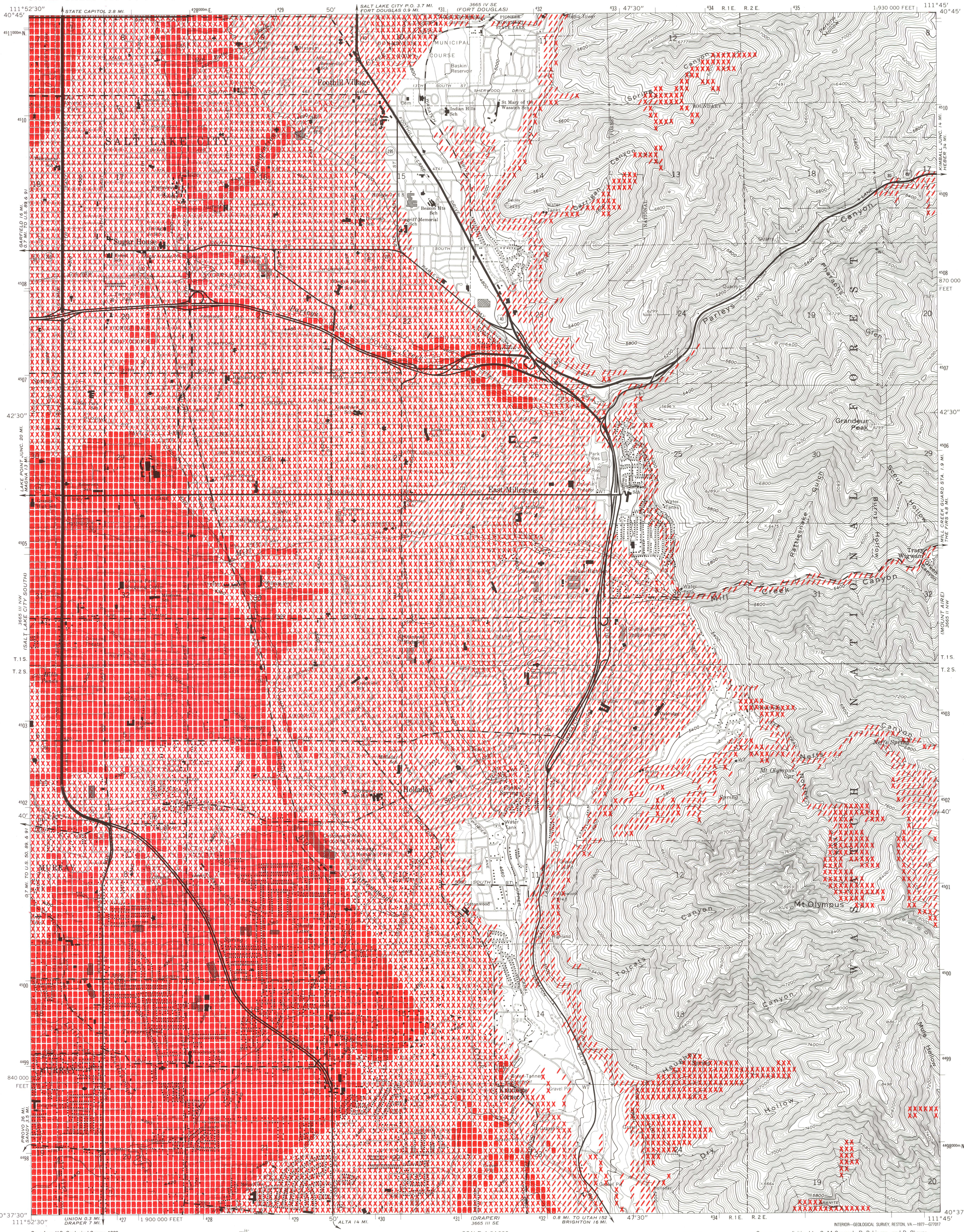
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

FOLIO OF THE SUGAR HOUSE QUADRANGLE, UTAH
MAP I–766–O



Base from U.S. Geological Survey, 1963
10,000-foot grid based on Utah coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in black

APPROXIMATE MEAN DECLINATION, 1977

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA.—1977—G77017

Source maps digitized by C. McCormack, B. Robinson, and D. Shaver.
Multi-Scale Data Analysis and Mapping Program written by G. H. Beavers; program development sponsored by the Land Use Analysis Laboratory and the Agricultural and Home Economics Experiment Station, Iowa State University.

DESCRIPTION OF MAP UNITS

MOST STABLE (MAP UNIT A)—These materials are believed to be the most stable in the quadrangle during an earthquake. Unit A is mostly steeply sloping bedrock, but also contains small amounts of surficial deposits just west of the mountain front. These deposits are less than 200 ft. (61 m) thick, are composed mostly of coarse-grained materials, are not saturated with water, and mostly slope moderately to gently westward. Locally, sharp ridge crests in the mountains may be subjected to violent shaking.

