DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF–1072
OBERMEIER–SLOPE STABILITY
FAIRFAX CO., VA.

EXPLANATION

The generalized map units are numbered sequentially from 1 to 8 to indicate in a general way the decreasing probability and severity of slope-stability problems at a given site. Units 1 through 4, slopes composed of Potomac Group deposits, are much more troublesome than Units 5 through 7, colluvium, saprolite, residuum, and alluvium. Units 5 through 7 are difficult to compare with one another because of the very different nature of the problems. Listed below are the geologic conditions and slopes represented by the map units.

1	Unit 1–Potomac Group deposits consisting of clay or interlayered sand and clay layers[2] existing slopes exceed 15 percent. Also in this zone is a narrow strip of the sand and gravel cap above Potomac Group deposits (fig. 1)
2	Unit 2–Same as Unit 1, except that slopes range between 8 and 15 percent
3	Unit 3–Potomac Group deposits predominantly of massive sand and minor clay-rich layers. Slopes exceed 15 percent. Unit 3 also includes a narrow strip of the sand and gravel cap above Potomac Group deposits and a narrow strip of colluvium at the base of Potomac Group deposits (fig. 1)
4	Unit 4–Same as Unit 3, except that slopes range between 8 and 15 percent
[redacted]	Unit 5–All slopes greater than 30 percent in the Piedmont and Triassic Lowland. The unit includes slopes of colluvium, slopes of saprolite to unweathered rock in the Piedmont, and slopes of residuum to unweathered rock in the Triassic Lowland. Some of this unit is located within the Coastal Plain region shown on the map
6	Unit 6–Slopes greater than 30 percent in the Coastal Plain. Composed of a sand and gravel cap on clay; any Potomac Group sediments underlying these slopes are buried so deeply (lithostatic stress is high) that no information on slope behavior
7	Unit 7–Slopes greater than 30 percent in the Coastal Plain. Composed of terrace alluvium or colluvium
XXXX	Unit 8–Vertical and very steep slopes along the Potomac River and its tributaries and coves where Pleistocene and Potomac Group depart in the upper 5 to 4 ft (1-2 m) of strata by mechanisms such as wave action, flooding, wetting and drying, and freezing. The unit includes slopes on the map by the symbol XXXX at the base of the slope.)

