GEOLOGICAL SURVEY
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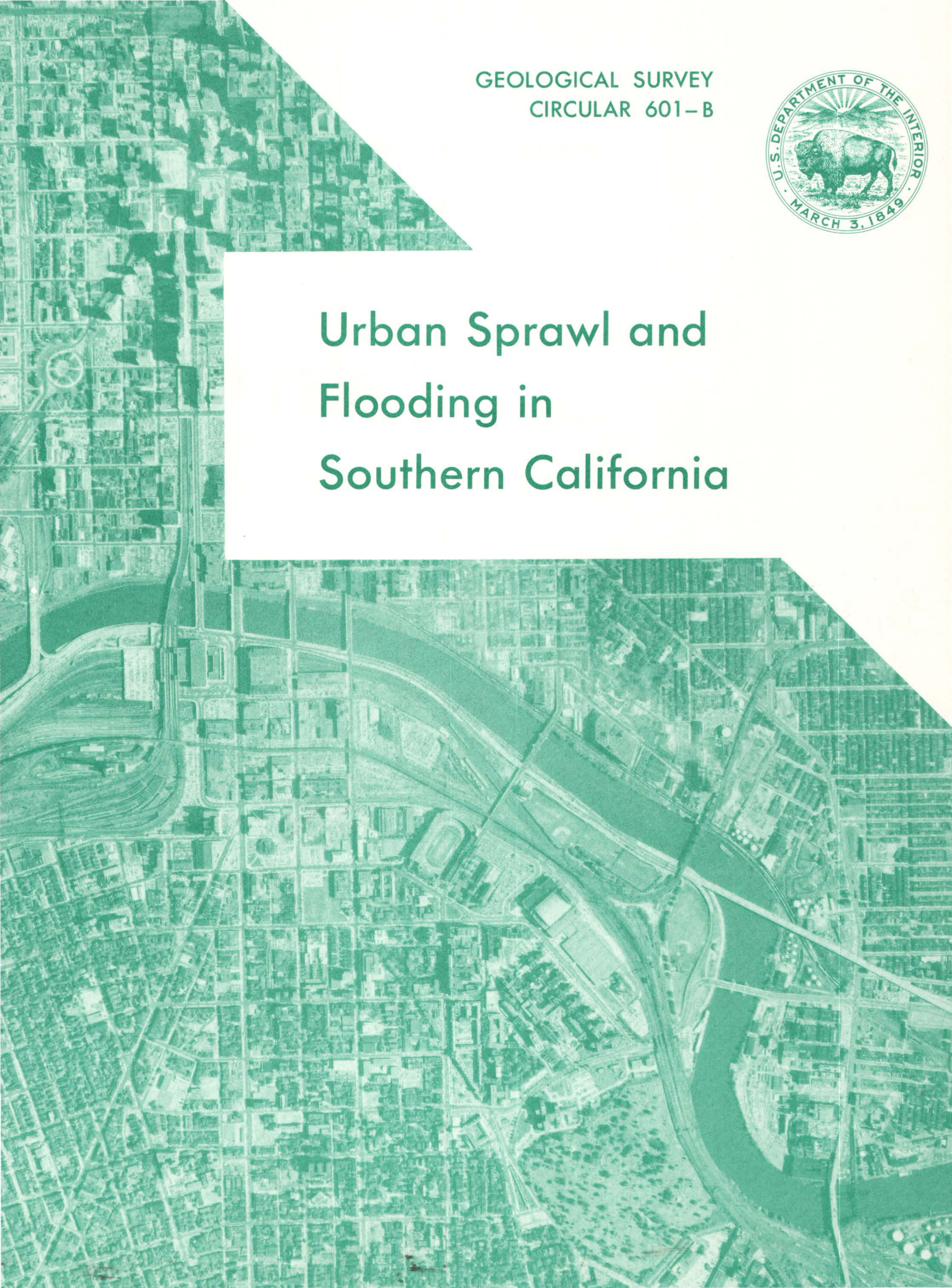
Urban Sprawl and Flooding in Southern California



URBAN SPRAWL AND FLOODING
IN SOUTHERN CALIFORNIA

Floodwater rushing through doorway of home in Mandeville Canyon, a Los Angeles suburb. Photograph courtesy of Los Angeles Times.

Urban Sprawl and Flooding in Southern California

By S. E. Rantz

WATER IN THE URBAN ENVIRONMENT

GEOLOGICAL SURVEY CIRCULAR 601-B

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FOREWORD

Urbanization—the concentration of people in urban areas and the consequent expansion of these areas—is a characteristic of our time. It has brought with it a host of new or aggravated problems that often make new demands on our natural resources and our physical environment. Problems involving water as a vital resource and a powerful environmental agent are among the most critical. These problems include the maintenance of both the quantity and quality of our water supply for consumption, for recreation, and general welfare and the alleviation of hazards caused by floods, drainage, erosion, and sedimentation.

