Chapter 1

Introduction

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This book is a successor to Highway Research Board Special Report 29, *Landslides and Engineering Practice* (*1.8*). Special Report 29, which was written by the Highway Research Board Committee on Landslide Investigations and published in 1958, achieved an excellent reputation, both in North America and abroad, as a text on landslides. Because of its popularity, the original printing was sold out within a few years after publication. Since then, there has been a continuing interest in reissuing the original text or publishing a worthwhile successor.

In 1972 the Highway Research Board organized the Task Force for Review of Special Report 29—Landslides. The membership of this task force was selected from several committees within the HRB Soils and Geology Group: its charge was

To review the out-of-print Special Report 29—Landslides—and to recommend what action should be taken in response to the high interest in revising this publication.

This task force was further instructed to act as the coordinating unit to implement its recommendations.

After considerable study of the original report, the task force concluded that, because of the large amount of new technical information that had become available since 1958 on landslides and related engineering, the best course of action would be to completely rewrite the book rather than to reprint it or to revise it in part. The task force decided that the general format of the original volume would be retained but that the contents would be expanded to include concepts and methods not available in 1958. To achieve that objective, the task force secured the aid of authors who have broad geotechnical expertise. They were drawn from the fields of civil engineering and geology and have specializations in soil mechanics, engineering geology, and interpretation of aerial photographs.

SCOPE OF THIS VOLUME

The scope of this volume is the same as that for Special Report 29: to bring together in coherent form and from a wide range of experience such information as may be useful to those who must recognize, avoid, control, design for, or correct landslide movement.

This new version, however, introduces geologic concepts and engineering principles and techniques that have been developed since publication of Special Report 29 so that both the analysis and the control of soil and rock slopes are addressed. For example, included are new methods of stability analysis and the use of computer techniques in implementing these methods. In addition, rock-slope engineering and the selection of shear-strength parameters for slope-stability analyses are two topics that were poorly understood in 1958 and therefore were given scant attention in Special Report 29. Since that time, these two subjects have received a significant amount of study and have become fairly well understood; thus, they are presented as separate chapters in the present volume.

The book is divided into two general parts. The first part deals principally with the definition and assessment of the landslide problem. It includes chapters on slope-movement types and processes, recognition and identification of landslides, field investigations, instrumentation, and evaluation of strength properties. The second part of the book deals with solutions to the landslide problem. Chapters are included on methods of slope-stability analysis, design techniques, and remedial measures that can be applied to both soil and rock-slope problems.

Although considerable effort has been made to eliminate presentation of the same material in different chapters, some repetition has been necessary to provide continuity of thought and to allow adequate explanation of specific topics. We consider this repetition to be more acceptable than constant referral in the text to other chapters.

DEFINITIONS AND RESTRICTIONS

In Special Report 29 the term landslide is defined as the downward and outward movement of slope-forming materials—natural rock, soils, artificial fills, or combinations of these materials. Today the term deserves further refinement because, as shown in Chapter 2, slope movements can now be divided into five groups: falls, topples, slides, spreads, and flows. As used in this text, a landslide constitutes the group of slope movements wherein shear failure occurs along a specific surface or combination of surfaces.

Although this volume deals primarily with slope failures belonging to the group designated as slides, some attention is given to the other four types of slope movements. The use of the term landslide in the title is somewhat inaccurate in that theoretically it does not cover the five basic failure modes described above; however, the decision was made to use this term because it is popular and easily recognized and because the book is mainly devoted to landslides.

In keeping with the practice followed in Special Report 29, surficial creep was excluded from consideration; however, creep of a more deep-seated nature is considered in discussions dealing with slope movements. Also excluded are subsidence not occurring on slopes and most types of movement primarily due to freezing and thawing of water. In addition, snow and ice avalanches and mass wasting due to slope-failure phenomena in tropic and arctic climates are not considered. Although a few examples are drawn from other parts of the world, most of the descriptions of slope movements and engineering techniques involve slopes in North America.

Of the five groups of potential slope movements considered, only slides are currently susceptible to quantitative stability analysis by use of the conventional sliding-wedge or circular-arc techniques. These methods of slope-stability analysis are not applicable to falls, topples, spreads, or flows. However, enough is now known about the kinematics and nature of development of such failures that qualitative or statistical approaches or both can be used to make reasonable assessments in problem areas or potential problem areas. Research dealing with such problems is currently being undertaken to enable at least crude quantitative stability analyses to be performed on slopes subject to spreads and flows and possibly even to falls and topples.

Although slope-stability problems related to transportation facilities are stressed, most of the examples apply equally well to all cases of slope failure, such as those relating to coastlines, mining, housing developments, and farmlands. As noted by Eckel in the Introduction in Special Report 29 (*1.7*, p. 2):

The factors of geology, topography, and climate that interact to cause landslides are the same regardless of the use to which man puts a given piece of land. The methods for examination of landslides are equally applicable to problems in all kinds of natural or human environment. And the known methods for prevention or correction of landslides are, within economic limits, independent of the use to which the land is put. It is hoped, therefore, that despite the narrow range of much of its exemplary material, this volume will be found useful to any engineer whose practice leads him to deal with landslides.

