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FLOOD AND RELATED DEBRIS-FLOW HAZARDS, SOUTH LAKE TAHOE QUADRANGLE, ALONG PRINCIPAL STREAMS, NEVADA AND CALIFORNIA

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ABSTRACT

The South Lake Tahoe quadrangle lies at the extreme western edge of the Great Basin and is tributary to the southeastern corner of Lake Tahoe, California and Nevada.

Estimates of 100-year frequency floods were made and flood plains defined for the principal streams in the area. Degrees of hazard were assigned to the flood plains of these streams on the basis of the potential for the occurrence of floodflows and debris movement.

The 100-year floodflows ranged from 5,000 ft^3/s (140 m^3/s) at the streamflow gaging station on the Upper Truckee River near Meyers, California, and 1,100 ft^3/s (31 m^3/s) at the Martin Avenue streamflow gaging station on Trout creek near Tahoe Valley, California to 75 ft^3/s (2.1 m^3/s) from Bijou Creek at its junction with Pioneer Trail, and 60 ft^3/s (1.7 m^3/s) from an unnamed tributary to Edgewood Creek in the vicinity of Stateline and U.S. Highway 50.

Development on flood plains has increased the potential hazard considerably; this is especially evident on Burke Creek where the Tahoe Village Casino and parking lot occupy part of the Burke Creek flood plain.

INTRODUCTION

Floods and their associated debris flows have plagued man in the past and will continue to do so in the future. If the potential for damage from these events is recognized and the character of the floods better understood, man can modify his use of the land to live in harmony with nature.

Purpose and Scope

This study was done in cooperation with the Nevada Bureau of Mines and Geology to estimate the 100-year flood peak and outline areas on the South Lake Tahoe quadrangle where there is a potential hazard from floods and the movement of debris. Study results can be used by planners to improve land-use decisions. Because of a lack of long-term streamflow records, reconnaissance techniques were used to estimate the 100-year floodflow and outline the corresponding flood plain; thus, study results should not be considered definitive, but should be used as a guide to problem areas.

Flood and Debris Flows

Floods and associated debris flows probably constitute one of the most common natural threats to life and property. Water velocities are commonly many feet per second, and water depths in main channels can be several feet deep. Concentrated runoff from high-intensity precipitation, generally from summer thunderstorms, commonly mobilized large quantities of sediment and initiated debris flows having great destructive potential. Flood-debris

flows are probably the most significant sediment-transport mechanism currently active in the Great Basin and contiguous areas. Often, debris quantities are measured in thousands of cubic feet; sediment size ranges from clay particles to boulders several feet in diameter, sediment yields per unit area are great and very difficult to quantify, transport time is generally less than an hour, and resulting landscape changes are striking. Subsequent sediment transport is affected by a disruption of any equilibrium state of sediment-transport conditions that may have existed prior to flooding.

The debris generally causes damage (1) through impact during transit, (2) by abrasion of fragile objects damaged during transport, (3) by burying objects and areas where the debris comes to rest, and (4) by erosion along path of flow. The degree of hazard posed by moving debris depends on several factors, including quantity of debris, the range of particle size, the water-sediment velocity, the specific land use in the path of the flow, and the effectiveness of a flood-warning system.

The map shows only those hazard areas of potential associated with principal drainage channels; additional areas not investigated undoubtedly also are subject to some degree of hazard from floods and debris. These additional areas, including those associated with smaller drainage units, could be the sites of intensive movement and deposition of debris.

Previous Work

The U.S. Army Corps of Engineers has published flood plain information on Trout and Bijou Creeks (1969a) and on the Upper Truckee River (1969b). These reports outline both the 100-year flood plain, called the intermediate flood, and the standard project flood plain, which is greater than the 100-year flood. The 100-year flood values estimated by the U.S. Geological Survey for the above streams are considerably lower than those previously determined by the Corps of Engineers, and consequently the respective flood plains are somewhat smaller in some areas; most notably on Bijou Creek and on the Upper Truckee River in the vicinity of the Tahoe Airport. One reason for part of this difference is the Geological Survey had the benefit of about 30 percent longer streamflow records. Additionally, the flood- estimating methodology is quite different.

The Corps of Engineers imposes a theoretical storm over the basin and estimates the resulting floodflow. The Geological Survey utilizes historical gaged records as an indicator of flood potential. Unfortunately, there are inherent weaknesses in both methods; one requires definitive knowledge of basin characteristics, the other needs a long period of record. Neither of those requirements was fully realized; however, additional information on certain basin characteristics has become available and the Corps of Engineers has stated (George C. Weddell, written commun., 1976) that this additional data may have the effect of lowering their flow estimates on Trout Creek.

