LANDSLIDES IN KENTUCKY

The reoccurrence of certain features of landslides in Kentucky suggests that the difficulties in the State can be readily classified. Because of this repetitive nature, one can be alerted to the possibility of slides in certain situations early in the planning and design stages of the facility to be constructed. Thus, the traveling public might be spared the inconvenience illustrated in Figure 1. Enough cannot be said concerning the necessity for having adequate soils and geological information concerning possible routes for highway locations, and a review of a number of landslides in Kentucky suggests that there are certain troublesome geologic formations.

The slides on Western Kentucky Parkway at Milepost 7 (Figures 3-7), Milepost 74, Milepost 75 (Figures 8-11), and Milepost 83 (Figures 12-18) occurred in materials of the Tradewater Formation (Figure 2). The slides seem to be associated with subsurface seepage waters (Figure 19) moving along impermeable shales and underclays.

Landslide conditions appear to correlate extremely well with the underclays of the Breathitt Formation (Figure 20) as suggested by investigations of slides on US 23 in Lawrence County (Figure 21), I 64 in Boyd County (Figures 22 and 23), and US 119 in Bell and Harlan Counties (Figures 24-41). The possible magnitude of such slides in relatively low-dipping beds (10°-20°) is suggested by the Gros Ventre River, Wyoming, slide of 1925 (Figure 42).

The slides near Milepost 20 on the Bluegrass Parkway occurred in shales of the Osgood Formation (Figures 43-50).

Many geologists correlate the Osgood in Western Kentucky with the Crab Orchard Formation, which is mapped in the eastern portion of the State (Figure 51). Slides under study on the Mountain Parkway in Clark County (Figures 52 and 53), on KY 89 and KY 52 in Clark and Estill Counties (Figures 54-61), and on KY 10 in Lewis County (Figure thought to have occurred in the Crab Orchard Formation and therefore to be associated with the same material involved in the Bluegrass Parkway slides of Western Kentucky.

Slides in north central Kentucky suggest that the Kope Formation (Figures 63 and 64) is a troublesome material (Figures 65-71).

Other geologic materials prone to landslide development include the New Providence Shale (Figure 72) and some materials of Mississippian age (Figure 73). Other slides throughout the State are illustrated in Figures 74-78.

It appears, then, that if an engineering structure is to involve these geological formations — particularly the Tradewater, the Breathitt, the Osgood or Crab Orchard, and the Kope — the planning and design engineers should be extremely cautious in the location and design of the facilities. Proper consideration of the geological and topographical conditions can minimize to a great extent the possibility of trouble at future times. A geological mapping program, unparalleled in the United States, is in progress.
in the State. This program is providing information, in the form of geological quadrangle maps concerning the geology of Kentucky which can be extremely useful to engineers in planning and designing engineering structures.

Several slides investigated have occurred in sidehill, cut-fill sections (Figure 79). The slides have been of the slip type and suggest the extreme difficulty involved with such a cross section. It is evident in several of these situations that the embankment portion of the section has in effect acted as a dam to significantly alter the groundwater seepage patterns. As illustrated in Figure 79, seepage zones along certain geologic formations, illustrated by line ab, normally outcrop on the natural slope (Figure 80) and cause no significant difficulty. However, when the fill section of the highway is placed, this seepage water may be blocked and the water table in the fill could possibly rise with time to a position indicated by line bc. The rise of the water table in the embankment causes the fill material to become saturated and to lose strength and causes excess pore pressures to develop, which also tends to decrease the strength of the fill material. The zone at the toe of the embankment slope may be weakened to such a point that it is unable to withstand the forces involved and thereby cause a slope failure. A possible solution is to design and construct a free-draining blanket beneath the embankment as indicated in Figure 79. Such a blanket would prevent the water table from rising above a line indicated by bc' and would protect and maintain the shearing resistance of the toe of the embankment, and thus critical situations with regard to slope stability would not be likely to develop.

In other situations, as on I 64 in Bath County (Figures 81 and 82) and on I 64 in Boyd County (Figures 83-86), the source of the difficulty was a weak foundation which was overloaded by a high embankment. If such weak foundation materials are overstressed, a bearing capacity failure will occur and thereby leave the embankment unsupported. The otherwise safe embankment would then crack and fail causing trouble at the roadway elevation. Failure of the embankment may also be caused by excessive settlements occurring within foundation materials. If such settlements are sufficiently large, the embankment may be distorted to such an extent that it will fail.

