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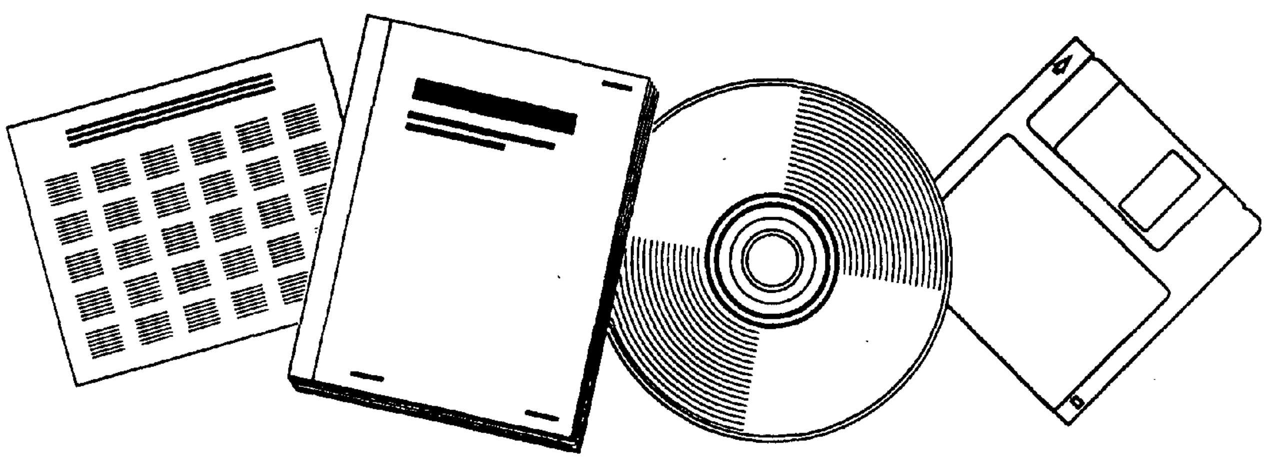
THE SAN FERNANDO EARTHQUAKE OF FEBRUARY 9, 1971. LESSONS FROM A MODERATE EARTHQUAKE ON THE FRINGE OF A DENSELY POPULATED REGION

NATIONAL ACADEMY OF SCIENCES, WASHINGTON, DC

1971



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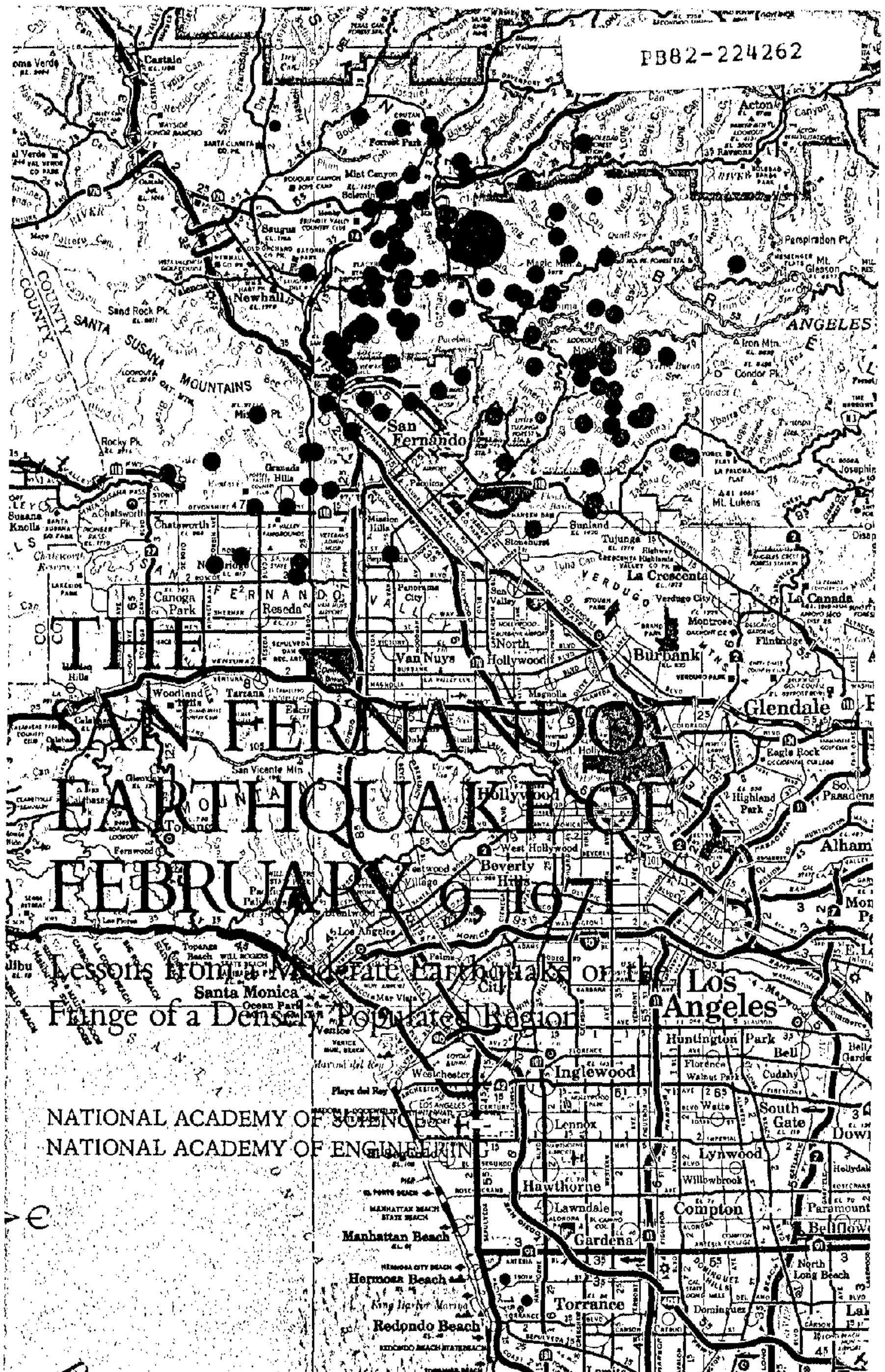