A prerequisite to anticipating, recognizing, and coping intelligently with these problems is an adequate base of information. This series of reports is intended to show the relevance of water facts to water problems of urban areas and to examine the adequacy of the existing base of water information.

E. L. Hendricks

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Chief Hydrologist

CONTENTS

ILLUSTRATIONS

TABLES

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By S. E. Rantz

ABSTRACT

The floods of January 1969 in south-coastal California provide a timely example of the effect of urban sprawal on flood damage. Despite recordbreaking, or near recordbreaking, stream discharges, damage was minimal in the older developed areas that are protected against inundation and debris damage by carefully planned flood-control facilities, including debris basins and flood-conveyance channels. By contrast, heavy damage occurred in areas of more recent urban sprawl where the hazards of inundation and debris or landslide damage have not been taken into consideration, and where the improvement and development of drainage or flood-control facilities have not kept pace with expanding urbanization.

INTRODUCTION

Intense storms during the period January 18–February 25, 1969, produced recordbreaking, or near recordbreaking floods in southern California in late January and again in late February. Particularly hard hit were the urbanized areas in the coastal region between the Santa Ana and Santa Ynez Rivers (fig. 1). The loss of life and physical damage attributable to the storms and ensuing floods in the report area—92 lives lost and an estimated physical damage of $62 million in January alone—have focused attention on the effect of urban sprawl on flood damage. Urban sprawl is defined here as the rapid expansion of suburban development without complete planning for the optimum control and development of water and associated land resources. The greatest damage during the storms was sustained in areas of urban sprawl where the hazards of inundation and debris or landslide damage have not been taken into consideration, and where the improvement and development of drainage or flood-control facilities have not kept pace with expanded urbanization.

Because the floods in south-coastal California provide a timely example of the effect of urban sprawl, a brief case history of that region is presented here. The discussions are related to the floods of January 1969; the floods of February 1969 were somewhat similar with respect to both the magnitude of discharge and the areal pattern of physical damage.

THE FLOOD PROBLEM IN SOUTHERN CALIFORNIA

To better understand the flood problem in south-coastal California, one should be familiar with the characteristics of the stream channels and the floodflows they carry. The upper reach of a typical stream channel occupies the floor of a steep mountain canyon. At the mouth of the canyon near the base of the mountain is a well-developed alluvial cone, a cone being a built-up slope of water-transported rock debris that extends from the canyon mouth down to the alluvial valley floor. Intense mountain storms cause swift sediment-laden streamflow in the canyon. When the streamflow reaches the flatter alluvial cone its velocity is reduced and

