CONTINUED FROM SHEET 1

Hazard

Debris flows are a natural process in steep hillside terrain, where they may be the chief method of hillside erosion. Like floods, their timing is sporadic because of the infrequent occurrence of rainfall sufficient to trigger them. Their specific locations are less predictable than floods, because even in large storms only a small fraction of the potential failure sites actually produce debris flows. Despite this limitation, areas subject to debris flow can be recognized and those parts of the landscape with more or less exposure to hazard can be identified.

Five basic elements are involved in the estimation of debris-flow hazard within areas subject to debris flow:

1. areas in the region that are subject to debris flows;
2. places in the landscape within those areas where debris flows can be generated;
3. rainfall required to trigger failure;
4. travel paths of debris flows from various points of origin;
5. size of debris flows and variation in energy along flow paths.

Debris flows thus differ from most other landslides in typically forming during heavy rain, moving swiftly, and imposing hazard at points considerably removed from the sites of initial slope failure.

The 1955 and 1982 debris-flow maps bear on several of these points. The distribution and abundance of soil-slip scars and debris-flow tracks, particularly for the 1982 storm, shows that nearly all of the map area is subject to debris flow. The absence of new debris flows north of Montara Mountain in the 1955 storm must reflect less rainfall there in 1955 than in 1982. The granitic area southwest of Montara Mountain seems particularly vulnerable. Other than that, no clear distinction between the susceptibility of various bedrock types is evident. The susceptible topography is steep and generally angular and has canyons that are V-shaped in the headwaters, giving way downstream to flat, alluvial bottoms. Debris flows have built small, steep alluvial fans at the mouths of many steep drainages.

The soil slips tend to form near the tops of steep slopes in first order (unbranched) drainages, but also occur anywhere along the first order drainages and on steep, nearly planar slopes. Failures of surficial mantle that yield debris flows also occur at the toes of steep slopes (particularly evident for the 1955 storm) and can occur along the axes of moderately inclined colluvial swales. Travel paths are straight downslope and then down along the drainage system. Many debris flows reach no farther than the first junction, but others continue down along the drainage network in V-shaped canyons for distances as great as 600 m (2000 ft) or more. Upon reaching flat-bottomed parts of the canyons, the debris flows tend to spread out and stop, leaving a thin layer of new sediment together with any trees or brush that were carried that far.

It is clear from the maps that points along the first order drainages have high exposure to debris flow and that points on the intervening ribs have little. Similarly, the exposure of points along the margins of the flat canyon bottoms range from relatively low opposite the ribs to high opposite the first order drainages. Given the termination of many debris flows at the base of the first order drainages, even modest setbacks from the base of the canyon wall should reduce exposure.

Flows that travel considerable distances down the drainage network must be quite energetic. Points along the drainage network in V-shaped canyons are thus exposed to serious hazard. Points on flat canyon bottoms near the mouth of such V-shaped canyons also have relatively high exposure, particularly compared to points farther down the alluvial valley.

Hazard Mitigation

The best method of mitigating the hazard from debris flow is to avoid it. Avoid areas subject to debris flow, or at least avoid points in the landscape that are vulnerable. Where avoidance is impossible, designs can be selected that partially accommodate debris flow. Culverts and drainage structures can be made overlarge, debris basins can be installed and maintained, and streets can be arranged to carry the flows. Houses can be protected by impact and diversion structures. In extreme cases, areas of potential failure might be modified by installation of drains, by covering to prevent infiltration of rainfall, or by stripping to remove the soil mantle entirely.

Acknowledgements

This work was inspired by the January, 1982, rainstorm and discussion with Stephen Ellen of the U.S. Geological Survey during early reconnaissance of the storm-damaged region. His generous sharing of knowledge and ideas during field and photo study helped improve my understanding of debris flows. S. H. Cannon determined storm history and helped in other ways. T. C. Smith of the California Division of Mines and Geology pointed out the durability of some soil-slip scars and debris-flow tracks in the map area, which led to the careful comparison of pre-storm and post-storm photos in preparing the 1982 map.

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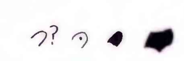
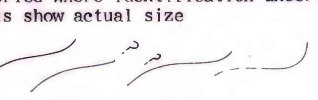
EXPLANATION

SOIL-SLIP DEBRIS FLOWS



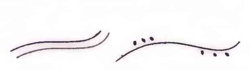
Soil-Slip Scar

Surface scar or upstream end of debris-flow track that marks soil slip or debris-flow source; shown by horseshoe symbol, curved end upslope, queried where identification uncertain; large or irregular symbols show actual size



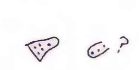
Debris-Flow Track

Flow track more than 20 m long, marked by cleared vegetation and-or new coating of sediment, queried where identification uncertain; query along track up or down channel where probable track concealed by trees or shadow; track dotted on steep slopes where intact vegetation overridden with little deposition (identification depends on lighting) or on gentle slopes where track is narrow



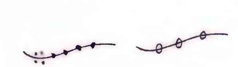
Tracks of Large Flows

Double line where track is wide and expands downslope and soil slip scar is typically deep or large; dotted adjacent to track line where flow rose well above channel on outside of bends in bobsled fashion



New Deposit

Deposit on gentle slope, typically at downstream end of debris flow track; boundary approximate, queried where identification uncertain



Gulley

Large gulley with downstream evidence of fresh deposition of sediment

Base from U.S. Geological Survey
Montara Mountian Quadrange 1956, 1:24,000

Landslides mapped as of May, 1956

MAPS OF DEBRIS FLOW FEATURES EVIDENT AFTER THE STORMS OF DECEMBER 1955 AND JANUARY 1982, MONTARA MOUNTAIN AREA, CALIFORNIA

by

Carl M. Wentworth

1986

CONTOUR INTERVAL 25 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MONTARA MOUNTAIN 7.5-MINUTE QUADRANGLE

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