THE SAN FERNANDO EARTHQUAKE OF FEBRUARY 9, 1971

Lessons from a Moderate Earthquake on the Fringe of a Densely Populated Region

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING

THE SAN FERNANDO EARTHQUAKE OF FEBRUARY 9, 1971

Lessons from a Moderate Earthquake on the Fringe of a Densely Populated Region

Prepared by
The Joint Panel on the San Fernando Earthquake

DIVISION OF EARTH SCIENCES
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
WASHINGTON, D.C. 1971

March 22, 1971

The President
The White House
Washington, D.C.

Dear Mr. President:

The National Academy of Sciences and the National Academy of Engineering convened a group of experts at Pasadena, California, during late February to determine what lessons could be learned at this time from the San Fernando Earthquake of February 9, 1971. We hope that the report of this group will aid in planning the means for minimizing losses from earthquakes that will certainly occur many times in the future in earthquake-prone regions of the United States.

Sincerely yours,

Philip Handler, President
National Academy of Sciences

Clarence H. Linder, President
National Academy of Engineering

Preface

The San Fernando Earthquake of February 9, 1971, offered a unique opportunity to assess many of the important scientific, engineering, and human concerns associated with earthquakes in a modern urban environment. The presence in California of major universities with strong and active earthquake research groups and of excellent scientific units of federal and state agencies, coupled with easy access to all affected areas, provided the prospect of rapid and comprehensive analysis of all major aspects of the event. The Division of Earth Sciences therefore established the Joint Panel on the San Fernando Earthquake to draw from the event and its effects significant lessons that can be of benefit in mitigating the impact of future earthquakes on man and his works.

The Panel is under the joint auspices of the NAS Committee on Seismology, the NAE Committee on Earthquake Engineering Research, and the NAS-NAE U.S. National Committee for Rock Mechanics (see Appendix A). The group met on February 25–27, 1971, at the California Institute of Technology, in Pasadena, to examine the earthquake area and to prepare this report. Invited observers from Federal agencies and agencies of the State of California visited earthquake sites with the Panel and participated in background discussions (see Appendix B).

Contents

THE JOINT PANEL ON THE
SAN FERNANDO EARTHQUAKE

CLARENCE R. ALLEN, California Institute of Technology, *Chairman*
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Introduction

The Los Angeles region, which was hard hit on its northern fringes by the moderate earthquake of February 9, 1971 (Richter magnitude 6.6), is a region in which much attention has been given to the earthquake hazard. Even then, this natural violence of the earth directly affected more than 400,000 people in the city of San Fernando and surroundings by damaging or destroying homes and public facilities and utilities—with a cost of 64 lives and perhaps as much as a billion dollars (see Figure 1). Collapse of a portion of the Van Norman Dam led to the evacuation of 80,000 inhabitants living below the dam for several days while water was drained from the reservoir to avert imminent rupture of the dam and a catastrophe unprecedented in this country.

The ground quaked early in the morning (about six a.m. local time) while highways were relatively free of traffic and before most workers had occupied offices in public buildings, and this minimized loss of life. Some of the earthquake losses can and will be restored in the near future; others, such as transportation disruption, severe damage to public utilities and facilities, and serious lowering of water-storage capacity, will take longer; and some losses can never be regained. These effects will force