Flood Frequency

Statistical analysis is a useful tool for characterizing floodflows. Flood-recurrence intervals are estimates of how often flows of a given magnitude might occur. Estimates are based on streamflow records; and generally the longer the period of record, the more meaningful the frequency estimates. However, no prediction is made for regularity of recurrence. For example, a floodflow magnitude having a 100-year recurrence interval can occur several times, or it may not occur at all, within a 100-year period. Statistically, a 100-year flood has a one percent chance of being equaled or exceeded in any one year. Flood magnitudes greater or less than the 100-year floodflow, however, may occur in any area at any time.

The 100-year floodflow for the principal streams in this study was estimated as follows: the 100-year floodflows, as defined by the Log-Pearson Type III analysis (U.S. Water Resources Council, 1976) for gaging stations on the Upper Truckee River near Meyers and Trout Creek near Tahoe Valley, and other nearby stations, were divided by their respective drainage areas to derive a runoff value in cubic feet per second per square mile. A regional runoff yield of 150 $(ft^3/s)/mi^2$ [1.6 $(m^3/s)/km^2$] was used for all streams except Trout and Cold Creeks. This yield, when multiplied by the drainage area, in square miles, gives the estimated 100-year floodflow in cubic feet per second. A yield of 30 $(ft^3/s)/mi^2$ [0.33 $(m^3/s)/km^2$] was used for Trout and Cold Creeks. This rate seems anomalously low; however, it is indicated by the gage record of Trout Creek, and a definitive examination of the basin characteristics is beyond the scope of this study.

The flood peaks for the Upper Truckee River and Trout Creek were estimated at their respective gaging stations, and the flood peaks for the other streams were estimated at the mountain front. All flood-peak estimates were used for the entire reach of their respective streams. Flood-peak variability upstream and downstream from the key data sites was not assessed because data necessary to improve accuracy beyond the presented estimates was generally unavailable. The estimates are probably accurate to about one significant figure, but are reported to two significant figures to allow comparison between streams. Flow estimates were generally rounded upward to provide an added safety factor. The 100-year floodflow peaks presented herein are slightly higher than those obtained using Hardison's method (Hardison, 1973). Part of this difference is probably due to rounding upward as an added safety factor.

Stream-channel cross sections were surveyed, Manning's roughness coefficients were estimated, and channel slopes were determined so that the Manning flow equation (Chow, 1964, p. 15-32) could be solved in terms of discharge to develop depth-discharge relations. The depths of the 100-year floods were determined from these relations, and the flood plains were defined on the basis of these depths. Cross-section information developed by the U.S. Army Corps of Engineers (1969a, b) was used for the Upper Truckee River and Bijou Creek.

In addition to the 100-year flood plain, the map shows the probable limits of the area of maximum inundation resulting from a very large catastrophic flood-debris event. The more frequently occurring medium to high flows that are continuously changing the course of a stream across its flood plain would also stay within those bounds. Debris-bearing floods can readily abandon shallow channels when debris unpredictably blocks the channel and diverts the floodflow. Thus, areas that might appear safe from water-dominated flooding could be subjected to serious flooding and debris hazards caused by the unpredictable debris-diverted flow. The boundaries between the various hazard zones are controlled by the relationship between water depth, velocity, and character of the debris. All zones are probably present to some degree in any given flood; however, it is impractical to show them. The change from one hazard zone to another is not a stable, definitive boundary and should be considered a gradational zone which can fluctuate under different types of flow conditions. Thus, adequate planning for a specific area requires detailed on-site mapping with great attention to the combined effects of the floodflows and their accompanying debris loads.

Investigations by the U.S. Geological Survey in many of the western states have shown maximum peak runoffs from outstanding floods (Glancy and Harmsen, 1974) to range from about 3,000 to 7,000 $(ft^3/s)/mi^2$ [33 to 98 $(m^3/s)km^2$] of contributing drainage area. These yields are many times greater than the 100-year floodflows presented here and they suggest that a potential exists for much greater floods within the general region. However, because of a lack of adequate technology, floodflow peaks in excess of the 100-year flood were not estimated.

Detailed site studies are required to predict more accurately water depths and degree of damage resulting from any given flood. Water depths and damage will generally increase from the 10-year to the 100-year flood in the canyons. However, this is not necessarily true for the valley margins and floor, where water may leave the channel and spread out to a shallow depth over a large area.