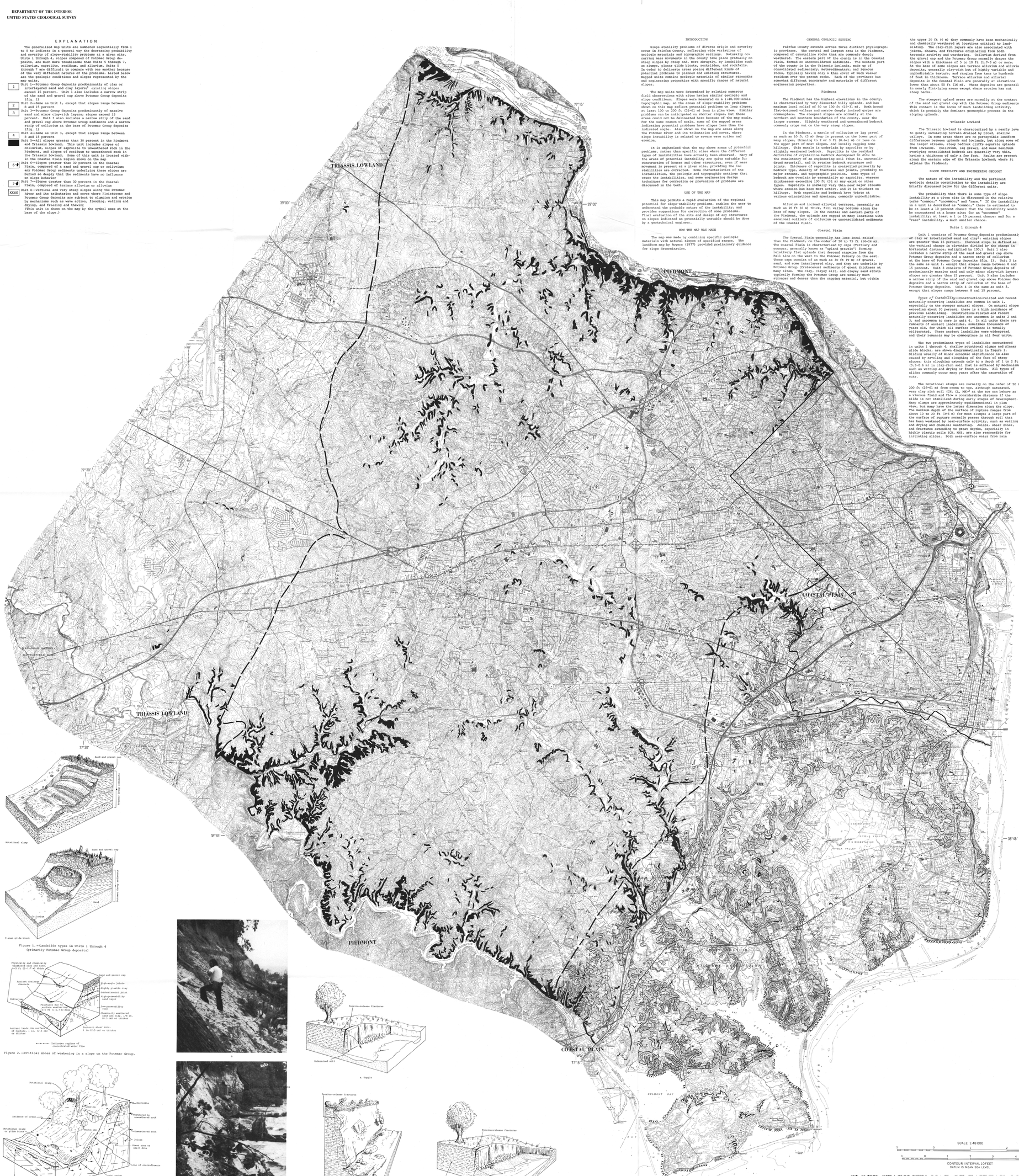

Figure 1.--Landslide types in Units 1 through 4 (primarily Potomac Group deposits)

Figure 2.--Critical zones of weakening in a slope on the Potomac Group.

Figure 3.--Types of slope instabilities in Unit 5, typical of the Piedmont.

Figure 4.--Typical high-bank failures in Pleistocene deposits of Unit 8.

Figure 5.--Probable mechanisms of soil falls in Unit 8.

INTRODUCTION

Slope stability problems of diverse origin and severity occur in Fairfax County, reflecting wide variations of geologic materials and topographic settings. Naturally occurring mass movements in the county take place gradually on steep slopes by creep and, more abruptly, by landslides such as slumps, planar slide blocks, rockfalls, and rockslides. In order to delineate areas posing different kinds of stability problems, we have mapped geologic structures, mapped and combine geologic materials of similar strengths and engineering properties with specific ranges of natural slopes.

The map units were determined by relating numerous field observations with sites having similar geologic and slope conditions. Slopes were measured on a 1:48,000-scale topographic map, so the areas of slope-stability problems shown on this map reflect potential problems on long slopes, at least 100 to 200 ft (31-61 m) long in plan view. Similar problems can be anticipated on shorter slopes, but these areas could not be delineated here because of the map scale. For the same reason of scale, some of the mapped areas indicating potential problems have slopes less than the indicated angle. Also shown on the map are areas along the Potomac River and its tributaries and coves, where slope instability is related to severe wave action and erosion.

It is emphasized that the map shows areas of *potential* problems, rather than specified localized sites, and that types of instabilities have actually been observed. Many of the areas of potential instability are quite suitable for construction of houses and other structures, even if mass movement is present at a given site, providing the instabilities are corrected. Some characteristics of the instabilities, the geologic and topographic settings that cause the instabilities, and some engineering design techniques for correcting certain types of problems are discussed in the text.

USE OF THE MAP

This map permits a rapid evaluation of the regional potential for slope-stability problems, enables the user to understand the probable nature of the instability, and provides suggestions for correction of some problems. Final evaluation of the site and design of any structures on slopes indicated as potentially unstable should be done by a geotechnical engineer.

HOW THE MAP WAS MADE

The map was made by combining specific geologic materials with natural slopes of specified ranges. The landform map by Rogers (1977) provided preliminary guidance for slope determination.