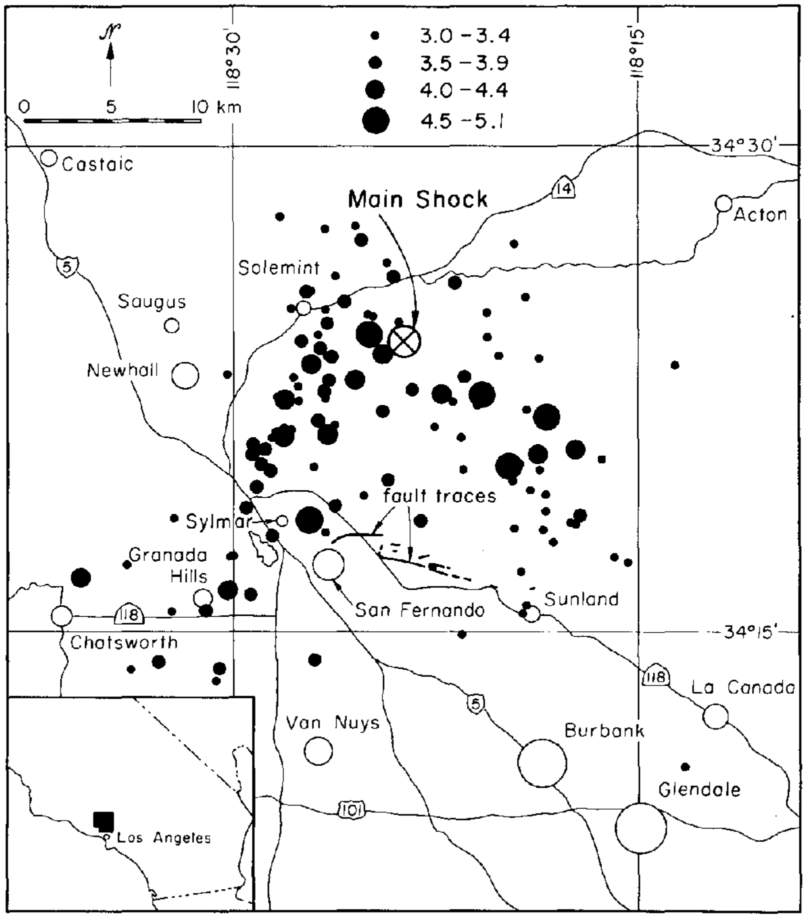

FIGURE 1 The San Fernando Earthquake of February 9, 1971. The map shows the location of the epicenter of the main shock (magnitude 6.6) and of representative aftershocks (magnitudes greater than 3) through March 1, 1971. Approximate traces of some of the faulting activated during this earthquake are also shown. *Prepared by the Seismological Laboratory, California Institute of Technology.*

stricter earthquake preparedness measures in the Los Angeles area—and, we may hope, in other areas as well—as it is now clear that better preparation could have been made.

The particular location of this shock was not previously suspect any more than the heart of Los Angeles, where the damage would have been more catastrophic. Earthquakes of this size are not uncommon: More than 100 occur yearly around the world, but this one struck the edge of a great metropolis. It is certain that earthquakes of this size—and larger—will rock other places in the United States, rural and urban, in the future.

Earth scientists and earthquake engineers have been deeply concerned about their generally limited understanding of the hazards of earthquakes and by the consequent limited understanding by public officials responsible for the safety of millions. During the past few years, several reports have been written that both provide background knowledge and recommend action toward the mitigation of earthquake effects. The recommendations made in the reports listed in Appendix C are as valid today as when they were written. What seems needed now is to learn from the San Fernando Earthquake how best to prepare for and cope with the effects of future disasters of this kind.

Lessons Learned

1. SIGNIFICANCE OF PERMANENT GROUND DISPLACEMENT

Disruptions of the ground surface by faulting and other closely associated permanent deformations of rock and soil were much more important causes of structural failure during this earthquake than in any previous United States earthquake. This emphasizes once again the hazards associated with urbanization of active fault zones. On the other hand, many of the faults that broke during this earthquake were not generally shown on geologic maps published prior to the event, and none had been considered particularly active. The need for making structures safe is obvious. At the same time, more-intensive geological, geophysical, and geodetic studies of earthquake-prone regions of the the country must be made. Were there unrecognized geological clues that might have revealed that this area, and these faults, were particularly hazardous? Are there other geologically similar areas in which comparable earthquakes might occur? Merely asking such questions points up the necessity for interdisciplinary effort by engineers, seismologists, and geologists in land-use planning for earthquake-prone regions.

2. MEASUREMENT OF STRONG GROUND SHAKING

An unprecedented description of the ground motions and the resulting building responses was provided by more than 200 strong-motion accelerographs. This National Oceanic and Atmospheric Administration network operated well during the earthquake. Among the records were several obtained on dams. One instrument, in the epicentral region, showed the highest acceleration ever measured during an earthquake; it indicated in detail the time sequence of the main shock and many of the major aftershocks (see Figure 2). These measurements will form the basis for a re-evaluation of earthquake-resistant design. The accelerograph records obtained in about 30 large modern buildings will permit many significant studies of the design of earthquake-resistant structures. The success of this network, and the potential value of such data for the protection of the public, leads us to recommend strongly that the currently very inadequate strong-motion-accelerograph coverage should include numerous building structures and ground sites in all urban areas in seismic regions and important engineering structures such as dams and nuclear power plants.

In addition, greater effort and appropriate instrumentation should be devoted to studies of the effects of topography and the character of geologic material on the distribution and amplitude of strong ground motion.

3. SIGNIFICANCE OF THE STRIKING LOCAL GROUND MOTIONS

This earthquake demonstrated that local ground motion is not a simple function of the size of the shock. This magnitude 6.6 earthquake was associated (mainly in a restricted region some ten miles long and five miles wide along the Valley edge) with a severity of ground motion that was probably close to the maximum generated by any earthquake. An earthquake of greater

