

## Chapter One

# Introduction

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Landslides are of profound interest to the common man. This interest stems from the fact that landslides, like volcanic eruptions, floods, and hurricanes, mean destruction of life and property by the forces of nature. Because landslides occur in a wide range of environments, they are seen and at least partly understood by almost everyone. It is little wonder that reports of "moving mountains," of rock avalanches, and even of trains or motor traffic held up by slides all capture the public imagination.

But to the scientist and the engineer, landslides are of even greater and more immediate interest than to the layman. The geologist is interested both academically and practically. He recognizes landsliding as one of the most widespread and effective agents in sculpturing of the earth's surface. To him, then, each landslide is an opportunity to understand a little better the makeup of the earth and the history of its surface. But his interest is also intensely practical, for his inquiry into the cause, character, and history of a landslide can and should provide the engineer with many of the answers that are needed for decisions as to effective methods of control, correction or prevention.

The engineer and the geologist who works with him are interested in landslides because their job is to build and maintain safe, economical, and useful structures on the earth's surface. A landslide, unforeseen or improperly provided for, may destroy their structure

or impair its usefulness. Such a landslide may mean death to people who have trusted the structure; repair of the structure will most certainly cost money. Even an insignificant little slide, sloughing off into a roadside ditch, may wreck an automobile; or if it is continuous, it may in time run up enormous maintenance costs.

It is the purpose of this volume to bring together in coherent form and from a wide range of experience such information as may be useful to any engineer who must recognize, avoid, control, design for, or correct the more important types of landslide movement.

Because the book is designed for practical use, theoretical discussions are minimized, whereas those phases held to be of greater interest to the practicing engineer are emphasized over others. As shown in the table of contents, the book is divided into two parts. Part I, called Definition of the Problem, is intended to provide the engineer with the tools and methods he needs to solve an actual or potential landslide problem. Part II, called Solution of the Problem, summarizes the methods known to have been applied to the prevention and control of landslides; it also discusses the methods of making stability analyses and of using them in the solution of design problems. In this part every effort has been made to distinguish between those methods that have proved successful under given circumstances and those that have not. The brief closing chapter points out the kinds of information on landslides and their con-

<sup>1</sup>Publication authorized by the Director, U. S. Geological Survey.

trol that are still lacking and suggests methods by which such information may possibly be obtained.

In its attempt to cover the entire field of landslides, from causes to cures, the volume is, to the authors' knowledge, unique in the English language. In fact, the only foreign-language book known to the committee that is of comparable scope is that of Knorre, Abramow, and Rogosin (1951). There are available, of course, excellent books and articles that treat one or more facets of the entire problem far more fully than can be done here; these have been drawn on heavily, and are listed in the bibliographies that close each chapter.<sup>2</sup>

Partly because of its comparatively wide scope, and partly because of the spread of interests and knowledge within the committee, the book may seem to assume a knowledge of more specialties than are commonly held by any individual engineer or geologist. Without expanding the book unduly, the reader can only be referred to the standard texts and handbooks on geology, soils, hydrology, mechanics, foundations, and construction methods, or to some of the specialized glossaries of scientific and engineering terms.

There is no expectation that the reader of this book will become an expert on all phases of the investigation and treatment of landslides. Rather, it has been the aim of the compilers to provide an introduction to all of the main factors that go into the solution of a given landslide problem. The average engineer, to whom a landslide is only one of many different problems that he encounters in his work, should be able to use the tools presented here himself or else should

be able to determine from the facts given here when it is time to call in a specialist on one or another phase of his investigation. On the other hand, the specialist in some phase of landslide studies should gain an appreciation of the many facets of a landslide problem and of how his specialized knowledge of one facet can best be applied toward solution of the total problem.

### Definitions and Restrictions

As described more fully in Chapter Three, the term "landslide" is defined for use in this volume as downward and outward movement of slope-forming materials—natural rock, soils, artificial fills, or combinations of these materials.

Normal surficial creep is arbitrarily excluded from consideration, as are subsidence without downslope movement and most types of movement due to freezing and thawing of water. Similarly, landslide phenomena in tropic and arctic climates, and their treatment, are almost entirely neglected here. A few examples are drawn from other countries, but as the writers and their informants are largely experienced in the United States, most of the descriptions of landslides and of engineering techniques are drawn from this country.