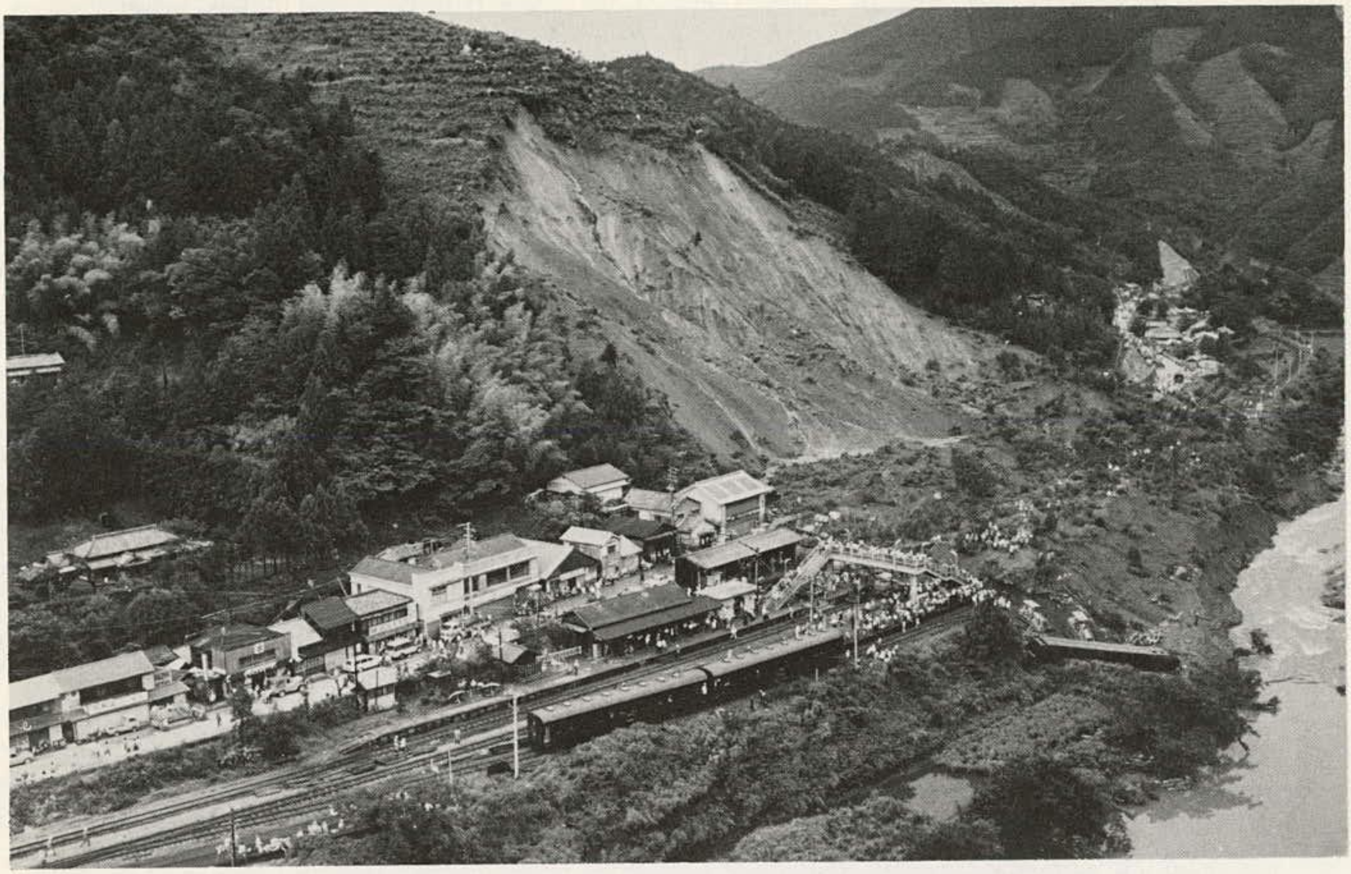
ECONOMICS OF SLOPE MOVEMENTS

Although individual slope failures generally are not so spectacular or so costly as certain other natural catastrophes such as earthquakes, major floods, and tornadoes, they are more widespread and the total financial loss due to slope failures probably is greater than that for any other

Figure 1.1. Damage to embankment on I-75 in Campbell County, Tennessee, from a landslide that occurred April 1972.

Figure 1.2. Homes and street damaged in October 1978 Laguna Beach, California, landslide.

Figure 1.3. Damage to railway facilities from 1972 Segeto landslide in Japan.



single geologic hazard to mankind. In addition, much of the damage occurring in conjunction with earthquakes and floods is due to landslides instigated by shaking or water.

