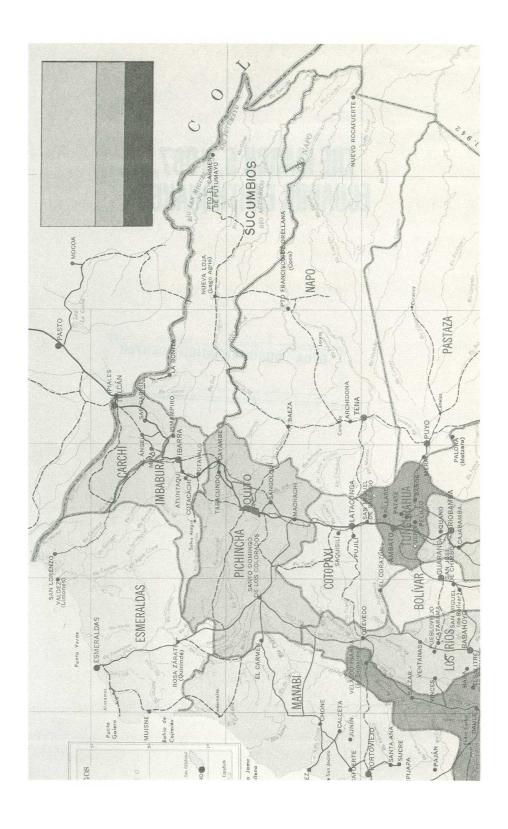
THE MARCH 5, 1987, ECUADOR EARTHQUAKES



NATURAL DISASTER STUDIES

Volume Five

THE MARCH 5, 1987, ECUADOR EARTHQUAKES MASS WASTING AND SOCIOECONOMIC EFFECTS

Study Team:

Robert L. Schuster (Team Leader and Technical Editor), Branch of Geologic Risk Assessment, U.S. Geological Survey, Denver, Colorado

Patricia A. Bolton, Battelle Institute, Seattle, Washington

Louise K. Comfort, Graduate School of Public and International Affairs, University of Pittsburgh, Pennsylvania

Esteban Crespo, School of Civil and Environmental Engineering, Cornell University, Ithaca, New York

Alberto Nieto, Department of Geology, University of Illinois, Urbana

Kenneth J. Nyman, School of Civil and Environmental Engineering, Cornell University, Ithaca, New York

Thomas O'Rourke, School of Civil and Environmental Engineering, Cornell University, Ithaca, New York

Contributing Authors:

José Egred, Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador

Alvaro F. Espinosa, Branch of Geologic Risk Assessment, U.S. Geological Survey, Denver, Colorado

Manuel García-Lopez, Departamento de Ingeniería Civil, Universidad Nacional de Colombia, Bogotá

Minard L. Hall, Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador

Galo Plaza-Nieto, Departamento de Geotécnica, Escuela Politécnica Nacional, Quito, Ecuador

Hugo Yepes. Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador

For:

Committee on Natural Disasters
Division of Natural Hazard Mitigation
Commission on Engineering and Technical Systems
National Research Council

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Frank Press is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Stuart Bondurant is acting president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Frank Press and Dr. Robert M. White are chairman and vice-chairman, respectively, of the National Research Council.

Library of Congress Catalog Card Number 91-67348 International Standard Book Number 0-309-04444-8

A limited number of copies of this monograph are available from:

Committee on Natural Disasters, HA 258 National Research Council 2101 Constitution Avenue, N.W. Washington, DC 20418 202/334-3312

Additional copies are available for sale from:

National Academy Press 2101 Constitution Avenue, N.W. Washington, DC 20418 202/334-3313 1-800-624-6242

Printed in the United States of America S-314

NATURAL DISASTER STUDIES

An Investigative Series of the Committee on Natural Disasters

The Committee on Natural Disasters and its predecessors, dating back to the committee that studied the 1964 Alaska Earthquake, have conducted on-site studies and prepared reports reflecting their findings and recommendations on the mitigation of natural disaster effects. Objectives of the committee are to:

- record time-sensitive information immediately following disasters;
- provide guidance on how engineering and the social sciences can best be applied to the improvement of public safety;
- recommend research needed to advance the state of the art in the area of natural disaster reduction; and
- conduct special studies to address long-term issues in natural disasters, particularly issues of a multiple-hazard nature.

