Chapter 2
Landslide Losses and the Benefits of Mitigation

The Landslide Hazard

Landsliding is a natural process which occurs and recurs in certain geologic settings under certain conditions. The rising costs of landslide damages are a direct consequence of the increasing vulnerability of people and structures to the hazard. In most regions, the overall rate of occurrence and severity of naturally caused landslides has not increased. What has increased is the extent of human occupation of these lands and the impact of human activities on the environment. Many landslide damages that have occurred might have been prevented or avoided if accurate landslide hazard information had been available and used.

Economic and Social Impacts of Landsliding

Costs of Landsliding

The most commonly cited figures on landslide losses are $1 to $2 billion in economic losses and 25 to 50 deaths annually. However, these figures are probably conservative because they were generated in the late 1970s. Since that time, the use of marginally suitable land has increased, as has inflation. Furthermore, there are no exhaustive compilations of landslide loss data for the United States, so these figures are basically extrapolations of the available data.

The high losses from landsliding are illustrated in Table 1. Surveys indicate that damage to private property accounts for 30 to 50 percent of the total costs (U.S. Geological Survey, 1982). Examples of costs associated with individual landslide events from representative areas across the country include:

ALASKA—It has been estimated (Youd, 1978) that 60 percent of the $300 million damage from the 1964 Alaska earthquake was the direct result of landslides.

CALIFORNIA—In 1982 in the San Francisco Bay Region, 616 mm (24.3 in.) of rain fell in 34 hours causing thousands of landslides which killed 25 people and caused more than $66 million in damage (Keefer et al., 1987).

TEXAS—In Dallas in the 1960s, a toppling failure occurred in a vertical exposure of a geological formation known as the Austin Chalk. This closed two lanes of a major downtown thoroughfare for eight months. Costs of construction of remedial measures and construction delays amounted to about $2.8 million (Allen and Flanigan, 1986).

UTAH—In 1983, a massive landslide dammed Spanish Fork Canyon, creating a lake. The landslide buried sections of the Denver and Rio Grande Western Railroad and U.S. Highways 6, 50, and 89 and inundated the town of Thistle. The estimated total losses and reconstruction costs due to this one landslide range from $200 million (University of Utah, Bureau of Economic and Business Research, 1984) to $600 million (Kaliser and Slosson, 1988).

WEST VIRGINIA—In 1975, landslide movements in colluvial soil damaged 56 houses in McMechen, West Virginia, located on a hillside above the Ohio River. This landslide was attributed to above normal precipitation. Mitigation was accomplished by grading and surface and subsurface drainage (Gray and Gardner, 1977).

Impacts and Consequences of Landsliding

Economic losses due to landsliding include both direct and indirect costs. Schuster and Fleming (1986) define direct costs as the costs of replacement, repair, or maintenance due to damage to property or facilities within the actual boundaries of a landslide (Figure 2). Such facilities include highways, railroads, irrigation canals, underwater communication cables, offshore oil platforms, pipelines, and dams. The cost of cleanup must also be included (Figure 3). All other landslide costs are considered to be indirect. Examples of indirect costs given by Schuster and Fleming (1986) include:

(1) reduced real estate values,
(2) loss of productivity of agricultural or forest lands,
(3) loss of tax revenues from properties devalued as a result of landslides,
(4) costs of measures to prevent or mitigate future landslide damage,
(5) adverse effects on water quality in streams,
(6) secondary physical effects, such as landslide-caused flooding, for which the costs are both direct and indirect,
(7) loss of human productivity due to injury or death.

Other examples are:

(8) fish kills,
(9) costs of litigation.

In addition to economic losses, there are intangible costs of landsliding such as personal stress, reduced quality of life, and the destruction of personal possessions having great sentimental value. Because costs of indirect and intangible losses are difficult or impossible to calculate, they are often undervalued or ignored. If they are taken into account, they often produce highly variable estimates of damage for a particular incident.

