NORTHRIDGE EARTHQUAKE

Turning Loss to Gain

Seismic Safety Commission
State of California

Report to Governor Pete Wilson

in response to
Governor's Executive Order W-78-94

SSC Report No. 95-01
Sacramento, California, 1995

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Seismic Safety Commission
1900 K Street, Suite 100
Sacramento, CA 95814

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Consultants

Project Director
Bruce Norton
ATI Consulting

Graphic Designer
Jodi Adkins-Weast
Adkins Design

Advisory Panels

Geosciences

Kevin J. Coppersmith
Geomatrix Consultants, Inc.
Team Leader

Clarence R. Allen
California Institute of Technology

George E. Brogan
Brogan Consultants, Inc.

Geoffrey R. Martin
University of Southern California

Land Use Planning

J. Laurence Mintier
J. Laurence Mintier & Associates
Team Leader

George G. Mader
Spangle Associates

Anthony Nisich
City Engineer, Santa Clarita

Dams, Bridges, & Lifelines

Joseph Penzien
International Civil Engineering Consultants, Inc.
Team Leader

Ronald T. Eguchi
EQE International, Inc.

John F. Hall
California Institute of Technology

Buildings

William T. Holmes
Rutherford & Chekene
Team Leader

John M. Coil
John Coil Associates

Roy G. Johnston
Brandow & Johnston Associates

John A. Martin, Jr.
John A. Martin & Associates, Inc.

Egor Paul Popov
University of California, Berkeley

Nonstructural Matters

Bob Reitherman
The Reitherman Company

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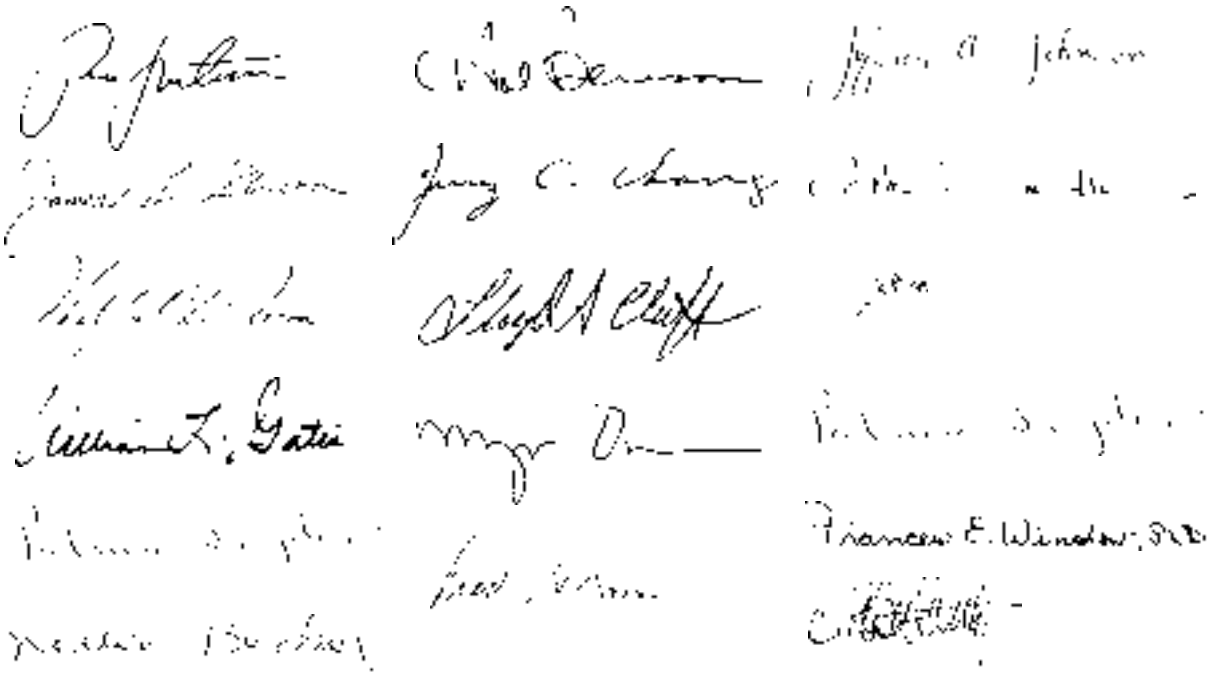
Preface

The Seismic Safety Commission is charged by statute to advise the Governor, the Legislature, local government, and the public on seismic safety. Recognizing this role, Governor Pete Wilson issued an executive order directing the Commission to study the Northridge earthquake and report on its policy implications for structural seismic safety and land use planning.

