7 Why are Landslides a Threat to City of San Dimas?

Landslides are a serious geologic hazard in almost every state in America. Nationally, landslides cause 25 to 50 deaths each year.[1] Landslide damage in the United can cost up to $2 billion annually![2] As a seismically active region, California has had significant number of locations impacted by landslides. Some result in private property damage, while other landslides affect transportation corridors, fuel and energy conduits, and communication facilities. They also pose a serious threat to human life.

Landslides can be broken down into two categories: rapidly moving (debris flows), and slow moving. Rapidly moving landslides present the greatest risk to human life, and people living in landslide prone areas are at increased risk of serious injury. Slow moving landslides can cause significant property damage, but are less likely to result in serious human injuries. Fortunately, since the settlement of the City in the 1800's, there have been few instances of liquefaction associated with seismic activity.

Historic Southern California Landslides

March 1928 St. Francis Dam failure, Los Angeles County
As the dam gave way, its waters swept through the Santa Clara Valley toward the Pacific Ocean, about fifty-four miles away. Sixty-five miles of valley was devastated, and over 500 people were killed. Damages were estimated at $672.1 million (year 2000 dollars).[3]

1956 Portuguese Bend, California
Cost: $14.6 million (2000 dollars) along California Highway 14 in Palos Verdes Hills. Land use on the Palos Verdes Peninsula consists mostly of single-family homes built on large lots. All of the houses were constructed with individual septic systems, generally with septic tanks and seepage pits. The Portuguese Bend landslide began its modern movement in August 1956, when displacement was noticed at its northeast margin. Movement gradually extended downslope so that the entire eastern edge of the slide mass was moving within 6 weeks. By the summer of 1957, the entire slide mass was sliding towards the sea.[4]

1958-1971 Pacific Palisades, California
Cost, $29.1 million (2000 dollars) along California Highway 1. One house damaged.[5]

1961 Mulholland Cut, California
Cost, $41.5 million (2000 dollars) On Interstate 405, 11 miles north of Santa Monica, Los Angeles County.[6]

December 1963 Baldwin Hills Dam Failure
The 650 foot long by 155-foot high earth fill dam gave way and sent 360 million gallons of water in a fifty-foot high wall cascading onto the community below, killing five persons, and damaging $50 million (1963 dollars) in property.[7]

1969 Glendora, California
Cost, $26.9 million (2000 dollars) Los Angeles County, 175 houses damaged by debris flows.[8]

1969 Seventh Ave., Los Angeles County, California
Cost, $14.6 million (2000 dollars) California Highway 60.[9]

1970 Princess Park, California
Cost, $29.1 million (2000 dollars) California Highway 14, 10 miles north of Newhall.[10]

1971 Upper and Lower Van Norman Dams, San Fernando, California
Earthquake-induced landslides Cost, $302.4 million (2000 dollars). Damage due to the February 1971, M7.5 San Fernando, California, earthquake.[11]

1971 Juvenile Hall, San Fernando, California
Cost, $266.6 million (2000 dollars) caused by the San Fernando Earthquake. In addition to damaging the San Fernando Juvenile Hall, this 1.2 km-long slide damaged trunk lines of the Southern Pacific Railroad, San Fernando Boulevard, Interstate Highway 5, the Sylmar electrical converter station, and several pipelines and canals.[12]

1977-1980 Monterey Park, Repetto Hills, Los Angeles County, California
Cost, $14.6 million (2000 dollars) 100 houses damaged in 1980 due to debris flows.[13]

1978 Bluebird Canyon Orange County
Cost, $52.7 million (2000 dollars). 60 houses destroyed or damaged. Unusually heavy rains in March of 1978 may have contributed to initiation of the landslide. Although the slide area was only 3.5 acres, it is suspected to be a portion of a larger, ancient landslide.[14]

1979 Big Rock, California, Los Angeles County
Cost, approximately $1.08 billion (2000 dollars) California Highway 1 rockslide.[15]

February 1980 Southern California slides
$1.1 billion in damage (2000 dollars) Heavy winter rainfall in 1979-80 caused damage in six Southern California counties. As much as 8 inches of rain fell in a 6 hour period in many locations. Observations in the field on February 16 and 17 showed that the mountains and slopes literally fell apart on those two days.[16]