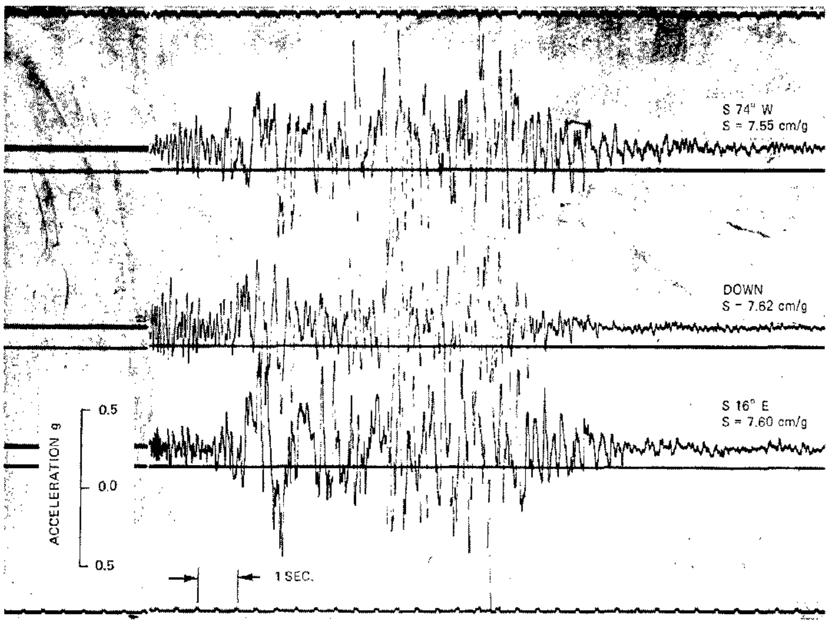

FIGURE 2 Strong-motion accelerograph record of the main shock of the San Fernando Earthquake of February 9, 1971, in the epicentral region on a mountain ridge at Pacoima Dam of the Los Angeles County Flood Control District. This station is part of the NOAA accelerograph network. *Record processed by the Jet Propulsion Laboratory, Pasadena; made available by the Earthquake Engineering Research Laboratory, California Institute of Technology, which is supported by the National Science Foundation.*

magnitude would involve strong ground motion over a greater area, consistent with longer fault breakage, and a greater duration of shaking.

The surface expression of the faulting and its character at depth as determined by seismological studies showed that the crustal materials beneath the San Gabriel Mountains were uplifted and thrust toward the northern margin of the Valley by six feet or more (see Figure 3). In the Upper San Fernando Val-

FIGURE 3 Fault scarp associated with the San Fernando earthquake, 1/4 mile east of the mouth of Lopez Canyon. Far (north) side has been relatively uplifted about 3 feet. *Photograph by Clarence R. Allen.*

ley and in Sylmar, buildings were called upon to withstand extremely strong ground motions. In this local region, the motion consisted of both severe shaking and a heave upward and toward the south (perhaps in several episodes). The strong-motion accelerometer at Pacoima Dam, on solid rock, showed ground motions 50 to 75 percent of the earth's natural gravitational acceleration (with a few peaks equal to gravity) lasting approximately 12 seconds overall. The dam is less than two miles from the Sylmar Veterans Hospital, which sustained severe damage and loss of life (see Figure 4).

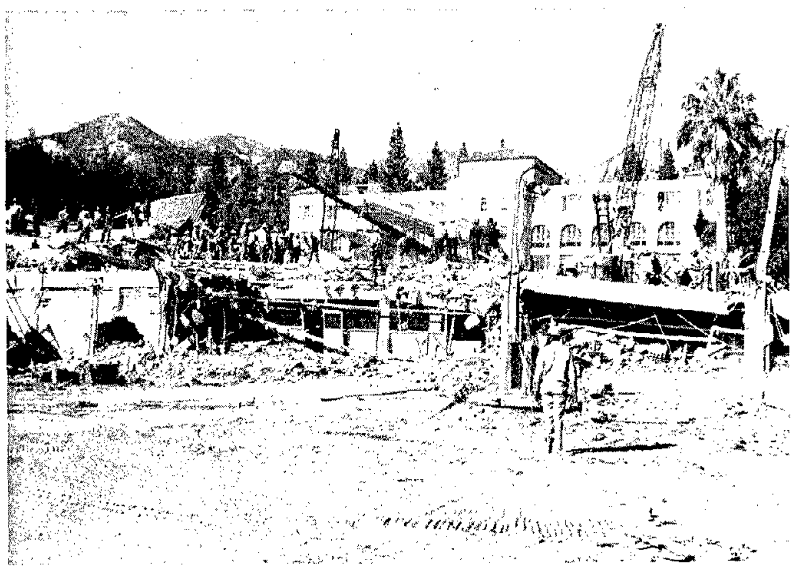

FIGURE 4 Collapsed portion of Sylmar Veterans Hospital being removed in search for survivors. The last of 14 survivors was found shortly after this photograph was taken. In this Hospital, built before the current building codes were established, 42 people were killed. *Photograph courtesy of Earthquake Engineering Research Laboratory, California Institute of Technology.*