GENERAL GEOLOGIC SETTING

Fairfax County extends across three distinct physiographic provinces. The central and largest area is the Piedmont, composed of crystalline rocks that are commonly deeply weathered. The eastern part of the county is in the Coastal Plain, formed on unconsolidated sediments. The western part is in the Triassic Lowland, made up of unconsolidated sedimentary, metasedimentary, and igneous rocks, typically less weathered than those in the Piedmont. Residuum over the parent rocks, which covered the province, has somewhat different topography and materials of different engineering properties.

Piedmont

The Piedmont has the highest elevations in the county, is characterized by very dissected hilly uplands, and has maximum local relief of 50 to 100 ft (15-31 m). Both broad flat-bottomed valleys and narrow deeply incised gorges are commonplace. The steepest slopes occur normally at the northern and southern boundaries of the county, near the larger streams. Slightly weathered or unweathered bedrock commonly crops out on the very steep slopes.

In the Piedmont, a mantle of colluvium or lag gravel as much as 10 ft (3 m) deep is present on the lower part of many slopes, thinning to 2 or 3 ft (0.6-1 m) or less on the upper parts of most slopes, and locally cloaking some hilltops. This mantle is underlain by saprolite or by slightly weathered bedrock. Saprolite is the residual derivative of crystalline bedrock decomposed in situ to the consistency of an engineering soil (that is, unconsolidated material), and it retains bedrock structure and joints. Thickness of saprolite is controlled primarily by bedrock type, density of fractures and joints, proximity to major stream, and topographic position. Some types of bedrock are overlain by essentially no saprolite, whereas other metamorphic rocks may be as much as 100 ft (30 m) thick. Saprolite is normally thin on the steep upper slopes, where erosion has been most active, and it is thickest on hilltops. Both saprolite and bedrock have joints at various orientations and spacings, commonly unpredictable.

Alluvium and inclined alluvial terraces, generally as much as 25 ft (8 m) thick, fill valley bottoms along the base of many slopes. In the central and eastern parts of the Piedmont, the alluvium commonly is composed of coarse colluvial debris of colluvium or unconsolidated sediments of the Coastal Plain.

Coastal Plain

The Coastal Plain generally has less local relief than the Piedmont, on the order of 50 to 75 ft (16-24 m). The Coastal Plain is characterized by caps (Tertiary and younger, generally known as "upland gravels") forming relatively flat uplands that descend stepwise from the Fall Line on the west to the Potomac Estuary on the east. These caps consist of sand, as 30 ft (9 m) of gravel, sand, and some interlayered clay, and they are underlain by Potomac Group interbedded sediments of great thickness at many sites. The clay, clayey silt, and clayey sand strata typically forming the Potomac Group are usually much stronger and denser than the capping material, but within the upper 20 ft (6 m) they commonly have been mechanically and chemically weathered at locations critical to landsliding. The clay-rich layers are also associated with joints, shears, and fractures originating from both tectonic activity and weathering. Colluvium derived from the gravel cap and the Potomac Group normally drapes the slopes with a thickness of 5 to 10 ft (1.5-3 m) or more. At the base of some slopes are terrace alluvium and alluvial deposits, generally clay-rich but of highly variable and unpredictable texture, and ranging from tens to hundreds of feet in thickness. Terrace alluvium and alluvial deposits are found in the valleys of streams and lower than about 50 ft (16 m). These deposits are generally in nearly flat-lying areas except where erosion has cut steep banks.

The steepest upland areas are normally at the contact of the sand and gravel cap with the Potomac Group sediments. This contact is the locus of much landsliding activity, which is probably the dominant geomorphic process in the sloping uplands.

Triassic Lowland

The Triassic Lowland is characterized by a nearly level to gently undulating terrain drained by broad, shallow valleys. In some areas there are no perceptible landform differences between uplands and lowlands, but along some of the larger streams, steep bedrock cliffs separate uplands from lowlands. Colluvium, lag gravel, and weak residuum overlying consolidated bedrock are generally very thin, having a thickness of only a few feet. Faults are present along the western edge of the Triassic Lowland, where it adjoins the Piedmont.

SLOPE STABILITY AND ENGINEERING GEOLOGY

The nature of the instability and the pertinent geologic details contributing to the instability are briefly discussed below for the different units.

