DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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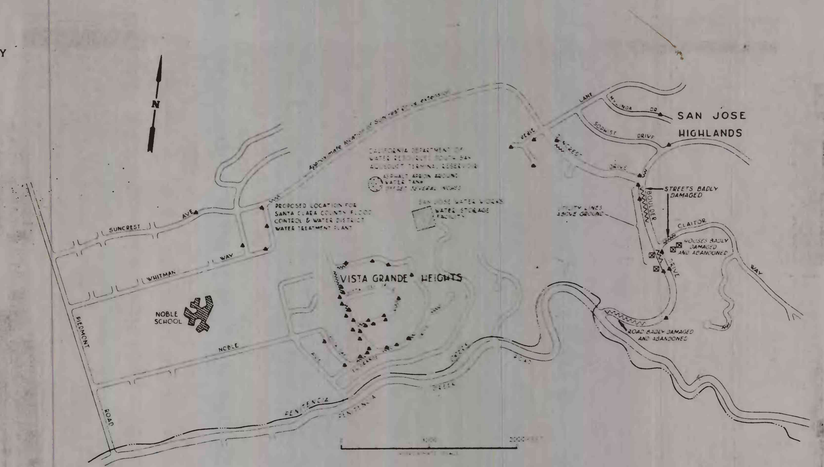
SYMBOLS

- Curb broken or offset at joints
- Road damaged
- House damaged

The damage observed appeared to be, or in some cases definitely is, related to landslide movement. No comparable damage was observed outside of the area mapped as landslide deposits. Several of the roads, curbs and houses within the landslide deposits were checked and had no apparent damage, but a more thorough survey should be made before the extent of the damage can be fully assessed.

Observations of damage were made during 2 days of field checks in July and September 1971. Damage repaired before those dates is not shown on the map.



BASE MAP FROM U.S. GEOLOGICAL SURVEY CALAVERAS RESERVOIR 7.5' QUADRANGLE (WITH SOME ADDITIONAL AND MAIN TECHNICAL INFORMATION BY ASSESSOR'S OFFICE, SANTA CLARA COUNTY)

MAP SHOWING DAMAGE OBSERVED IN JULY AND SEPTEMBER 1971

ECONOMIC FACTORS

The economic loss as a consequence of development on these landslide deposits is already large, will continue to grow, and will probably become significantly greater if additional development is permitted without thorough engineering geologic investigations of the areas. The estimated 1969-70 loss in market value for 31 houses in San Jose Highlands, for example, was $228,000, the loss for lots was $145,000, and the loss in the valuation for specific landslide damage to certain houses was $61,400, yielding a total of $434,520 (Santa Clara County Assessor's office, written comm., 9/27/71). These additional cost data provided by the San Jose Department of Public Works (written comm., 9/20/71) reveal the variety and magnitude of expenses to a municipality when landslide activity takes place within a subdivision area:

ACTIONS TAKEN BY AND FINANCED BY THE CITY OF SAN JOSE IN THE SAN JOSE HIGHLANDS AREA, 1966-71

Soils study and consultant fees	1968	$ 10,000
Soils study and consultant fees	1969	10,000
Consultant fee new road	1970	10,000
Construct 1400' gravel fill interception ditch (no water was apparently removed)	1969	15,000
Clean hydraughers several times		3,000
Construct de-watering wells (deactivated after 1 year, no apparent help)	1969	25,000
Above-ground flexible aluminum sanitary sewer	1969	2,000
Sewer photo survey	1971	3,000
Replace sanitary sewer	1971	7,000
Aerial photography		2,000
Abandon 600' of only access road and build 400' of new access around landslide area		15,000
Winter and spring road maintenance to remove ground swells and increasing grade due to downward creep	1967	-0-
	1968	9,000
	1969	30,000
	1970	32,000
	5 months of 1971	30,000
	Total	$160,000
(Estimated value of City streets in San Jose Highlands (exclusive of new access road)		$250,000
Estimated value of City utilities (street lights and sewers) in San Jose Highlands		300,000

Landslide damage to gas lines in San Jose Highlands totaled $20,000 by late 1970 (Pacific Gas and Electric Company, written comm., 11/18/71) and damage to water lines owned by a private water company was presumably extensive.

