DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

OPEN FILE

SLOPE STABILITY

This map is an interpretation of the relative stability of natural slopes in the Anchorage area. Slope stability is the ability of the ground to remain fixed in position and resist failure by landsliding and other forms of downslope movement, including erosion. Slope stability is here divided into five categories that range from most stable to least stable. The interpretation is based on data contained in the Slope Map of Anchorage and Vicinity, Alaska (Map I-787-B), the Generalized Geologic Map of Anchorage and Vicinity (Map I-787-A), and on inferences about the probable response of the geologic materials to strong earthquakes and other geologic processes which are taken in large part from Hansen (1965), Dobrovolny and Schmoll (1968), and Dobrovolny (1971).

The primary criterion for determining stability is the amount of slope; areas of steep slopes are generally the chief sites of instability; areas of gentle slopes are generally the sites of stability. However, the degree of stability depends considerably on the geologic materials underlying the slope; slopes underlain by metamorphic rocks are generally more stable than similar slopes underlain mainly by coarse-grained surficial deposits, and, in sequence, slopes underlain by coarse-grained surficial deposits are generally more stable than similar slopes underlain mainly by fine-grained surficial deposits. Accordingly, the slope map and the geologic map were combined in preparing the slope-stability map.

The procedure used in combining the two basic maps to make the interpretive slope-stability map is presented in figure 1 and illustrated in figure 2. In figure 1, slope categories appear in the column at the left side of the diagram, with nearly flat slopes at the top and precipitous slopes at the bottom. Geologic-map units appear at the top of the diagram grouped according to their dominant materials. This grouping resulted from inferences made about the probable response of these materials to geologic processes related to slope stability. The most stable geologic materials in the area (metamorphic rocks) were placed on the upper left side of the diagram and the least stable geologic materials (mainly finer grained surficial deposits) on the upper right. Slope stability map units appearing within the diagram are the result of assigning relative values to the groups of geologic map units and combining them with the slope map units. By this arrangement of the data the slope categories and geologic materials represented in the upper left side of the diagram identify the most stable combination of factors used in compiling the slope-stability map and those in the lower right as the least stable combination.

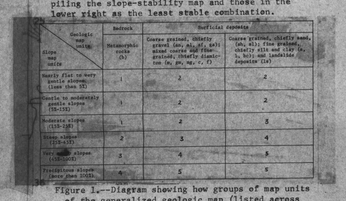

Figure 1.--Diagram showing how groups of map units of the generalized geologic map (listed across the diagram) and the map units of the slope map (listed down the diagram) were combined to yield the map units of the slope stability map.

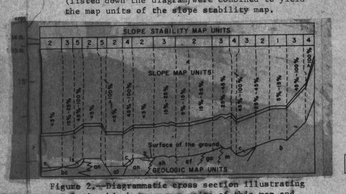

Figure 2.--Diagrammatic cross section illustrating relationship between map units of this map and map units of the slope map and of the generalized geologic map (af, af, an, gs--chiefly gravel; c, s--mixed gravel, sand, silt, and clay; sh--chiefly sand; bs, i, s--chiefly silt and clay; ls--landslide deposits).

The slope-stability map was constructed according to the procedure outlined above. In a few places these rules appear to differ from strict application of this method because subsurface and other data not shown on the slope and geologic maps indicated the need to modify slightly the slope-stability category.

The boundaries of the slope stability map units are approximations and within the range of stability that extends from most stable to least stable, because they were compiled from slope and geologic map units, some of whose boundaries are themselves approximations. In addition, small areas within each of the slope and geologic map units do not have the requisites for inclusion within that unit, but were included because they are too small to be mapped separately in the appropriate unit or because insufficient data are available to identify them; these deviant areas on the basic maps lead to similar deviations when the basic units are combined to make this map.

The ability of a slope to remain fixed is continually altered by many geologic processes which tend to induce the ground to change from its state of rest (stability) to a state of motion (instability). Changes in the state of the ground may be brought about by running water, causing either erosion or loss of support by erosion at the base of a sea bluff or riverbank; by overmantling of slopes incident to construction activities, which are not usually considered a geologic process but which have the same effect of lowering slope stability by that shoreline erosion and stream erosion have; by exposure to the atmosphere (weathering), inducing chemical and physical changes in the material that may cause the material to become less cohesive; or by increase in water content, which may cause the material to lose strength. Particularly in association with such weakening of the ground, shaking is likely to induce the material to cross the threshold from stability to instability. This threshold may, of course, be crossed without any ground shaking. Rockfalls, soil creep, and mudflows on steeper slopes commonly occur as a result of normal erosion processes independent of shaking. However, larger and more catastrophic ground displacements are more likely to occur in greater numbers when triggered by ground shaking caused by earthquakes.

All of south-central Alaska lies in a zone in which large-magnitude earthquakes occur; thus the likelihood of earthquake-triggered instability is relatively high throughout this area. The distribution in time of such large-scale events is such that the probability of occurrence affecting Anchorage at any given time is low, but ever present. The possible damaging response of the ground within each map unit to seismic shock is indicated in the description of the map units.