Reliable estimates of the overall costs of landslides are difficult to obtain for geographic entities as large as the United States or Canada. In 1958, Smith (*1.32*) stated that "the average yearly cost of landslides in the United States runs to hundreds of millions of dollars," an estimate that was probably realistic at that time. However, in the 20 years since Smith assembled his data, a combination of inflation, increased construction in landslide-prone areas, and use of larger cuts and fills in construction has resulted in considerably increased annual costs of landslides. For example, environmental and political considerations and right-of-way costs control the selection of highway routing today to a much greater degree than was the case 20 years ago; thus, highway planners often cannot avoid construction in landslide-prone areas. Landslide costs include both direct and indirect losses from landslides affecting highways, railroads, industrial installations, mines, homes, and other public and private properties. Direct costs are those losses incurred in actual damages to installations or property; examples of such damages are shown in Figures 1.1, 1.2, and 1.3. Examples of indirect costs are (a) loss of tax revenues on properties devalued as a result of landslides, (b) reduced real estate values in areas threatened by landslides, (c) loss of productivity of agricultural or forest lands affected by landslides, and (d) loss of industrial productivity due to interruption of transportation systems by landslides. Indirect costs of landslides are difficult to evaluate, but they may be larger than the direct costs.

In 1976, Krohn and Slosson (*1.16*) estimated the annual landslide damage to buildings and their sites in the United States to be $400 million (1971 dollars). This figure does not include other damages, such as those to transportation facilities and mines, or indirect costs. In the same year, Jones (*1.13*) estimated the direct landslide damage losses to buildings and their sites to be about $500 million annually. Based on the above estimates plus indirect costs and estimated damages to facilities not classed as buildings, a reasonable estimate of present-day direct and indirect costs of slope failures in the United States exceeds $1 billion/year.

Somewhat more accurate cost estimates can be made for individual landslides or for landslides occurring in relatively small geographic areas. For instance, the Portuguese Bend landslide in Palos Verdes Hills, California, has been estimated to have cost more than $10 million in damage to roads, houses, and other structures between 1956 and 1959 (*1.23*). Jones, Embody, and Peterson (*1.14*) noted that the filling of the reservoir behind Grand Coulee Dam in the state of Washington cost taxpayers and private property owners at least $20 million to avoid and correct the damage due to landslides that occurred between 1934 and 1952.

Within the United States, greater effort at detailing the costs of slope movements has been expended in California than in any other state. In a classic study of slope-movement costs in the San Francisco Bay area, Taylor and Brabb (*1.35*) documented information on these costs for nine Bay-area counties during the winter of 1968-1969. The data were derived largely from interviews with planners and assessors in the county government and engineers and geologists in city, county, and state governments. Costs of slope movements totaled at least $25 million, of which about $9 million was direct loss or damage to private property (due mainly to drop in market value); $10 million was direct loss or damage to public property (chiefly for repair or relocation of roads and utilities); and about $6 million consisted of miscellaneous costs that could not be easily classified in either the public or the private sector. This is a tremendous expense for the relatively small area involved. In addition, Taylor and Brabb noted that their data are incomplete in that they were not able to obtain costs on many of the slope movements. They felt, therefore, that the total cost of the 1968-1969 slope movements for the San Francisco Bay area may possibly have been several times greater than the estimated $25 million.

A survey conducted by the Federal Highway Administration indicates that approximately $50 million is spent annually to repair major landslides on the federally financed portion of the national highway system (*1.3, 1.4*). This system includes federal and state highways but does not include most county and city roads or streets, private roads and streets, or roads built by other governmental agencies such as the U.S. Forest Service. Distribution of the direct costs of major landslides for 1973 by Federal Highway Administration regions within the United States is shown in Figure 1.4 (*1.3*). The cost for an individual region is based on both the landslide risk and the amount of highway construction in the area. In addition, the given costs represent a single year; the average annual cost for a particular region could vary significantly from the given cost.

Total annual costs of landslides to highways in the United States are difficult to determine precisely because of the difficulty in defining the following factors: (a) costs of smaller slides that are routinely handled by maintenance forces; (b) costs of slides on non-federal-aid routes; and (c) indirect costs that are related to landslide damage, such as traffic disruption and delays, inconvenience to motorists, engineering costs for investigation, and analysis and design of mitigation measures. If these factors are included, Chassie and Goughnour (*1.3*) of the Federal Highway Administration believe that $100 million is a conservative estimate of the total annual cost of landslide damage to highways and roads in the United States.