EDITOR

Riley M. Chung National Research Council

EDITORIAL BOARD

| Dennis S. Mileti, Chair |
|---------------------------|
| Colorado State University |
| Fort Collins |

Arthur N. L. Chiu University of Hawaii at Manoa Honolulu

Joseph H. Golden National Oceanic and Atmospheric Administration Washington, D.C.

| Dale C. Perry |
|----------------------|
| Texas A&M University |
| College Station |

| Norbert S. Baer | | | | |
|-----------------|------------|-------|--|--|
| New | York Unive | rsity | | |
| New | York, New | York | | |

| Hanna J. Cortner |
|-----------------------|
| University of Arizona |
| Tucson |

Wilfred D. Iwan California Institute of Technology Pasadena

| William J. Petak |
|------------------------|
| University of Southern |
| California |
| Los Angeles |

Earl J. Baker Florida State University Tallahassee

Peter Gergely Cornell University Ithaca, New York

Ahsan Kareem University of Notre Dame Notre Dame, Indiana

Robert L. Schuster U.S. Geological Survey Denver, Colorado

SPONSORING AGENCIES

Federal Emergency Management Agency
National Oceanic and Atmospheric Administration
National Science Foundation

INVITATION FOR DISCUSSION

Materials presented in *Natural Disaster Studies* often contain observations and statements that inspire debate. Readers interested in contributing to the discussion surrounding any topic contained in the journal may do so in the form of a letter to the editor.

COMMITTEE ON NATURAL DISASTERS (1987–1990)

- NORBERT S. BAER, Conservation Center of the Institute of Fine Arts, New York University, New York
- EARL J. BAKER, Department of Geography, Florida State University, Tallahassee
- ARTHUR N. L. CHIU, Department of Civil Engineering, University of Hawaii, Manoa
- HANNA J. CORTNER, Water Resources Research Center, University of Arizona, Tucson
- JOHN A. DRACUP, Civil Engineering Department, University of California, Los Angeles
- DANNY L. FREAD, National Weather Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland
- PETER GERGELY, Department of Structural Engineering, Cornell University, Ithaca, New York
- JOSEPH H. GOLDEN, Chief Scientist Office, National Oceanic and Atmospheric Administration, Washington, D.C.
- WILFRED D. IWAN, California Institute of Technology, Pasadena
- AHSAN KAREEM, Civil Engineering Department, University of Notre Dame, Notre Dame, Indiana
- DENNIS S. MILETI, Department of Sociology, Colorado State University, Fort Collins
- JOSEPH PENZIEN, Department of Civil Engineering, University of California, Berkeley
- DALE C. PERRY, Department of Construction Science, College of Architecture, Texas A&M University, College Station
- WILLIAM J. PETAK, Institute of Safety and Systems Management, University of Southern California, Los Angeles
- ROBERT L. SCHUSTER, Branch of Geologic Risk Assessment, U.S. Geological Survey, Denver, Colorado
- RANDALL G. UPDIKE, Office of Earthquakes, Volcanoes and Engineering, U.S. Geological Survey, Reston, Virginia

Staff

RILEY M. CHUNG, Committee Director EDWARD LIPP, Editor SUSAN R. MCCUTCHEN, Administrative Assistant SHIRLEY J. WHITLEY, Project Assistant

Liaison Representatives

- WILLIAM A. ANDERSON, Earthquake Systems Integration, Division of Biological and Critical Systems, National Science Foundation, Washington, D.C.
- BRUCE A. BAUGHMAN, Hazard Mitigation Branch, Public Assistance Division, Federal Emergency Management Agency, Washington, D.C.
- FRED COLE, Office of U.S. Foreign Disaster Assistance, Agency for International Development, U.S. Department of State, Washington, D.C.
- TERRY FELDMAN, Disaster Assistance Program, Federal Emergency Management Agency, Washington, D.C.
- ROBERT D. GALE (deceased), U.S. Department of Agriculture/Forest Service, Washington, D.C.
- EDWARD M. GROSS, Constituent Affairs and Industrial Meteorology Staff, National Weather Service, National Oceanic and Atmospheric Administration, Silver Spring, Maryland
- WILLIAM HOOKE, Chief Scientist Office, National Oceanic and Atmospheric Administration, Washington, D.C.
- PAUL KRUMPE, Office of U.S. Foreign Disaster Assistance, Agency for International Development, U.S. Department of State, Washington, D.C.
- ELEONORA SABADELL, Division of Biological and Critical Systems, National Science Foundation, Washington, D.C.
- GERALD F. WIECZOREK, Office of Earthquakes, Volcanoes and Engineering, U.S. Geological Survey, Reston, Virginia
- ARTHUR J. ZEIZEL, Office of Natural and Technological Hazards Programs, State and Local Programs and Support, Federal Emergency Management Agency, Washington, D.C.
- LAWRENCE W. ZENSINGER (Alternate), Office of Disaster Assistance Programs, State and Local Programs and Support, Federal Emergency Management Agency, Washington, D.C.