No information was obtained on the cost of landslide damage in the map area outside of the San Jose Highlands, but landslides were a substantial and presumably costly problem during and after construction of terminal facilities for the South Bay Aqueduct (California Department Water Resources, 1966).

PRELIMINARY PHOTOINTERPRETATION AND DAMAGE MAPS OF LANDSLIDE AND OTHER SURFICIAL DEPOSITS IN NORTHEASTERN SAN JOSE, CALIFORNIA

by Tor H. Nilsen and Earl E. Brabb

1971

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INTRODUCTION

Landslide deposits in the northeastern portion of the City of San Jose were first shown on a published map of bedrock geology by Crittenden (1951, pl. 1). The area thought to be covered by landslide deposits has been expanded in the present map, with damage to cultural features within part of the landslide deposits shown for the first time. Although this damage is thought to result from movement of the landslide deposits, additional work will be necessary to determine the full extent of the problem. Some areas shown as bedrock, for example, may also be involved in some downslope movement, while others may be relatively secure building sites. In addition, some landslide deposits shown on the map may be very old and quite stable at the present time. Drill holes may be required to determine the depth of landslide movement and activity, as well as more detailed geologic and engineering studies of the deposits themselves.

These maps present preliminary information about one aspect of the physical environment necessary to sound land-use planning--the distribution and probable nature of surficial deposits. Because surficial deposits are common in much of the Bay region, it is useful to know how and why they have formed, as well as what properties they possess. When these or other maps of surficial deposits are used in combination with other types of environmental information, such as data on soils, bedrock geology, slopes, vegetation, climatic variation, seismic response, and hydrology, then planners and others may be in a better position to make sound judgments regarding the physical aspects of land use. The U.S. Geological Survey is presently studying many of these factors in the Bay region and will provide the community with much of the required information as part of its San Francisco Bay Region Study, in cooperation with the Department of Housing and Urban Development.

The photointerpretation map has been prepared by viewing overlapping vertical aerial photographs through a stereoscope. This permits a three-dimensional relief model of the ground surface to be seen, thus enabling the geologist to study and interpret the origins of landforms. Photointerpretation provides many advantages over both ground observations and laboratory studies of surficial materials in the mapping of surficial deposits, particularly for reconnaissance-type studies. Preliminary photointerpretation maps such as this are the initial stage of a continuing, more detailed study of surficial deposits in the Bay region, but they will hopefully provide map users with immediately useful information about the regional distribution of landslide and other surficial deposits.

The photointerpretation map indicates the dominant geological processes that have probably been operative over the map area by showing the distribution of different types of surficial deposits. Natural processes such as weathering, erosion, sedimentation, and the slow as well as rapid downslope movement of earth materials, have been constantly shaping and reshaping the land surface in the past. These processes will continue to do so in the future, although their locations and rates of activity may change through time. The processes are not completely independent of one another, but are interrelated to varying degrees. For example, crustal uplift of the Coast Ranges will lead to increased erosion and downcutting by streams, which in turn generally results in increased deposition of sediments in river valleys, lakes, and shoreline areas. Older flood plains and river deposits may be cut into, leaving elevated terrace deposits. In addition, downcutting by the streams may cause the adjacent slopes to become unstable, thereby increasing the possibility of slope failures.

The photointerpretation map, then, shows the cumulative effect of various geological processes that have yielded surficial deposits up to the time the photographs used for the photointerpretation were taken. Thus, the map does not directly indicate future sites or rates of surficial processes. For example, the landslide deposits shown on the map record past slope failures, not areas of present or future slope instability. However, knowledge of the past history of geologic events is the most important key to understanding and predicting the future behavior of a particular kind of geologic process in the most important way to understanding and predicting the future behavior of a particular kind of geologic events in the most important way to understanding and predicting the future behavior of a particular land area, even where man's activities significantly change the character of the land. The overwhelming majority of new landslides, for example, occur in areas with a history of past landslide activity. As such, this map can be used to evaluate the regional importance of different surficial deposits in land-use planning.

Note: Nilsen is responsible for the photointerpretation map and explanation; Brabb for the map showing the extent of damage thought to be related to landslide activity.