It was perhaps inevitable, considering the makeup of the committee and the sources of information easily available to it, that the volume should seem to stress the landslide problems related to highways and railroads almost to the exclusion of many other landslide problems, such as those of shorelines and waterways, of city, suburban, and resort developments, and of farmlands. This apparent neglect has not been intentional—nor should it necessarily detract from the applicability of the facts contained herein to the solution of landslide problems other than those encountered by highway and railroad engineers. 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.

<sup>2</sup> Just as the manuscript of this volume was ready for submittal to the Highway Research Board there appeared an English translation of a more than worthy forerunner of this book (Collin, 1846, 1956). Although the French original is more than a century old, this fascinating and remarkable volume bears much resemblance to the present one. To include adequate references to Collin's pioneer work would have required some revision of fully one-half the chapters in this book, a job that would have unduly delayed its appearance. Suffice it to call attention to it here and to commend it as a "must" to every serious student of landslides or of the application of soil mechanics and stability analyses to landslide problems.

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.

### Method of Compilation

Early in May 1949 the present chairman was asked by Mr. Harold Allen, then Chairman, Department of Soils Investigations, Highway Research Board, to set up a committee on landslide investigations. This invitation was accepted soon after, but it was not until January 1951 that a committee was finally formed and the first meeting held.

In choosing the committee, and in adding to it from time to time, deliberate efforts were made to get wide geographic representation. An approximate balance between practicing engineers and geologists, as well as the spread of the membership between state highway, educational, and governmental organizations, was also a deliberate objective in setting up the committee.

By the end of 1951 the committee had sponsored publication of a bibliography on landslides (Tompkin and Britt, 1951) and had decided to put its main efforts into compiling the present volume. It had also adopted a general outline for the book and had made tentative assignments of authors to prepare the individual chapters. Since early 1952 progress and content of each chapter has been thoroughly discussed and reviewed by the entire committee, not only through correspondence but also at a series of semiannual meetings. Therefore, even though the individual chapters are credited to those authors who had primary responsibility for preparing them, each chapter is actually the

product of the entire committee and represents its combined views.

The editor of the volume has merely woven the units into the whole, in an effort to make the book stand as a unit rather than as a symposium of related papers. Despite this effort, the critical reader may soon find that some if not most of the chapters tend to have a provincial flavor, in that much of the exemplary material comes from the state or region most familiar to the author of that chapter. This was almost inevitable, for each author quite naturally drew on his own experience in preparing his material. This provinciality of its parts need not, however, be an obstacle in the usefulness of the whole. As was mentioned previously in relation to the stress on highways and railroads, the basic problems presented by landslides are much alike everywhere, so that examples taken from one part of the country can usually be applied in another part. In addition, it is believed that if taken all together, the examples given in this volume provide a fairly representative cross-section of landslide problems throughout the United States.

### The Questionnaire

Early in its work the committee realized that it needed many more data, based on actual experience, than were available in the literature or in the minds and files of the dozen or so committee members themselves. After exploring a number of possible methods for gathering additional data it was decided to prepare and circulate a questionnaire to all available geologists and engineers whose work was likely to bring them into contact with the landslide problem. This decision was not taken without misgivings; preparing and distributing the questionnaire meant much additional work and delay for the committee, and far more work in analyzing and using the results. More important was the imposition on the time, energy, and good will of countless busy men who would be asked to contribute to the

questionnaires in some way. The results were gratifying beyond all expectations; they form the basis of much that is new and worthwhile in this book.

Questionnaires were sent to the state highway departments, state geologists, the larger railroads in the United States, the Canadian railroads, and all Federal Government agencies concerned with major engineering construction work. By personal requests of committee members and through announcements in the technical press, several turnpike authorities and many company and private engineers and geologists, as well as the civil engineering and geology departments of some colleges and universities, were also asked to help.

Of some 250 questionnaires that were sent out to individuals and groups, about 75 were returned. Naturally, these varied in their degree of completeness, but all contained information of value to the committee. In addition to the data contained in the completed questionnaires, there were many special reports on individual landslide problems that would not have come to the attention of the committee or of the engineering profession except as a result of the questionnaire. A great number of useful facts also came in letters, with or without completed questionnaires. Even those that were confined to negative statements were valuable. The fact that certain states have no landslide problems, for instance, is just as useful in a study of this kind as full descriptions of landslide problems in some other states.

