California. Department of Water Resources. Southern Wrightwood debris and mud flow investigation:
WRIGHTWOOD

Debris and Mud Flow Investigation

STATE OF CALIFORNIA
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Southern Division
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Southern Division

WRIGHTWOOD
Debris and Mud Flow Investigation

Division Report
September 1976
FOREWORD

The community of Wrightwood in the San Gabriel Mountains is popular as a recreation area and site for vacation homes. Unfortunately, it has experienced a number of destructive floods in the past 66 years, most notably in 1938, 1941, 1965, 1966, and 1969. In addition, the San Andreas fault underlies the entire area, increasing the possibility of large-scale soil and rock movement and subsequent debris and mud flows.

Recognizing the need for land use planning and floodplain regulations to protect the community, the San Bernardino County Flood Control District requested the Department of Water Resources to evaluate the extent of the potential danger. This report presents the results of that study, which was financed jointly by the Department and the County. It evaluates Flume, Acorn, Heath, and Sheep Canyons as sources of debris and mud flows by determining their relative degree of erodibility. The report delineates the most likely locations of debris and mud damage from a once-in-100-year event and estimates the volume of debris and/or mud flow for such an event.

Special appreciation is due Dr. D. M. Morton of the U. S. Geological Survey for his consultation, as well as the San Bernardino County Flood Control District and Mr. Glenn A. Brown of Glenn A. Brown & Associates, consulting geologists, for assistance and cooperation in the conduct of this study.

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# CONVERSION FACTORS

English to Metric System of Measurement

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\frac{9F - 32}{5} = °C
\] | Degrees Celsius (°C) |
CHAPTER I. FINDINGS AND RECOMMENDATIONS

Findings

1. The community of Wrightwood is exposed to a definite hazard from debris and mud flows.

2. Debris flows are caused by short-duration, high-intensity rainfall or by a high seasonal rainfall followed by one or two days of moderately heavy rainfall.

3. Major mud flows have occurred only in the Heath Canyon drainage area. In addition, they have historically been limited to those years with at least 76 centimetres (30 inches) of precipitation. Mostly snow, this precipitation remains on the slopes until it melts in the spring, triggering the mud flows.

4. Volumes of source material available to contribute to debris and mud flows are estimated—in millions of cubic metres (cubic yards) as follows: Flume, 2.8 (3.6); Acorn, 3.4 (4.3); Heath, 11.3 (14.7); and Sheep Canyons, 4.4 (5.8).

5. Volumes of debris for a once-in-100-year event are estimated—in cubic metres (cubic yards) as follows: Flume, 12 000 (16,000); Acorn, 31 000 (40,000); Heath, 810 000 (1,060,000); and Sheep Canyons, 183 000 (240,000).

6. Geologists and seismologists expect that earthquakes exceeding 8.0 magnitude will be generated along the San Andreas fault zone, which underlies the entire Wrightwood area. Severe ground shaking would increase the potential for damage from debris or mud flows by increasing the amount of material available for transport into the valley.

Recommendations

1. San Bernardino County should use data from this report in conjunction with the general plan it is developing for the Wrightwood area. The data should also be considered in land use planning and flood regulations.

2. The San Bernardino County Flood Control District should monitor all debris and mud flows, recording and evaluating pertinent data, with the objective of developing a predictive capability.

3. In the event of major debris and mud flows or seismic disturbances, the results of this study should be reevaluated.
Figure 1 - VICINITY MAP

DEPARTMENT OF WATER RESOURCES, SOUTHERN DIVISION, 1976
CHAPTER II. INTRODUCTION

Rapid growth in San Bernardino County has resulted in extensive development on a number of alluvial fans. Development within its mountain canyon areas has increased, despite recurrent damaging debris and mud flows.

Recognizing the need to minimize loss of life and damage to property, the Department of Water Resources undertook this study of debris and mud flow hazards to the community of Wrightwood (Figure 1) at the request of the San Bernardino County Flood Control District.

Objective of the Investigation

The objective of the investigation was to determine the areas of potential damage from debris and mud flows for an event with a frequency of once in 100 years. Use of the 100-year frequency was requested by the County in order to conform with their existing ordinances.