Figure 2. Major damage to homes in Farmington, Utah as a result of 1983 Rudd Creek mudslide (photograph by Robert Kistner, Kistner and Associates).

Figure 3. Local volunteers form "bucket brigade" to help clean mud and debris from homes in Farmington, Utah in 1983 (photograph by Robert Kistner, Kistner and Associates).

Long–Term Benefits of Mitigation

Studies have been conducted to estimate the potential savings when measures to minimize the effects of landsliding are applied. One early study by Alfors et al. (1973) attempted to forecast the potential costs of landslide hazards in California for the period 1970-2000 and the effects of applying mitigative measures. Under the conditions of applying all feasible measures at state-of-the-art levels (for the 1970s), there was a 90 percent reduction in losses for a benefit/cost ratio of 8.7:1, or $8.7 saved for every $1 spent. Nilsen and Turner (1975) estimated that approximately 80 percent of the landslides in Contra Costa County, California are related to human activity. In Allegheny County, Pennsylvania, 90 percent are related to such activity according to Briggs et al. (1975).

Because most landslides triggered by man are directly related to construction activities, appropriate grading codes can significantly decrease landslide losses in urban areas. Slosson (1969) compared landslide losses in Los Angeles for those sites constructed prior to 1952, when no grading codes existed and soils engineering and engineering geology were not required, with losses sustained at sites after such codes were enacted. He found that the monetary losses were reduced by approximately 97 percent.

The Cincinnati, Ohio Study

In 1985, the U.S. Geological Survey, in cooperation with the Federal Emergency Managament Agency, conducted a geologic/economic development study in the Cincinnati, Ohio area. This study developed a systematic approach to quantitative forecasting of probable landslide activity. Landslide probabilities derived from a reproducible procedure were combined with property value data to forecast the potential economic losses in scenarios for proposed development and to quantitatively identify the potential benefits of mitigation activities.

The study area was divided into 14,255 grid cells of 100-square meters each. Information calculated for each cell included: probability of landslide occurrence, economic loss in the event of a landslide, cost of mitigation, and economic benefit of mitigation. This information was used to develop a mitigation strategy. In areas where both slope and shear strength information were available, the optimum strategy required mitigation in those cells with slopes steeper than 14 degrees or where materials had effective residual stress friction angles of less than 26 degrees. This strategy yielded $1.7 million in estimated annualized net benefits for the community. In areas where only slope information was used, the best strategy required mitigation in those cells where slopes were greater than 8 degrees. This yielded an estimated annualized net benefit of $1.4 million. Therefore, using regional geologic information in addition to slope information resulted in an additional $300,000 net benefit. The Cincinnati study cost only $20,000 to prepare (Bernknopf et al., 1985).

The Benefits of Mitigation in Japan

Japan has what is considered by many to be the world's most comprehensive landslide loss reduction program. In 1958, the Japanese government enacted strong legislation that provided for land-use planning and the construction of check dams, drainage systems, and other physical controls to prevent landslides. The success of the program is indicated by the dramatic reduction in losses over time (Figure 4). In 1938, 130,000 homes were destroyed and more than 500 lives were lost due to landslides in the Kobe area. However, since the Japanese program went into effect, losses have decreased dramatically. In 1976—one of Japan's worst years for landsliding—only 2000 homes were destroyed with fewer than 125 lives lost (Schuster and Fleming, 1986).