The importance of locating the highway facility properly with respect to the slope of the bedding planes of the geological deposits is illustrated in Figure 67. The difficulty encountered on US 119 in Bell and Harlan Counties is illustrated in Figure 87a. In many topographical situations, the natural ground slopes often exist at near-equilibrium conditions. If material is excavated, as shown in Figure 87a, there is a natural tendency for the material to slip along the bedding planes into the excavated area. This situation may be further aggravated by the presence of seepage water on certain bedding planes, causing a reduction in strength in these areas. If the tilt of the bedding planes is sufficient and(or) the strength of material is not adequate, the material in the highwall of the embankment must fail and move into the excavated area. If, on the other hand, the highway had been located on the other side of the slope, as illustrated in Figure 87b, such difficulties may have been avoided. If there is any tendency for movement in Figure 87b, this movement is along the bedding planes and into the hillside. Since the slope is in natural equilibrium, the construction of the highway may not upset this equilibrium and cause a landslide problem.

A knowledge of the slope of the bedding planes is also important in designing a drainage system to adequately divert subsurface waters and to
protect the embankment. If the bedding plane slopes toward the highway location, as shown in Figure 79 and Figure 87a, the quantities of water to be collected and discharged by any drainage system can be enormous. If the slope of the bedding planes is away from the highway location, as in Figure 87b, subsurface waters have a tendency to drain away from the embankment and therefore the drainage system required to protect sidehill embankments may not necessarily be elaborate.

It is interesting to note that many of the slides which have occurred as a result of the damming effect of a sidehill embankment have been located in the transition zone between full cut and full fill sections. In addition to the natural subsurface waters which may be impounded by the sidehill fill, additional waters from the cut section may be finding a way into the embankment in this transition area. Figure 88 is a photograph of a construction project on I 75 south of the Richmond Bypass. Although specifications require that any depressions requiring refilling to the designated rock line will be provided with positive drainage, the figure suggests some doubt that this is being accomplished. The coarse refill material apparent in the photograph should be choked with a fine-grained impervious material to produce a smooth grading line upon which to place the dense graded aggregate base. The quantity of water which can be collected from a pavement section in a long rock cut could be enormous. In addition, waters moving down the ditches may actually be lost from the ditches and enter the subgrade or embankment beneath the pavement. This situation has been noted to exist in the rock cut adjacent to a slide in Clark County. Surface waters are disappearing from the side ditches through cracks or joints in the bedrock and apparently are moving beneath the pavement and into the sidehill fill.

The importance of situational surveys for highway locations cannot be over emphasized. It is desirable to prepare columnar sections and to identify each of the horizons or layers geologically. Much geological and soil data are available for Kentucky. As a result of the geological mapping program, there is already a rather widespread coverage of the State by geological quadrangle maps. Eventually, as the mapping program comes to a conclusion, there will be complete coverage of the State. Use should also be made of the soils and geology information contained in the soil survey reports and maps prepared by the Soil Conservation Service and published by the U. S. Department of Agriculture. In addition, the Division of Research has prepared a summary of the engineering properties of soils mapped in Kentucky on the basis of data contained in the files (see "Engineering Properties of Kentucky Soils" by R. C. Deen, August 1966). It is extremely important that design and location engineers refer to geological and soils information for guidance and forewarning signs of potential landslides. Failure to do so in the early planning and design stages of a highway compounds construction and maintenance problems.
Figure 1. In addition to the inconvenience and hazard to the traveling public, landslides often require the scheduling of equipment and personnel for maintenance and necessitate emergency funding in order to return the highway facility to normal conditions.
Figure 2. Generalized columnar section showing the Tradewater Formation (from "Availability of Ground Water in Butler and Ohio Counties, Kentucky" B. L. Maxwell and R. W. Devaul, U.S. Geological Survey, 1962).
Figure 3. Sidehill, cut-fill section at Milepost 7 on the West Kentucky Parkway soon after the highway had been opened to traffic. Note the berm, which had been constructed to stabilize the area as a result of a slide which occurred during construction. Photograph taken October 1963.
Figure 4. Photograph at Milepost 7, West Kentucky Parkway, in March 1964 showing the distress of the pavement, shoulders, and embankment slope.
Figure 5. Slide area at Milepost 7, West Kentucky Parkway, in April 1965.
Figure 6. Extreme pavement distress at Milepost 7, West Kentucky Parkway, in April 1965.
Figure 7. Failure in cut slope indicated in Figure 6 (Milepost 7, West Kentucky Parkway).
Figure 8. Installation of rail piles in August 1966 at Milepost 75 on the West Kentucky Parkway. Note the failure of most of the piles put in by maintenance forces at the shoulder of the slope in an effort to stabilize the material. Design calculations indicated that the zone in which the piles did not fail had sufficient number of piles to withstand the forces involved.
Figure 9. View of slope at Milepost 75, West Kentucky Parkway, showing the installation of a total of three rows of rail piles. The double row of piles indicated in Figure 8 are those nearest the top of the slope. Photograph taken September 1966.
Figure 10. Photograph at Milepost 75, West Kentucky Parkway, taken in April 1967, indicating slight continued movement of the shoulder several months after corrective action.