The probability that there is some type of slope instability at a given site is discussed in the relative terms "common," "uncommon," and "rare." If the instability is common, it is described as "common," there is estimated to be at least a 10 percent chance that the instability would be encountered at a house site; for an "uncommon" instability, at least a 1 to 10 percent chance; and for a "rare" instability, a much smaller chance.

Units 1 through 4

Unit 1 consists of Potomac Group deposits predominantly of clay or interlayered sand and clay[1]; existing slopes are greater than 15 percent. (Percent slope is defined as the vertical change in elevation divided by the change in horizontal distance, multiplied by 100.) Unit 1 also includes a narrow strip of the sand and gravel cap above Potomac Group deposits and a narrow strip of colluvium at the base of Potomac Group deposits (fig. 1). Unit 2 is the same as unit 1, except that slopes range between 8 and 15 percent. Unit 3 consists of Potomac Group deposits of predominantly massive sand and only minor clay-rich layers; slopes are greater than 15 percent. Unit 3 also includes a narrow strip of the sand and gravel cap above Potomac Group deposits and a narrow strip of colluvium at the base of Potomac Group deposits. Unit 4 is the same as unit 3, except that slopes range between 8 and 15 percent.

Types of instability—Construction-related and recent naturally occurring landslides are common in unit 1, especially on the steeper natural slopes. On natural slopes exceeding about 30 percent, there is a high incidence of previous landsliding. Construction-related and recent naturally occurring landslides are uncommon in units 2 and 3 and rare in units 4. Most of the slides in these units are remnants of ancient landslides, sometimes thousands of years old, for which all surface evidence is totally obliterated. These ancient landslides were widespread, and their remnants may be commonplace in all four units.

The two predominant types of landslides encountered in units 1 through 4, shallow rotational slumps and planar glide blocks, are shown diagrammatically in figure 1. Sliding usually of minor economic significance is also caused by raveling and sloughing of the face of steep slopes; this sloughing extends only to a depth of 1 to 2 ft (0.3-0.6 m) in clay-rich soil that is softened by mechanisms such as wetting and drying or frost action. All types of slides commonly occur many years after the excavation of cuts.

The rotational slumps are normally on the order of 50 to 200 ft (16-61 m) from crown to toe, although saturated, very clay rich soil (CH, CL, MH)[3] at the toe can behave as a viscous fluid and flow a considerable distance if the slide is not stabilized during early stages of development. Many slumps are approximately equidimensional in plan view, but many have the larger dimension along the slope. The maximum depth of the surface of rupture ranges from about 10 to 20 ft (3-6 m) for most slumps; a large part of the surface of rupture normally passes through soil that has been weakened by near-surface activity, such as wetting and drying and chemical weathering. Joints, shear zones, and fractures extending to great depths, especially in highly plastic soils (CH, MH), are also responsible for initiating slides. Both near-surface water from rain storms and ground water are normally involved in initiation of rotational slumps; the crowns of many slumps are in the sand and gravel cap, because ground water is generally retained at the contact of the cap and the underlying nearly impermeable Potomac Group sediments.

Planar glide blocks resulting in translational movement downslope of the sand and gravel caps are much less common than rotational slumps. The rupture initiates generally in softened soil at the contact between the plastic sediments (CH, CL, MH) of the Potomac Group and the gravel cap. Many of these slides have names have eroded and filled channels, some have cut channels locally have slopes of as much as 15 degrees and are commonly concentrated ground-water flow. Width of the buried channels are only 15 to 30 ft (4-9 m) at many localities, making them difficult to detect during exploration.

Another manifestation of slope instability is tilting or bending of trees. Bent, tilted, or uprooted trees can be indicators of recent or long-term movement or of incipient landsliding. It is highly probable that slumping usually begins in areas of weakness, such as softened zones, coincident with either a prolonged rainy season or an intense rainstorm. Many years may elapse before any movement is re-initiated. After slumping has begun, the rate of incremental movement normally accelerates with subsequent rains until catastrophic failure occurs, and the slope moves several feet per day. Total elapsed time between first-noticed slumping and catastrophic failure is often 5 to 10 years, but on rare occasions is much more rapid.