Area of Investigation

The study area lies within the San Bernardino National Forest in that portion of the San Gabriel Mountains known as Blue Ridge, about 42 kilometres (26 miles) northwest of the City of San Bernardino and just east of the Los Angeles-San Bernardino County Line (Figure 1). Principal drainages in the area include (from west to east): Flume, Acorn, Heath, and Sheep Canyons, all of which emanate from Blue Ridge and drain northeasterly through the community of Wrightwood into Swarthout Creek (Figure 2).
The area supports a coniferous forest of mainly ponderosa pine at elevations from 1700 to 2100 metres (5700 to 6800 feet) with some white fir and Jeffrey pine at higher elevations. Scrub oak is interspersed. From 1400 to 1700 metres (4700 to 5700 feet) the predominant trees are oak, pinon, and joshua. There is considerable brush, including manzanita.

The unincorporated settlement of Wrightwood covers approximately 2.4 square kilometres (0.9 square mile). Its April 1975 population of 1,280 reflects an average family size of 2.8. The community has 460 occupied housing units, but an additional 810 units presently classified as either vacant or as second-homes allow a potentially large percentage increase in population on weekends, holidays, or vacation periods.

Related Studies

The County provided several reports on prior studies of the Wrightwood area which proved useful in preparing this report. These included:

U. S. Department of Agriculture, U. S. Forest Service, Interim Survey Reports, Watershed of Sheep Creek (February 1947) and Tributary of Mojave River at Wrightwood, California (August 1953).


CHAPTER III. HYDROLOGIC AND GEOLOGIC CHARACTERISTICS

Estimates of flow volumes and amounts of material available for transport depend on evaluations of the hydrologic and geologic characteristics of the watershed. This chapter presents a discussion of these factors.

Hydrologic Characteristics

The study area is located in a semiarid region subject to temperature extremes. Most of the precipitation occurs in winter as a result of the landward movement of moisture-laden Pacific maritime air masses. The area is subject to infrequent summer storms of high intensity and short duration which generally originate from tropical air masses developed over the warm waters of the Gulf of Mexico.

Average annual precipitation at Wrightwood is 64 centimetres (25 inches), but on the slopes above the valley this average may be as high as 88 centimetres (35 inches). Some precipitation occurs as snow, which remains until early summer and sometimes until mid-July in protected, higher areas with a northern exposure.

Geologic Characteristics

Geologic characteristics examined in preparing this report include the topography, lithology, and seismicity of the study area.

Topography

The valley floor at Wrightwood is at elevation 1800 metres (6000 feet). Gradients in the canyons are very steep, some as much as 65°. Northern slopes of Swarthout Valley rise gradually to about elevation 2050 metres (6750 feet), while the southern slopes rise to about elevation 2500 metres (8500 feet).
Figure 3 - Earthquake Frequency and Magnitude Relationships

Department of Water Resources, Southern Division, 1976
Lithology

Bedrock is blue-gray Pelona schist, composed of muscovite-quartz-albite schist, with some chloritic schist, quartzite, and talc-actinolite rock. Foliation dips southerly into the slopes. Severe fracturing and the micaceous, slippery nature of Pelona schist contribute to the unstable soil conditions in the area.

Seismicity

Swarthout Valley (Figure 2), aligned along the San Andreas fault zone, is the result of rapid erosion on this fault zone. Movement along the fault in the geologic past has left a wide zone of fracture rock. The area is seismically very active.

The historic seismic activity of the study area was determined from a computer search of a California Institute of Technology catalog which listed 1932-74 earthquakes and from data on large 1812-1931 earthquakes compiled by Dr. Charles F. Richter and the U. S. National Oceanic and Atmospheric Administration.

Within 50 kilometres (31 miles) of Wrightwood, 268 earthquakes of Richter magnitude 3.0 or greater were identified. Within 100 kilometres (62 miles), 327 earthquakes of magnitude 4.0 or greater were identified. In addition, earthquakes in 1857 (estimated to have exceeded magnitude 8.0) and 1890 (estimated at magnitude 7.0) caused severe ground shaking in the Wrightwood area.