A disaster such as the Northridge earthquake puts great strain on state government and on the individuals who must respond. The Commission appreciates the generous spirit of dedication and cooperation displayed by the many agencies and individuals who participated in our review of the earthquake and its effects at a time when they needed most to attend to their own losses, jobs, and families. Thanks are also due to the Governor's Office of Emergency Services and the Federal Emergency Management Agency for providing the matching funds necessary for this review. The Commission believes the availability of these funds will allow California to build on the lessons learned from Northridge to reduce our losses in future earthquakes and responsibly manage the risk that remains.

Although the Commission believes California's seismic safety practices for building and land use are among the best in the world, there remain weaknesses that result in unacceptable risks to life and the economy. In light of these vulnerabilities, the Commission believes that California cannot continue with business as usual, particularly when there is the clear knowledge of the high likelihood that major earthquakes will strike our urban areas. This report recommends policy changes and implementation measures needed to lessen future losses.

In the end, it will be the will of the people, expressed through personal acts to mitigate earthquake risk as well as their support for earthquake programs, that will determine whether California attains an acceptable level of seismic safety by the end of this century.



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Without the cooperation and support of many design and construction professionals, as well as academia and federal, state, and local governmental agencies, this project could not have succeeded. The Commission appreciates the efforts of all who helped, including:

Local Governments

City of Los Angeles

City of Fillmore

City of Santa Monica

County of Los Angeles

State Agencies

Business, Transportation, and Housing Agency

Department of Housing and Community Development

Department of Transportation

Governor's Office of Emergency Services

California Office of Planning and Research

Health and Welfare Agency

Office of Statewide Health Planning and Development

Public Utilities Commission

Resources Agency

Office of Historic Preservation,
Department of Parks and Recreation

Division of Mines and Geology,
Department of Conservation

State and Consumer Services Agency

Building Standards Commission

Board of Registration for Professional Engineers and Professional Land Surveyors

State Historical Building Code Board

Division of the State Architect,
Department of General Services

University of California

Federal Agencies

Federal Emergency Management Agency

United States Geological Survey

Private Organizations

American Institute of Architects, California Council

Associated General Contractors of California

California Building Industry Association

California Building Officials

California Fire Chiefs Association

California Institute of Technology

Consulting Engineers & Land Surveyors of California

Earthquake Engineering Research Institute

Southern California Earthquake Center

Southern California Gas Company

Structural Engineers Association of California

Among the dozens of individuals who reviewed and commented on draft materials, Robert Patrick, Frank E. McClure, and Barry Pascal gave extraordinary effort.

In addition, the Commission would like to thank Bruce Norton, ATI Consulting, for undertaking the difficult task as Project Director, and team leaders Kevin Coppersmith, William Holmes, J. Lawrence Mintier, and Joseph Penzien and their teams for their work on the *Compendium of Background Reports on the Northridge Earthquake*, published as Seismic Safety Commission Report No. SSC-94-08, which provided much of the information on which the Commission based the recommendations in this report.

A special thanks for their dedication, long hours, and hard work are also due to the Commission's staff, especially to Deborah Penny for formatting the document and to Brenda Boswell for editing it. The Commission also extends its appreciation to Jodi Adkins-Weast, Adkins Design, for her work on the report's design, illustrations, and layout.

Executive Summary

California is a remarkable place in which to live and work. In spite of its earthquake hazards, its residents are relatively safe from earthquakes. Its building stock and lifelines and the people and programs that address its earthquake risk are among the best in the world.