Mechanisms of slope failure—The critical factors in most landslide problems in units 1 through 4 are the permeability and strength of the sand and clay layers, upper 10 to 20 ft (3-6 m) of the Potomac Group and the presence of soft zones or lightly cemented zones (such as joints) in otherwise stiff to hard[3] moderate-to-rich clays and clay-cemented sands. The critical zones of softening for all types of landslides in the Potomac Group are summarized in figure 2. Especially commonly are near-surface weathering joints, many at random orientations and spaced an inch (2.5 cm) to a foot (0.3 m) apart in the upper 3 to 5 ft (1-2 m) of the Potomac Group. These joints are much more prevalent in the clay-rich platies than in the interbedded clayey sand and silt deposits. Vertical to subhorizontal joints of tectonic origin traverse all types of Potomac Group deposits. They are sparse in the sand layers, but rather common in the clay-rich deposits. Joints contribute to slides in at least three ways: (1) they are discontinuities through which water can flow to the critical softened zones; (2) the surface of the joints are usually softened or have soft fillings of more plastic soil; and (3) they allow entry of water, resulting in high pore pressure.

Figure 2 also shows a tectonic shear zone and associated joints. These shear zones can be as thin as a fraction of an inch. The soil in the shear zone is typically at the residual-shear-strength state (the weakest possible state), but the soil on both sides of the shear zone is unaltered from its original strength. Although not commonplace, tectonic shear zones are sufficiently widespread and numerous to cause concern for the stability of excavations; these shear zones can be very difficult to detect using conventional soil-exploration methods, utilizing SPT (Standard Penetration Test) blow counts and Shelby tube samples.

Weak shear zones from ancient and modern landslides are also widespread and possibly commonplace. Although these shear zones can be quite thin, the adjacent soils are softened or disturbed and remolded that they are detectable with conventional soil-exploration tools. Soils in the shear zone are at the residual-shear-strength state.

Stability of slopes—As previously noted, physically and chemically weathered and softened clays, clayey silts, and sands are usually at the contact of the sand and gravel cap with the Potomac Group sediments; additionally, such softening is present at the contact of colluvium and underlying Potomac Group sediments. The softening is especially deep in zones of concentrated water flows. The clays and clay-rich soils can be weakened to a soft consistency, and residual or near-residual shear strengths can be appropriate for use in long-term stability calculations.

Chemically weathered and softened clays and clayey silts and sands also occur within Potomac Group sediments, where ground water flows through a sandy or silty layers that is bounded by clay-rich layers. Such softened layers are widespread and possibly commonplace, but not often recognized. The zone of softening can be as thin as 1/8 inch (0.3 mm), and thus difficult to detect using conventional exploration methods. Abnormally high water contents, low SPT blow counts, and perched water tables indicate the possible presence of these softened zones. Some of these clay and sand zones are weakened so severely that residual or near-residual shear strengths can be appropriate for use in long-term stability calculations. Failure may occur through weakened sands or silts rather than clays, where the chemically unstable minerals have softened the silt or sand fraction and the pore-water pressure is high. However, such weathering in sands and silts has been observed infrequently by the writer.

Because of the rather serious problem of landsliding many years after the excavation of cuts, the previous discussion has been oriented primarily toward the long-term stability of slopes in the Potomac Group. It is previously mentioned that use of residual or near-residual shear strengths is appropriate for design of many of these slopes, especially where failure can endanger people or where critical structures are located. Limited data for "first-time failure" landslides which supports this conclusion were orally presented by representatives of Law Engineering Testing Company, McLean, Va., at an American Society of Civil Engineers seminar (American Society of Civil Engineers, National Capital Section, Geotechnical Engineering Seminar, Washington, D.C., January 28 and February 4, 1977). Their data showed that "first-time failures" occurred at least occasionally on slopes having shear strengths approximately as low as the residual state.

Local consulting engineers commonly use shear strengths at least approaching the residual state for the design of permanent slopes of clays (CH, CL) and highly plastic silts (MH), where ensuring the stability of the slope is important; for soils of lesser plasticity, shear strengths much in excess of residual are used by many consultants, but these are still much lower than peak values.

Most major local consultants have the opinion that previously unfailed slopes whose stability must be maintained permanently should be designed by using shear strengths that do not exceed the "fully softened" state[4] for highly fissured, very plastic soils (CH, MH). design strength parameters are reduced somewhat from this state. For all previously failed slopes, residual-shear-strength parameters are used. Both surface and subsurface drainage systems are commonly used to maintain stability.