A statistical analysis was used to develop data for Figure 3, which relates the number of earthquakes in a 100 year period to their magnitudes, within 50 and 100 kilometres (31 to 62 miles) of Wrightwood.

Figure 4 represents rock acceleration attenuation curves developed by Schnabel and Seed in 1972. By using these curves in conjunction with Figure 3, one may relate rock acceleration to earthquake magnitude for given distances from
Wrightwood. Although data for earthquakes of magnitudes less than 5.5 were not
developed, Figure 4 does imply that earthquakes of lesser intensity, especially
if centered within 16 kilometres (10 miles) of Wrightwood, would impose sufficient
stresses to trigger mass movements of soil and loose rock.

Geologists and seismologists expect that earthquakes exceeding magnitude
8.0 will be generated along the San Andreas fault in this region. However, the
occurrence interval of these anticipated events cannot be estimated on the basis
of presently available data.

Severe ground shaking would increase the potential for damage from debris
flows in two main ways: (1) loose masses of soil and rock, now resting on the can-
yon slopes, could be set into motion. The resultant landslide would increase the
amount of debris available for transport into the valley; and (2) the dikes for
channeling the flows are constructed of loose alluvial material which is apt to
fail or undergo marked seismic settlement during a severe earthquake.

In addition, wet year conditions which resulted in an extended period of
soil saturation would increase the possibility of extensive debris and mud flows.

The Alquist-Priolo Geologic Hazard Zones Act went into effect on March 7,
1973. It resulted in Special Studies Zones maps of the Mount San Antonio and
Telegraph Peak quadrangles, which depict the areas of potential fault rupture
hazard in the vicinity of Wrightwood. These maps are available from the County.
Historic Debris and Mud Flows

Wrightwood has been subjected to a number of extensive debris and mud flows during the past 60 years. The following are the main events of these types in recent years.

1913. Major slumping at the head of Heath Canyon.

1916. Major flood over the cones of the canyons.

1926. Flood in the Wrightwood area.

1938. Prolonged spring storm deposited 30 centimetres (12 inches) of rain in 48 hours on 1.2 metres (four feet) of snow, causing debris and mud flows. Hectares (acres) inundated in each canyon: Flume, 15.8 (39); Acorn, 67.6 (167); Heath, 74 (183); and Sheep, 46.5 (115).

1941. Mud flows from Heath Canyon, estimated at 917,000 cubic metres (1.2 million cubic yards), inundated 77.3 hectares (about 190 acres).

1943. Minor mud flows.

1945. Fall thunderstorm caused debris flows which broke through the dike near the mouth of Heath Canyon.

1960. Summer thunderstorm caused flows which closed Lone Pine Canyon Road.

1965. Prolonged heavy rains in early winter caused debris flows from Heath and Sheep Canyons, inundating 42.5 hectares (105 acres) in Heath and 34.8 hectares (86 acres) in Sheep Canyons. Volume was estimated at 350,000 cubic metres (455,000 cubic yards) for Heath Canyon and 92,000 cubic metres (120,000 cubic yards) for Sheep Canyon. Damage was widespread.

1966. Flows from Heath Canyon filled channels designed to handle precipitation runoff with mud and debris.

1969. Snowfall covered Wright Mountain to depths up to 223.5 centimetres (88 inches). The spring thaw caused a series of daily flows that taxed the capabilities of existing channels.

CHAPTER IV. DEBRIS AND MUD FLOW ANALYSIS

This chapter presents a discussion of the different causes and characteristics of debris and mud flows and an evaluation of the four canyons as potential sources of flow material. Volumes of debris and mud flows (expressed in cubic yards and cubic metres) for a once-in-100-year frequency event are also estimated.

Causes of Debris and Mud Flows

A distinction is made in this report between debris and mud flows. Debris flows are water-borne flows of loose material, such as boulders, rocks, logs, and organic material. Mud flows, composed of landslide material, are lava-like flows with blunt fronts of 15- to 60-centimetre (6- to 24-inch) fragmented rocks. Behind these fronts, laminar flows of mixed rock and mud are progressively diluted, finally becoming turbulently flowing muddy water.