1983 San Clemente, California, Orange County
Cost, $65 million (2000 dollars). Litigation also involved approximately $43.7 million.[17]

1983 Big Rock Mesa, California
Cost, $706 million (2000 dollars) in legal claims condemnation of 13 houses, and 300 more threatened rockslide caused by rainfall.[18]

1978-1980 San Diego, Orange and Los Angeles Counties, California
Cost, in excess of $1 million. One hundred and twenty landslides were reported to have occurred

in San Diego during these 2 years. Rainfall for 78-79 and 79-80 was 14.82 and 15.61 inches respectively, compared to a 125-year average of 9.71 inches. Of the nine landslides, seven occurred in the Friars Formation, and two in the Santiago Formation in San Diego County.[19]

1994 Northridge, California earthquake landslides
As a result of the magnitude 6.7 Northridge Earthquake, more than 11,000 landslides occurred over an area of 10,000 km^2. Most were in the Santa Susana Mountains and in mountains north of the Santa Clara River Valley. They destroyed dozens of homes, blocked roads, and damaged oil-field infrastructure. Numerous deaths resulted from Coccidioidomycosis (valley fever), from a spore which was released from the soil and blown toward the coastal populated areas.[20]

March 1995 Los Angeles and Ventura Counties, Southern California
Above normal rainfall triggered damaging debris flows, deep-seated landslides, and flooding. Several landslides were triggered by the storms, with the most notable being the La Conchita landslide. This slide destroyed or badly damaged 12 homes. There also was widespread debris-flow and flood damage to homes, buildings, and roads in areas along the coast that had been devastated by wildfire 2 years before.[21]

Landslide Characteristics

What is a landslide?
A landslide can be defined as the movement of a mass of rock, debris, or earth down a slope. Landslides are a type of mass wasting which denotes any down slope movement of soil and rock under the direct influence of gravity. The term landslide encompasses events such as rock falls, topples, slides, spreads, and flows. Natural events such as rainfall, earthquakes, and changes in slope, as well as manmade construction activities can initiate landslides. While improbable in San Dimas, landslides can also occur underwater.[22]

The size of a landslide usually depends on the geology and the initial cause of the event. Landslides vary greatly in their volume of rock and soil, the length, width, depth of the area affected, frequency of occurrence, and movement. Some characteristics that determine the type of landslide are slope of the hillside, moisture content, and the nature of the underlying materials. Slides move in contact with the underlying surface. These movements include rotational slides where sliding material moves along a curved surface and translational slides where movement occurs along a flat surface. The slides are generally slow moving and can be deep. Slumps are small rotational slides that are generally shallow. Slow-moving landslides can occur on relatively gentle slopes and can cause significant property damage, but are far less likely to result in serious injuries than rapidly moving landslides.[23]

Failure of a slope occurs when the force that is pulling the slope downward exceeds the strength of the earth materials that compose the slope. They can move slowly, (millimeters per year) or can move disastrously. Depending on the slope angle, water content, and type of earth, debris-flows can travel down a hillside of speeds from as slow as 30 mph up to 200 miles per hour. These flows are initiated by heavy, usually sustained, periods of rainfall, but sometimes as a result of short bursts of concentrated rainfall in susceptible areas. Burned regions charred by wildfires are particularly susceptible to debris flows.[24]

What is a Debris Flow?
A debris or mudflow is a river of rock, earth and other materials, including vegetation that is saturated with water. This high percentage of water gives the debris flow a very rapid rate of movement down a slope. Debris flows often with speeds greater than 20 mile per hour, and can often move much faster.[25] This high rate of speed makes debris flows extremely dangerous to people and property in its path.

Landslide Events and Impacts

Weathering and the decomposition of geologic materials produces conditions conducive to landslides further exacerbates many landslide problems. Many landslides are difficult to mitigate, particularly in areas of large movement with weak underlying geologic resources.

The increasing scarcity of buildable land, particularly in urban areas, increases the tendency to build on geologically marginal land. As communities continue to modify the terrain and influence natural processes, it is important to be aware of the physical properties of the underlying soils as they, along with climate, create landslide hazards. Even with proper planning, landslides will continue to threaten the safety of people, property, and infrastructure, but without the proper measures, landslide hazards will be even more destructive.