For planning purposes, other studies have attempted to project costs of slope movements. In a study predicting the cost of geologic hazards in California from 1970 to 2000, the California Division of Mines and Geology (*1.1*) estimated that the costs of slope movements throughout the state during that period would be nearly $10 billion, or an average of more than $300 million a year. This estimate is based on the assumption that loss-reduction practices in use in California in 1970 for slope failures will remain unchanged. Figure 1.5 (*1.1*) shows a comparison of the estimated losses due to slope movements and losses due to other geologic hazards and urbanization. Of the so-called "catastrophic" geologic hazards included in the study, losses due to slope movements exceed those due to floods and, in turn, are exceeded by those due to earthquakes. California, however, is particularly prone to earthquake activity, and in most other parts of the United States and Canada losses due to slope movements probably would be greater than those due to earthquakes.

Various studies have shown that most damaging landslides are human related; thus, the degree of hazard can be reduced beforehand by introduction of measures such as improved grading ordinances, land-use controls, and drainage or runoff controls (*1.37*). For example, Nilsen and Turner (*1.25*) showed that in Contra Costa County, California, approximately 80 percent of the landslides have been caused by human activity. Briggs, Pomeroy, and Davies (*1.2*) noted that more than 90 percent of the landslides in Allegheny County, Pennsylvania, have been related to human activities. The study by the California Division of Mines and Geology (*1.1*) indicated that the $9.9 billion estimated losses due to slope movements can be reduced 90 percent or more by a combination of measures involving adequate geologic investigations, good engineering practice, and effective enforcement of legal restraints on land use and disturbance.

Chassie and Goughnour (*1.4*) further substantiated the concept that improved geologic and geotechnical studies can significantly reduce the landslide hazard. They noted that

Figure 1.4. Costs of landslide repairs to federal-aid highways in United States for 1973 (*1.3*).

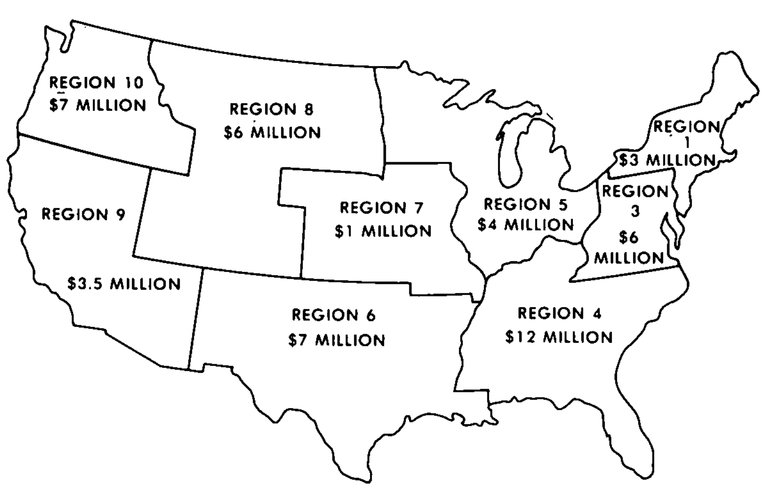
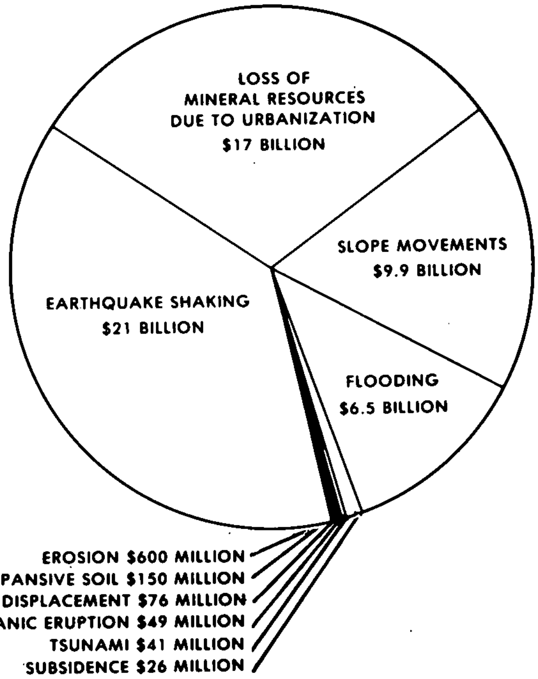


Figure 1.5. Predicted economic losses from geologic hazards and urbanization in California from 1970 to 2000 (*1.1*).



improved geotechnical techniques in New York State reduced landslide repair costs by as much as 90 percent in the 7 years prior to 1976. Slosson (*1.31*) showed that landslide losses sustained by the city of Los Angeles as a result of the 1968-1969 winter storm were 97 percent lower for those sites developed under modern grading codes by using modern geotechnical methods than for sites developed before 1952, when no grading codes existed and engineering geology and geotechnical engineering studies were not required. For the state of California, Leighton (*1.19*) estimated that reductions of 95 to 99 percent in landslide losses can be obtained by means of preventive measures that incorporate thorough preconstruction investigation, analysis, and design and that are followed by careful construction procedures.

