DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with
STATE OF WASHINGTON, DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND EARTH RESOURCES

FOLIO OF KING COUNTY, WASHINGTON
MAP I-852-B

Topographic contours from U.S. Geological Survey, 1:24,000
Olalla, 1953; Des Moines, Vashon, Renton, and Maple Valley, 1949
Orthophoto map from aerial photographs taken in 1968

SCALE 1:48 000

1 ½ 0 1 2 3 MILES

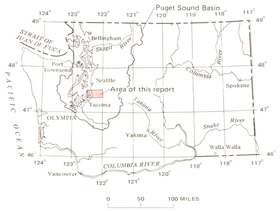
1 .5 0 1 2 3 4 5 KILOMETERS

CONTOUR INTERVAL 25 FEET
(EXCEPT IN WESTERN VASHON ISLAND WHERE
THE CONTOUR INTERVAL IS 20 FEET)
DATUM IS MEAN SEA LEVEL

Interior—Geological Survey, Washington, D.C.—1974—R74015

EXPLANATION

Location of reported landslide damage, 1972



INDEX MAP OF WASHINGTON

This map is one of a series being prepared by the U.S. Department of the Interior in cooperation with several agencies to present basic environmental information and interpretations to assist land-use planning in the Puget Sound area.

INTRODUCTION

Landslides are a common geologic hazard in the Puget Sound lowland of western Washington. Each winter at least a few slides occur in the relatively unconsolidated material that underlies the slopes along Puget Sound and adjacent valleys. A particularly large number of slides occurred in King County during early 1972, resulting in millions of dollars in damages and markedly increasing public awareness of the hazard. This map shows the location of landslides reported during that period in a part of west-central King County. A substantial part of the economic losses due to the slides could have been averted had the geologic, climatic, and human factors responsible for landslides in this area been recognized and efforts made to minimize their effects.

SOURCES OF INFORMATION

Widespread flooding and landsliding in western Washington during early 1972 caused the President to designate a large part of the Puget Sound lowland as a natural disaster area. This action made Federal disaster assistance available and encouraged both public and private property owners to apply for funds to aid reconstruction. Federal funds compensated most of the economic losses due to the slides, and the resulting disaster assistance records include information on the location and the amount of damage from landslides during this period. Both the Office of Emergency Preparedness and the Small Business Administration generously provided information from their files for the purposes of this study.

To evaluate the completeness of such records, news accounts in the Seattle Times were reviewed for the period January through April, 1972. Only one landslide was noted in the study area for which information was not available in Federal agency files. That landslide is not included in this report because information on its location and the damage caused was inadequate. The landslides shown on the map and described here probably include most of the slides which caused significant property damage during the first four months of 1972. However, a number of landslides probably occurred during this period but were not reported because they caused little or no property damage. Each of the landslides shown on the orthophoto map were examined in the field to verify their location and to determine the causes of sliding.

GEOLOGIC FACTORS

The landslides in this area are generally related to the topography and the nature of the underlying materials, which in turn are largely a function of the glacial history of the Puget Sound lowland (see references). They can be grouped into 3 general categories, based on the style of movement and the type of material involved; these 3 general types of slides have been called "earthflows", "slumps", and "debris flows" by Miller (1973), and that terminology is followed here (table 1).

Table 1. Types of landslides

Type of landslide	Number of slides	Estimated damages
Earthflow	67	$198,000
underlying material:		
most recent till	15	46,000
other deposits from most recent glaciation	10	18,000
older deposits	42	134,000
Slump	9	17,000
Debris flow (3 debris flows developed from other types of slides during later stages of movement)	7	61,000
All types	80	276,000

Earthflows typically involved movement of a few feet of soil over relatively impermeable deposits (fig. 1). These slides occurred where the soil became saturated by water which was prevented from seeping into the underlying material. The additional weight of the water and the related seepage forces within the soil decreased its stability. All but 13 of the 80 landslides were of this type. Most (42) of the 67 earthflows occurred in areas underlain by poorly permeable material (largely silt and clay) older than the most recent glaciation. Till (a mixture of gravel, sand, silt, and clay) deposited by glacial ice during the latest glacial age was present under 15 of the slides; the remaining 10 earthflows occurred over other deposits of the most recent glacial age.