Short-term (that is, construction-period) stability of steep cuts is also a potential problem because of the possibility of failure along joints, fractures, shear zones, or softened zones. Pore-water pressure in these zones may be critical to stability.

Slope stabilization—Methods commonly used to stabilize existing and potential landslides include subsurface drainage systems combined with surface grading, and slope flattening; retaining walls are normally impractical or uneconomical except for stabilizing very small slides.

Unit 5

Unit 5 includes all slopes greater than 30 percent in the Piedmont and Triassic Lowland. These slopes consist of colluvium, saprolite to unweathered rock in the Piedmont, and residuum to unweathered rock in the Triassic Lowland.

Small landslides are rare to uncommon on alluvial terraces; slumping is restricted almost exclusively to areas where gullies are incised into the terrace to depths of 4 ft (1 m) or more. Evidence of active creep is found on slopes greater than about 30 percent where colluvial gullies have been cut into the base of the slope. It was not possible to show these small areas on the map because of the scale.

Slopes in the Piedmont—The great majority of the potential problems associated with this unit are in the Piedmont; only rarely do problems occur in the Triassic Lowland. The most common naturally occurring slope instability in this unit is creep, the effects of which are evident on many but not all slopes. At some places, rockslides and rockfalls are common on very steep slopes, and rotational slumps also occur but are rare. Figure 3 shows instabilities that may be present in a generalized geologic setting in the Piedmont.

The discussion following is directed exclusively to the Piedmont, using terminology for Piedmont rock in different states of weathering. Most of the concepts can be extrapolated directly to the setting of the Triassic Lowland; important deviations are noted.

Slopes of colluvium--Creep believed to have the potential to distress some types of structures commonly occurs on colluvial slopes exceeding 30 percent. The primary evidence of active creep is the presence of bent at the base of trees (fig. 3). Positive evidence that this creep is actually harmful to structures is difficult to obtain because of the paucity of construction on such steep slopes; however, distressed houses and retaining walls have been observed on slopes having bent trees. It is probable that potentially harmful creep on these slopes normally extends only to shallow depths, 3 ft (1 m) or less. This is based on the observation that pipelines, footings, and other structures buried to greater depths show no evidence of distress (oral commun., 1977, W. E. Davies, U.S. Geological Survey).

A colluvial slope can normally be detected in the field as the region beneath the line of contraflexure along the slope (fig. 3); the colluvium merges into rather flat valley floors of alluvial terrace or into alluvium. Rock ranging from soil-like saprolite to fresh unweathered bedrock underlies colluvium. Slope movements should not adversely affect houses and walls built on colluvial slopes exhibiting a small amount of creep, providing that the foundations are in stable rock or saprolite (both materials are typically much stronger than colluvium), and that creep-related forces are taken into account in design.

Slumps are rare to uncommon in colluvium; they occur only on slopes that greatly exceed 30 percent and that are undercut by streams, and on slopes having a "blanket" of colluvium over the jointed rock; the latter situation causes a buildup of high pore pressure. The slumps generally have approximately equal dimensions across and down the slope; they may be as much as 100 ft (31 m) across in plan view, but they are usually much smaller. Slumps can sometimes be stabilized most economically by draining the jointed rock beneath.

About a dozen undisturbed large block samples of colluvium have been collected by the writer throughout the Piedmont, and subjected to triaxial testing under drained conditions. The angle of internal friction ranged from 25 to 26 degrees, averaging about 23 degrees; associated cohesion values were very small and commonly approached zero. Comparisons of natural and predicted slope angles based on calculations using these laboratory data show that good drainage of ground water can be critical to stability. Thus at many sites drainage-control measures should be taken around structures such as walls and buildings that can impede ground-water flow.

Slopes of saprolite to unweathered rock--Active creep movement is not evident on slopes less than 35 to 40 percent that are made up of material ranging from saprolite to unweathered rock, and even many slopes greater than 50 percent are very stable. Rotational slumps through saprolite are rare on any natural slopes, and they occur only on slopes greater than 50 percent. The rupture surface can traverse the massive, unjointed portions of the saprolite or extend along joint and parting planes for part of the length. The slumps are small and equidimensional in plan view, having diameters of about 30 ft (9 m) and depths of as much as 10 ft (3 m).