Rock falls occur when blocks of material come loose on steep slopes. Weathering, erosion, or excavations, such as those along highways, can cause falls where the road has been cut through bedrock. They are fast moving with the materials free falling or bouncing down the slope. In falls, material is detached from a steep slope or cliff. The volume of material involved is generally small, but large boulders or blocks of rock can cause significant damage.

Earth flows are plastic or liquid movements in which land mass breaks up and flows during movement.[26] Debris flows normally occur when a landslide moves downslope as a semi-fluid mass scouring soils from the slope along its path. Flows are typically rapidly moving and also tend to increase in volume as they scour out the channel.[27] Flows often occur during heavy rainfall, can occur on gentle slopes, and are able to move rapidly for long distances.

Landslide Conditions

Landslides are often triggered by periods of heavy rainfall. Earthquakes, subterranean water flow, and excavations may also trigger landslides. Certain geologic formations are more susceptible to landslides than others. Locating development near steep slopes can also increase susceptibility to landslide events.

Although landslides are a natural geologic process, the incidence of landslides and their impacts on people can be exacerbated by human activities. Grading for road construction and development can increase slope steepness. Grading and construction can decrease the stability of a hill slope by adding weight to the top of the slope, removing support at the base of the slope, and increasing water content. Other human activities effecting landslides include: excavation, drainage and groundwater alterations, and changes in vegetation.[28]

Wild fires in hills covered with chaparral are often a precursor to debris flows in burned out canyons. The extreme heat of a wildfire can create a soil condition in which the earth becomes impervious to water by creating a waxy-like layer just below the ground surface. Since the water cannot be absorbed into the soil, it rapidly accumulates on slopes, often gathering loose particles of soil in to a sheet of mud and debris. Debris flows can often originate miles away from unsuspecting persons, and approach them at a high rate of speed with little warning.

Natural Conditions

Natural processes can cause landslides or re-activate historical landslide sites. The removal or undercutting of shoreline-supporting material along bodies of water by currents and waves produces countless small slides each year. Seismic tremors can trigger landslides on slopes historically known to have landslide movement. Earthquakes can also cause additional failure (lateral spreading) that can occur on gentle slopes above steep streams and riverbanks.

Particularly Hazardous Landslide Areas

Locations at risk from landslides or debris flows include areas with the following conditions:

- On or close to steep hills
- Steep road-cuts or excavations
- Existing landslides or places of known historic landslides Steep areas where surface runoff is channeled, such as below culverts, V-shaped valleys, canyon bottoms, and steep stream channels
- Fan-shaped areas of sediment and boulder accumulation at the outlets of canyons
- Canyons below hillside and mountains that have recently been subject to wild fire

Impacts of Development

Although landslides are a natural occurrence, human impacts can substantially affect the potential for landslide failures in San Dimas. Proper planning and geotechnical engineering can be exercised to reduce the threat of safety of people, property, and infrastructure.

Excavation and Grading

Slope excavation is common in the development of home sites or roads on sloping terrain. Grading these slopes can result in some slopes that are steeper than the pre-existing natural slopes. Since slope steepness is a major factor in landslides, these steeper slopes can be at an increased risk for landslides. The added weight of fill placed on slopes can also result in an increased landslide hazard. Small landslides can be fairly common along roads, in either the road cut or the road fill. Landslides occurring below new construction sites are indicators of the potential impacts stemming from excavation.

Drainage and Groundwater Alterations

Water flowing through or above ground is often the trigger for landslides. Any activity that increases the amount of water flowing into landslide-prone slopes can increase landslide hazards.

Broken or leaking water or sewer lines can be especially problematic, as can water retention facilities that direct water onto slopes. However, even lawn irrigation in landslide prone locations can result in damaging landslides. Ineffective storm water management and excess runoff can also cause erosion and increase the risk of landslide hazards. Drainage can be affected naturally by the geology and topography of an area; Development that results in an increase in impervious surface impairs the ability of the land to absorb water and may redirect water to other areas. Channels, streams, ponding, and erosion on slopes all indicate potential slope problems.