GENERALLY STABLE (MAP UNIT B)—These materials are potentially less stable during an earthquake than the materials in map unit A. The unit consists of moderately thick surficial deposits that mostly are not saturated with water and mostly slope moderately to gently westward.

MODERATELY STABLE (MAP UNIT C)—These materials are potentially less stable during an earthquake than the materials in map unit B. Unit C consists of thick mostly fine-grained surficial deposits in which the lower part is generally water saturated. Slopes are mostly gentle except in the mountains, where the slope of the landslide deposits included in the unit is moderate to steep.

LEAST STABLE (MAP UNIT D)—These materials are potentially less stable than unit C during an earthquake, and occurs in the western part of the quadrangle. Unit D consists of gently sloping thick fine-grained surficial deposits that are mostly water saturated. At a few places in the central part of the quadrangle, surficial deposits included in this unit have moderately to steeply sloping valley walls, fault scarps, and artificial cuts.

INTRODUCTION

Although we often speak of terra firma (firm earth), all normal rules of earth stability are suspended during an earthquake. The accompanying map shows an interpretation of the relative stability of the land surface during an earthquake in the Sugar House quadrangle, which includes the southeastern part of Salt Lake City, Utah. The kinds of instability considered for this report that occur during earthquakes result from shaking (with or without permanent displacement), landslides, liquefaction, (the flowing of granular material) and subsidence. Disruption of the land surface by faulting has not been evaluated in this report as it has been considered in an earlier report (Van Horn, 1972b).

Van Horn (1972d) shows the relative stability of the land surface under normal conditions where no consideration was given to the effect of shaking resulting from an earthquake. That report and the present one differ in that the more stable area under static conditions may be less stable during an earthquake. This results from the additional factors considered in preparing this map. Potential rockfall areas were included as fallen boulder accumulations in one of the source maps (Van Horn, 1972d), but the effect was masked by the regrouping of the units, so these areas mostly now fall into map units A and B.

PURPOSE OF THE MAP

This map was prepared to show how geologic information can serve as a guide in land-use planning and to explain how different types of information can be blended into a single simplified map (a how-to-do-it-yourself report).

Because the map shows the inferred relative stability of different tracts of land during an earthquake, it should provide a guide to type of construction, land-use planning, location of critical emergency control centers (fire stations, police stations, communication centers, etc.), water reservoirs and diversion controls, supply depots, hospitals, and transportation routes. The types of instability considered would have relatively less effect on conventional single story, wood frame single occupancy dwellings. The map will also give an indication of those areas which will probably sustain most damage to structures and public utilities during an earthquake, and thus should be useful for seismic safety planning and for seismic risk analysis.

PHYSICAL CHARACTERISTICS EVALUATED

The reasons that make one tract of land less stable during an earthquake than an adjoining tract are many and complex. There is much that is not known about relative stability, and much of what we think we know about it is based on indirect evidence. Therefore, the user of this map should be aware that what are presented are not facts but interpretations based upon experience and the best available field data.

The map units are defined on the basis of (1) steepness of slope, (2) type of geologic material at the surface, (3) thickness of loosely packed (poorly consolidated or unconsolidated) geologic materials, (4) average texture (grain size) of geologic materials at depth, and (5) depth to water-saturated geologic materials (principal aquifer). Using these criteria, the stability of the land surface is mostly determined by what is present from the surface downward to a depth of a few hundred yards (meters).

ASSUMPTIONS

Each of the foregoing characteristics is assumed to influence the stability of the land surface under earthquake forces. It is important for the user to understand the reasons for such assumptions in order to understand this map.

STEEPNESS OF SLOPE

Steep slopes at the land surface will tend to fail because the material making up the slope has a free face available for the outward movement of material. A gentle slope not having a steep face is much more confined because it does not have a free face available for the outward movement of material.

TYPE OF GEOLOGIC MATERIAL

The type of geologic material influences the strength of the surface. An old landslide deposit has an existing plane of failure and is thus weakened. Bedrock will not settle (become more consolidated) as much as will an unconsolidated (loosely packed) silt when both are subjected to earthquake vibrations.

THICKNESS OF POORLY CONSOLIDATED DEPOSITS

Thick deposits of poorly consolidated materials may amplify ground motion during earthquakes as compared to the amount of ground motion experienced in bedrock. This amplification is dependent upon the frequency of vibrations and can cause much larger movement of particles within the deposit and more intense local ground motion than in bedrock. The thickness of the deposit controls the narrow band of frequencies which are amplified; the thicker the deposit the lower the dominant resonant frequency. Thinner deposits cause amplification of higher frequencies and, therefore, can enhance the ground acceleration. The result of ground motion amplification is greater shaking of poorly consolidated deposits (and those structures built thereon which have natural frequencies near the resonant frequency of the deposit) than shaking experienced in bedrock. Permanent surface displacement may also result from the amplified ground-shaking levels, if extreme.