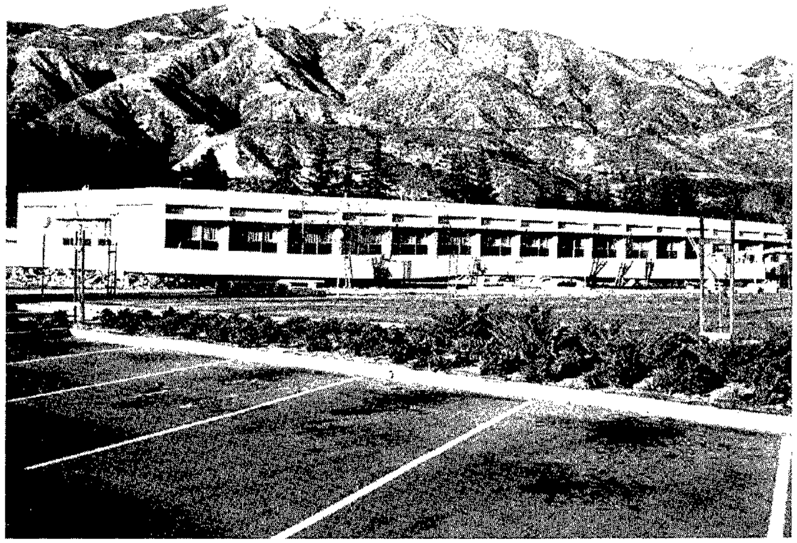

FIGURE 5 Two-story Olive View Hospital psychiatric building, constructed in accordance with current building codes, collapsed so that the second floor is now at ground level. The first floor contained administrative offices and examination rooms that were, fortunately, unoccupied at the early hour of the earthquake. *Photograph courtesy of Earthquake Engineering Research Laboratory, California Institute of Technology.*

4. BUILDING CODE REVISION

This earthquake has provided the first really comprehensive practical test of United States earthquake codes in and close to an epicentral region. Modern structures designed according to the earthquake requirements of the building code performed well in the regions of moderately strong ground shaking (peak accelerations of 10 to 20 percent g). In the region of very strong ground motion, however, some modern buildings were severely damaged (see Figure 5). A few that collapsed would have caused many additional deaths had they been occupied at this early hour. If the duration of strong ground shaking had been appreciably longer than ten seconds, as it would be in a great earthquake, some of the severely damaged structures would almost certainly have collapsed. It is clear that existing building codes do not provide adequate damage-control features. Such codes should be revised.

5. BACK-UP EMERGENCY SERVICES

In earthquake-prone regions, service organizations such as the police and fire departments, and medical services, will be put under heavy stress following an earthquake of significant size. The San Fernando Earthquake affected an area of only moderate size. It is necessary, therefore, to examine the organization and distribution of emergency services in the light of the fact that a major earthquake would affect a much larger area. Moreover, much of the loss of life and damage to property associated with an earthquake are attributable to aftereffects such as fire, flood, or seismic sea waves.

The opportunity should be seized to make a careful evaluation of the performance of emergency services following the San Fernando Earthquake and to determine the kinds and extent of back-up required to prepare for a much larger event. Such a study, preferably involving federal, state, and other organizations, would provide guidelines for other earthquake-prone regions of high population density as well.

6. RAPID RECONNAISSANCE STUDIES

The vital need for rapid reconnaissance studies immediately following a damaging earthquake is once again emphasized by the experience of the San Fernando Earthquake. For example, the entire northern part of the San Fernando Valley should have been systematically photographed from the air at very large scale (one inch equal to several hundred feet) on the morning of the earthquake in order, as quickly as possible, to locate sites of severe damage and to delimit the overall extent of such damage, as well as to identify visible surface expression of the faulting. But apparently no agency had the responsibility to initiate such an effort. It is clear, therefore, that an agency should be designated to assume the responsibility to initiate rapid reconnaissance studies of this type following future major earthquakes, and that adequate funding should be provided.

7. PROTECTION OF CRITICAL PUBLIC BUILDINGS

A striking consequence of the earthquake was the fact that four hospitals in the San Fernando area were damaged so severely that they were no longer operational just when they were most needed. Certain critical structures should be designed so that they will remain functional even after experiencing the most severe ground shaking. Included are hospitals, schools, and other high-occupancy buildings, as well as buildings housing police and fire departments and other agencies relied upon to cope with disasters. Basic utilities that must be depended upon to mitigate a disaster must also receive an extra measure of protection. Ordinary building codes cannot be depended upon to provide this extra protection, and special damage-control provisions should be mandatory to ensure such additional safety in high-risk areas.

8. EARTHQUAKE SAFETY OF DAMS

The near failure of the lower Van Norman Dam (see Figure 6) endangered the lives of tens of thousands of people. Such risks are clearly unacceptable. An improved program for bringing older dams in earthquake-prone areas up to the best modern safety standards is imperative, and these best standards should themselves be constantly reviewed. Many existing dams in all parts of the country have not been designed to resist significant earthquake forces; these structures should be thoroughly examined and measures should be taken to reduce such hazards. Additional basic research into the behavior of dams and soil

FIGURE 6 The Van Norman Dam, which was so severely damaged by the earthquake that 80,000 people living in the Valley below were evacuated because complete failure appeared imminent. They returned to their homes four days later, after the reservoir had been lowered to a safe level. *Photograph courtesy of Earthquake Engineering Research Laboratory, California Institute of Technology.*

structures during earthquakes will be required for the implementation of such a program. The fact that the Van Norman Dam did not quite fail totally should not be a source of comfort.

9. EARTHQUAKE HAZARD OF OLD STRUCTURES

During the San Fernando Earthquake, many old, weak buildings in the regions of strong and moderately strong shaking suffered severe damage, and the major loss of life occurred in one old building, the Sylmar Veterans Hospital, designed before the adoption of modern building codes (see Figure 4). There are many thousands of such old buildings in California that will collapse if subjected to strong ground shaking. Programs should be undertaken to render such buildings safe, or to raze them, over a reasonable period of time.

A successful effort to improve or eliminate old structures has been underway for some time in the city of Long Beach, and in the city of Los Angeles especially hazardous parapet walls have been removed from several thousand buildings or have been strengthened. This earthquake dramatically demonstrated the value of such procedures. A much more extensive program to eliminate the major hazard of old buildings is strongly recommended. Urban renewal programs can provide a suitable opportunity for such improvements in California and in other earthquake-prone areas.