Instability can be caused by movement of the ground along a fault either during an earthquake or by nearly imperceptible creep along the fault. The Castle Mountain fault, on the northwest side of Knik Arm about 25 miles (40 km) from Anchorage, is known to have been active within the geologically recent past (the last 10,000 years) (Karlstrom, 1964, p. 21; Barnes, 1966, p. C15). The Knik fault, postulated to lie along the Chugach Mountain front, enters the map area about 1 1/2 miles (2.4 km) east of the mouth of Rabbit Creek and extends northeastward toward Bishne Pond, where it continues beyond the map boundary (Clark, 1972). This fault apparently has not been active since at least the end of the last glaciation, about 10,000 years ago. Conceivably there have been small amounts of undetected movement, and there might be future movement along the Knik fault.

The map shows the relative possibility of slope failures of different kinds. No firm prediction can be made from the map as to where failures will occur within a given map unit. The map points out areas of potential slope failure problems that require more detailed investigation before land is developed; it is a preliminary guide. A more detailed study may show that the overall ground conditions at a particular site are safe if certain regulations and methods of construction are followed. On the other hand, detailed investigations may show the site to be unsafe for the intended facility and may require an exceptional engineering solution as a condition of development or protection, such as the buttress that was judged necessary for stabilization of the Fourth Avenue landslide area (Shannon & Wilson, Inc., 1964, p. 43). It is emphasized that this map is an overall assessment of the relative slope stability intended to supply background information in establishing guidelines and procedures in land-development planning.

REFERENCES

Barnes, F. F., 1966, Geology and coal resources of the Beluga-Yentna region, Alaska: U.S. Geol. Survey Bulln 1202-C, 34 p.

Clark, S. H. B., 1972, Reconnaissance bedrock geologic map of the Chugach Mountains near Anchorage, Alaska: U.S. Geol. Survey Misc. Field Studies Map MF-350.

Dobrovolny, Ernest, 1971, Landslide susceptibility in and near Anchorage as interpreted from topographic and geologic maps, in The great Alaska earthquake of 1964: Washington, D.C., Natl. Acad. Sci., p. 735-743.

Dobrovolny, Ernest, and Schmoll, H. R., 1968, Geology as applied to urban planning--An example from the Greater Anchorage Area Borough, Alaska, in Internat. Geol. Cong., 23d, Prague, 1968, Proc., Sec. 12, Engineering geology in country planning: Prague, Academia, p. 39-56.

Hansen, W. R., 1965, Effects of the earthquake of March 27, 1964, at Anchorage, Alaska: U.S. Geol. Survey Prof. Paper 542-A, 68 p.

Karlstrom, T. N. V., 1964, Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geol. Survey Prof. Paper 443, 69 p.

Schmoll, H. R., and Dobrovolny, Ernest, 1972, Generalized geologic map of Anchorage and vicinity, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-787-A.

_____ 1972, Slope map of Anchorage and vicinity, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-787-B.

Shannon and Wilson, Inc., 1964, Report to U.S. Army Engineer, Anchorage District, Alaska--Anchorage area soil studies: Seattle, Wash., Shannon and Wilson, Inc., 109 p.

DESCRIPTION OF MAP UNITS

1 HIGHEST STABILITY--Nearly flat to moderate slopes underlain by metamorphic rock. Loose material is thin or absent in most places. There is little likelihood of any significant downhill movement of rock or loose material.

2 GENERALLY HIGH STABILITY--Nearly flat to moderately gentle slopes underlain by surficial deposits; moderate slopes underlain by surficial deposits consisting of gravel and mixed gravel, sand, silt, and clay; and steep slopes underlain by metamorphic rock. In most of this area there is little likelihood of significant downslope movement. However, in some places the following situations may produce minor and, at times, major slope failures: (1) In response to strong earthquake shock, such as occurred in 1964, nearly flat areas behind the tops of sea and river bluffs may sustain displacement caused by landslides, and the nearly flat areas at the base of sea and river bluffs may be covered by slide debris. This situation and the processes are more fully described under the arrow symbol that identifies areas potentially subject to large landslides. (2) Areas adjacent to major streams may be subject to erosion and consequent total loss of stability on an intermittent but continuing basis. (3) The modern tidal flats are covered by water on a daily or intermittent basis, and are subject to some instability caused by minor erosion. (4) In areas of steep slope the metamorphic rock is covered in places by unmapped loose surficial deposits, chiefly stream and slope deposits and weathered bedrock; such deposits may be subject to some downslope movement and minor erosion. (5) At the top of one area of steep slope in Little Rabbit Creek valley a landslide has been identified, and the occurrence of future landslides in similar places cannot be ruled out, although the probability of such an occurrence at any one point is small.