Californians are fortunate that seismic codes have been written and enforced here for the last half century, making California buildings better able to withstand earthquakes than buildings elsewhere. People can live and invest safely in California, knowing that earthquake risk is addressed and that desired levels of seismic safety can be achieved if an effort is made.

Unless seismic safety is afforded a priority that is now lacking, Californians will continue to experience avoidable losses from earthquakes.

Nevertheless, the messages from the Northridge and earlier earthquakes are clear. Despite our codes and world-renowned expertise, too many of our buildings and other structures remain vulnerable to earthquake damage. There are significant weaknesses in the way we exercise land use planning laws and design and construct buildings and lifelines. Too much of what we do is done by people who lack the will, knowledge, or support to deal with a hazard that has the public-safety and economic implications of earthquakes. Much of what we have learned in past earthquakes—and were reminded of by Northridge—is not applied with the appropriate level of commitment, consistency, and priority.

Steps can be taken to reduce future losses to more acceptable levels. California's state and local agencies, building owners, lifelines organizations, construction industry, geologists, architects, and engineers can and must do more to reduce future damage. Earthquake risk will not be reduced significantly until earthquake lessons are consistently applied with a new sense of urgency. The Seismic Safety Commission's recommendations lay out needed actions, but unless seismic safety is afforded a higher priority, Californians will continue to experience avoidable economic and personal losses from earthquakes.

Governor Pete Wilson issued Executive Order W-78-94 after the Northridge earthquake struck the San Fernando Valley and surrounding areas. In that order, he asked the Commission to review the effects of the earthquake and make recommendations on seismic safety and land use planning. The Commission responded by directing the preparation of 39 background reports and relying on research done by others (including members of the Commission), testimonies received at hearings, commissioner-prepared issue statements, and 27 case studies of buildings damaged in the Northridge earthquake.

Effects of the Earthquake

The magnitude 6.7 Northridge earthquake occurred at 4:31 in the morning of January 17, 1994, on a national holiday, when most Californians were at home asleep. Fifty-seven people lost their lives, nearly 9,000 were injured, and damage exceeded $20 billion.

The summary of the Northridge earthquake's impact is "It could have been a lot worse." In fact, it *would* have been a lot worse if the earthquake had occurred later in the day and if its duration and intensity had been of the nature anticipated for most of California. Most of the collapses and other life-threatening failures were to commercial, industrial, and institutional buildings and to freeway bridges, which were virtually empty at the time.

Hundreds of apartment buildings, many of them perched over open parking areas, were damaged; 16 people died in one collapse. Today, concentrations of these buildings are ghost towns, since many owners have not yet been able to rebuild. Thousands of homes and apartments were damaged; though much of the damage was not severe enough to compromise safety, it will cost billions to repair or replace these residences.

Thousands of commercial buildings were damaged. Building codes that were revised for tilt-up concrete buildings after the 1971 San Fernando earthquake need to be further revised, and they need to be better enforced; once again, tilt-ups suffered major damage. The performance of steel moment-frame buildings, thought to be state-of-the-art in earthquake resistance, surprised the engineering community; studies are now underway to determine why failures occurred in connections between beams and columns. Much of the damage to these buildings was hidden under fireproofing and finishes, so previous earthquakes may also have caused undiscovered damage and weakened buildings.

Although fires following earthquakes are significant hazards for California, fires were not a major problem in this event. However, mobile home parks suffered disproportionately when fires fed by natural gas swept through them.

Freeway bridges built or designed before the mid-1970s that had not yet been addressed by Caltrans' retrofitting program suffered major damage and collapse; with a few exceptions, bridges built or retrofitted since then performed well. The cost of repair was over $350 million.

Predictably, telephone systems were compromised, not primarily because of equipment failures but because of system overloads. And as usual, the various emergency response units—firefighters, police, highway patrol, sheriff, medical, and mutual-aid units—and hospitals had difficulty communicating because of incompatible radio equipment, loss of power, inadequate backup power supplies, and damage to equipment.