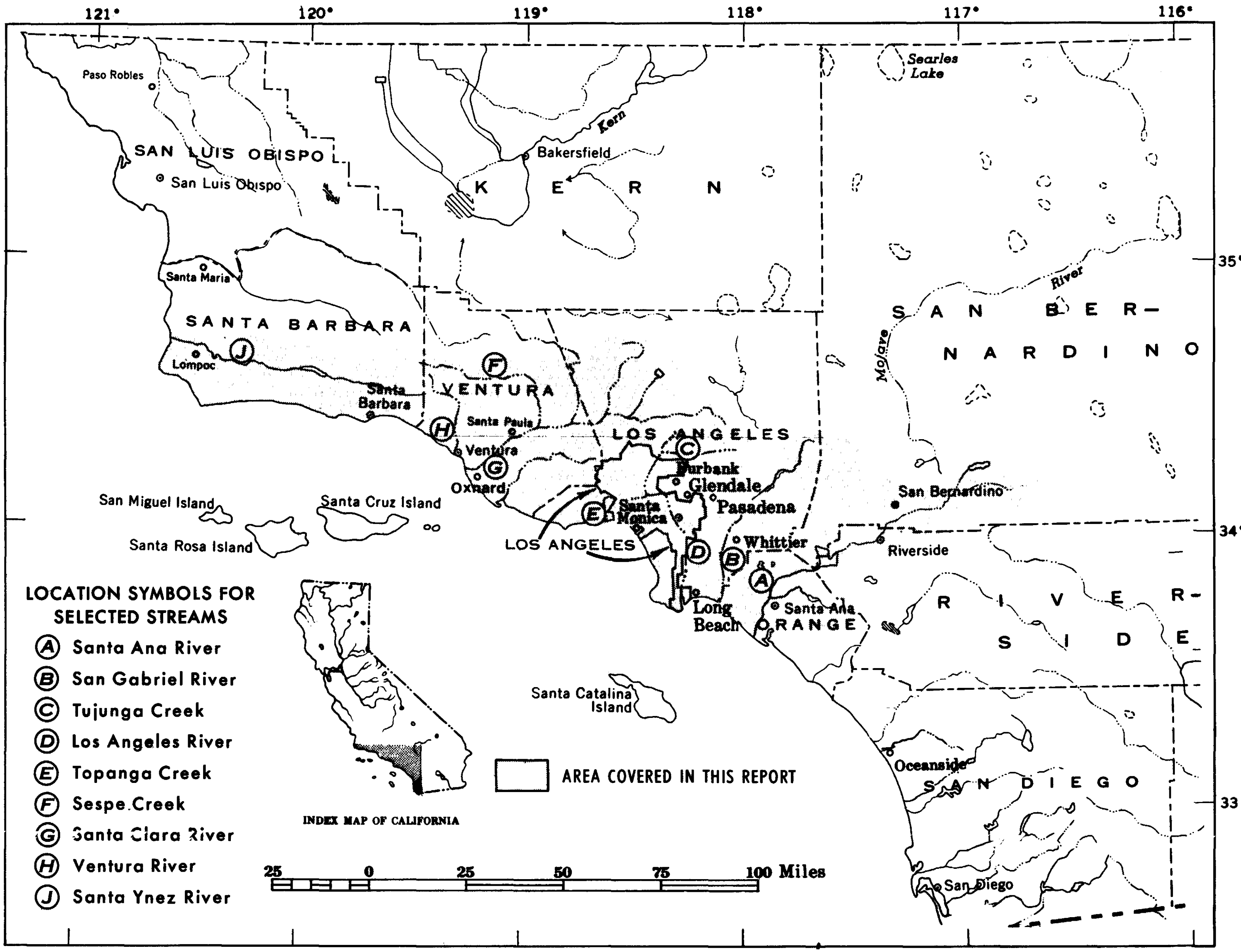

Figure 1.—Report area.

the larger water-transported rock debris is deposited on the cone. The discharge of the stream is also reduced in the course of its travel down the cone as water seeps into the permeable bed material. From the base of the cone the stream crosses the valley floor to empty into the ocean. When southern California was first settled, channels on the cones and in the alluvial valleys were often poorly defined and semipermanent, and during periods of flood, the waters spread over wide flood plains.

The rapid growth of California changed conditions. On thousands of acres of alluvial cones, old river bottoms, and flood plains, where floodflows once ran relatively unconfined, there are now homes, orchards, highways, railroads, towns, and cities. The development has created a complicated, if not unique, flood problem. Flood hazards now are not confined to water runoff alone but include debris that is brought down the steep mountain slopes and is deposited on streets and developed property. To some extent the problem has been aggravated by increased runoff and erosion in mountain areas where erodible soils have been laid bare as a result of forest and brush fires of both natural and manmade origin.

A permanent solution to the problem is a difficult one. Geologically speaking, the mountains are young and break down rapidly under the combined action of the elements. Reservoirs and debris basins fill with sediment and rapidly lose their useful capacity. Storm rainfall is often excessive and even such tremendous floods as those of January 1916, January 1934, March 1938, and January 1969 may not be indicative of the maximum flood potential. For example, the storm of January 21–23, 1943, was the most intense of record in much of the region from a standpoint of flood-producing potential. However, flooding was not disastrous in 1943 because the rains fell on dry ground that absorbed much of the rainfall. There is no doubt that despite the application of our most advanced hydrologic principles and flood-control practices, an element of risk still exists for those who occupy natural flood channels, flood plains, and alluvial cones. However, without application of those principles and practices, such occupancies are virtually an invitation to future disaster.

Social and economic considerations compound the flood problems associated with the physical environment. The region has been growing at a tremendous rate. For example, in 1935 the population of greater Los Angeles was about 2.5 million; it is now about 7 million and is still increasing. The pressure to provide building sites to house the increasing population and attendant industrial and commercial activity places a great burden on city and county planners. Furthermore, no direct central planning authority exists for the heavily urbanized areas because local jurisdiction over planning resides in the many incorporated communities. The local planning, although often based on regional concepts, is not uniform in quality. The number of municipalities has also been increasing over the years. Using the Los Angeles area again as an example, the number of incorporated areas in Los Angeles County increased by 75 percent between 1935 and the present (1969) from 44 to 78. Many of these municipalities are contiguous and form a continuous urban sprawl. The difficulty of planning on a regional scale to provide a logical pattern of zoning to protect residents from the hazards associated with storm and flood is apparent.