In addition to the economic losses due to slope movements, a significant loss of human life is directly attributable to landslides and other types of slope failures. Fatalities due to catastrophic slope failures have been recorded since people began to congregate in areas subject to such failures. One such catastrophe (probably a debris flow) was noted by Spanish conquistadors in Bolivia in the sixteenth century (*1.30*). According to the priest Padre Calancha, who observed the event from a distance, Hanco-Hanco, a community of about 2000 inhabitants, disappeared "in a few minutes and was swallowed by the earth without more evidence of its former existence than a cloud of dust which arose where the village had been situated."

In the twentieth century many individual slope failures have resulted in large numbers of fatalities. Probably the best known of these catastrophic failures are the debris avalanches of 1962 and 1970 on the slopes of Mt. Huascarán in the Andes Mountains of Peru. In January 1962, a debris avalanche, which started as an ice avalanche from a glacier high on the north peak of Mt. Huascaran but soon became a mixture of ice, water, rock, and soil, roared through valley villages, killing some 4000 to 5000 people (*1.5, 1.22*). An even greater number of people were killed in a repeat of this tragedy 8 years later, when an earthquake of magnitude 7.75 occurred off the coast of Peru and triggered another disastrous debris avalanche on the slopes of Huascarán (*1.5, 1.28*). This debris avalanche descended at average speeds of roughly 320 km/h (200 mph) into the same valley but over a much larger area and killed more than 18 000 people. The village of Ranrahirca, which had been rebuilt after being destroyed by the 1962 debris avalanche in which 2700 of its people were killed, was partially destroyed by the 1970 avalanche. The 1962 avalanche was prevented from flowing into the town of Yungay by a protective ridge, but the 1970 avalanche overtopped this ridge and buried the town along with an estimated 15 000 of its 17 000 inhabitants. Only the tops of a few palm trees in the central plaza and parts of the walls of the main cathedral were left protruding above the mud to mark the site of this formerly prosperous and picturesque city (*1.28*).

In 1974, another massive landslide in the Andes Mountains of Peru killed approximately 450 people (*1.18*). This landslide, which occurred in the valley of the Mantaro River, had a volume of 1.6 Gm^3 (2.1 billion yd^3), making it one of the largest in recorded history. It temporarily dammed the Mantaro River, forming a lake with a depth of about 170 m (560 ft) and a length of about 31 km (19 miles). In overtopping this landslide dam, the river caused extensive damage downstream, destroying approximately 20 km (12 miles) of road, three bridges, and many farms.

On October 9, 1963, the most disastrous landslide in European history—the Vaiont Reservoir slide—occurred in northeastern Italy. A mass of rock and soil having a volume of about 250 Mm^3 (330 million yd^3) slid into the reservoir, sending a wave 260 m (850 ft) up the opposite slope and at least 100 m (330 ft) over the crest of the dam into the valley below, where it destroyed five villages and took 2000 to 3000 lives (*1.15, 1.17*).

Japan has also suffered continuing large loss of life and property from landslides and other slope movements. Although some slope failures in Japan have been triggered by earthquakes, most are a direct result of heavy rains during the typhoon season. Data from a Japan Ministry of Construction publication (*1.12*) and a written communication in 1974 are given in Table 1.1 and show the number of deaths and damaged houses caused by slope failures in Japan for the 4-year period from 1969 through 1972.

Table 1.1. Deaths and damage due to recent slope-failure disasters in Japan.

		Deaths	
Year	Houses Damaged	Number	Percent[a]
1969	521	82	50
1970	38	27	26
1971	5205	171	54
1972	1564	239	44

[a]Of deaths due to slope failure in relation to deaths due to all other natural disasters.

Of particular interest is the high ratio of deaths due to slope failures to deaths from all other natural disasters, including earthquakes.

North American slope failures have not commonly resulted in major losses of life, because most catastrophic slope failures have occurred in nonpopulated areas. However, there have been several notable exceptions in this century. The first was in Canada in 1903, when a great landslide killed approximately 70 people in the coal mining town of Frank, Alberta (*1.21*). More recently, the Hebgen Lake earthquake struck southwestern Montana in 1959 and triggered the Madison Canyon landslide. That catastrophic landslide, shown in Figure 1.6 (*1.36*), had a volume of 28 Mm^3 (37 million yd^3) and buried 26 people who were camped along the banks of the Madison River (*1.10, 1.39*).

Probably the worst natural disaster in central Virginia's recorded history was the 1969 flooding and associated debris flows resulting from hurricane Camille (*1.38*). Although no exact number of deaths due to slope movements can be ascertained, estimates are that a substantial percentage of the 150 people who died in Virginia as a result of hurricane Camille were victims of debris flows resulting from the hurricane.

Another recent catastrophic slope failure in North America was the debris flow that occurred in 1971 in Champlain clay in the Canadian town of Saint-Jean-Vianney, Quebec (*1.34*). That flow carried 40 homes to destruction and 31 persons to their deaths.