Other utilities also suffered failures. Electricity was out for up to three days in some areas, but power was restored to most customers within 24 hours. Most of the natural-gas lines that broke were old pipe, which is being replaced as part of a continuing pipeline replacement program. Water lines broke, and water had to be trucked to some of the hardest-hit areas for several weeks.

To these physical damage losses must be added the losses from business interruption, closings of universities and schools, foreclosures, and

reduction of the tax base. Insurance claims reached around $11 billion.

Although many scars remain, and the life losses and some financial losses are permanent, the Los Angeles area as a whole will recover from the Northridge earthquake. The new debts assumed to make repairs will be paid off, the affected businesses will recover, the people will return to their daily rounds. All too quickly, measures to reduce losses from future earthquakes seem less and less important to residents and government officials unless steps are taken to reverse the usual pattern observed after past earthquakes.

Buildings

The Northridge earthquake demonstrated that, although California's current building codes and practices are generally adequate to protect lives, they are not intended to protect Californians from the economic disaster that a major earthquake would cause. California has many of the world's best earthquake safety experts and one of the most comprehensive building codes for earthquake resistance. The low loss of life in the Northridge earthquake compares favorably to similar earthquakes in other parts of the world, but the unprecedented economic losses indicate that California still needs to make major efforts to reduce the earthquake damage vulnerability of its buildings.

The Northridge earthquake exposed a large urban building stock to intense shaking for the first time in California since the advent of modern building codes. Strong shaking lasted only about nine seconds; nevertheless, it vividly demonstrated that, although California has come a long way since the 1971 San Fernando earthquake, there are many improvements that still should be made to ensure that California's economy, as well as its citizens, survive major urban earthquakes:

- *The quality of design and construction must be improved.* Poor quality in design, plan review, inspection, and construction were encountered over and over again in the buildings damaged by the earthquake. California's current system of building design and construction encourages individual gambles that add up to a significant risk, both for those who own the buildings and for those who depend on them as employees, tenants, or customers. Improving the quality of design and construction for new buildings and retrofit projects would increase safety dramatically at relatively minor increases in building costs.
- *Building codes must be improved.* As expected, damage was more prevalent in older buildings. Modern buildings—those built to current codes—in general met the intended life safety objective of the building code. Notable exceptions to this included poor performance in modern concrete parking structures, tilt-up buildings, and welded-steel moment-frame buildings. Code changes have been proposed to begin to address these and other problems for future construction. Future codes and seismic design guidelines should take better account of enhanced performance objectives and geologic and near-source effects on structures. In light of the extensive and costly damage to modern buildings, the state should be more active in its support of efforts to establish acceptable levels of earthquake risk in buildings and to develop codes and design guidelines to meet performance objectives.
- *Nonstructural hazards must be reduced.* A building's heating and air conditioning systems, lighting fixtures, fire sprinklers, furniture, and equipment can become hazards in an earthquake if they are not adequately secured, and their loss can make a building unusable. Making these systems more secure is a relatively inexpensive way of improving seismic safety and post-earthquake functioning of both new and existing buildings.
- *Risks from existing buildings need to be identified, disclosed, and reduced.* Some types of older buildings pose significant threats to both life and economy in earthquakes, but it is impractical to

The Northridge earthquake exposed a large urban building stock to intense shaking for the first time since the advent of modern building codes.

recommend replacement or retrofit of all such buildings overnight. Local governments can reduce the risk through better land use planning and zoning incentives, but financial incentives are needed to encourage owners to retrofit.

California's current system of building design and construction encourages individual gambles that add up to a significant risk.

Some types of buildings demonstrated special problems during the Northridge earthquake. Old, poorly built or maintained single-family dwellings and multistory wood-frame buildings with inadequately braced ("soft") first stories are vulnerable to damage. Many mobile homes were thrown from their supports; some were destroyed by fires fed by sheared natural-gas connections. Despite code changes after the 1971 San Fernando earthquake, tilt-up and masonry buildings and aboveground concrete parking structures sustained significant damage with serious economic implications. Many older concrete-frame buildings are vulnerable to sudden collapse and pose serious threats to life.