Flood and Debris Hazard Factors

The potential hazards from flooding and debris within any drainage area depend on the inter-relations of several factors; the main factors are storm type, geology, land cover, and channel characteristics, discussed as follows:

Storm Type

The two general storm types that have produced flooding and debris flows in the Lake Tahoe Basin are winter rains and summer thunderstorms. Table 1 characterizes these two storm types.

Known serious flooding in the study area has been caused only by winter rainstorms; however, in other parts of the Lake Tahoe Basin thunderstorms have produced very destructive floods and debris flows (Glancy, 1969).

TABLE 1. Storm type characterization

Storm type	Areal extent	Antecedent conditions	Precipitation character			Runoff character			Source of fluvial sediment	Debris hazard
			Intensity	Duration	Volume	Peak flow $(m^3/s)/km^2$	Duration	Flow viscosity		
Winter rain channels	Large, many square miles	Generally snow cover, ground may be frozen, saturated, or dry. Highest risk from fresh saturated snow	Maybe a few inches per hour	Usually several days	Very large	Low	Hours	Low, largely a water-dominated mixture	Overland runoff generally dominant; channel erosion significant	Generally low, but can be high in and near main can be
Thunderstorm	Usually only a few square miles or less, occasionally, large areas	Generally dry, has occurred on snow cover and saturated ground	Often several inches per hour	Several hours or less	Low	Generally high	Generally minutes occasionally hours	Low or high; often a debris-dominated mixture	Often channel and existing flood plains are dominant; occasionally substantial overland rill erosion occurs	Often high

Geology

Runoff rates and the availability of sediment with potential to become debris flows are dependent on the local geology and geomorphic characteristics of individual drainages. Drainage patterns and channel development may be strongly influenced by geologic structure. Faulting contributes to enlarging fracture systems and joint patterns within the bedrock which increases the erodibility of the rock. The study area is mainly within a granitic terrain, which physically decomposes rapidly to fine-grained sediment that is commonly highly erodible (Bailey, 1974). Additionally, repeated stages of glaciation have concentrated unconsolidated sediments in areas where they would be easily mobilized if exposed to high floodflows.

Land Cover

Much of the Great Basin land surface is scantily covered by vegetation typical of arid and semi-arid environments. This type of vegetation does little to retard or reduce erosion from intense storms. The study area, although on the edge of the Great Basin, is within a different vegetation province, and the dense brush and heavily forested slopes characteristic of the Sierra Nevada tend to reduce flow velocities, thus reducing erosion and promoting infiltration. This type of land cover greatly reduces downstream hazards from floods and debris flows compared to those of the more arid parts of the Great Basin region. Stream channels generally have a very thick vegetal growth covering their banks and flood plains. This growth increases channel roughness which reduces flow velocities and causes water depth to be deeper than they would be without the growth. Thus, channel capacities will be greater in the winter, without the foliage, than in the summer.

Channel Characteristics

Channel characteristics which control flooding and debris flows are slope, shape, roughness, capacity, and bedbank material. While all of these are interrelated, slope has a dominating influence. The slope strongly controls the initial movement of the water and debris, and also its continued motion and subsequent disposition.

LAND ALTERATION

The hazardous areas outlined on the map may either increase or decrease in the future because of man's and nature's activities. For example, there is an unnamed ephemeral stream just north of the Heavenly Valley Ski Lodge that flows in a northwesterly direction and intersects Keller Avenue (not labeled on map) near Pioneer Trail. This stream had its upper drainage area modified by the construction of a drain, a parking lot, ski runs, and a road crossing. Some part of floodflow will be intercepted by the drain and parking lot, and will not reach the lower drainage area of the stream. It is possible that with sufficient flow, debris may plug the drain and divert the flow onto the roadway, bypass the stream completely, and deliver a greater amount of water

with increased velocity to the downstream residential area than would have been delivered if the water had been allowed to flow down its natural channel.

Construction of flood plains may divert floodflows into areas that otherwise would be flood free. Removal or loss of the vegetal cover from upper drainage areas, by events such as forest fires, will certainly increase downstream hazards. Channel improvement projects could increase channel capacities and thereby locally reduce hazards but potentially increase them downstream. Thus, any modification of the present hydrologic system has many ramifications, and should be made only after careful evaluation of the probable effects.

HISTORICAL FLOODS

Quantitative data were generally unavailable to categorize known past floods in terms of magnitude and probable frequency of recurrences. The U.S. Army Corps of Engineers (1969, p. 10) has concluded that flooding probably occurred in 1853, 1860, 1862, 1867, 1868, 1886, 1907, 1914, 1928, 1937; and more recently in November 1950, February and October 1952, December 1955, January-February 1963, and December 1964.