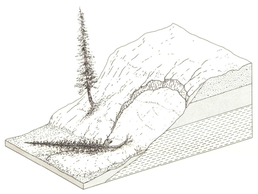


Figure 1. Earthflow

The slumps involved a significant amount of the underlying deposits as well as the surface soil (fig. 2). Nine slides were of this type, and they were generally located where a relatively permeable deposit (such as sand or gravel) rests upon a relatively impermeable layer (such as silt, clay, or till). Under such conditions, water readily percolated downward until it was halted by the impermeable layer. It then moved laterally to a hill slope, where it emerged as a spring or seep. Pressure gradients within the ground water immediately above the impermeable layer reduced the stability of the overlying material.

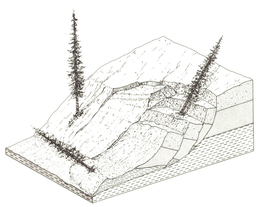


Figure 2. Slump

In contrast to the other types of landslides, which were fairly local in their effects, the debris flows moved down gullies as flowing masses of mud and debris and sometimes spread out onto the more level ground beyond the mouths of the ravines (fig. 3). Three of the 7 slides of this type began either as earthflows or slumps and developed into debris flows as they moved down the gullies.

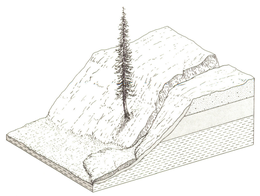


Figure 3. Debris flow

The landslides can be related to the inferred slope stability classes shown on a map of the same area (see references), on which least stable areas are mapped as class 3, marginal areas as class 2, and the most stable areas as class 1. Of the 80 landslides examined, 48 occurred in class 3 areas, 23 occurred in class 2 areas, and 9 occurred in class 1 areas (table 2). The slides in class 1 areas actually occurred in areas which fit class 2 or 3 criteria, but which were too small to show at the scale and with the contour interval of the slope stability map.

Table 2. Relationship of landslides to slope stability categories of Miller (1973)

Slope category	Number of slides	Estimated damages
Class 1 (most stable)	9	$ 36,000
Class 2 (marginal stability)	23	71,000
Class 3 (least stable)	48	169,000

SOME ECONOMIC ASPECTS

Eighty landslides, which caused a total of more than $250,000 in damages, were evaluated during this study. Approximately 30 percent of this damage occurred to public property and about 70 percent to private property. These estimates, however, represent only the monetary cost of restoring the property as nearly as possible to the original condition. They do not include less easily quantifiable losses such as traffic delays, personal inconvenience, and the costs in time and energy to property owners, or the decrease in property value due to the subsequent identification of the property as having had a landslide problem.

None of the reported damage was covered by insurance. Flood and mud slide insurance is now available in the unincorporated parts of King County under the National Flood Insurance Program, which is administered by the Department of Housing and Urban Development; however, King County was not participating in the program during early 1972.

HUMAN FACTORS

A relationship between the number of landslides per unit area and the amount of urbanization is apparent from the map. This relationship is most obvious east of Puget Sound, but it also holds true on Vashon Island where there has been considerable development along the shoreline. This apparent relationship reflects, in part, the economic bias in reporting landslide locations. Because damage claims to Federal agencies required loss of property, relatively few landslides were reported from less densely developed areas. On the other hand, considerable landscape modification accompanies development and seems to have been a contributory factor in many of the slides (table 3).

Table 3. Some human influences contributing to the landslides

Contributing cause (a single slide may have several causes)	Number of slides	Estimated damages
Hillside excavation (such as road cuts)	30	$ 33,000
Retaining wall failure	2	34,000
Artificial fill failure	25	94,000
Drainage diversion	28	182,000
Any of the above	69	250,000

CLIMATIC FACTORS

While the locations of the landslides appear to have been governed by geologic and human factors, the timing and large number of the slides were the result of unusual climatic conditions. The early part of 1972 was considerably wetter than usual: the first 4 months of the year received approximately 60 percent more precipitation than normal, as measured at the Seattle-Tacoma airport (fig. 4).