Where poorly consolidated deposits lap onto bedrock, the thinner deposits will have less total settlement than the thicker deposits as consolidation takes place. In areas near bedrock outcrops, this differential settlement can lead to significant distress in structures built on these deposits.

TEXTURE OF MATERIAL

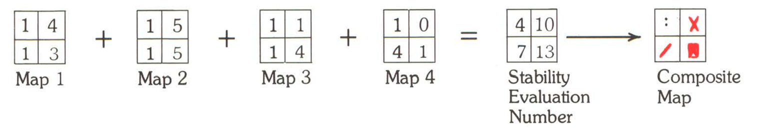
Thick deposits of water-saturated fine-grained unconsolidated deposits are more mobile under loads than are coarse-grained deposits and may liquefy during earthquakes. Fine-grained unconsolidated deposits are weaker (have less compressive strength) than coarse-grained unconsolidated deposits, so water-saturated fine-grained deposits will settle more when shaken than will the coarse-grained deposits.

DEPTH TO WATER-SATURATED GEOLOGIC MATERIAL

The depth to the water-saturated geologic material (principal aquifer) is particularly important in this area because of the geologic setting. Below the top of the principal aquifer, the unconsolidated beds are mostly water saturated and under hydrostatic pressure. In the western part of the area, the water-saturated deposits are very thick, and they thin eastward to the recharge area, just west of the mountains. In the recharge area, the beds are not water saturated. The water and hydrostatic pressure tend to support, or buoy up, the poorly consolidated material. During an earthquake, beds confining the water to aquifers may break, allowing the supporting water to escape. The drop in confining pressure may cause settlement and liquefaction.

HOW THIS MAP WAS MADE

This map is a computer-generated composite map of four source maps of the Sugar House quadrangle. Source maps were stored in the computer by a process called digitizing, which was accomplished by superimposing a grid on the source map and recording a location and numeric code for the map unit that occurs in each cell. A cell is one sampling unit, which measures 200 ft (60 m) by 250 ft (76 m) and covers 1.14 acres (0.5 ha). There are 31,480 cells on the map. Numbers were assigned to the digitized map units in order of increasing instability, and the computer added these numbers to produce a stability evaluation number for each cell. A symbol was assigned to each number, and the composite map was printed by the computer.



The four maps of the Sugar House quadrangle that were used to derive the surface stability map show: 1) relative slope stability (Van Horn, 1972d) derived by combining two geologic maps (Crittenden, 1965; Van Horn, 1972a) with a slope map (Van Horn, 1972c), 2) thickness of loosely packed materials (McGregor and others, 1974), 3) texture or grain size (Marine and Price, 1964, pl. 12), and 4) depth to top of the principal aquifer (Mower, 1973). A stability-evaluation number was assigned to each map unit, or to the interval between contours for those maps that contoured some physical property. The least stable units were assigned the highest number, and the numbers were decreased as the stability increased (see table).

SOURCES AND CRITERIA FOR THE GEOLOGIC STABILITY MAP UNITS USED IN THIS REPORT

Source map	Map unit or bounding contours of source map[1]	Stability-evaluation number
Relative slope stability map of the Sugar House quadrangle, Salt Lake County, Utah[2] (Van Horn, 1972d).	4 (potentially unstable)	5
	3 (moderately stable)	4
	2m (generally stable)	3
	2 (generally stable)	2
	1 (most stable)	1
Map showing the thickness of loosely packed sediments and depth to bedrock in the Sugar House quadrangle, Salt Lake County, Utah (McGregor and others, 1974).	More than 600 ft (185 m)	5
	600–400 ft (185–120 m)	4
	400–200 ft (120–60 m)	3
	200–100 ft (60–30 m)	2
	Less than 100 ft (30 m)	1
	For areas within 500 ft (150 m) of bedrock outcrop	Add 2 to basic number.
Map of the Jordan Valley, Utah, showing ratio of gravel-bearing intervals to total depth of wells, in percent (Marine and Price, 1964, fig. 12).	Less than 25 percent gravel	5
	25 to 50 percent gravel	4
	More than 50 percent gravel	3
	Bedrock	1
Map showing depth to top of the principal aquifer, Sugar House quadrangle, Salt Lake County, Utah, February 1972 (Mower, 1973).	0–50 ft (0–15 m)	5
	50–100 ft (15–30 m)	4
	100–200 ft (30–60 m)	3
	200–300 ft (60–90 m)	2
	More than 300 ft (90 m)	1
	No measurable water table	0

[1] Conversions to metric units are approximate.
[2] This map was derived by combining two geologic maps with a steepness of slope map. Earthquake shaking was not considered in preparing the slope stability map.