FLOOD-CONTROL FACILITIES IN SOUTHERN CALIFORNIA

Local organizations, cities, counties, the State, and the Federal Government have been, and are, attempting to remedy the hazardous flood situation through the following measures:

1. The construction of reservoirs designed to store as much of the flood waters as possible.
2. The construction of debris basins to catch debris and sediment that otherwise would be deposited on the alluvial cones and valley floors.

3. The diversion, wherever possible, of sediment-laden waters onto areas where sediment can be deposited and excess water can percolate into the ground-water reservoir.

4. The realinement, enlarging, and paving of permanent channels to convey excess runoff to the ocean.

5. Such measures are possible in the mountain areas to retard erosion and surface runoff through the prevention of forest fires, the reseeding of areas denuded by fire, the regulation of land use, and the stabilization of channels.

Flood control on a major scale in southern California had its inception in 1915 with the organization of the Los Angeles County Flood Control District. That district, organized under the laws of the State, had as its objective the control of the waters of the Los Angeles and San Gabriel Rivers, the Rio Hondo, Ballona Creek, and major tributaries and washes of Los Angeles County. This task was much later described by an eminent engineer as being "well-nigh impossible of complete solution on the one hand and a necessity on the other." Impetus to the flood-control activities in the region followed the passage of several Federal flood-control acts, the first of which was approved in 1936. Those acts provided the U.S. Army Corps of Engineers with the authority and funds for the construction of flood-control basins, debris basins, and several hundred miles of levee-and-channel improvement.

In Los Angeles County, the Corps of Engineers and the Los Angeles County Flood Control District have constructed all 20 of the flood-control reservoirs and 61 of the 106 debris basins planned for the county. They have also improved more than 350 miles of stream channel for the conveyance of floodwaters. The improvement is usually made by fully lining a reach of channel with reinforced concrete or by constructing levees faced with concrete or rip-rap. The improvement of an additional 275 miles of channel is planned in the county. The storage capacities of the flood-control reservoirs are maintained, as much as possible, by sluicing debris through them during periods of low flow, but periodically some must be cleaned mechanically. The debris basins, too, must be cleaned mechanically; the material must be removed and then must be transported by truck to disposal areas. That process becomes increasingly costly as nearby disposal areas are filled and longer trucking hauls are required to reach new disposal areas.

Another important function of the Los Angeles County Flood Control District is the construction and maintenance of a supplemental system of storm drains in the urbanized areas of the county to collect storm waters close to their source and carry them to the main system of flood-conveyance channels. About 950 miles of storm drain have been built at a cost of about $700 million, and it is estimated that $1 billion more will be needed to provide the additional 625 miles of storm drain that are planned. The eventual total cost of the entire supplemental storm-drain system will far exceed that of the main system of flood-conveyance channels.

East of Los Angeles County, in the Santa Ana River basin, the Corps of Engineers has undertaken the protection of the urban areas of Orange, San Bernardino, and Riverside Counties. They have constructed five of eight authorized flood-control reservoirs and many miles of flood channels, such as those on Lytle Creek and Cajon Creek. The flood-control program of the Corps of Engineers for the Santa Ana River basin has been augmented by the work of flood-control districts in the three counties involved. These organizations cooperate in integrating the flood-control programs, in consolidating local levee and storm-drainage districts, and in building storm drains and flood channels.

West of Los Angeles County, the Ventura County Flood Control District has constructed Matilija Reservoir, and along the Ventura River downstream from that reservoir the Corps of Engineers has built 13,000 feet of levees. On the Santa Ynez River in Santa Barbara County the U.S. Bureau of Reclamation has built Cachuma Reservoir downstream from the older Juncal and Gibraltar Reservoirs.

The U.S. Department of Agriculture is another agency active in southern California. They operate under a directive to implement a program of "runoff and water-flow retardation and soil-erosion prevention." Funds have been used by the Department for the following purposes:

1. Fire control, including the construction and improvement of fire-truck roads.
2. Mountain channel improvements, including debris barriers.
3. Farmland improvements.
4. Stabilization of highway fills in the mountain areas.
5. Debris basins.
6. Improvement of vegetative cover.

Many reservoirs in the region have been constructed primarily for water supply by public, private, and mutual enterprises. Those reservoirs have also proven effective for flood control within the limits of the storage space they have available at the time a flood starts.