The most recent major catastrophe involving slope failure in the United States was the Buffalo Creek dam failure at Saunders, West Virginia, in 1972 (*1.6*). Heavy rains led to the failure of three coal-refuse impoundments. The resulting debris flow consisting of released water, coal wastes, and sludge traveled 24 km (15 miles) downstream, killing 125 people and leaving 4000 homeless.

The landslides and other types of slope movements mentioned above can all be classified as major disasters. In addition to catastrophes of this magnitude, however, slope failures of lesser importance occur continually throughout the world. Because no systematic records of these day-to-day slope failures have been maintained in the United States and Canada (as contrasted to Japan, Table 1.1), ascertaining the number of deaths per year owing to slope failures is not possible. However, Krohn and Slosson (*1.16*) estimated that the total loss of life in the United States from all forms of landslide activity exceeds approximately 25 lives per year, a greater total than the average number of deaths due to earthquakes.

Figure 1.6. Madison Canyon landslide of August 21, 1959, in southwestern Montana.

LEGAL ASPECTS OF SLOPE MOVEMENTS

In Special Report 29, Smith (*1.32*, p. 13) stated:

Few legal precedents have been established to guide the courts in determining responsibility for landslides or in assessing the damages caused by them. This dearth of specific laws and legal decisions is perhaps due to two main factors–many, if not most, cases that involve private companies are settled out of court; most cases against state or federal agencies are settled out of court or the public agency exercises its sovereign right of refusal to consent to be sued.

In the United States during the 20 years since this statement was made, the number of legal cases resulting from property damage due to landslides has been ever increasing; the cases involve private companies and landholders as well as public agencies. For that reason it is important that those who undertake activities that involve the use of slopes have an understanding of the legal implications of that use. This section deals briefly with the legal aspects of landslides and provides references for those wishing to explore the subject further. The discussion is based on perusal of current literature and on substantial information provided in a written communication in 1975 from C. L. Love, attorney for the Legal Division of the California Department of Transportation. Because of the constantly changing status of litigation involving natural hazards, some of these concepts will likely change within the next few years.

Landslides and Transportation Routes

Since most litigation involving landslides on transportation routes relates to construction and maintenance of public highways or roads, we will assume in this discussion that a public entity is the defendant. As noted by Love, the law relating to public agencies is based on the concept of sovereign immunity; thus, the consequent liability of public agencies for landslides is generally more limited than the liability of private individuals under similar circumstances.

Love further states that, when liability for a landslide is discussed, it must, of course, be assumed that a landslide has caused injury to some legally protected interest of a party, thus enabling an action against the public entity. The legally protected interest of the injured party may be his or her personal property, real estate, or physical well-being. It also must be assumed that the public entity is in some way responsible for the landslide. Such responsibility, or liability, can be based on construction or maintenance operations that create or activate a landslide on public property or on mere public ownership of property that either contains or is in the immediate vicinity of an active or potentially active landslide.

Love notes that there have been numerous cases in which private property has been damaged or personal injury has resulted from landslides or rock falls or both on public highways in the United States. In these instances the liability of the public entity having jurisdiction over the highway has varied from state to state. Some states, for all intents and purposes, bar suits against public entities because of sovereign immunity; however, many states have established statutory provisions under which recovery can be realized. Such statutes generally delineate specific duties and responsibilities of public agencies, specific circumstances of the slope failure, procedural requirements for bringing action against the public entity, and specific defenses available to the public entity.

Although the protection of sovereign immunity commonly has been invoked successfully in cases in which a reasonable degree of prudence has been exercised by those who have designed and constructed the works, Professor G. F. Sowers of the Department of Civil Engineering, Georgia Institute of Technology, stated in a written communication in 1976:

While it is presently true that states and the federal government as owners invoke the protection of "sovereign immunity," there are many indications that this sheltered position will not always be the case. Public sympathy has generated pressure on state legislatures that has caused them to admit liability. In cases where the doctrine of sovereign immunity has held, the injured party and, too often, some overly zealous members of the legal profession have sought other sources of relief. These involve the designers of the works, the builders, and even private maintenance forces. While presently employees of the governmental bodies appear to be held harmless from legal action, there are indications that it is possible to bring personal suits for negligence against such employees. While such lawsuits may eventually be lost, there are enough lawyers who will take the statistical chance that some cases will not be thrown out of court that we should expect to see personal suits against political administrators, public employees, and everyone who has anything to do with construction, whether they are responsible or not.

Lewis and others (*1.20*) divided the legal rights of private citizens against public agencies with regard to landslides into two categories:

1. A property owner's rights in response to invasion of the property by sliding material or interference with the lateral support of the property by construction or maintenance of a public way and
2. A highway traveler's rights in tort against a public entity for injuries sustained from a landslide that resulted in part from the negligent construction or maintenance of a public way.

The extent of such rights varies among states, but a general discussion is given below.