10. SAFETY OF BRIDGES AND FREEWAY OVERPASSES

A number of freeway overpass bridges collapsed during the San Fernando Earthquake (see Figure 7), causing some deaths and resulting in significant local disruption of traffic. In an earthquake of greater extent, such interruption of transportation could greatly magnify the disastrous effects of the earthquake. Freeway bridges and important highway bridges should be designed for adequate safety against collapse. Present standard code requirements for earthquake design of highway bridges in high-risk areas are grossly inadequate and should be revised.

11. SAFENESS OF SCHOOL BUILDINGS

It is noteworthy that school buildings in the region of strong shaking designed and constructed since enactment of the Field Act of the California State Legislature did not suffer structural damage that would have been dangerous to the occupants had the schools been in session (see Figure 8). This demonstrated that one- and two-story school buildings can indeed be made safe by practicable code requirements, permitting them to withstand very strong shaking combined with appreciable ground deformation beneath the structure.

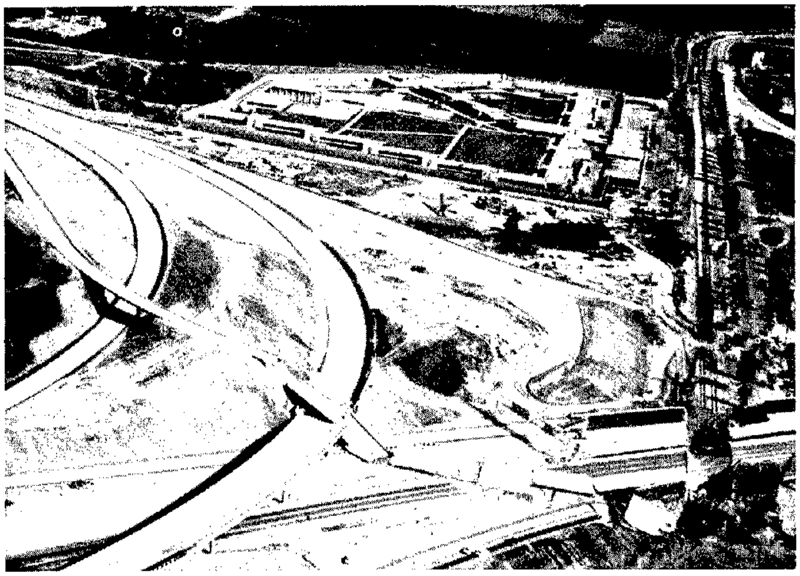

FIGURE 7 One of several freeway overpass bridges that collapsed during the earthquake. *Photograph courtesy of Earthquake Engineering Research Laboratory, California Institute of Technology.*

Older school buildings, which did not meet the requirements of the Field Act, suffered potentially hazardous damage as a result of moderately strong ground shaking. The lesson is clear that such hazardous school buildings must be eliminated or strengthened. Appropriate authorities in all seismic regions of the country should take this lesson to heart.

12. STUDY OF DAMAGED URBAN DWELLINGS

This earthquake throws an almost unique light on seismic hazard in a modern urban environment. Extensive damage to small homes and small-business structures occurred in zones where severe shaking was accompanied by permanent ground displacement associated with the faulting. Therefore, much crucial information can be gained by an immediate dwelling-by-dwelling study of earthquake damage. Such a study should be conducted by appropriate federal, state, and local agencies, with a view toward developing sounder guidelines for building construction, particularly of one- and two-story buildings.

13. EARTHQUAKE INSURANCE FOR HOUSES AND SMALL BUSINESSES

Because recognized geological evidence of active faulting was lacking in this particular area, the people who lost their homes and businesses in the Sylmar–San Fernando areas could have had no warning of the special hazards to which they were ex-

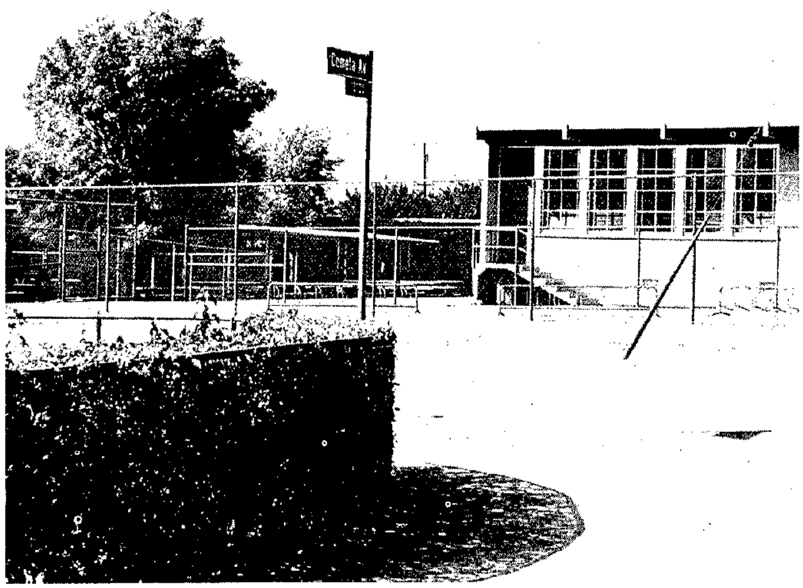

FIGURE 8 Post-earthquake photograph of school building in vicinity of severe ground motion in San Fernando. The building was constructed in accordance with current building code requirements and no appreciable damage occurred. *Photograph by Bruce A. Bolt.*

posed. Permanent displacement of the ground caused by surface faulting, landslides, and consolidation and slumping of soils were responsible for much damage to structures. In many places, deformation of the ground beneath a structure greatly magnified the damaging effect of the ground shaking.