3 MODERATE STABILITY--Moderate slopes underlain chiefly by sand, silt, and clay; steep slopes underlain chiefly by gravel and mixed gravel, sand, silt, and clay; and very steep slopes underlain by metamorphic rock. In hummocky terrane, small hills of silt or sand are fairly stable in their natural state of vegetation, but are subject to some instability when disturbed. On steep slopes at lower altitudes in the mountains, slope deposits are subject to downward movement and minor erosion on an intermittent basis; this activity increases when the surface is disturbed. At higher altitudes on the very steep slopes, bedrock is at or near the surface, and these slopes are inherently more stable than those underlain by surficial deposits, but locally on these bedrock-floored slopes there is a thin cover of loose material which is less stable and subject to more frequent and more rapid downward movement here than on the lower slopes. Some rock debris is carried downslope in snow avalanches which occur most commonly on these slopes. Major landslides are not known to have occurred on these slopes within the area of this map, but have occurred on similar slopes in the mountains to the east, and possibly could occur here as well.

Figure 3.--Block diagram of a translatory slide. (From Hansen, 1965, p. A60.)

4 GENERALLY LOW STABILITY--Steep slopes underlain chiefly by sand, silt, and clay; very steep slopes underlain chiefly by gravel and mixed gravel, sand, silt, and clay; and precipitous slopes underlain by metamorphic rock. Sea and river bluffs and other escarpments have achieved some degree of natural stability, especially where covered by vegetation; however, they become unstable when disturbed either by natural processes such as earthquakes or erosion, or by construction activities. Small-scale downslope movement may occur in many places; erosion in gullies produces significant instability, and locally small landslides are expectable. Cliffs high in the mountains and bedrock gorges in mountain valleys are the sites of continuing minor rockfalls, and talus accumulates at the base of these slopes; occasional major rockfalls or landslides may dump substantial quantities of material on areas of lower slopes below.

5 LOWEST STABILITY--Very steep slopes underlain by sand, silt, and clay; and precipitous slopes underlain by the entire range of surficial deposits. The least stable slopes occur mainly in sea bluffs along Knik Arm and Turnagain Arm and river bluffs in nearby valleys. Erosion processes are active throughout the area of this unit; continuing downslope movement ranges from nearly imperceptible soil creep, through observable viscous earth flows, to small landslides. These bluffs have been the sites of catastrophic earthquake-induced major landslides in the past, and similar landslides will occur in the future.

POTENTIAL SITE OF LARGE LANDSLIDES--Areas along sea and river bluffs most likely to be the sites of large translatory landslides that may occur in response to strong earthquake shock. The area is defined by the presence of the Bootlegger Cove Clay in the lower part of the bluff, because that formation is the essential ingredient for the occurrence of such slides. The arrows indicate the direction of potential landslide movement. Areas behind the tops of bluffs (near the tails of the arrows) may sustain displacement and even total collapse as a result of movement of the landslide blocks toward the face of the bluffs; ground fractures may occur behind the head scarp of such landslides, and elsewhere along the tops of bluffs. The maximum known width of displaced area behind the top of a bluff is about 1,500 feet (457 m), at the prehistoric landslide near Inlet View School. Areas adjacent to the bases of bluffs (near the points of the arrows) may be overridden by landslide debris and disrupted by pressure ridges. The maximum known width of overridden area is about 2,000 feet (609 m), at the Turnagain Heights landslide of 1964 (Hansen, 1965, p. A59). The process mentioned here is illustrated in figure 3. It cannot be stated with certainty that a translatory landslide can occur everywhere within the areas indicated by symbol, nor can it be predicted where the next landslide will occur or how far behind and in front of the bluffs it will extend. Data are not available to evaluate other factors such as the presence of sensitive clay layers and sand beds, or critical water-content values necessary before landslides will occur. Some of these factors may be variable with time, and so present values may not be valid as well for the future. In addition, not all factors necessary for landslide development are known at present. However, the history of landsliding shows that about 20 percent of the area of potential slides underwent translatory landsliding during the single earthquake event of 1964, and that about 50 percent of the area had been subjected to similar sliding before then; it is likely that this is a minimum figure, because some landslide deposits probably have been removed by erosion.

Base from U.S. Geological Survey, 1962; modified in 1971
10,000-foot grid based on Alaska coordinate system, zone 4
1,000 meter Universal Transverse Mercator grid ticks, zone 6

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10 FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 27 FEET

SLOPE-STABILITY MAP OF ANCHORAGE AND VICINITY, ALASKA

By
Ernest Dobrovolny and Henry R. Schmoll

1973

PROPERTY OF DGGS LIBRARY

U.S. Geological Survey
OPEN FILE REPORT
This map is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

OF-580

FOR SALE BY U.S. GEOLOGICAL SURVEY, FAIRBANKS, ALASKA DENVER 25, COLORADO WASHINGTON 25, D.C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION
Hard surface
Unimproved dirt
State Route

ANCHORAGE AND VICINITY, ALASKA
N6100-W14937-5/16X27-5
1962

"Anchorage Revised"