Doubtless because the committee worked under the auspices of the Highway Research Board and because its work emphasized the problems of highways and railroads, responses from the state highway departments and from the United States and Canadian railroads were more numerous and comprehensive than the responses from most other sources. Some Federal agencies, however, were not far behind the railroads and highways; some of the most useful specific descriptions and illustrations came from them and from a few

state geologists and private engineers.

Because it is of possible interest to the reader in seeing the kind of information made available to the committee, the entire questionnaire is reproduced in the Appendix.

#### PERMANENT FILE OF QUESTIONNAIRES

Every effort was made to wring the last drop of value from the questionnaires received. All of them were studied by each member of the committee, and pertinent material was abstracted by the authors of the several chapters for use in their compilations. Even so, the completed questionnaires, together with numerous letters relating to them, obviously must contain far more data than could possibly be condensed into a book of this kind. Moreover, they represent an incalculable investment of time, energy, and good will by a great many engineers and geologists. To do justice to these men and to their data, it has seemed essential that the material be preserved in its original form. Accordingly, except for the few that contained confidential information and that have been returned to their authors, all questionnaires, together with pertinent extracts from letters received by the committee, have been deposited with the Highway Research Board Library in Washington, D. C. There they will be accessible for research purposes to any future student of landslides, whether he be interested in generalizations such as are represented in this book or in the details of particular case histories with which much of the material abounds.

#### Acknowledgments

The efforts of this committee, large though they were, would have been well-nigh valueless without the assistance of countless others. Literally hundreds of engineers and geologists, living and dead, have contributed in greater or lesser degree to the quantity of facts condensed within these pages. Many such contributions are in the international literatures of geology and of engi-

neering; many others were in the minds of individuals or in official files and come to light now through the medium of the committee's questionnaire or of conversations and correspondence with members of the committee. To list all the contributors, direct and indirect, is impossible; to list those who contributed most would be unfair to others. All that can be done is to express deep appreciation to all who added anything whatever to the wealth of technical and scientific facts that have been considered. All of them are assured that the committee, individually and collectively, considers itself a compiler of their information, rather than an originator of new information.

To the entire staff of the Highway Research Board, thanks are owed, not only for moral and financial support but also for many other tangible and intangible aids given throughout the work. In particular, mention should be made of Messrs. Fred Burggraf and Roy W. Crum, Director and former Director; Frank R. Olmstead and Harold Allen, Chairman of the Department of Soils, Geology and Foundations, and former Chairman of the Department of Soils Investigations; and A. Walton Johnson, Engineer of Soils and Foundations, for their constant encouragement and advice. W. A. Warrick, the only committee member not specifically credited with authorship of any of its parts, nevertheless contributed much to the volume. Acting as friendly advisor and critic, he kept the rest of the committee on the track of practicality.

Two members of the U. S. Geological Survey — John R. Stacy, who prepared many of the illustrations, and Bernice M. Peterson, who acted as secretary to the chairman, hence to the committee — contributed much. To them and to the technical and secretarial staff members of each of the committee members we are grateful, as we all are to the officers of our parent organizations who permitted us to devote so much official time and energy to this undertaking.

Finally, not as chairman of this committee, nor as editor of this book, but as a person, I want to express my deepest gratitude and thanks to all the members of the committee. For more months than I care to count each one has worked earnestly; each has put into the job far more than he could hope to take out of it. From all our discussions, formal and informal, has come a comradeship and a mutual understanding of the problems of engineers and geologists that is all too rare. We have worked together — and we have had fun doing it.

### References

- Knorre, M. E., Abramow, S. K., Rogosin, I. S., "Erdbeben und ihre Bekämpfung (Landslide and Its Control.)" Moscow, 1951. German translation: Schriftenreihe des Verlages Technik, Band 89, 141 p., 60 figs., 15 bibl. refs., VEB Verlag Technik, Berlin, 1953.
- Tompkin, J. M., and Britt, S. H., "Landslides." A selected annotated bibliography. Highway Research Board Bibliography 10, 53 p., 1951.