Liability in Invasion of Property or Loss of Support

When a landslide results in damage to property, either by invasion of the property or loss of its lateral support, the liability of a public entity is not necessarily based on statutes. Under the fifth amendment to the U.S. Constitution, just compensation must be paid when public works or other governmental activities result in the taking of private property; that concept can be extended to the damaging of property as a result of an action of a public agency. The owner of the property brings an action known as an inverse condemnation suit to recover damages. According to Love, many state constitutions contain provisions similar to those of the fifth amendment, but, even in the absence of such a limitation in a state constitution, the courts have held that a state cannot take (or damage) private property for public use without just compensation.

The case of *Albers v. County of Los Angeles* [62 Cal. 2d 250, 42 Cal. Rptr. 89 (1965)], which established, or broadened, the concept of inverse condemnation in California, provides an outstanding example of the manner in which the state courts have interpreted constitutional provisions for the payment of just compensation in the event that private property is either taken or damaged. In that litigation, which was concerned with the Portuguese Bend landslide on the Palos Verdes Peninsula in southern California, the plaintiffs alleged that the county of Los Angeles had constructed Crenshaw Boulevard through an ancient landslide area and that in the course of carrying out the construction program had placed some 134 000 m^3 (175 000 yd^3) of earth at a critical spot in the landslide area, causing reactivation of movement and consequent damage to the plaintiffs' properties (*1.26, 1.29*). The constitution of the state of California guarantees that property of a private property owner will not be damaged or taken for public use unless just compensation for it is given to the property owner. This constitutional protection is the basis on which the property owners recovered $5 360 000 from the county of Los Angeles (*1.24*).

It can be concluded that, if public-works activities result in the creation of a new landslide or the reactivation of an old landslide that causes damage to private property, the public entity is liable to the full extent of such damage if the particular state has such a constitutional provision. According to Love, even in jurisdictions that do not have a provision relating directly to damage of private property, the courts have tended to find that the damage that resulted to the private property constitutes a taking for which just compensation must be paid.

Liability for Injuries Sustained From a Landslide

Love states that, although the courts have made it clear that a public entity is not an insurer of the safety of persons using its highways, in certain circumstances travelers are protected by law from landslides. In general, the public entity will not be held liable for injuries if it can be shown that the acts or omissions that created the dangerous condition were reasonable or that the action taken to protect against such injuries or the failure to take such action was reasonable. The reasonableness of action or inaction is determined by considering the time and opportunity that the public employees had to take action and by weighing the probability and gravity of potential injury to persons foreseeably exposed to the risk of injury against the practicality and cost of protecting against such injury.

In California, most actions involving personal injury to highway travelers as a result of landslides are based on a statute that imposes liability for the dangerous condition of public property. The injured person must prove that the public property was in dangerous condition at the time of the injury, that the injury resulted from that dangerous condition, and that the dangerous condition created a foreseeable risk of the kind of injury incurred. Love points out that, in addition, the dangerous condition must be the result of negligence, a wrongful act, or failure of an employee of the public entity to act within the scope of his or her employment, and the public entity must have had notice of the dangerous condition in sufficient time prior to the injury to have taken measures to protect against it. Thus, liability depends on whether circumstances and conditions were such that the danger was reasonably foreseeable in the exercise of ordinary care and, if so, on whether reasonable measures were taken by the public entity to prevent injury (39 Am. Jur. 2d *Highways* §532, p. 939).

A public entity, since it is not an insurer of the safety of travelers on its highways, need only maintain highways in reasonably safe condition for ordinary travel under ordinary conditions or under such conditions as should reasonably be expected (*1.20*). In the case of *Boskovich v. King County* [188 Wash. 63, 61 P. 2d 1299 (1936)], the court held that a motorist was not entitled to recover from the highway department for injuries sustained when a landslide broke loose from a steep hillside bordering a highway and struck his automobile because there was no proof that negligence in construction or maintenance of the highway was the cause of the landslide.

Landslides and Property Development

This section discusses liability related to damages from landslides caused by the development of private property. Detailed information on litigation related to landslides in property developments is given by Sutter and Hecht (*1.33*).

The current trend in public policy is toward protection of the consumer, a reversal of the days when caveat emptor (let the buyer beware) reflected public policy (*1.27*). This trend has extended to home purchasers since they are protected by law against losses due to improper workmanship or poor planning, including certain losses due to landslides.

The trend toward increased protection for the homeowner has resulted in a drastic increase in the number of legal cases involving landslides on private property. After consulting with an attorney, the owner of a home that has suffered damage from a landslide typically files legal action against the developer, the civil engineer who laid out the development, the geotechnical engineer, the geologist, the grading contractor, the city, the builder, the lending agency, the insurance company that insured the home, the former owner, and the real estate agent handling the sale if the property was not purchased directly from the developer (*1.11*). A typical complaint may seek recovery on theories of strict liability (i.e., liability without fault), negligence, breach of warranty, negligent misrepresentation, fraud, and, if a public entity is involved, inverse condemnation (*1.27*). In most cases, the developer is the prime target because he is subject to strict liability for "defects" in the construction of the house or grading of the lot; to establish strict liability against any of the other parties such as the soils engineer or the geologist is much more difficult.