Road and driveway drains, gutters, downspouts, and other constructed drainage facilities can concentrate and accelerate flow. Ground saturation and concentrated velocity flow are major causes of slope problems and may trigger landslides.[29]

Changes in Vegetation
Removing vegetation from very steep slopes can increase landslide hazards. Areas that experience wildfire and land clearing for development may have long periods of increased landslide hazard. In addition, certain types of ground cover have a much greater need for constant watering to remain green, especially those that are non-native to the area.

Landslide Hazard Assessment

Hazard Identification

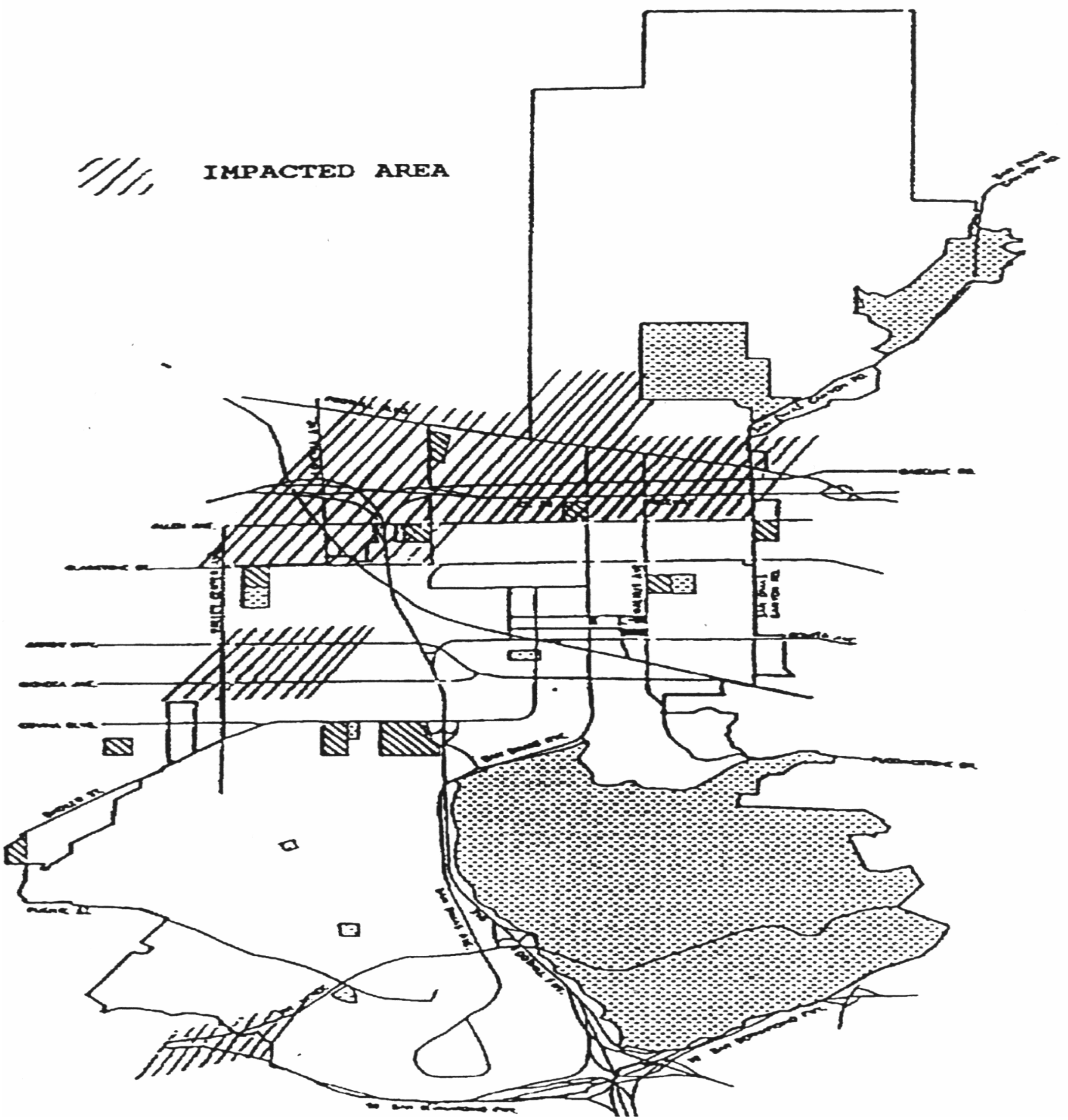
Identifying hazardous locations is an essential step towards implementing more informed mitigation activities**.** There is a low potential for liquefaction in San Dimas, however there are certain areas that are prone to this hazard, as identified in Map 7-1. Soils most prone to liquefaction are medium to fine san fractions in areas where the water table is high. Since these unfavorable conditions overlap in only a few areas in the community, the risk is relatively low. The area north of Way Hill, southeast of the spreading grounds, the central-southwestern border, and the flood plains of San Dimas Wash near the western-central part of the City are at high risk for landslides.