Continuous streamflow records are available for U.S. Geological Survey measurement sites known as the Upper Truckee River near Meyers, Calif., and Trout Creek near Tahoe Valley, Calif., since October 1960. The maximum floodflows recorded at these sites during this period were 2,550 ft^3/s (72 m^3/s) for the Upper Truckee River and 535 ft^3/s (15.2 m^3/s) for Trout Creek; both peak flows occurred on February 1, 1963. A flood-frequency analysis based on the short period of record suggests that these peak flows represent about the 25-year floodflow on the Upper Truckee River and between the 10- and 25-year floodflow on Trout Creek.

PRINCIPAL STREAMS

McFaul Creek

The hydrologic regime of McFaul Creek is complicated by a rockslide across the creek about 300 ft (90 m) upstream from a small reservoir located about 0.5 mi (0.8 km) east of U.S. Highway 50. All streamflow to the reservoir passes through restricted openings in the rockslide, which will damp out flood peaks and cause some debris to be deposited in a small catchment area just upstream from the rockslide. During a major flood, this catchment basin may fill to sufficient depth to overflow through an adjacent roadcut and reach the reservoir by short circuiting the normal route. Debris, mobilized by erosion of the roadcut route, would be deposited in the reservoir. According to Starr Hill, Nevada State Engineer's Office (Oral commun., 1974), the reservoir has a capacity of about 22 acre-feet (27,100m^3). A downstream peak flow resulting from dam failure from a full or near full reservoir would depend on how the failure occurred. However, the areas of maximum inundation as illustrated allow for a flood peak of about 2,000 ft^3/s (57 m^3/s). Most coarse debris, cobbles, and boulders mobilized by such a flow would be deposited in the

flood plain immediately upstream from U.S. Highway 50. Overtopping and undercutting of Highway 50 would result in flooding of the meadowland between the highway and Lake Tahoe. This area downstream from the highway would generally be an area of deposition of sand and gravel.

Burke Creek

The estimated 100-year floodflow peak of 360 ft^3/s (10 m^3/s) would stay within the channel for most of its length. Erosion and deposition would be minor in most of the stream reaches. The homes built near the channel in the NE1/4 sec. 23, T13N, R18E, might suffer damage. Tahoe Village and its parking lot would be inundated to some degree. Vehicle damage in the parking lot might be heavy because of possible movement of large granite boulders available immediately upstream.

Hydrologic conditions that existed prior to the start of the construction of a large casino immediately downstream from U.S. Highway 50 were used in routing the flood peak downstream. The effect of the flood on this casino and on downstream areas can not be accurately assessed until construction is completed.

Some of the residences between Highway 50 and Lake Tahoe would probably suffer water and fine-grained debris damage.

Edgewood Creek

The channel is incised sufficiently to contain most floodflows in the upper reaches of the main stream. Damage to secondary roadways, however, would probably occur. The ski resort parking lot in NW1/4 sec. 30, T13N,R19E, would be a depositional area and some damage to vehicles could occur.

A small reservoir about 1,000 ft (300 m) upstream from Highway 50 would attenuate the estimated 100-year floodflow of 760 ft^3/s (22 m^3/s) and might contain it entirely. There is abundant channel sediment upstream from the reservoir to be mobilized; however, this material would be deposited in the reservoir. Conceivably, the dam could fail and U.S. Highway 50 could be overtopped or undercut. This would cause inundation of parts of the golf course and deposition of mainly fine sand and gravel.

Edgewood Creek Tributary

Immediately east of Harrah's Hotel and Casino is a small unnamed tributary to Edgewood Creek. The 100-year floodflow peak of 60 ft^3/s (1.7 m^3/s) would probably leave its channel as the tributary turns west into the developed area. Debris transported by this flood peak would be mainly sand with a minor amount of gravel.

Bijou Creek

The 100-year floodflow of 75 ft^3/s (2.1 m^3/s) would deposit fine sand and gravel in the vicinity of Pioneer Trail. Because of a poorly-defined channel, the flow would spread out at shallow depth in the meadow downstream from Pioneer Trail. A diagonal levee and drainage ditch just upstream from the Bijou Golf Course would tend to channelize the flow prior to its reaching U.S. Highway 50. Small amounts of fine-grained sediment might be deposited on the eastern edge of the golf course. The culverts carrying Bijou Creek under Highway 50 might plug, resulting in flooding of the highway and also the shopping center north of the highway.