Liability of Engineers and Geologists for Landslide Damages

There has been a certain amount of variability in legal interpretations of liability of geotechnical engineers and geologists in regard to landslide losses; such liability is discussed below, but the conclusions reached are general in nature and not necessarily valid in any specific court.

Liability of geotechnical engineers and engineering geologists for landslide damages to home sites is based most often on the theory of negligence and occasionally on negligent misrepresentation. Although allegations seeking to recover damages from geotechnical engineers and geologists on the basis of strict liability, breach of warranty, or intentional misrepresentation are often included in a complaint, they are not usually applicable under normal circumstances. Patton (*1.27*) discussed each of these theories of liability as it applies to engineering geologists as follows, and it is felt that Patton's line of reasoning can be extended to include geotechnical engineers involved in development of private property.

1. Negligence

The most common theory of liability alleged against engineering geologists is negligence. Negligence is the omission to do something which an ordinarily prudent person would have done under similar circumstances or the doing of something which an ordinarily prudent person would not have done under those circumstances. An engineering geologist is required to exercise that degree of care and skill ordinarily exercised in like cases by reputable members of his profession practicing in the same or similar locality at the same time under similar conditions. He has the duty to exercise ordinary care in the course of performing his duties for the protection of any person who foreseeably and with reasonable certainty may be injured by his failure to do so.

Although failing to comply with a state statute or with county or municipal ordinances normally is considered to be negligence per se, the mere compliance with the letter of the law in such cases does not necessarily relieve one of liability since it generally is recognized that statutes and ordinances set forth only minimum requirements and circumstances may require more than the minimum. An engineering geologist cannot rely upon the approval of a project by an inspector for a governmental agency to relieve him of liability.

2. Negligent misrepresentation

Negligent misrepresentation is a species of fraud along with intentional misrepresentation and concealment. Negligent misrepresentation is simply the assertion, as a fact, of that which is not true by one who has no reasonable ground for believing it to be true. Although misrepresentations of opinions generally are not actionable, they become actionable where the person making the alleged misrepresentation holds himself to be specially qualified to render the opinion. A statement of opinion by an engineering geologist that no unsupported bedding occurs in a particular slope, could be actionable as negligent misrepresentation if he has no basis for that opinion.

3. Intentional misrepresentation and concealment

Intentional misrepresentation (the assertion, as a fact, of that which is not true by one who does not believe it to be true) and concealment (the suppression of a fact or condition by one who is bound to disclose it) are species of fraud which are seldom if ever applicable to engineering geologists. Such conduct on the part of an engineering geologist is not only legally actionable but raises serious doubts about the professional integrity of the geologist involved.

4. Breach of warranty

Breach of warranty is generally not available as a viable theory of recovery against an engineering geologist.

5. Strict liability

Although the theory of strict liability is still developing and its limits are not as yet clearly defined, it would appear now that an engineering geologist would not be liable on the theory of strict liability lacking some participation as the developer of mass produced property. Other cases indicate that the theory is available only against the developers of mass-produced property and would not be available against the developer of a single lot or building site. There is no clear indication as to at what point between development of a single lot and development of a tract the theory becomes applicable. It does seem clear at this time that if an engineering geologist offers only professional services in connection with the development of even a large tract he will not subject himself to strict liability.

In regard to negligence, Sowers noted:

Unfortunately, the legal profession has been expanding the definition of negligence to any act committed by the public official, engineer or contractor. Some courts have applied the most extravagant standards of professional knowledge to average run-of-the-mill design and construction. In other words, some courts would presume that every engineer must possess the wisdom and expertise of a Terzaghi.

In voicing an opinion somewhat different from Patton's in regard to strict liability, Fife, another California attorney active in litigation involving geologists and geotechnical engineers, stated in 1973 that professional liability of the technical professional was approaching a major crossroad in its development (*1.9*). Fife felt that the scope of professional liability in the technical disciplines was at the point where it would proceed either toward strict liability under pressure from skilled plaintiff's counsel or toward a "reasonableness standard" by which adherence to the average standards of the profession involved would constitute a complete defense. However, unless professional groups become more actively involved in the process of shaping the future scope of their professional liability, eventual application of strict liability to technical professionals seems inevitable.

In their book, *Landslide and Subsidence Liability* (*1.33*), Sutter and Hecht present considerable information on strict liability in California. Since November 1973, the cutoff date for the cases included in this reference, certain California court decisions have changed the liability of geologists and geotechnical engineers from strict liability to liability for negligence only. The publisher, California Contunuing Education at the Bar, plans periodic supplements to cover changes that have occurred since Sutter and Hecht's book was published.

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Figure 1.1	Courtesy of Tennessee Department of Transportation
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