Vulnerability and Risk

Vulnerability assessment for landslides will assist in predicting how different types of property and population groups will be affected by a hazard.[30] Data that includes specific landslide-prone and debris flow locations in the city can be used to assess the population and total value of property at risk from future landslide occurrences.

While a quantitative vulnerability assessment has not yet been conducted for City of San Dimas landslide events, there are many qualitative factors that point to potential vulnerability. Factors included in assessing landslide risk include population and property distribution in the hazard area, the frequency of landslide or debris flow occurrences, slope steepness, soil characteristics, and precipitation intensity. This type of analysis could generate estimates of the damages to the city due to a specific landslide or debris flow event. At the time of publication of this plan, data was insufficient to conduct a risk analysis and the software needed to conduct this type of analysis was not available.

Map 7-1 Liquefaction Potential in San Dimas



Community Landslide Issues - What is Susceptible to Landslides?

Landslides can affect utility services, transportation systems, and critical lifelines. Communities may suffer immediate damages and loss of service. Utilities, including potable water, wastewater, telecommunications, natural gas, and electric power are all essential to service community needs. Loss of electricity has the most widespread impact on other utilities and on the whole community. Natural gas pipes may also be at risk of breakage from even minute landslide movements as small.

Roads and Bridges

Losses incurred from landslide hazards in the City of San Dimas have been associated with roads. Public Works is responsible for responding to slides that inhibit the flow of traffic or are damaging a road or a bridge. The Department does its best to communicate with residents impacted by landslides, but can usually only repair the road itself, as well as the areas adjacent to the slide where the city has the right of way.

It is not cost effective to mitigate all slides because of limited funds and the fact that some historical slides are likely to become active again even with mitigation measures. The City alleviates problem areas by grading slides, and by installing new drainage systems on the slopes to divert water from the landslides. This type of response activity is often the most cost-effective in the short-term, but is only temporary. Unfortunately, many property owners are unaware of slides and the dangers associated with them.

Lifelines and critical facilities

Lifelines and critical facilities should remain accessible, if possible, during a natural hazard event. The impact of closed transportation arteries may be increased if the closed road or bridge is critical for hospitals and other emergency facilities. Therefore, inspection and repair of critical transportation facilities and routes is essential and should receive high priority. Losses of power and phone service are also potential consequences of landslide events. Due to heavy rains, soil erosion in hillside areas can be accelerated, resulting in loss of soil support beneath high voltage transmission towers in hillsides and remote areas. Flood events can also cause landslides, which can have serious impacts on gas lines that are located in vulnerable soils.

Existing Landslide Mitigation Activities

Landslide mitigation activities include current mitigation programs and activities that are being implemented by local or city organizations.

Landslide Building/Zoning Codes

The San Dimas Municipal Code addresses development on steep slopes in Section 17. This section outlines standards for steep slope hazard areas on slopes of 20 percent or more. Since the City is in the highest seismic zone in the United States, the codes require soils and engineering geologic studies for all developments proposed, regardless of slope stability. Stringent amendments to these codes were adopted in Ordinance No. 1126 in 2002. Detailed surface and subsurface investigations shall be warranted if indicated by engineering and geologic studies to sufficiently describe existing conditions. This may include soils, vegetation, geologic formations, and drainage patterns.

Post Fire Mitigation Activities

As mentioned in the introduction, the northern Foothills in and above the City were ravaged in the 2002 Williams fire. Much of the area suffered a significant loss of vegetation. Post fire mitigation that both the City and the National Forest Service implemented a number of reduced the potential impacts of debris flows in the following rainy season. Two trash racks were installed upstream of Sycamore Canyon and Hamms Canyon to trap large debris before it entered populated areas. Pipes in the San Dimas Canyon dip crossing were modified to handle larger volumes of water and debris. K-rails and sand bags were placed at strategic locations prior to the rain season to divert debris flows away of roadways and structures. The City provided residents in the area with free sand and sand bags for use on their private property. These mitigation measures were successful in minimizing damage during the rains that have occurred in the last two years since the Williams fire.