Acknowledgments

The study team was organized by the NAS/NRC Committee on Natural Disasters. Funding for travel for field studies and working meetings by the team was provided by NAS/NRC. Salaries for the study participants were provided by the individual organizations with which team members and other authors are affiliated. Dr. Espinosa's travel was funded by the U.S. Agency for International Development.

Within Ecuador, assistance and cooperation were provided by numerous governmental agencies, companies, and academic institutions. Although specific acknowledgments are presented in following chapters for the contributions of individual Ecuadorian organizations, we would especially like to thank officials and personnel of the Ministerio de Energía and the Instituto Ecuatoriano de Minería (INEMIN) and the Institute of Governmental Studies, who helped us both technically and logistically; Corporación Estatal Petrolera Ecuatoriana (CEPE)/Texaco, Inc., which provided helicopter transportation and lodging in the field area; and Instituto Ecuatoriano de Electrificación (INECEL), which provided technical support. We also would like to acknowledge the valuable technical advice and support we received from faculty members of the Instituto Geofísico of the Escuela Politécnica Nacional in Quito and Professor O. Lara of the Escuela Politécnica del Litoral in Guayaquil, who assisted in the initial stage of field reconnaissance.

Preface

After the March 5, 1987, earthquakes in Ecuador, the National Research Council, in cooperation with several other institutions, organized a postdisaster reconnaissance team to visit the disaster sites. The team was multidisciplinary, reflecting expertise in seismology, geology, geotechnical engineering, lifeline engineering, sociology, and the political sciences, in order to study the physical, social, and economic impacts on the nation resulting from the earthquakes. The team's effort in conducting its field work was greatly enhanced by a number of experts from local organizations and institutions. The eight chapters presented in this report are the contributions of the official members of the National Research Council team and their Ecuadorian colleagues working hand in hand to document and analyze these earthquakes. The individual chapters are the independent contributions of one or more of the individuals involved in the study. Efforts have been made by the team leader and the report's editor to eliminate duplications as much as possible. Remaining duplications are retained to allow the presentations to stand alone so that readers will not be burdened with cross referencing.

Robert L. Schuster
Team Leader and Technical Editor

Contents

| E | XECUTIVE SUMMARY 1 |
|---|--|
| 1 | INTRODUCTION (R. L. Schuster) |
| 2 | GENERAL GEOLOGY OF NORTHEASTERN ECUADOR (A. S. Nieto) |
| 3 | TECTONICS AND SEISMICITY (A. F. Espinosa, M. L. Hall, H. Yepes) |
| 4 | INTENSITY AND DAMAGE DISTRIBUTION (A. F. Espinosa, J. Egred, M. García-Lopez, E. Crespo) |
| 5 | MASS WASTING AND FLOODING (A. S. Nieto, R. L. Schuster, G. Plaza-Nieto) |

xii CONTENTS

| | Flooding of River Valleys in the Vicinity of Reventador Volcano, 73 References, 80 |
|----|--|
| 6 | EFFECTS ON LIFELINES (E. Crespo, T. D. O'Rourke, K. J. Nyman) |
| 7 | LOCAL-LEVEL ECONOMIC AND SOCIAL CONSEQUENCES (P. A. Bolton) |
| 8 | ORGANIZATIONAL INTERACTION IN RESPONSE AND RECOVERY (L. K. Comfort) |
| ΑI | PPENDIXES |
| | Disaster-Management Organizations—General, 156 |
| В. | International Organizations Involved in the March 1987 Disaster Operations, 158 |
| | Ecuadorian Organizations Involved in the March 1987 Disaster Operations, 160 |
| D. | Most-Damaged Areas, 163 |