Debris Flows

Debris flows have two main causes: (1) high-intensity rainfall of short duration, most likely to occur in summer or early fall; or (2) a high seasonal rainfall, followed by one or two days of heavy rainfall.

Because debris flows are caused by rain and flood runoff, they are most accurately described as a flushing action. Debris flows last for a shorter time than mud flows, usually from 30 minutes to several hours.

Mud Flows

Mud flows are caused primarily by the rapid melting of heavy snowpack. The source material for these flows is derived from highly fragmented Pelona schist, which is triggered by the rapid snowmelt. Mud flow sequences have been known to last more than five weeks.
These mud flows have the consistency of wet concrete. Depending on the fluidity of the mass, they either continue downstream without interruption or they stop until mobilized by snowmelt or by additional mud flow from a higher elevation.

**Volume Estimates of Source Material**

Of the four canyons studied, Heath Canyon is probably the most potentially hazardous because of its active landslides, the major source of debris. In 1913, a reported slide at the head of Heath constricted the canyon above the area known as the "bedrock narrows". Because the narrow permits only limited material to flow through it, landslide material has accumulated upstream. The 1913 failure is considered only one in a series of much larger and older landslides in the Wright Mountain area.

The next most potentially hazardous area is Sheep Canyon, which, although not thought to have been subjected to a major landslide as recently as Heath Canyon has, is by no means stable. Conditions conducive to debris production exist here: steep slopes, incompetent and highly fractured bedrock, and little vegetative cover. In addition, material from an old landslide deposit remains in Sheep Canyon, available for transport in the event of a debris flow.

Acorn Canyon is presently a far less active source for material than Heath or Sheep Canyons. However, there are indications of minor slumping on the steeper slopes and an old failure is visible along much of the rim just below the road along Blue Ridge. The large area of deposition in the channel areas suggests that Acorn Canyon was once active. The fanhead in Acorn Canyon is highly terraced, suggesting a high incidence of debris flows.

Of the four canyons studied, Flume Canyon shows the least evidence of recent failure. There is heavy vegetative cover here and in Acorn Canyon.
Geologic, topographic, and slope stability factors were used to estimate the volume of material available for debris production within each canyon. These factors were evaluated through field reconnaissance and the examination of aerial photographs.

During the field reconnaissance, field mapping was prepared and notes were taken of rock types, their foliation and jointing, degree of fracturing and weathering, slope stability, evidence of hill creep and previous large-scale movements, measurements of side slopes, and the degree and nature of vegetative cover. Field mapping was reviewed and revised through interpretation of aerial photographs.

From this information an erodibility map (Plate 1) was prepared, showing three major soil classifications:

1. Unstable, highly erodible areas. Landslide material, deeply weathered rock on moderate to steep (35° - 50°, with occasional 65°) slopes, and channel material on generally gentle (5° - 15°) gradients and poorly consolidated levees. This is the main source of debris flow material.

2. Potentially unstable material on moderate (25° - 35°) slopes. It includes moderate to poorly consolidated overburden and moderately fractured rock, terrace material, and relatively stable older landslide material. It is a moderate contributor to debris flows, unless it occurs in combination with both seismic activity and soil saturation.

3. Relatively stable material, including exposed rocks on gentle to moderate (5° - 25°) slopes. Generally moderate to heavy vegetative cover, it is a minor contributor to debris, and even then only during periods of prolonged precipitation.

The areas of these classifications were determined with the aid of a planimeter. The minimum depth for each unit in the classification area was estimated by using field notes and aerial and ground photographs. In addition, slopes, elevations, orographic exposure (directional orientation), and degree of vegetation were determined for representative units in each classification by using topographic maps prepared by the County to the scale of 1:2400.
Volumes of source material were then estimated by using the minimum depths and the areas of the individual units. Volumes (Table 1) were adjusted by using slopes, elevation, exposure, vegetation, and geologic evaluation. These factors were weighted according to stability and erosion potential.

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These adjusted estimates demonstrated that the amount of source material available was sufficient to assume the reasonability of the estimated volumes of flows for the once-in-100-year frequency event.

Methodology for Determining Volumes of Flows

The following paragraphs describe the methods used to determine the potential volumes of debris and mud flows.