Figure 11. Photograph taken in April 1967 showing significant seepage on the slope at Milepost 75, West Kentucky Parkway.
Figure 12. Slide at Milepost 83, West Kentucky Parkway, in February 1966.
Figure 13. Slide at Milepost 83, West Kentucky Parkway, in April 1966.
Figure 14. Slide at Milepost 83, West Kentucky Parkway, in May 1966.

Figure 15. Toe of slide at Milepost 83, West Kentucky Parkway, in May 1966.
Figure 16. Photograph at Milepost 83, West Kentucky Parkway, in July 1966 showing the excavation of the unstable material and the placement of a granular drainage blanket and pipe. A granular blanket will also be placed at the vertical face of the cut and the blanket then will be recovered by embankment material.
Figure 17. Photograph of cut face in Figure 16 showing seepage zones.
Figure 18. Photograph at Milepost 83, West Kentucky Parkway, in April 1967 showing the development of a second slide adjacent to the area corrected in 1966.

Figure 19. Photograph on the West Kentucky Parkway showing natural seepage on cut slopes.
Figure 20. Columnar section showing the Breathitt Formation (from "Geology of the Ashland Quadrangle, Kentucky-Ohio and the Catlettsburg Quadrangle in Kentucky" E. Dobrovolny, J. A. Sharps, and J. C. Fern, U. S. Geological Survey, 1963).
Figure 21. Slide on US 23 in Lawrence County, March 1966.
Figure 22. Slide on I 64 in Boyd County caused by underclays associated with the Breathitt Formation.
Figure 23. Photograph taken during the construction of roadway cut on I 64 in Boyd County. Sufficient coal was encountered to justify strip mining by the contractor.
Figure 24. Typical section of slide area on U.S. 119, Bell County.
Figure 25. Slide area on US 119, Bell County, taken from the northeast. Photographed in August 1966.
Figure 26. High wall of slide area, US 119, Ball County, showing unstable top mantle. Photograph taken August 1966.
Figure 27. Low wall of slide area, US 119, Bell County. Photograph taken August 1966.
Figure 28. Crevasse at the top of the slope caused by the moving soil mantle, US 119, Bell County. Photographed August 1966.
Figure 29. Cut on US 119, Bell County, showing the manner in which a moderately steep slope is stripped to a bedding plane intersecting the bottom of the ditch line.
Figure 30. Rock cut on US 119, Bell County, illustrating the necessity of stripping cut slopes to a bedding plane intersecting the bottom of the ditch line.
Figure 31. View showing extensive damage to the community of Tremont on US 119, Harlan County, as a result of a slide in July 1967.

Figure 32. View showing the damming of the Cumberland River as a result of the slide at Tremont.
Figure 33. Condition of the slope after the occurrence of the slide at Tremont. Photograph taken in July 1967.
Figure 34. View showing the relocation of the Cumberland River in the area dammed by the Tremont slide. Photograph taken September 1967.
Figure 35. Slope after a portion of the unstable material had been excavated and dressed. Note the scarp of the new slide as well as the scarp of an ancient slide. Photograph taken September 1957.
Figure 36. View of the "church" slide on US 119, Harlan County. This photograph was taken March 1968 after the slope had been flattened and dressed after the occurrence of a previous slide. The grade of the new location of US 119 was raised in order to reduce the depth of cut. Reducing the cut and flattening the slope of the cut was not sufficient to stop earth movement.
Figure 37. Overall view of the church slide area in March 1968.
Figure 38. Scarp of an ancient slide uncovered by roadway excavation on US 119 in Harlan County. Note the slickensides.

Figure 39. Evidence of movement of cut slopes illustrated by offset boreholes on US 119, Harlan County.
Figure 40. Evidence of movement of relatively competent rock illustrated by offset boreholes on US 119, Harlan County.
Figure 42. Geologic section of the bedding-plane slide at Gros Ventre River, Wyoming, 1925 (from "Landslides, Subsidences and Rock-Falls" G. E. Ladd, Bulletin, American Railway Engineering Association, Vol. 37, No. 377, July 1935).
Figure 43. Generalized columnar section showing the Osgood Formation (from "Geology of the New Haven Quadrangle, Nelson and Larue Counties, Kentucky" W. L. Peterson, U. S. Geological Survey, 1966).
Figure 44. Osgood landscape in Nelson County.