Such innocent victims of earthquakes should be protected by insurance, or the authorities must be prepared to consider better relief measures than those now used. The cost of repairing such unforeseeable damage should be shared by all who live in disaster-prone regions. A form of earthquake insurance that will be much more widely used should be developed, with Federal Government back-up if necessary.

14. PRESERVATION OF VITAL SUPPORT SYSTEMS

Damage to the Sylmar Converter Station, a key link in a system for transmission of electric power into the Los Angeles area, will keep this system inoperable for about a year while replacement parts are manufactured (see Figure 9). This demonstrates in a dramatic way the increasing vulnerability to earthquakes of our society's vital support systems. Networks for the distribution of electrical power, water, and gas, for disposal of sewage, and for transportation of food and other essentials continue to grow in size and complexity as the numbers of people dependent upon them reach into the multimillions.

The collapse of several highway overpasses during the earthquake had a limited effect on transportation, but such destruction could be more widespread in a larger earthquake, perhaps compounding transportation difficulties to disaster proportions.

A major unit of the water supply system, the Van Norman reservoir, was virtually eliminated without seriously disrupting distribution of water. Compounding of such effects in a larger earthquake is clear cause for concern.

For the crucial systems vital to millions of people, design of individual components is not adequate in the face of the known earthquake hazard. Continuing efforts must be exerted to build

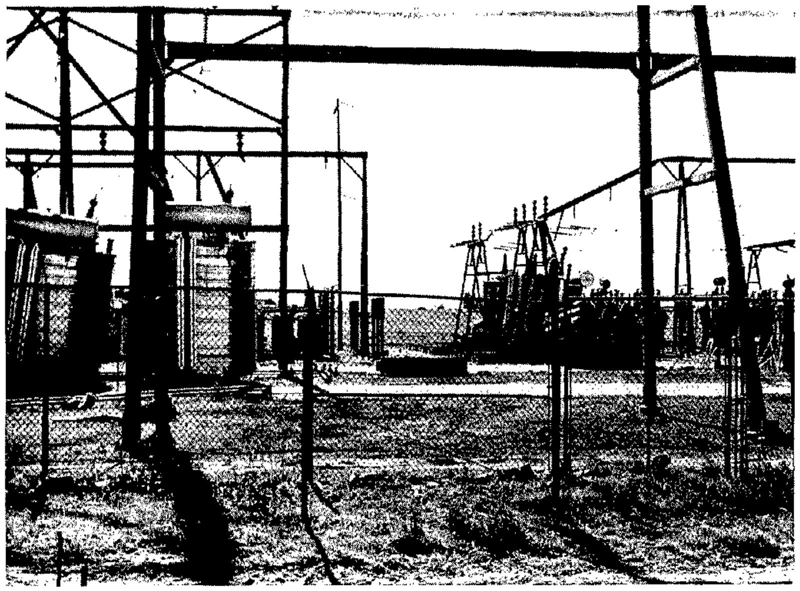

FIGURE 9 Severely damaged equipment at the Sylmar Converter Station. *Photograph courtesy of Earthquake Engineering Research Laboratory, California Institute of Technology.*

into the system sufficient redundancy to ensure against complete failure in the event of a major earthquake.

15. THE PROBLEM OF SEISMIC ZONING

The unexpected occurrence of an earthquake in this location and the concentration of the most severe damage in zones of ground breakage forcefully illustrate both the importance and the difficulty of responsible and practicable seismic zoning. No evidence from previously completed geological or seismological studies had been generally interpreted as indicating that the region affected was a more likely place for a damaging earthquake than many other parts of the southern California seismic region.

This experience points out once again that the short-term local seismic history is not in itself an adequate base for estimating earthquake risk. Until we gain a better understanding of earthquake processes and probabilities, due regard for public safety demands that seismic hazard be considered high throughout wide areas, and seismic zoning maps must reflect this. Many agencies and groups are working constructively on the problem of recognizing seismic hazards, but this effort is so important that it deserves more support.

16. LAND USE AND GEOLOGIC HAZARDS

More than ever before, local communities are seeking guidance concerning environmental hazards of all types that should be taken into account in planning for the use of land to be developed. Permits for construction of residential and commercial buildings in areas subject to earthquakes, landslides, and flooding, for example, should only be issued on the basis of a meaningful evaluation of the potential risks and only after the purchaser is aware of all the known facts.

State and local government needs support in the form of well-conceived regulations in order to resist political and economic pressures to develop land in ways that are unwise in terms of environmental hazards.

17. STUDY OF THE SOUTHERN SECTOR OF THE SAN ANDREAS FAULT

The redistribution of crustal stresses caused by the San Fernando Earthquake cannot help but have some effect on the nearby segments of the San Andreas Fault, which has long been considered a source for much larger earthquakes. Because of this changed situation, the San Andreas Fault in this temporarily "locked" segment is a particularly critical area to study and to monitor, especially in view of its proximity to the largest metropolitan center in the Western United States. (The closest point on the San Andreas Fault to the center of Los

Angeles is less than half again as far as was the epicenter of the San Fernando Earthquake.) It is strongly recommended that additional research programs be started at once to study the southern sector of the fault.

