is after a heavy rain or during the spring thaw.

The effect of a rock fall depends on the quantity of rock, the distance through which it falls, and the suddenness of the occurrence. In some cases, the disturbance results in only minor inconvenience to traffic. In other cases, a rock fall can constitute a serious hazard to life and property.

The causes of rock falls and the conditions leading to their occurrence are much better understood than are those associated with slides and slips. Also, preventative and corrective measures are more direct and simple.

A typical rock formation in which a fall may occur is shown in Figure 09-10. In order to prevent a rock fall, care must be taken not to cut through a layer of rock or shale and to leave the material above the cut unsupported.

Figure 09-11 shows other conditions that can result in a rock fall. Here, a shelf

consisting of fragmented ledge rock or containing clusters of boulders lies over a bed of shale, soil, or other material which weathers more rapidly than does the ledge rock or the material of the boulders. As a result of seepage of water, the action of surface water, or alternate freezing and thawing, the soft material may be worn away. When the support for the harder overlying material is thus removed or weakened, rock fragments or boulders are free to descend into the side ditch or onto the roadway. Disintegration of the soft underlying material can be prevented by covering the exposed face of that material with a retaining wall of concrete, stone or masonry.

09.03.02 CONTROL MEASURES

Several means for controlling rock falls have been found to be effective. The best method will depend on the conditions in the vicinity of the particular disturbance. It is sometimes possible to form a fairly wide shelf or bench in a dangerous cut slope, so that falling rock will collect on the bench and not reach the roadway. Another possible control method is to remove overhanging rock fragments or boulders, one or several at a time, before they are dislodged by natural forces. Occasionally such material may be removed by hand methods, but it is usually necessary to loosen rock by blasting and to use heavy equipment for its removal. All of these operations involve considerable danger, and every precaution should be taken to safeguard maintenance personnel and the public.

The face of a layer of shale beneath a ledge of rock may be protected from erosion by constructing a masonry wall extending from the bottom to the top of the soft layer, as shown in Figure 09-11. Such a wall also gives added support to the overhanging ledge.

In a few cases, where no simple method of preventing rock fragments from falling seems feasible, effective protection to traffic and the roadway can be provided by the erection of wire-mesh fencing of suitable height. This fencing can be held securely in place by substantial metal posts set adjacent the face of the cut slope.

09.03.03 DEBRIS REMOVAL

The procedures for clearing a roadway after a rock fall and for disposing of the waste material are similar to those described in Sections 09.02.03. In certain rock cuts, removal and disposal of fallen rock is often a continuing operation. An accumulation of small rock fragments can be a nuisance to traffic and the presence of large boulders on the roadway can be a real hazard. Prompt removal of debris is necessary in order to restore the roadway to safe use and to protect the road from damage that may result from clogged drainage channels.

09.03.04 REPAIR MEASURES

When large rock fragments or boulders drop on the roadway with considerable force; substantial damage to the road surface may result. Holes and depressions must be filled promptly, so there will be as little interference with traffic as possible. If permanent repairs cannot be made immediately, scars and holes in asphalt or concrete pavement may be filled temporarily with cold bituminous mixture.

09.03.05 WARNING SIGNS

To warn drivers of vehicles that a rock-fall area is ahead, standard signs shall be placed at suitable locations. These signs will be designed and erected in accordance with the proper procedures.

09.04 PATROL PERSONNEL DUTIES AND INSTRUCTIONS

09.04.01 DUTIES

On a section of highway where slides, slips, and rock falls are likely to occur, it may be necessary to maintain frequent patrols during a period of prolonged or heavy rain or when there is alternate freezing and thawing.

If a slide, slip, or rock fall found by a maintenance crew is located on the road or shoulder and repairs can be made by them, the work shall be immediately performed by that crew. If a slide, slip or rock fall causes damage for which repairs require additional manpower and equipment, the person in charge of the crew will report the conditions immediately to the proper County Headquarters, and take the necessary steps to warn motorists until proper signs have been erected. If the damage caused by a slide or slip does not present an immediate hazard to the traveling public, the location and conditions will be reported to the appropriate supervisor. On the basis of this information, the necessary repairs can be scheduled.

09.04.02 EQUIPMENT

Each patrol person will be provided with a transportation vehicle equipped with a flasher light. Patrol personnel will be supplied with proper hand tools, suitable signs, and lights. The hand tools are intended for use in removing small amounts of debris from the roadway.

09.04.03 INSTRUCTIONS

Each patrolman shall comply with the following instructions:

09.04.03.01 BEFORE PATROL

While at headquarters the following "checks" shall be performed:

1) **Check Equipment**

   a) **Hand tools such as shovel, ax, push broom and sledge hammer**

   b) **An adequate supply of proper signs and lights.**

2) **Check on the name of the person to be notified in case of an emergency during off hours and how he/she or an alternate can be contacted.**

3) **Be sure that the list of roads to be patrolled is correct.**

09.04.03.02 PATROLLING

l) Cover each road to be patrolled with the required frequency.

2) Locate and determine the extent of the hazard. Place proper signs and lighting.

a) Eliminate obstruction with available hand tools, if possible.

b) Advise designated person of assistance necessary to restore safe travel.

3) Report any condition which may create future traffic hazards to the County Maintenance Superintendent.

FOOTNOTE

As more fully set forth in Section 01.01.01, nothing in this manual is intended to create a legal or moral duty and has been created for internal guidance only.