Debris Flows

A statistical approach was taken in determining the potential volumes of debris flow for an event with a frequency of once in 100 years. Since 1910, debris flows have been reported in nine years: 1916, 1926, 1938, 1945, 1960, 1965, 1966, 1967, and 1969.
Debris volumes for historic flows originating from Heath and Sheep Canyons were estimated from the following data supplied by the County: (1) areas of both canyons inundated in 1938 and 1965; (2) volumes of debris flows for both canyons in 1965; (3) volume of debris flow for Heath Canyon in 1966.

The 1938 debris volumes for both canyons were estimated by multiplying the ratios of the 1938 and 1965 areas inundated in the respective canyons, by the respective 1965 debris volumes. The 1966 debris volume for Sheep Canyon was estimated by multiplying the ratios of the volumes at Heath Canyon for 1965 and 1966, by the 1965 volume of flow in Sheep Canyon.

To establish plotting positions of an exceedence frequency curve for known volumes, order numbers (highest combined storm and antecedent rainfall = 1) were assigned to the events according to the amount of antecedent rainfall and that immediately causing the debris flow. These data, and those developed in previous studies, indicated that a minimum amount of antecedent rainfall, followed by rainfall of moderately high intensity, was a prerequisite for debris flow.

Figure 5 shows the amounts of antecedent rainfall and the amounts of debris-producing rainfall at Big Pines for 1916, 1938, and 1965. A correlation was made between Big Pines and Squirrel Inn Gaging Station for 1910–1925.

The following order numbers were assigned to the years with recorded debris flows: 1 – 1916, 2 – 1938, 3 – 1965, and 4 – 1966. The exceedence frequency (frequency with which a given magnitude is exceeded) was obtained, based on the 66 years of record (1910–1975).

From the debris volumes of 1938, 1965, and 1966, curves of volume versus the exceedence frequency were drawn for Sheep and Heath Canyons (Figures 6–7, respectively). Extrapolation of these curves indicated volumes
**EXCEEDENCE FREQUENCY PER HUNDRED YEARS**

<table>
<thead>
<tr>
<th>Year of Flow</th>
<th>Exceedence Frequency (in percent)</th>
<th>Volumes of Debris Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>cubic metres</td>
</tr>
<tr>
<td>1916</td>
<td>1.0</td>
<td>*(184 000)</td>
</tr>
<tr>
<td>1938</td>
<td>2.5</td>
<td>135 000</td>
</tr>
<tr>
<td>1955</td>
<td>4.1</td>
<td>92 000</td>
</tr>
<tr>
<td>1966</td>
<td>5.6</td>
<td>28 000</td>
</tr>
<tr>
<td>1926</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1945</td>
<td>-</td>
<td>Volume of debris flow for these years was less than shown for other years above.</td>
</tr>
<tr>
<td>1960</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1967</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

*Extrapolated from curve*

---

**Figure 6 - VOLUME OF DEBRIS FLOW - SHEEP CREEK**

DEPARTMENT OF WATER RESOURCES, SOUTHERN DIVISION, 1976
### Exceedence Frequency Per Hundred Years

<table>
<thead>
<tr>
<th>Year of Flow</th>
<th>Exceedence Frequency (in percent)</th>
<th>Volumes of Flow</th>
<th>Cubic Metres</th>
<th>Cubic Yards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1916</td>
<td>1.0</td>
<td><em>810,000</em></td>
<td><em>(1,060,000)</em></td>
<td></td>
</tr>
<tr>
<td>1938</td>
<td>2.5</td>
<td>576,000</td>
<td>753,000</td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>4.1</td>
<td>348,000</td>
<td>455,000</td>
<td></td>
</tr>
<tr>
<td>1966</td>
<td>5.6</td>
<td>108,000</td>
<td>141,000</td>
<td></td>
</tr>
<tr>
<td>1926</td>
<td>-</td>
<td>Volume of debris flow for these years was less than shown for other years above.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1945</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1967</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1941</td>
<td>1.0</td>
<td>918,000</td>
<td>1,200,000</td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>2.5</td>
<td>99,000</td>
<td>130,000</td>
<td></td>
</tr>
<tr>
<td>1943</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1973</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Extrapolated from curve*

---

**Figure 7 - Volume of Debris and Mud Flow - Heath Creek**
of 183,000 cubic metres (240,000 cubic yards) for Sheep Canyon and 810,000 cubic metres (1,060,000 cubic yards) for Heath Canyon, with an exceedence frequency of .01 (once in 100 years).