DESCRIPTION OF THE SOUTHERN CALIFORNIA STORMS OF JANUARY 18–26, 1969

Southern California, until January 12, 1969, was experiencing an unseasonal winter drought, and the moderate precipitation that occurred on January 13–14 gave little indication that the drought was soon to be broken. The series of storms that was to plague the region did not begin until the evening of January 17. Precipitation was relatively light until January 19 when intensities increased sharply. The center of the eastward-moving low-pressure area that generated the storms stagnated about 700 miles off the coast on January 21, with the result that a succession of storm waves passed over southern California. Except for a lull on January 22, heavy precipitation occurred during most of the period January 19–26, and this was climaxed by the intense downpour of January 25. During most of the storm period the freezing level was at an altitude 7,000 feet; precipitation occurred as rain below that altitude and as snow at the higher altitudes. Table 1 summarizes precipitation data for selected stations throughout the area. Some of the storm totals exceed the heaviest January precipitation previously recorded at the stations. The wide range of precipitation values in the table reflects the general decrease of precipitation with distance from the storm center and the local increase of precipitation with altitude.

DESCRIPTION OF THE SOUTHERN CALIFORNIA FLOODS OF JANUARY 18–26, 1969

Heavy rains during the 4-day period January 18–21 brought widespread, but generally minor, damage to southern California. Damage was severe, however, in localized areas. Streams rose but even those that were uncontrolled by reservoirs generally stayed within their banks and flooding was localized. Ten campers,

Table 1.—*Summary of precipitation data at selected stations*

Precipitation station		Precipitation, in inches, for dates shown				
Name	Altitude (feet)	Jan. 25	Jan. 25–26	Jan. 18–21	Jan. 23–26	Entire storm, Jan. 18–26
Big Bear Dam	6,800	11.05	18.59	13.60	21.82	35.42
San Bernardino	1,100	2.53	4.99	3.35	6.08	9.43
Mount Baldy	4,280	11.04	21.42	20.08	27.54	47.62
Glendora West	820	6.00	7.35	8.28	9.22	17.50
Opids Camp	4,250	15.56	21.11	21.01	24.16	45.17
Burbank	680	4.43	5.98	7.10	7.16	14.26
Topanga	745	9.54	12.18	12.98	14.20	27.18
Matilija Dam	1,050	9.15	14.76	20.84	17.17	38.01

however, lost their lives when trapped by the rising waters of Sespe Creek in Ventura County, and four other drownings were reported elsewhere in the region. Transportation was snarled as floodwaters in Cajon Canyon cut the main east-west lines of the Southern Pacific and Santa Fe Railroads, and more than 100 Los Angeles streets were blocked by felled trees. The greatest monetary damage occurred in the Glendora-Azusa foothill area of the San Gabriel Mountains. A brush fire in August 1968 had burned off erosion-retarding vegetation in the canyon area above the town of Glendora. The 4 days of rain on the bare soil were climaxed by a local precipitation burst of 2 inches in 3 hours, which brought down a torrent of sediment- and debris-laden water. Streets were boulder-strewn and sediment spread over streets and lawns and into homes (fig. 2). In places the streets were covered with sediment to depths of as much as 4 feet. Damage in Glendora was estimated at $2 million.

It was with a feeling of relief, therefore, that southern Californians viewed the rainless skies of January 22. The relief was short-lived, however. The rains of the preceding 4 days had saturated the ground and had produced a condition favorable for heavy runoff from ensuing rains; the stage was set for the deluge that was to follow. The rains started again on January 23 as the second 4-day phase of the storm arrived. Not only were antecedent conditions favorable for

Figure 2.—Result of mudflow in Glendora, January 22. Photograph courtesy of Los Angeles Times.

heavy runoff, but the time distribution of precipitation during this phase was conducive to high peak discharges, because the heaviest precipitation came near the end of the storm when streams were already swollen.

In Los Angeles County, flooding was confined primarily to the headwater tributaries of the principal streams—the San Gabriel and Los Angeles Rivers—and to the smaller canyon streams that are directly tributary to the ocean. The heavy runoff of the San Gabriel and Los Angeles Rivers was stored in flood-control reservoirs and released at rates compatible with the capacity of downstream flood channels. In the mountain and foothill areas, however, the rapidly rising tributaries of those two rivers left their banks and created havoc. Bridges, roads, and streets were washed out and homes were destroyed or damaged; thousands of persons were evacuated. The sediment and debris carried by the streams added to the misery. Debris flows occurred again at Glendora to add to the damage suffered in the earlier phase of the storm. Damage of a similar nature, but not as severe, occurred in Highland Park, Sherman Oaks, Verdugo Hills, Brentwood, Bel-Air, Hollywood Hills, Encino, and Glendale. Landslides, more aptly termed mudslides, also created much damage in those towns and buried seven persons alive in their beds when the slides entered their homes. Topanga Creek, a small stream directly tributary to the ocean, swelled to the size of a river. Almost 1,000 persons in Topanga Canyon were isolated when homes and roads were destroyed by water and mudslides, and three persons were smothered when mud swept through their home. On the coastal plain, street flooding occurred in many towns such as Manhattan Beach, El Segundo, and Long Beach. (See figures 3, 4, and 5.)