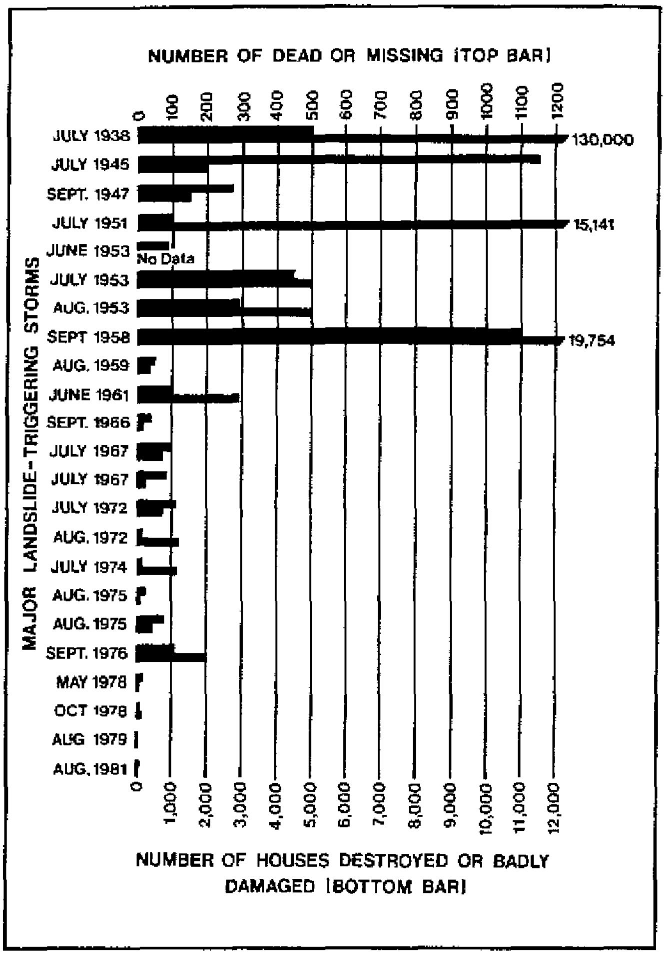

Figure 4. Losses due to major landslide disasters (mainly debris flows) in Japan from 1938–1981. All of these landslides were caused by heavy rainfall, most commonly related to typhoons, and many were associated with catastrophic flooding (data from Ministry of Construction, Japan, 1983).

Planning as a Means of Loss Reduction

The extent and severity of the landslide hazard in a particular area will determine the need for a landslide hazard mitigation plan.

> Communities that have landslide problems are encouraged to assess the costs of damage to public and private property and weigh those costs against the costs of a landslide reduction program The prevention of a single major landslide in a community may more than compensate for the effort and cost of implementing a control program (Fleming and Taylor, 1980, p. 20).

Avoiding the costs of litigation is an additional incentive to undertaking a local program of landslide hazard mitigation.

When landslide disasters do occur, the existence of a program for loss reduction should help ensure that redevelopment planning takes existing geologic hazards into account.

In the U.S., only a few communities have established successful landslide loss reduction programs. The most notable is Los Angeles, where, as mentioned above, loss reductions of 97 percent have been achieved for new construction since the implementation of modern grading regulations (Slosson and Krohn, 1982).

In communities that have achieved loss reductions, decisions about building codes, zoning, and land use take into account identified landslide hazards. The U.S. Geological Survey (1982) has found that these communities have in common four preconditions leading to successful mitigation programs: (1) an adequate base of technical information about the local landslide problem, (2) an "able and concerned" local government, (3) a technical community able to apply and add to the technical planning base, and (4) an informed population that supports mitigation program objectives. While the technical expertise to reduce landslide losses is currently available in most states, in many cases it is not being utilized. Still, the success of loss reduction measures clearly depends upon the will of leaders to promote and support mitigation initiatives.

Local Government Roles

At the local government level, hazard mitigation is often a controversial issue. Staff and elected officials of local governments are usually subjected to diverse and sometimes conflicting pressures regarding land use and development. Local officials, as well as builders, realtors, and other parties in the development process, are increasingly being held liable for actions, or failures to act, that are determined to contribute to personal injuries and property damages caused by natural hazards. Consequently, a model community landslide hazard management planning process should encourage citizen participation and review in order to identify and address the perspectives and concerns of the various community groups affected by landslide hazards.