Within this general period of high precipitation (and presumably high water table), several days of exceptionally intense rainfall occurred, during which most of the landsliding took place (fig. 5). Specific dates of failure are known for only 24 of the 80 slides; all but 1 of these occurred on one of the 4 days during early 1972 on which approximately 1.5 inches or more of rain fell during a 24-hour period. Although the exact dates of occurrence are not known for the other 56 landslides, discussions with neighbors and property owners suggest a similar relationship to rainfall intensity.

Low temperature may also have played an indirect role in causing some of the landslides. An unusually severe cold spell during late January and early February (fig. 6) caused freezing of the upper part of the soil. Subsequent thawing of the ice crystals probably left the soil in a highly porous condition, allowing increased penetration by the heavy rains that followed.

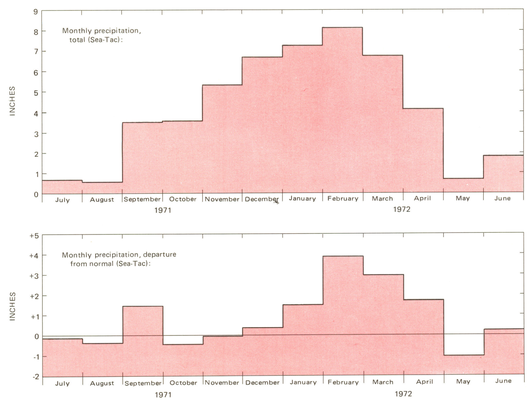


Figure 4. Monthly precipitation

SELECTED REFERENCES

Luzier, J. E., 1969, Geology and ground-water resources of southwestern King County, Washington: Washington Dept. Water Resources Water Supply Bull. 28, 260 p.

Miller, R. D., 1973, Map showing relative slope stability in part of west-central King County, Washington: U.S. Geol. Survey, Misc. Geol. Inv. Map I-852-A.

Molenaar, Dee, 1965, Geologic map and diagrammatic sections of the Kitsap Peninsula and certain adjacent islands, pl. 1 *of* Garling, M. E., and others, Water resources and geology of the Kitsap Peninsula and certain adjacent islands: Washington Div. Water Resources Water Supply Bull. 18, 309 p.

Mullineaux, D. R., 1965, Geologic map of the Renton quadrangle, King County, Washington: U.S. Geol. Survey Geol. Quad. Map GQ-405.

——1970, Geology of the Renton, Auburn, and Black Diamond quadrangles, King County, Washington: U.S. Geol. Survey Prof. Paper 672, 92 p.

Varnes, D. J., 1958, Landslide types and processes, chap. 3 *of* Eckel, E. B., ed., Landslides and engineering practice: Natl. Research Council, Highway Research Board Spec. Rept. 29, p. 20-47.

Vine, J. D., 1962, Preliminary geologic map of the Hobart and Maple Valley quadrangles, King County, Washington: Washington Div. Mines and Geology Geol. Map GM-1.

Waldron, H. H., 1962, Geology of the Des Moines quadrangle, Washington: U.S. Geol. Survey Geol. Quad. Map GQ-159.

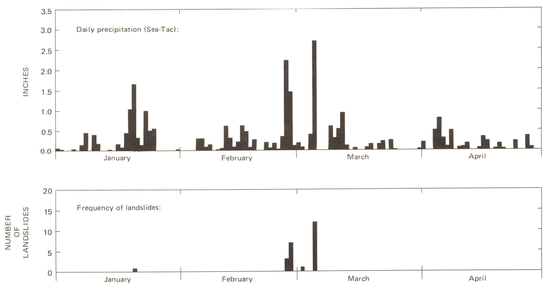


Figure 5. Relationship of landslides to daily precipitation

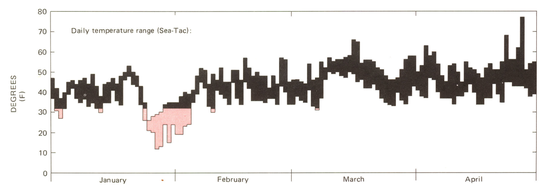


Figure 6. Daily temperature range

LANDSLIDES AND ASSOCIATED DAMAGE DURING EARLY 1972 IN PART OF WEST-CENTRAL KING COUNTY, WASHINGTON

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1974

For sale by the U.S. Geological Survey, price 75 cents