East of Los Angeles County, in the Santa Ana River basin, major flooding was confined to the upper reaches of the river and its mountain tributaries. The rampaging waters of such creeks as Cucamonga, Deer, Day, and Cajon damaged or destroyed by erosion an aggregate of several hundred miles of improved flood channels. Roads and bridges were washed out and the main lines of the Southern Pacific and Santa Fe

Railroads, which had received emergency repair after being cut during the first phase of the storm, were severely damaged as a result of repeated attack by the waters of Cajon Creek. Nor were homes spared by the deluge; in the town of Cucamonga alone, flooding caused the evacuation of 1,000 persons. Farther downstream, near the junction of the San Bernardino, Riverside, and Orange County lines, the Santa Ana River was effectively controlled by storage in the Prado flood-control basin, and released flows were within the capacity of the river channel downstream through the populous areas of Orange County.

Figure 3.—Result of landslide (mudslide) in Glendora, January 26. Water has cut a channel through the mudslide. Photograph courtesy of Los Angeles Times.

Figure 4.—Street flooding in El Segundo. Photograph courtesy of Police Department, city of El Segundo.

Figure 5.—Floodwater flowing down Casiano Road in Bel-Air (suburban Los Angeles) jams parked car against fence and lamppost. Photograph courtesy of World-Wide Photos.

In Ventura and Santa Barbara Counties, to the west of Los Angeles County, peak discharges were unprecedented and damage was correspondingly high. In the Santa Paula-Fillmore-Piru area, the Santa Clara River and Santa Paula Creek spilled over their banks and caused the evacuation of about 3,000 persons. Evacuations were also necessary along the Ventura River and in the Ojai Valley where such communities as Live Oak, Oak View, and Meiners Oaks were hard hit. Highway damage was heavy throughout Ventura County. In Santa Barbara County all the small streams south of the Santa Ynez River were in extreme flood; the severest damage occurred in the towns of Montecito and Carpinteria. In both those towns, streams changed their courses and cut new channels through residential areas. On the Santa Ynez River, the spillways of Gibraltar and Cachuma Dams carried flows that equaled or slightly exceeded those for which they had been designed. There was no damage to the structures but damage was severe in the Solvang and Lompoc areas downstream.

In general the flood of January 1969 was comparable to that of March 1938. The 1938 flood had been the most damaging flood of recent times in southern California and its peak discharges are usually used as a standard for

Table 2.—*Peak discharges at selected stations for the floods of March 1938 and January 1969*

[Discharge figures for 1969 are provisional and therefore subject to revision]

Stream-gaging station	Drainage area (square miles)	Peak discharge, in cubic feet per second	
		March 1938	January 1969
East of Los Angeles County			
East Twin Creek near Arrowhead Springs	8.8	3,360	2,300
Waterman Canyon Creek near Arrowhead Springs	4.6	2,350	1,180
Lytle Creek at Colton	172	21,500	14,500
Santa Ana River at Prado Dam	1,485	100,000	[1]75,000
Los Angeles County			
San Gabriel River near Azusa	214	65,700	48,000
Los Angeles River at Sepulveda Dam	158	12,000	13,800
Arroyo Seco near Pasadena	16.0	8,620	8,540
Los Angeles River at Long Beach	832	99,000	101,000
Ballona Creek at Sawtelle Blvd., near Culver City	111	22,500	15,600
West of Los Angeles County			
Sespe Creek near Fillmore	251	56,000	60,000
Santa Clara River at Saticoy	1,595	120,000	165,000
Ventura River near Ventura	188	39,200	55,000
Santa Ynez River near Lompoc	789	45,000	100,000

[1] Inflow of 75,000 cfs was reduced by storage to outflow of 5,800 cfs.

comparing flood magnitudes. West of Los Angeles County peak discharges were greater in 1969, and east of Los Angeles County the 1938 peak discharges were greater. In Los Angeles County itself, the relative magnitude of the two floods varied somewhat randomly, but more commonly the greater peak discharges were those that occurred in 1938. Table 2 lists peak flows for the two floods at selected stations.