Figure 45. Slide at Milepost 20, Bluegrass Parkway, Nelson County, in June 1966.
Figure 46. Slide at Milepost 20, Bluegrass Parkway, Nelson County, in the Osgood Formation. Photographed July 1966.
Figure 47. Slide at Milepost 20, Bluegrass Parkway, Nelson County. Photograph taken July 1966.
Figure 48. Slide at Milepost 20, Bluegrass Parkway, Nelson County, showing excavation of unstable material and replacement with granular blanket and compacted embankment. Photograph taken August 1966.
Figure 49. Excavated slide area at Milepost 20, Bluegrass Parkway, Nelson County, showing drainage pipe augered into original ground. Photograph taken August 1966.
Figure 50. Slide condition on Bluegrass Parkway in Nelson County in Osgood Formation.
Fig. 51. Generalized columnar section showing the Crab Orchard Formation (from "Geology of the Tollesboro Quadrangle, Lewis and Fleming Counties, Kentucky" J. H. Peck, U. S. Geological Survey, 1967).
Figure 52. Landslide area on Mountain Parkway at Clark-Powell County line in October 1963.
Figure 53. Slide area on Mountain Parkway at Clark-Powell County line in October 1963.
Figure 54. Slide area on KY 89 near the Clark-Estill County line in October 1963. Note that the top row of timber piles placed by maintenance crews proved unsuccessful in stabilizing the slope. Concrete-filled pipe piles at the lower level installed at a later date proved to be more successful in stabilizing the slope.
Figure 55. General landscape of the Crab Orchard Formation at the slide area on KY 89 near the Clark-Estill County line.

Figure 56. Crab Orchard landscape on KY 89 in Estill County.
Figure 57. Slide area on KY 52, Estill County, in December 1967.
Figure 58. Slide area on KY 52, Estill County, in February 1968.

Figure 59. Boyle Dolomite cliffs on KY 52, Estill County.
Figure 60. Ohio Black Shale, Boyle Dolomite, and Estill Shale on KY 52, Estill County.
Figure 61. Lulbegrud Shale and Brassfield Dolomite on KY 52, Estill County.
Figure 62. Berea Sandstone, Bedford Shale, and Ohio Shale on KY 10 in Lewis County. In this area of Kentucky, the Ohio Shale and the Boyle or Bisher Dolomite are often quite thin, overlying the Crab Orchard Formation.

Figure 63. Generalized columnar section showing the Fairview and Kope Formations.
Figure 64. Fairview and Kope Formations at the Covington, I 75 slide area.
Figure 65. Area of major distress at slide on I 75, Kenton County, in April 1962.
Figure 66. Evidence of reoccurrence of movement shown by depressed curb line at slide area on I-75, Kenton County, in April 1963.
Figure 67. Main scarp of landslide on I 75, Kenton County, in May 1963.
Figure 68. Toe of slide area on I 75, Kenton County, in May 1963.
Figure 69. Overall view of slide area on I 75, Kenton County, in January 1964 prior to reconstruction.
Figure 70. Construction on I 75, Kenton County, of drainage cutoff ditches using sheet piling to brace sides of trenches. Sheet piling on the upstream side of all trenches was coated and left in place in an effort to provide more positive sealing against the transmission of waters.
Figure 71. Major slip plane observed in the trench at the toe of the original embankment on the I 75 landslide, Kenton County.
Figure 72. Slide in New Providence Shale on the Bluegrass Parkway.
Figure 73. Landslide on US 27, Pulaski County.
Figure 74. Slide on Slade Mountain on KY 15 and Mountain Parkway.
Figure 75. Slide on KY 30 near Quicksand, Kentucky.
Figure 76. Slide on KY 28 near Booneville, probably a result of undercutting and rapid drawdown of high river waters.
Figure 77. Landslide on old US 25 in Rockcastle County.
Figure 78. Landslides on US 25, Rockcastle County, south of Livingston.
Figure 79. Sidehill cut-fill section showing damming effect on fill.
Figure 80. Natural seepage outcrops on cut slopes.
Figure 81. Overall view of failed embankment on I 64 in Bath County.
Figure 82. View of upheaval at toe of failed embankment on I 64 in Bath County.
Figure 83. Embankment failure on I 64 in Boyd County at bridge approach.
Figure 84. Mud row at toe of failed embankment on I 64 in Boyd County. Note the free water forced from the underlying material.
Figure 85. Sand boils in the channel of the East Fork of the Little Sandy River as a result of the overloading of the foundation by the approach embankment on I 64 in Boyd County. Resulting excess pore pressures eventually were sufficient to cause a foundation failure causing the embankment to crack.
Figure 86, Bridge pier on I 64 in Boyd County was moved vertically by the embankment failure and laterally by the movement of the underlying materials.
Figure 87. Cut-fill sections showing effect of dip of bedding planes.
Figure 88. Rock cut construction on I 75 near Richmond.