18. SEISMOLOGICAL STUDIES

The San Fernando Earthquake was the best monitored earthquake in United States history because of the high level of scientific preparedness in this area and the immediate response of earthquake researchers. Immediately available seismic data were important in delineating the scope of the disaster, aided repair and reconstruction, and facilitated further scientific studies.

In the Los Angeles area, a telemetry-equipped seismic network that was in operation prior to the earthquake provided excellent records of pre- and post-earthquake seismicity, but even this network could have been markedly improved in effectiveness by a greater number of telemetry-equipped stations and a more-comprehensive seismic monitoring program. It is clear that, prior to the earthquake, seismological information even for this region was not as complete as it could have been, and indeed should have been, given the capabilities of present technology. Pre- and post-earthquake geodetic observations should be an intrinsic part of such monitoring systems. Both seismologic and geodetic capabilities are urgently in need of upgrading in all earthquake-prone regions of the country.

The seismic data gathered during and following the earthquake provided the basis for locating the sources and determining the mechanics of the faulting at depth. Such studies, together with geologic and geodetic studies, will also yield important information about the earth deformation that occurred in association with this earthquake and its aftershocks. This will be important in assessing the seismic hazard elsewhere. The San Fernando Earthquake is a reminder that a vastly improved understanding of earth movements at all scales is needed.

Support for the Study

Funding support for the work of the Panel and its Parent Committees is provided by the following agencies of the Federal Government: Atomic Energy Commission, Advanced Research Projects Agency, National Science Foundation, National Oceanic and Atmospheric Administration, Bureau of Mines, Bureau of Reclamation, U.S. Geological Survey, Department of Transportation, Army Research Office, and Army Corps of Engineers.

APPENDIX A

Sponsoring Committees

Committee on Seismology, NAS

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JACK E. OLIVER, Lamont-Doherty Geological Observatory, Columbia University
ROBERT PHINNEY, Princeton University
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DAVID B. SLEMMONS, National Science Foundation
VALENTINE E. ZADNIK, Army Research Office

Committee on Inspection of Structural Damage Due to Earthquakes, Winds, and Other Natural Disasters, NAE

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NATHAN M. NEWMARK, University of Illinois
ROBERT A. CLIFFE, Division of Engineering, National Research Council, *Executive Secretary*

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WILLIAM R. JUDD, Purdue University
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C. BARRY RALEIGH, National Center for Earthquake Research, U.S. Geological Survey, Menlo Park, California
GEORGE B. WALLACE, U.S. Bureau of Reclamation, Denver
ALBERT N. BOVE, Division of Earth Sciences, National Research Council, *Executive Secretary*

Liaisons

JOHN P. GNAEDINGER, Soil Testing Services, Incorporated, Northbrook, Illinois
JOHN W. GUINNEE, Highway Research Board, NAS
JAMES R. SMITH, Building Research Advisory Board, NAS

APPENDIX B

Participants in General Discussion Sessions

February 25 and 26, 1971

In addition to the members of the Joint Panel on the San Fernando Earthquake, the following invited guests participated in general discussions that helped provide background for the Panel's report:

DONALD W. BUTLER, Office of the Chief of Engineers, U.S. Army
LEONARD M. MURPHY, National Ocean Service, National Oceanic and Atmospheric Administration
GORDON OAKESHOTT, California Division of Mines and Geology
ANDREW J. PRESSESKY, U.S. Atomic Energy Commission
CARL H. SAVIT, Office of Science and Technology, Office of the President
LEON STEIN, Office of Architecture and Construction, State of California
ROBERT L. TRACY, Office of the Chief of Engineers, U.S. Army
JACOB N. WASSERMAN, Committee on Government Operations, U.S. House of Representatives
ARTHUR J. ZEIZEL, U.S. Department of Housing and Urban Development

APPENDIX C

Published Reports

Report of the Task Force on Earthquake Hazard Reduction, Program Priorities. Office of Science and Technology, Executive Office of the President, 1970.

Seismology: Responsibilities and Requirements of a Growing Science. Part I, *Summary and Recommendations*; Part II, *Problems and Prospects*. NRC Committee on Seismology, National Academy of Sciences, Washington, D.C., 1969.

Toward Reduction of Losses from Earthquakes. NRC Committee on the Alaska Earthquake, National Academy of Sciences, Washington, D.C., 1969.

Earthquake Engineering Research. NAE Committee on Earthquake Engineering Research, National Academy of Sciences, Washington, D.C., 1969.

Proposal for a Ten-Year National Earthquake Hazards Program. Report of the Ad Hoc Interagency Working Group for Earthquake Research of the Federal Council for Science and Technology, Interior—U.S. Geological Survey, Washington, D.C., 1968.

Earthquake Prediction. Report of the Ad Hoc Panel on Earthquake Prediction of the Office of Science and Technology, Executive Office of the President, 1965.

COVER ILLUSTRATION: Los Angeles–San Fernando Valley region showing epicenter of the main shock of February 9, 1971, and epicenters of aftershocks that occurred during approximately the following three weeks. (Base map courtesy of the Automobile Club of Southern California.)

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