EFFECT OF FLOOD-CONTROL MEASURES ON FLOOD DAMAGE

The various storage and conveyance facilities for flood control—reservoirs, debris basins, improved channels, and storm drains—operated effectively during the January flood, and the damage they prevented has been estimated at $1.2 billion. The flows received by the flood-control reservoirs during the first phase of the storm, January 18–21, were released quickly, and consequently the reservoirs were essentially either empty or at conservation-pool level when the critical second phase of the storm began on January 23. During this second phase, none of the large reservoirs that were built primarily for flood control by the Corps of Engineers were completely filled by the heavy runoff. The other reservoirs in the area have an important water supply and conservation function, and although most of them filled during the storm, many were effective in reducing the magnitude of peak flows downstream from the reservoirs. The discharge

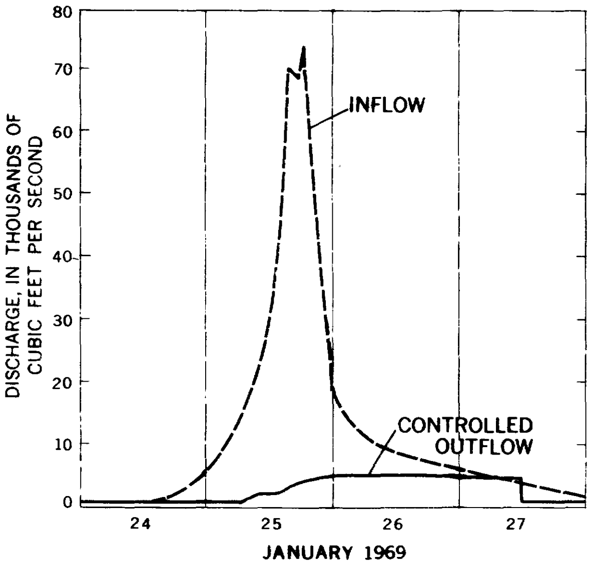

Figure 6.—Inflow and outflow hydrographs of Santa Ana River at Prado flood-control basin.

hydrographs in figure 6 show the effect of the Prado flood-control basin on the floodflows of the Santa Ana River; the peak inflow to the reservoir of 75,000 cubic feet per second was reduced by storage to such degree that the peak outflow was only 5,800 cubic feet per second.

The debris basins in Los Angeles County trapped an estimated 2 million cubic yards of debris. Of the 61 debris basins only seven were completely filled, and only three of those had debris pass over their spillways into downstream drains. The improved channels, in general, contained the floodflows within their banks or levees; the only serious flooding associated with such channels occurred on the streams tributary to the upper Santa Ana River. Most of the storm-drain system in Los Angeles County was not overtaxed; where flooding associated with drains occurred, it was primarily due to the drains becoming filled with sediment and debris.

The system of storage and conveyance works for flood control in Los Angeles County prevented damage estimated at $900 million; the Prado flood-control basin prevented damage in Orange County estimated at $260 million; improved channels throughout the remainder of the report area prevented damage estimated at $40 million.

Although $1.2 billion of damage was prevented, losses were still heavy. The death toll for the storm and flood of January 1969 was 92 persons, and 10,000 persons were driven from their homes. Of the 92 that died, 19 drowned, 12 were buried alive in mud and debris, 55 were killed in storm-associated automobile accidents, four were killed in storm-associated plane crashes, and two died of heart attacks brought on by physical exertion connected with the flood. Physical damage caused by the storm and flood is estimated at $62 million. (Physical damage refers to rehabilitation or replacement costs of structures or facilities that were damaged or destroyed. It does not include such emergency costs as those associated with evacuation or police work, nor does it include such indirect costs as loss of income due to interruption of commercial activities or depreciation of property values in areas that suffered damage.) Table 3 shows damage figures for urban and rural areas, and for comparison,

Table 3.—*Estimated physical damage, in millions of dollars, in the report area in March 1938 and January 1969*

Location	March 1938			January 1969		
	Urban	Rural	Total	Urban	Rural	Total
East of Los Angeles County	11	3	14	18	10	28
Los Angeles County	25	2	27	14	1	15
West of Los Angeles County	3	2	5	12	7	19
Total for report area	39	7	46	44	18	62

similar figures are given for the flood of March 1938. It is to be expected that for floods of equivalent magnitude, monetary damage would be greater in 1969 than in 1938 because of the greater degree of development in 1969 and the lower purchasing power of the dollar. The lesser damage in Los Angeles County in 1969 is conclusive evidence that flood-control measures taken since 1938 were effective in evidence that flood-control measures taken since 1938 were effective in protecting areas that have been occupied or fully developed for at least the last 30 years.