EXPLANATION FOR PHOTOINTERPRETATION MAP

Qal

Landslide deposits

Arrows indicate general direction of downslope movements; queried where identification is uncertain

Debris composed of fresh and weathered fragments derived from rocks, sediment, soil, and artificial fill, or any combinations thereof, that have been transported downslope by falling, sliding, rotational slumping, or flowing. Landslide deposits smaller than approximately 200 feet in longest dimension are not shown on the map. Complex landslide deposits, which result from combinations of different types of downslope movement, are perhaps the most common type of landslide deposit in the Bay region. In particular, materials near the head of landslide deposits typically move in a different manner than materials at the toe. The landslide deposits shown on this map have not been classified according to either type of movement or type of material of which the deposit is composed. The deposits vary in appearance from clearly discernible, terrain unweathered and unroded topographic features to indistinct, highly weathered and eroded features, recognizable only by their characteristic topographic configurations. The time of formation of the mapped landslide deposits ranges from possibly a few hundred thousand years ago to 1970, with no landslide deposits formed since 1970 shown. The thickness of the landslide deposits probably varies from about 10 feet to perhaps several hundred feet, being in general greater in the larger deposits; many of the small landslide deposits may be very thin and involve only surficial materials.

Qal

Alluvial deposits

Irregularly stratified, poorly consolidated deposits of clay, silt, sand and gravel deposited in stream and river beds and on adjoining flood plains. Alluvial deposits less than about 200 feet in width, common along smaller streams, have not generally been mapped, where colluvial deposits are adjacent to such narrow strips, the alluvial deposits have been included within them.

Qcf

Colluvial deposits and alluvial fan deposits

Colluvial deposits: unstratified or poorly stratified, unconsolidated to poorly consolidated deposits, composed of fresh and weathered fragments derived from rock, soil, sediments, or irregular mixtures of these materials, that accumulate by the slow downslope movement of surficial material predominantly by the action of gravity, but assisted by running water that is not concentrated into channels. Colluvial deposits have been mapped only where they form a distinct apron near the base of slopes or fill and flatten canyon, ravine, and valley bottoms. Colluvial deposits are probably forming on almost every slope in the Bay region--however, only the thicker and more extensive accumulations that are recognizable on aerial photographs have been mapped. In some narrow stream valleys, colluvial deposits include alluvial deposits. Colluvial deposits may have downslope along the axes of ravines and form fan-shaped deposits where they emerge onto more gently sloping valley floors.

Alluvial fan deposits: irregularly stratified, unconsolidated to poorly consolidated, fan-shaped accumulations of water-laid sediment formed where narrow canyons emerge onto more gently sloping valley floors. The fan sediments are composed of clay, silt, sand and gravel deposited by streams and thin water-rich mudflows. These deposits commonly grade upslope into colluvial deposits, and may be interbedded with them.

Note: because of the difficulties in distinguishing fan deposits from fan-shaped colluvial deposits on aerial photographs, the two units have not been distinguished on this map.

Qaf

Artificial fill

Highway, railroad and canal fills composed of rock and soil derived from nearby cuts or quarries; only large fill areas are shown on the map.

Bedrock and associated soil (queried where identification uncertain)

Igneous, metamorphic, and sedimentary rocks of various ages, physical properties, and engineering characteristics. Areas not shown on the map as covered with surficial deposits probably contain bedrock either exposed at the surface or mantled by a thin veneer of surficial deposits, most commonly soils or other colluvial material. The bedrock is commonly weathered to a considerable depth, so that there is a gradual change downward from soils to fresh bedrock. Because of this, many of the small landslide deposits and some of the large landslide deposits that are shown on the map to be within bedrock areas probably involve only material derived from soils, weathered bedrock fragments, and other colluvial material.

PROPER USE OF THE PHOTOINTERPRETATION MAP

Planning departments and developers:

The density of landslide deposits is a crude measure of the importance of slope failure as an erosional process and therefore also of the overall slope stability of a particular area. However, quantitative determinations of the probability of future landslides based on information available from this map are not possible, primarily because geologic and climatic changes have occurred during the past few hundred thousand years that have altered slope stability, and because detailed information regarding the style of movement and composition of individual landslide deposits is not available from the map. Therefore, this map must not be used as a substitute for detailed site investigations by engineering geologists and soils engineers, on the contrary, areas of relatively high susceptibility to landslide activity, in particular, require very careful study prior to any development.