Because most landslide damages are related to human activity—mainly the construction of roads, utilities, homes, and businesses—the best opportunities for reducing landslide hazards are found in land-use planning and the administration and enforcement of codes and ordinances.

The vulnerability of people to natural hazards is determined by the relationship between the occurrences of extreme events, the proximity of people to these occurrences, and the degree to which the people are prepared to cope with these extremes of nature. The concept of a hazard as the intersection of the human system and the physical system, is illustrated in Figure 5. Only when these two systems are in conflict, does a landslide represent a hazard to public health and safety.

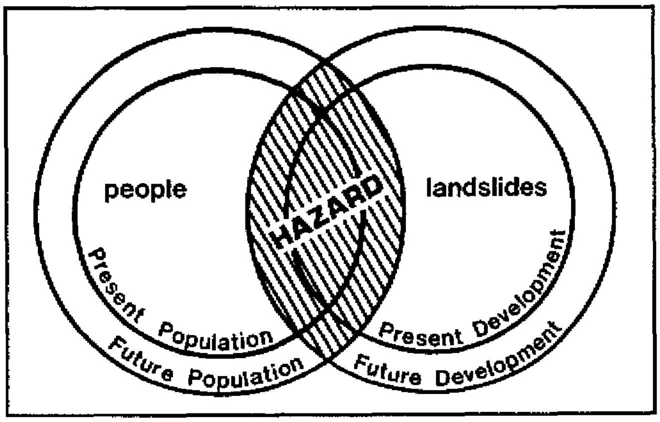

Figure 5. The relationship of people, landslides, and hazards (modified from Colorado Water Conservation Board et al., 1985).

The effectiveness of local landslide mitigation programs is generally tied to the ability and determination of local officials to apply the mitigation techniques available to them to limit and guide growth in hazardous areas. A list of 27 techniques that planners and managers may use to reduce landslide hazards in their communities is presented in Table 2. The key to achieving loss reduction is the identification and implementation of specific mitigation initiatives, as agreed upon and set forth in a local or state landslide hazard mitigation plan.

Table 2. Techniques for reducing landslide hazards (Kockelman, 1986).

Discouraging new developments in hazardous areas by:
- Disclosing the hazard to real-estate buyers
- Posting warnings of potential hazards
- Adopting utility and public-facility service-area policies
- Informing and educating the public
- Making a public record of hazards

Removing or converting existing development through:
- Acquiring or exchanging hazardous properties
- Discontinuing nonconforming uses
- Reconstructing damaged areas after landslides
- Removing unsafe structures
- Clearing and redeveloping blighted areas before landslides

Providing financial incentives or disincentives by:
- Conditioning federal and state financial assistance
- Clarifying the legal liability of property owners
- Adopting lending policies that reflect risk of loss
- Requiring insurance related to level of hazard
- Providing tax credits or lower assessments to property owners

Regulating new development in hazardous areas by:
- Enacting grading ordinances
- Adopting hillside-development regulations
- Amending land-use zoning districts and regulations
- Enacting sanitary ordinances
- Creating special hazard-reduction zones and regulations
- Enacting subdivision ordinances
- Placing moratoriums on rebuilding

Protecting existing development by:
- Controlling landslides and slumps
- Controlling mudflows and debris-flows
- Controlling rockfalls
- Creating improvement districts that assess costs to beneficiaries
- Operating monitoring, warning, and evacuating systems

Although certain opportunities for reducing landslide losses exist at the state government level (selection of sites for schools, hospitals, prisons, and other public facilities; public works projects that protect highways and state property), the greatest potential for mitigation is in the routine operations of local government: the adoption and enforcement of grading and construction codes and ordinances, the development of land-use and open-space plans, elimination of nonconforming uses, limitation of the extension of public utilities, etc. For this reason, state mitigation plans should emphasize mitigation activities that will essentially encourage and support local efforts. Local mitigation plans should provide guidelines and schedules for accomplishing local mitigation projects, as well as identify projects beyond local capability that should be considered in the state plan. ❑