Heavenly Valley Creek

The 370 ft^3/s (10 m^3/s) 100-year floodflow of Heavenly Valley Creek would remain within its channel upstream from Pioneer Trail. Extensive erosion would probably occur in the headwater regions of the cleared ski slopes. Most of the eroded material would probably reach the Pioneer Trail area and the coarser-grained sediments would be deposited upstream from the highway fill. Overtopping or undercutting of the Pioneer Trail would cause the meadowland immediately downstream from the road to be shallowly inundated. Houses near the stream in the vicinity of cross section 12 might suffer some minor foundation damage.

Cold Creek

The 100-year floodflow of 370 ft^3/s (10 m^3/s) would be attenuated by the culvert under Pioneer Trail. Virtually all coarse-grained sediment reaching this point would be deposited upstream from the culvert. It is unlikely that the road would be overtopped; however, during prolonged flow, the culvert might plug with debris and cause a significant amount of water to pond upstream prior to the peak flow, thereby allowing the peak flow to overtop the roadway. Lake Christopher, an off-channel reservoir, is immediately downstream from the road crossing. If the dam forming this reservoir should fail, either in conjunction with a floodflow or for other reasons, the meadow between the reservoir and Trout Creek would be inundated. The small amount of debris deposited in the Trout Creek flood plain by the flow would be mainly sand and gravel.

Trout Creek

The 100-year peak floodflow estimate of this study for Trout Creek near cross section 18 (gaging station) is 1,100 ft^3/s (31 m^3/s). This flow would probably inundate most road crossings and virtually cover the meadowland bordering lower Trout Creek. Sedimentary deposits of fine-to medium-grained particle size throughout the reach would cause problems only at road crossings. Sediment would probably consist mainly of organic debris. Channel erosion may be significant in some reaches.

Upper Truckee River

The 100-year floodflow peak estimate for the Upper Truckee River at the gaging station near Meyers is 5,000 ft^3/s (140 m^3/s). The 5,000 ft^3/s (140 m^3/s) flow would probably inundate most road crossings, completely inundate the adjoining flood plain, and erode the channel considerably. Sediment deposited outside of the main channel on the adjoining flood plain generally would be mainly sand and gravel.

LAKE TAHOE

No attempt was made to estimate the volume of inflow to Lake Tahoe from the 100-year flood from any of the streams in the basin.

The maximum flow that can be released from Lake Tahoe is about 2,600 ft^3/s (74 m^3/s) or about $5(ft^3/s)/mi^2$ [$0.5(m^3/s)/km^2$] of Tahoe Basin drainage area. Thus, any basinwide storm that produces runoff from the land mass and direct precipitation on the lake in excess of $5(ft^3/s)mi^2$ [$0.05(m^3/s)/km^2$] would result in a rise in the lake. In fact, any inflow greater than the sum of outflow plus evaporation will cause the lake to rise.

Inflow from individual drainages experiencing the 100-year flood at separate times would not raise the lake level noticeably. A basinwide 100-year flood would undoubtedly raise the lake level sufficiently to cause extensive damage to structures on the shore and to the beach areas, especially if strong winds accompanied or followed shortly after the storm. The lower the preflood lake level, the less damage there would be.

REFERENCES

Bailey, R. G., 1974, Land-capability classification of the Lake Tahoe Basin, California-Nevada: South Lake Tahoe, Calif., Tahoe Regional Planning Agency, 32 p.

Chow, Ven te, 1964, Handbook of applied hydrology: New York, McGraw-Hill Book Co. Inc., 1418 p.

Glancy, P. A., and Harmsen, Lynn, 1975, A hydrologic assessment of the September 14, 1974, flood in Eldorado Canyon, Nevada: U.S. Geol. Survey Prof. Paper 930, 28 p.

Glancy, P. A., 1969, A mudflow in the Second Creek drainage, Lake Tahoe Basin, Nevada, and its relation to sedimentation and urbanization: U.S. Geol. Survey Prof. Paper 650-C, p. C195-C200.

Hardison, C. H., 1973, Estimation of 100-year flood magnitudes at ungaged sites: U.S. Geol. Survey open-file report, 10 p.

Moore, D. O., 1968, Estimating mean runoff in ungaged semiarid areas: Nevada Dept. Conserv. and Nat. Resources, Water Resources Bull. 36, 11 p.

U.S. Army Corps of Engineers, 1969a, Flood plain information, Trout and Bijou Creeks, South Lake Tahoe, California: Sacramento, Calif., U.S. Army Corps of Engineers, 23 p.

_____ 1969b, Flood plain information, Upper Truckee River, South Lake Tahoe, California: Sacramento, Calif., U.S. Army Corps of Engineers, 27 p.

U.S. Water Resources Council, 1976, Guidelines for determining floodflow frequency: Hydrology Committee, U.S. Water Resources Council, Bull. 17, 197 p.