Rockslides (also called block slides) are rare on slopes less than 50 percent and are rare to uncommon on slopes from 50 to 70 percent. Although called rockslide, this type of slide can also develop in saprolite and partly weathered rock. Joint and parting-plane orientations or other discrete planar zones of weakness are critical to initiation of a rockslide.

In the Piedmont, other planar zones of weakness can also be critical to development of rockslides in material varying from saprolite to partially weathered rock. Aplite dikes as thin as 1/2 inch (1 cm) weather to a medium consistency; they are commonly near the contacts with granitic igneous rocks mapped in the county[5] but are also found miles away from the nearest contact. Talc and chloritic shear zones as thin as 1/4 inch (0.6 cm) are associated with shearing where strong, massive ultrabasic rocks are in contact with granitic bodies. The strength of the material in the shear zones is generally much lower than that of the surrounding rocks, and the sheared material typically has a medium or weaker consistency near the ground surface. Commonly associated with foliated rocks are planes of parting in chlorite- and very mica rich layers, 1 in (2 cm) to 3 ft (1 m) thick.

Saprolite usually has joints that are weakly to well cemented in the upper 10 ft (3 m), contributing greatly to the long- and short-term stability of cuts. Vertical cuts and natural slopes of as much as 10 ft (3 m) or more in height are normally stable, but commonly large blocks slide along joint planes, parting planes, or other weak zones. Joints are commonly open in the upper 3 ft (1 m), because of cementation normally decreases, making vertical cuts less stable. Cementation in partly weathered to unweathered rock is very weak to absent. In contrast, near-vertical cuts and natural slopes in partly weathered to unweathered rock can be many tens of feet high and quite stable, the stability depending entirely on joint and foliation orientation.

Excavations higher than 10 ft (3 m) cut into saprolite and stronger rock rarely fail on slopes less than 50 percent and are usually stable on much steeper slopes. With the exception of moderately plastic saprolite on mafic and ultramafic rocks, failures almost invariably initiate along joint and parting planes and along shear zones.

Special precautions should be observed in cuts made in saprolite beneath Potomac Group deposits. The joints in the saprolite can be coated with clay, apparently washed in from the overlying Potomac Group sediments. The drained friction angle of this coating is as low as 10 degrees (measured in a direct-shear apparatus), and the associated cohesion is of very soft consistency. Even where not buried beneath unconsolidated sediments, some bedrock types occasionally have associated saprolite with clay-coated joints, which can greatly increase the susceptibility to sliding. Most troublesome are rocks that can weather to highly plastic clay[3]; such rocks include mafic and ultramafic rocks in the Piedmont and diabase in the Triassic Lowland.

The most practical solution for stabilizing almost all long slopes in saprolite and weathered rock is to flatten the slopes.

Slopes in the Triassic Lowland—In the Triassic Lowland, the joints and bedding planes of the sedimentary rocks are generally consistent with the pattern anticipated in layered, slightly to moderately dipping sedimentary rocks, posing no unusual problems except that rapid weathering of some siltstones underlines stronger, more resistant rocks. For rocks interbedded with siltstone, slopes less than 50 percent should be considered permanently stable. Some of the igneous and associated metasedimentary rocks[6] are highly jointed and deeply weathered in the Triassic Lowland, especially near their contacts. Problems associated with Triassic Lowland igneous and metasedimentary rocks are similar to those of jointed rocks of the Piedmont.

Faults along the eastern edge of the Triassic Lowland have at some places associated joints and thin shear zones (1/2 in (1 cm) or less) containing weak, soft soil near the ground surface. These weakened zones are probably continuous for long distances, and caution in construction should be exercised when they are encountered.

As in the Piedmont, the most practical solution for stabilizing almost all long slopes in saprolite and weathered rock is by slope flattening.

Unit 6

Unit 6 includes slopes greater than 30 percent in the Coastal Plain and is composed of terrace alluvium or colluvium. Any Potomac Group sediments underlying these slopes are buried so deeply that the sediments have no influence on slope behavior. Slumps are rare in this unit, and the problems associated with the interbedded and intermixed sands, gravels, and clays are amenable to standard engineering exploration and design techniques.