Volumes for Acorn and Flume Canyons for a once-in-100-year frequency event were based on 1938 volumes. By proportioning these volumes with those estimated for Heath and Sheep Canyons, the respective volumes for Acorn and Flume Canyons were estimated to be 31,000 cubic metres (40,000 cubic yards) and 12,000 cubic metres (16,000 cubic yards).

The volumes for a once-in-100-year event were estimated by using existing geologic conditions. These volumes could be considerably greater if a strong earthquake occurred in the area. The potential for damage from mass movement of soil increases with the canyon slopes and the dikes saturated, allowing conditions for soil liquefaction to prevail. If saturation conditions remained for an extended period in a wet year, the possibility of damaging soil movement would be greatly increased.

Mud Flows

Although mud flows have occurred in all four canyons, major activity has been limited to two events in Heath Canyon:

1. In May 1941, muddy debris surged daily for a week to ten days, with occasional flows continuing for as long as three weeks. The flows came in a series of waves, usually starting at about 9 a.m., peaking in frequency in the early afternoon, and tapering off to end by late afternoon. Surge front velocities were estimated at from 0.3—4.3 metres (1—4 feet) per second. Volume was estimated at 917,000 cubic metres (1.2 million cubic yards).

2. In 1969, the rapid melting of the snowpack caused another flow, but one with a much smaller volume than that of 1941. Beginning in May, it lasted about 40 days. Estimates of its volume ranged from 76,000 to 99,000 cubic metres (100,000 to 130,000 cubic yards).
Prolonged heavy rains in early winter caused debris flows, resulting in widespread property damage.

Sun Co. Photo

Similar but minor mud flows occurred in 1943 and 1973 in Heath Canyon. Based on the period of 1910-1975, the 1941 volume has an exceedence frequency of once in 100 years (Figure 7). These mud flows have only occurred when the annual precipitation has been at least 76 centimetres (30 inches).

Although mud flows have, to a small degree, occurred in Flume, Acorn, and Sheep Canyons, the area inundated by this type of flow is not shown for these canyons. Past records indicate that the area inundated and the volumes of mud flows are considerably less than those for debris flows.

The pictures on this page, taken November 22, 1965, show the damage to a home on Sparrow Road, east of Lone Pine Canyon Road, Wrightwood.

Sun Co. Photo
CHAPTER V. AREAS OF POTENTIAL DAMAGE

This report has emphasized the causes and effects of debris and mud flows, the major sources of flood damage in Wrightwood. Because considerable volumes of potential source material are available within the tributary watersheds, it is expected that any flooding of major proportions would be debris-laden. Debris-free flows would not normally have magnitudes sufficient to cause significant damage.

Identifying the locations at which debris or mud flows are likely to break out or to overtop the creek channel is an important element in delineating the areas of potentially damaging inundation. These locations were determined by field investigations and by the use of topographic maps (November 1974) furnished by the Flood Control District. The maps were drawn to a horizontal scale of 1:2400 with 1.2-metre (4 feet) contour intervals. The resultant information was combined with data on areas inundated by past flood flows. By considering the steep streambed slopes and the bends of the creeks, it was determined that a high velocity flow could cause the uncompacted levees to fail at the bends. Past experiences have also shown that these flows overtop the channels where the slope flattens out and velocity is reduced. This causes debris deposition, which increases the potential for damage.

Plate 2 delineates the most likely locations of debris and mud damage from a once-in-100-year event. However, the flows from any single event would not necessarily cause damage to the entire area within these limits. The darker shaded areas are those considered most likely to become the flowpath of the once in 100-year event. The lighter shaded areas are thought to be less vulnerable to storm flows. In addition, they would be expected to have a lower potential for damage from debris and mud flows than the darker shaded areas.

Courtesy WrightwoodCall23.com