EFFECT OF URBAN SPRAWL ON FLOOD DAMAGE

Damage in areas of urban sprawl is of two types. The first type is damage by inundation. Encroachment on natural flood plains, in the absence of facilities for the storage and conveyance of floodwaters, exposes homes and other structures to the damaging effect of rampaging streams carrying large sediment and debris loads. Urban development has encroached on alluvial cones, which in their virgin state are highly permeable. Urbanization almost waterproofs the ground surface, with the result that storm runoff from urbanized areas on the cones is increased in volume and intensity and is virtually dumped on lower-lying developed areas.

The second type of damage in areas of urban sprawl is that which occurs as a result of landslides or mudflows during storm periods. The steep flanks of many mountains and foothills in south-coastal California are unstable when saturated by heavy rainfall and often slide, particularly under stresses associated with the construction of buildings and roads. It is not enough that one consult an experienced engineering geologist before building on or near such slopes, because a safely designed structure may be endangered by subsequent improper design and building practices by others in the vicinity. Appropriate studies on a broader scale should be made before development, and if adequate zoning and (or) building codes are not established, prospective developers and residents should at least be made aware of the potential hazard.

Urban development that takes place too close to the head of an alluvial cone, in the absence of an upstream debris basin, exposes structures to mudflows. A mudflow is a viscous mixture of water, sediment, and rock debris that often has the consistency of wet concrete. Water-transported rock debris has been deposited on alluvial cones from time immemorial, and the cones, in fact, have been naturally built by that process. The distance the large material is carried downslope on a cone is, to a large degree, dependent on the amount of flowing water available to supply the energy for transport. Under natural conditions the cone is permeable and streamflow decreases in its course down the cone. When the streamflow decreases sufficiently the coarser material comes to rest. Development that extends far up the cone provides an impermeable surface that prevents the seepage of large amounts of water, and the streamflow reaching the developed area will be undiminished as it travels downstream, or may even be augmented by local runoff from the impermeable area. When that occurs, the "mud" and rock debris that reaches the developed area will be carried downstream until the slope of the cone becomes too flat to support such transport, or until the water has spread far enough laterally to effectively reduce its energy for further transport. The situation is often aggravated by brush fires in the mountains that consume the erosion-retarding vegetation and thereby increase the potential for damage by sediment and debris. During the 1969 flood, however, it was only in the Glendora-Azusa area that recent brush fires were responsible for significantly increased production of sediment and debris. That area received intense precipitation in January. In other areas where recent burns had occurred, as in the Little Tujunga basin, erosion rates were not significantly increased because precipitation intensities there were moderate in January.

Because debris damage is usually accompanied by water damage, it is not possible to differentiate the monetary damage attributable to each in the flood of January 1969. However, with regard to deaths, 19 lives were lost in drownings and 12 lives were lost in landslides.

The bulk of the urban damage in the flood of January 1969 occurred in areas of urban sprawl. In those areas, development plans and related zoning did not prevent the occupancy of land exposed to the hazards of inundation and (or) debris damage, and the improvement and development of drainage of flood-control facilities did not keep pace with expanded urbanization. Ideally, adequate zoning and drainage design should be incorporated in the planning stage of any new development.

The narrow coastal plain in the region is now almost fully occupied and housing is moving into the upland areas in the alluvial cones and in the canyons. To a large degree the move to the uplands is for aesthetic reasons as people look for homes with a view. However, it is the upland areas that are hardest to protect because of the myriad small watercourses, each of which requires individual control measures for protection against inundation and debris damage. A high degree of protection now exists along the larger streams in the older established areas on the coastal plain. The greatest concentration of future effort will most likely be on the protection of urbanized areas in the uplands.

SUMMARY AND CONCLUSIONS

Urban sprawl is defined here as the rapid expansion of suburban development without complete planning for the optimum control and development of water and associated land resources. By that definition any suburban area is an area of urban sprawl if its zoning ordinances do not take into consideration the hazards of inundation and debris or landslide damage, or if its drainage and flood-control facilities are not fully developed. During the calamitous floods of January 1969 in south-coastal California, flood-control measures were effective in minimizing flood damages in areas that they were designed to protect. It was in the areas of urban sprawl that the largest part of the total physical damage of $62 million occurred.

The construction of additional flood-protection facilities will assure some reduction in the damage from future floods. However, the problems associated with floodflows and storm-induced mudslides can never be completely solved; only an accomodation to those problems can be achieved. The most effective accomodation is that based on adherence to a truly comprehensive regional plan.

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