Unit 7

Unit 7 includes slopes greater than 30 percent in the Coastal Plain and is composed of terrace alluvium or alluvium. Slumps are uncommon in this unit, and potential problems are amenable to standard engineering exploration and design methods. Bank failure caused by stream erosion at the base is the predominant type of landslide activity.

Unit 8

This unit is made up of vertical and very steep slopes along the Potomac River and its tributaries and coves.

Types and mechanisms of slope failure—Pleistocene and Potomac Group deposits are subject to slumping and erosion by mechanisms such as wave action, flooding, wetting and drying, and freezing and thawing. Recent natural occurrences of soil falls and landslides are common. Materials outcropping in this unit are Cretaceous deposits of sand, silt, and clay (see above) and Pleistocene deposits of medium to hard clay-rich soils and weakly bound sands. Serious problems are present in the Pleistocene deposits, especially along the Potomac Estuary at Mason Neck, Dogue Creek, and Pohick Run. At those and other sites, large retreats of the shoreline are being actively eroded and are threatening (fig. 4) nearby houses. Bank heights are as high as 30 ft (10 m), and some slopes have retreated as much as 20 ft (6 m) during the last 20 years. Very limited field observations have been made to document the various types of instabilities in this unit, but soil falls probably take place by topples, block falls, or compression failure of soil columns (fig. 5); landslides are probably dominantly shallow rotational slumps. Toppling behavior has been observed on vertical banks of clay-rich soils on vertical banks 5 ft (1.7 m) or more in height. Undercutting due to wave action and stream flow during high water are thought to be the dominant mechanisms causing toppling, but water pressure in near-vertical joints may also be a mechanism for failure. Wave action causes some block falls, but some blocks may be loosened by wetting and drying, frost action, or water pressure in joints. Nearly vertical high banks of soil having tension-release fractures parallel to the slopes may fall simply by compression failure of the soil at the base of the slope, as shown in figure 5c. Such a jointed slope can also be seen in the background of figure 4b. Clay-rich strata at various heights along banks serve as barriers to downward movement of water, which possibly softens the clay and removes support of the soil higher up the slope.

At the base of many banks, there is debris composed of many recently fallen trees and loose, very soft soil. Apparently wave action is efficient in removing this debris, effectively precluding natural stabilization. At some sites rip-rap and bulkheads are locally suitable for achieving short- and intermediate-term stability.

[1]The distinctions between the Potomac Group deposits included in Units 1 and 2 and in Units 3 and 4 are based on mapping by Force (1975).
[2]The capital letters refer to the Unified Soil Classification System, shown below:

First letter	Second letter
G, gravel	W, well graded
S, sand	P, poorly graded
M, silt	M, silty
C, clay	C, clayey
O, organic	L, low plasticity
	H, high plasticity

[3]Terms referring to material consistency, such as stiff, hard, soft, etc., are intended to be semi-quantitative; they are referenced to table 1.
[4]Justification for use of the "fully softened" state for design of permanent slopes in a fissured clay is given in a paper by Skempton (1977). Partial discussion of the applicability of Skempton's techniques to Potomac Group sediments is in a paper by Lasnger and Obermeier (1978).
[5]The author wishes to acknowledge the help of D. L. Ierley, U.S. Geological Survey, in interpreting evidence of active creep.
[6]These contacts can be determined by using the bedrock map by Drake and Froelich (1977).
[7]Bedrock types associated with highly plastic soils can be determined by using the surface materials map by Langer (1978).

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Table 1.--Qualitative and quantitative expressions of material consistency

Consistency	Field identification	Unconfined compressive strength (tons/ft^2 = 1.02 kgf/cm^2)
Very soft	Easily penetrated several inches by fist.	<0.25
Soft	Easily penetrated several inches by thumb.	0.25-0.5
Medium	Can be penetrated several inches by thumb with moderate effort.	0.5-1.0
Stiff	Readily indented by thumb but penetrated only with great effort.	1.0-2.0
Very stiff	Readily indented by thumbnail.	2.0-4.0
Hard	Indented with difficulty by thumbnail.	>4.0

SLOPE STABILITY MAP OF FAIRFAX COUNTY, VIRGINIA

By
Stephen F. Obermeier
1979

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1979

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