Welded-steel moment-frame buildings, once considered to be state-of-the-art in earthquake resistance, suffered serious damage to their connections, damage with serious implications that must be investigated and solved. Public school and modern hospital structures generally performed well, thanks to the extra care taken in their design and construction, but nonstructural damage was serious enough to prevent some from functioning immediately after the earthquake. California State University at Northridge suffered major damage to a parking structure and serious damage to several other buildings, demonstrating the need for better design review and construction inspection.

The earthquake demonstrated that unreinforced masonry buildings that had been retrofitted to preserve life safety withstood the earthquake better than those that were not retrofitted. However, many were still damaged beyond hope of repair, and owners who did not understand the goal of retrofitting were disappointed. Retrofitted older concrete and wood buildings also appear to have performed better than their unretrofitted counterparts.

An overriding question that arises from the Commission's study of the effects of the Northridge earthquake on buildings is "What level of risk to the public is acceptable?" Professionals can describe the risks, but policy makers, owners, and others may not understand the implications and, therefore, not be able to make truly informed decisions about what is acceptable. We could build nothing but square one-story houses with few windows on flat ground well away from any known fault; that would minimize earthquake risk, but would significantly reduce the livability of our homes. Or we could build "disposable" buildings, intended to be replaced after the first damaging earthquake. The answer lies somewhere between these extremes, and the Commission believes the question must be answered at a policy level before building codes and state law can adequately address the practical issues of improving buildings.

Lifelines

All the affected area's lifeline systems—freeways, railroads, and communications as well as natural-gas, water, power, and sewage-disposal systems—suffered damage in the Northridge earthquake. The most spectacular failures, those of the freeway bridges, raise questions regarding design and construction of new bridges as well as retrofitting of existing ones. Although Caltrans is addressing these problems, the Commission believes the toll bridge retrofit program must be accelerated and properly funded.

Power outages and system overloads were the culprits in most communications difficulties. In this earthquake cellular telephones were also overloaded. The cellular system must have an emergency priority system similar to that of land lines. The most serious failures of communications were in medical and emergency services. Many failures of hospital communications systems were caused by damage to unanchored equipment and failure

of emergency power generating equipment, which in turn was a result of a lack of regular testing or, in some cases, because operators were unfamiliar with the equipment.

That few fires caused by natural gas followed this earthquake was due more to favorable weather and good luck than to the strength of the system. The gas companies need to accelerate their replacement of old vulnerable pipe and to address other weaknesses in the system, such as the hazard created when mobile homes fall off their supports and break gas connections.

The Northridge earthquake caused extensive power outages. A few high-voltage transmission towers were damaged when their footings were displaced. This and other areas of damage should be investigated, and the electric utilities should continue their efforts to improve the ability of their facilities to resist earthquake damage.

In addition to disrupting the delivery of water from the Colorado River and northern California, the earthquake caused many local breaks in water distribution lines; some areas were without water for weeks. The potential for massive disruption of water systems poses significant public health hazards as well as inhibiting firefighting ability and disrupting businesses in the affected area. Like other utilities, water districts must strengthen their systems to withstand earthquakes.

Several dams were damaged but none failed, a testimony to the effectiveness of the owners' strengthening efforts and the Department of Water Resources' Division of Safety of Dams. However, damage patterns indicate that in stronger or longer-lasting earthquakes, it will be a different story. Federal dams, which are built to different standards from the state's, and dams for which failures would inundate heavily populated areas should be reevaluated.

Land Use Planning

Community general plans can be used to identify, avoid, or mitigate seismic hazards, and they can also provide information that local officials need to predict earthquake damage patterns and plan for recovery. Zoning can also be used to discourage seismic hazards. Waivers of zoning regulations are one of the options that cities and counties have for encouraging retrofit or demolition of seismically hazardous buildings. State guidelines for environmental impact reports should include instructions for dealing with seismic hazards of development and redevelopment projects.