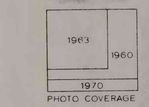
Geologists and engineers:

This map has been prepared to provide a regional context for interpreting detailed site investigations, and is best used in conjunction with slope maps, bedrock geology maps, soils maps, and other available information. It is certainly not intended as a substitute for site investigations, and its limitations should be clear. The Geological Survey would appreciate any comments regarding the usefulness and accuracy of the map.

Home-buyers:

Areas of the map with relatively low densities of landslide deposits probably have good slope stability compared to areas with high densities of landslide deposits. However, it must be remembered that landslide deposits less than 200 feet in longest dimension have not been mapped, and also that areas shown on the map as landslide deposits are not necessarily less stable than adjacent areas not mapped as landslide deposits. The map, therefore, should not be used as a substitute for a more detailed investigation by a competent engineering geologist; site investigations are necessary for judgments about the slope stability of individual areas. In addition to landslide deposits, other surficial deposits may cause problems to building and should be carefully investigated.

SOURCE MATERIALS FOR THE PHOTOINTERPRETATION MAP



Three series of vertical aerial photographs taken for the U.S. Geological Survey were principally used in the preparation of this map (see diagram at left for area of coverage): (1) series CIV, scale 1:20,000, taken in July and September of 1963, including photograph numbers 200-13 to 200-16 and 600-11 to 600-122; (2) series GS-VAG, scale 1:30,000, taken in August 1960, including photograph numbers 2-71 to 2-74; and (3) series GS-VCMI, scale 1:80,000, taken in April 1970.

CHARACTERISTICS OF SURFICIAL DEPOSITS RELEVANT TO LAND-USE PLANNING

All of the natural factors that provide landslide activity are present in the Bay region. In addition to these factors, man's activities have had varying effects upon the potential for slope failures, often decreasing it by the leveling of slopes, building of retaining walls at the base of slopes, planting of trees or other vegetation, as well as through soil conservation practices. However, other activities of man may increase the potential for slope failures. These include the increasing of slope angles for road or building construction, the addition of water to marginally stable slopes by watering of lawns, improper sanding of rate water runoff, and use of septic tank drainfields, the addition of weight to marginally stable slopes by building structures as well as adding fill for foundations, and removal of natural vegetation. Thus, slope failure, a natural phenomenon that has occurred many times in the past throughout most parts of the Bay region, may be encouraged and promoted through improper use of the land.

The landslide deposits shown on the photointerpretation map may or may not be continuously or intermittently active. Many of the deposits are probably presently inactive, but have been active in the geologically recent past, and, under many conditions, could become active again. Inactive landslide deposits may be reactivated by man's activities, such as those mentioned above, or by natural causes, such as unusually high rainfall or earthquakes. Reactivation of inactive landslide deposits may be no problem for many years, but then a year of unusually high rainfall may cause a landslide to move rapidly, damaging or destroying houses and other structures built on it. Inactive landslide deposits are commonly recognized by hummocky topography, locally abundant ponds, lakes, and undrained depressions, abundant natural springs, irregular and irregular patches in slope and drainage pattern, a hummocky surface, and by the presence of scarps that are crudely arcuate and face within it. Active landslide deposits, in short, include all of the above, plus fresh scarps at the upper edge of the deposit, irregular soil and vegetation patterns, and areas of obvious recent movement that would appear suitable for reactivation. In general, fewer of these characteristics will be noted in the smaller deposits. Detailed ground studing, in short, are required for predicting the future behavior of landslide deposits under changing conditions of use.

FACTORS AFFECTING THE ACCURACY OF THE PHOTOINTERPRETATION MAP

Date of photography:

Modifications of the landscape that have occurred since the time the aerial photographs were taken (mid to late 1970) have not been incorporated into this map. Thus, landslide deposits and large artificial fill deposits that have been formed since then are not delineated on the map, although the topographic base maps were photorevised in 1968 and do show the extent of urbanization to that date.

Scale of maps and photography:

Landslide and other surficial deposits less than approximately 200 feet in longest dimension are not shown on this map because they are too small to be clearly identified on the photographs used or clearly portrayed on the topographic base map. In addition, no attempt has been made to show the numerous small areas covered by artificial fill along highways, railroads and airstrips, in cemeteries, in populated and farming areas, or near quarries and mines, even though some are greater than 200 feet in longest dimension.