The first approximation of stability evaluation resulted from adding all the stability-evaluation numbers that fell within a tract of land. Theoretically, these numbers could have ranged from 22 to 2; in actual practice, they ranged from 17 to 2. These evaluation numbers were then regrouped into the four map units, as follows: map unit A contained stability-evaluation numbers 2 to 6, unit B contained 7 to 9, unit C contained 10 to 12, and unit D contained 13 to 20. Only about 1000 acres (400 ha) of land fell into 17 and above, so 16 was essentially the upper limit. Thus, four stability-evaluation numbers were in map unit A, three in unit B, three in unit C, and four (not counting 17) were in unit D.

HOW TO READ THIS MAP

The map units are plotted on a topographic base map which shows the shape and steepness of the land surface by conventional contour lines. The base map also shows the location of streets and highways, major community buildings, parks, surface water, and political boundaries.

The four relative-stability map units are labeled A, B, C, and D, in order of decreasing relative stability. The boundaries between the units are approximately located and are gradational. Thus, one should not consider the boundary to be an exact position, where one suddenly steps from a more stable position to a less stable position. Rather, one should think of the boundary as a midpoint one might pass if one started from the center of a more stable unit and walked toward the center of a less stable unit. Thus, as one walks from center to center, each step would cross ground that would be slightly less stable during an earthquake.

It is not known how much more stable one map unit is than another. Nor is it known whether the different map units are separated by the same relative amount of instability. It would be most desirable to be able to say that map unit C was 4 times as stable as unit D, and that unit B was 4 times as stable as unit C—unfortunately, this cannot be done because not enough is known about evaluating the factors that have gone into synthesizing the map.

The reader should be aware that individual tracts of land probably will behave differently when subjected to different magnitudes of earthquakes. Thus, a particular place may be relatively stable when subjected to small earthquakes but fail completely when subjected to moderate or large earthquakes.

The bedrock area in the eastern part of the quadrangle is the most stable area. Although all places within this area are not equally stable according to the first approximation of stability-evaluation numbers (see "How this map was made"), when the first approximation numbers were regrouped all the bedrock units were in map unit A. The areas of inferred least relative stability are mostly near the western edge of the map, where the surficial deposits are thickest, mostly fine grained, and water saturated near the surface.

UNEVALUATED CRITERIA

Many factors affect the stability of the land surface during earthquakes. The factors used to prepare this map are important for evaluating stability: they are available from published reports and required no additional fieldwork. Some of the other factors that undoubtedly should enter into a more complete evaluation are as follows: the violent local seismic shaking (churning) of ridge crests, the degree of recementation of fractured rock along old faults, the amount of seismic shock that might be absorbed by existing faults and thus not be transmitted across the fault plane, the thickness and physical characteristics of the moderately packed material that commonly forms a layer between loosely packed material and bedrock, and the seismic response of the geologic deposits (requires measurement of the physical properties by geophysical methods). Some information about all but the seismic response and recementation of fractured rock can be obtained and evaluated by the interested reader from already published sources (Van Horn, 1972b, 1972c; McGregor and others, 1974; or the topographic map of the Sugar House quadrangle).

CONCLUSIONS

The results of this investigation agree with the general observation that during earthquakes surficial deposits are less stable than bedrock. However, the inferred pattern of instability, based on the criteria used in this report, is rather complex, and may not be readily apparent from the deposits that occur at the land surface. At a few places, some surficial deposits may be more stable than some of the bedrock, but, because of the way the map was made, the more stable surficial deposits are shown in the same category as the bedrock—unit A on the map.

REFERENCES CITED

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Van Horn, Richard, 1972a, Surficial geologic map of the Sugar House quadrangle, Salt Lake County, Utah: U.S. Geol. Survey Misc. Geol. Inv. Map I–766–A.
________ 1972b, Map showing relative age of faults in the Sugar House quadrangle, Salt Lake County, Utah: U.S. Geol. Survey Misc. Geol. Inv. Map I–766–B.
________ 1972c, Slope map of the Sugar House quadrangle, Salt Lake County, Utah: U.S. Geol. Survey Misc. Geol. Inv. Map I–766–C.
________ 1972d, Relative slope stability map of the Sugar House quadrangle, Salt Lake County, Utah: U.S. Geol. Survey Misc. Geol. Inv. Map I–766–E.

COMPUTER COMPOSITE MAP SHOWING INFERRED RELATIVE STABILITY OF THE LAND SURFACE DURING EARTHQUAKES, SUGAR HOUSE QUADRANGLE, SALT LAKE COUNTY, UTAH

By
Richard Van Horn and J. Nicholas Van Driel
1977

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