Landslide Mitigation Action Items

The action items provide direction on specific activities that the City and residents can undertake to reduce risk and prevent loss from landslide events. Each action item is followed by initiatives for implementation, which can be used by the Steering Committee and local decision makers.

Action Item 2.1: Provide education outreach on the dangers of potential landslides.
Implementation Initiatives:

> *Implementation Initiative 2.1.1* Provide information on vegetation and rodent control on slopes.

Coordinating Organizations: City Public Works Department
Time line: Short term.
Plan Goals Addressed: Increase public awareness.

Action Item 2.2: Increase emergency preparedness specific to landslides.
Implementation Initiatives:

> *Implementation Initiative 2.2.1* Continue to supply various locations with free sandbags and sand.

> *Implementation Initiative 2.2.2* Maintain the existing stockpile of k rails and update staging plans

> *Implementation Initiative 2.2.3* Develop an evacuation plan for Sycamore Canyon Equestrian Center.

> *Implementation 2.2.4* Maintain a database of debris basins from LA County Public Works and monitor the ongoing threat of sediment overflow.

> *Implementation 2.2.5* Include a USGS layer on GIS system to maintain a database of properties subject to landslide liquefaction.

Implementation 2.2.6 Develop an Action Plan to address the risk of isolation for residents in San Dimas Canyon because evacuation routes may be blocked by landslides.

Coordinating Organizations: Public Works, LA County Sheriff's Dept., Administration Dept.
Time line: Short-term
Plan Goals Addressed: Strengthen City emergency services.

Action Item 2.3: Reduce the risk of landslides in San Dimas Canyon, Sycamore Canyon and Hamm's Canyon.
Implementation Initiatives:

Implementation Initiative 2.3.1 Continue to require soils engineer's reports for new construction.

Implementation Initiative 2.3.2 Evaluate the potential for upgrade or replacement of identified bridge crossings.

*Implementation Initiative 2.3.3*Evaluate the potential for street intersection upgrades at Sycamore Canyon Road and San Dimas Canyon Road.

Coordinating Organizations: City Public Works Department
Time line: Long-term
Plan Goals Addressed: Protect life and property.

Action Item 2.4: Mitigate post fire debris flow.
Implementation Initiatives:

Implementation Initiative 2.4.1 Continue to supply various locations with free sand and sandbags.

Implementation Initiative 2.4.2 Continue to maintain the stockpile of k rails and update staging plans.

Implementation Initiative 2.4.3 Amend lease agreements with private property owners for the continued placement of trash racks in the canyons. Continue to monitor and maintain the trash racks.

Implementation Initiative 2.4.4 Monitor existing capacities and sediment flows with LA County Public Works.

Coordinating Organizations: City Public Works Department
Time line: Ongoing.
Plan Goals Addressed: Strengthen City emergency services.

Landslide Resource Directory (See details in Appendix A)

County Resources

- Los Angeles County Department of Public Works

State Resources

- Department of Conservation Headquarters
- California Geological Survey Headquarters/Office of the State Geologist
- California Division of Forestry
- Department of Water Resources
- Governor's Office of Emergency Services
- California Department of Transportation (Cal Trans)

Federal Resources and Programs

- Federal Emergency Management Agency (FEMA)
- Natural Resource Conservation Service (NRCS)
- US Geological Survey, National Landslide Information Center

Publications

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Olshansky, Robert B. & Rogers, J. David, *Unstable Ground: Landslide Policy in the United States* (1987) Ecology Law Quarterly.

Public Assistance Debris Management Guide (July 2000) Federal Emergency Management Agency. The Guide was developed to assist local officials in planning, mobilizing, organizing, and controlling large-scale debris clearance, removal, and disposal operations.

USGS Landslide Program Brochure. National Landslide Information Center (NLIC), United States Geologic Survey. The brochure provides general information on the importance of landslide studies and a list of databases, outreach, and exhibits maintained by the NLLC. The brochure also includes information on the causes of landslides, rock falls, and earth flows.

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