Quality of photography:

The accuracy of the map varies directly with the clarity and contrast of the aerial photographs used. Accordingly, the presence of haze or cloud cover, or poor sun angles, will make photointerpretation more difficult, also, the steepness of the topography and the location and extent of shaded areas affect the usefulness of individual photographs. In general, however, the photographs used to prepare this map are of excellent quality.

Forest cover:

The recognition of surficial deposits in forested areas may be difficult, resulting in decreased map accuracy in these areas as opposed to grass-covered areas. Many landslide deposits, in fact, may be impossible to recognize on slopes covered with dense stands of tall trees.

Urbanization and farming:

Surficial geologic features can be obscured by (1) modification of the natural landscape by grading (leveling, cutting, filling, terracing, cultivation, etc.), and (2) covering the natural land surface with man-made structures.

Problems of interpretation:

Mapping of surficial deposits by photointerpretation alone presents a number of difficult problems, some of which can only be resolved through field checking. Situations and problems that are especially difficult and which affect the accuracy of the map include: (1) the distinction of terrace-shaped slump-type landslide deposits from alluvial terrace deposits where both are located adjacent to stream courses; (2) the recognition of bedrock cropping out beneath surficial deposits, especially where a creek or stream has cut down through the overlying surficial deposit to expose bedrock along the stream-bed; (3) the location of boundaries between adjacent surficial deposits that laterally grade into or interfinger with one another without leaving any easily discernible topographic boundaries, e.g., the downstream gradation of alluvial terrace deposits into alluvial deposits; (4) the recognition of landslide deposit boundaries--whereas the upslope boundary is commonly defined by a readily recognized scarp, the toe or downslope boundary is often not well-defined and difficult to locate accurately; (5) the recognition of stable masses of bedrock within landslide deposits, especially where the bedrock may appear to be just a large block within the surrounding landslide deposit; and (6) the distinction between irregular or hummocky topography caused by variations in the erosional resistance of bedrock and that produced by the erosion of landslide deposits.

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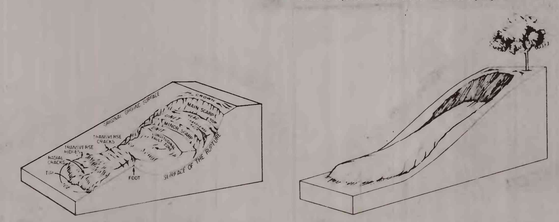
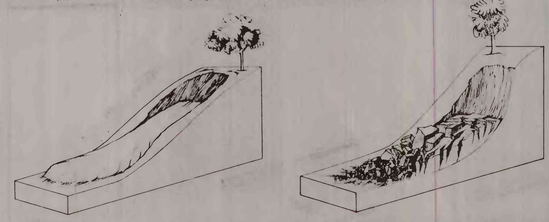
APPENDIX

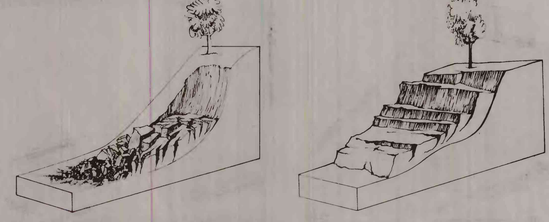
These illustrations show, respectively, the nomenclature used to describe landslide deposits, and four common types of landslide deposits found in the San Francisco Bay region:



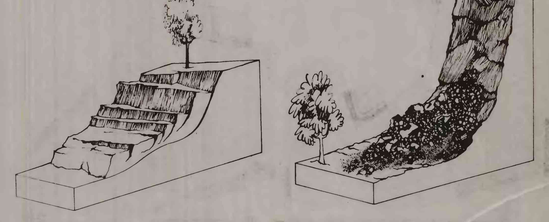
Nomenclature of parts of a landslide (from Eckel, 1958):



Earthflow: soil and other colluvial materials that move downslope in a manner similar to that of a viscous fluid.



Debris slide: incoherent or broken masses of rock and other debris that move downslope by sliding on a surface that underlies the deposit.



Slump: coherent or intact masses that move downslope by rotational slip on surfaces that underlie as well as penetrate the landslide deposit.

Rockfall: rock masses that move primarily by falling through the air.