Most local officials do not have up-to-date geologic information to help them apply land use planning as a tool to reduce their communities' seismic hazards. The California Division of Mines and Geology's Seismic Hazards Mapping Program must provide this information to the majority of urban California within a reasonable time.

Geologic and Geotechnical Lessons

Like the Coalinga and Whittier Narrows earthquakes in the 1980s, the Northridge earthquake—which also occurred on a blind, or buried, fault—proved that buried faults can cause significant damage. Geologists believe that such faults underlie many California urban areas—not only the Los Angeles basin and the San Fernando Valley, but also the Ventura-Santa Barbara region, the Santa Clara-San Jose region, and other areas.

California has a program under the Alquist-Priolo Earthquake Fault Zoning Act to identify faults that break the surface and mitigate their hazards. These efforts should be broadened to identify areas with buried and other active faults that do not meet the law's definitions of an "active" fault.

Shortly after the Northridge earthquake, there was speculation that the high level of damage resulted from unusual vertical accelerations, but the Commission has received no evidence that vertical accelerations were unusual relative to the horizontal accelerations.

The 168 recommendations in this report form a blueprint to reduce earthquake risks.

Though the Northridge earthquake produced the largest set of ground motion records ever obtained from a California earthquake, many of the badly shaken areas were not fully instrumented. Shaking in the near-source area—the area above and near a fault—has unique characteristics that can increase damage. Near-source and geological effects should be considered in the design of important buildings and in land use planning. More instruments are needed, as well as research to determine what implications the generally more severe ground motions near the epicenter of the earthquake might have for structural design.

Local site conditions played an important part in the level of damage. The Seismic Hazards Mapping Program being pursued by the California Division of Mines and Geology must be accelerated to identify site conditions that might create or add to seismic risks, particularly those under urban areas, so that appropriate precautions can be taken, both in buildings and in land use planning, to minimize earthquake damage.

Reducing Earthquake Risk in California

The 168 recommendations in this report form a blueprint to reduce earthquake risks, but will only be effective if they are carried out with the level of effort needed. To begin, government agencies, businesses, and private individuals must be made accountable for managing their earthquake risks to achieve four basic goals:

- *Make seismic safety a priority.* Responsibility for seismic safety actions and programs is diffuse; seldom can one person or one agency be held accountable for reaching seismic safety goals. Seismic safety is usually only a small part of a business' or public agency's activity—and not the part that brings big rewards or promotions if successful. Indeed, it takes a damaging earthquake to prove that risk-reduction efforts were successful. Efforts and laws to carry out seismic safety programs must receive the attention they need to ensure that California's earthquake risk is reduced. The recommendations clarify responsibility and require accountability. Every agency secretary should be made responsible for the efforts of departments, boards, and commissions within their jurisdictions to make seismic safety a priority.
- *Improve the quality of construction.* Improving the quality of construction from top to bottom is a far-reaching goal in terms of number of people affected—owners, architects, engineers, contractors, workers, inspectors, code writers, materials suppliers, researchers, and more. But it is also the most cost-effective way of reducing California's earthquake risk. The many actions that should be taken reflect the complex nature of the problem, but they boil down to one simple fact: buildings that are properly designed and constructed are better able to resist earthquakes.
- *Reduce the risk from seismically vulnerable structures.* California's greatest earthquake risk is from structures that fail in earthquakes. The types that fail are well known, but identifying individual structures that are likely to collapse and strengthening or phasing them out of use is a monumental task that will take decades of efforts. Nevertheless, the risk must be addressed as a priority. State government can help by developing building retrofit guidelines and financial incentives as it has with Proposition 122 local government grants, but local governments must take the lead in developing similar incentives for individual owners.
- *Improve the performance of lifelines.* Caltrans and most utility companies are aware of the seismic risks to their facilities and are working to reduce or eliminate them. Additional resources and actions are needed to strengthen systems and speed earthquake recovery. Vulnerable structures, pipelines, and equipment must be replaced and reliable backup power and communications provided.

Those four goals can be reached by implementing the Commission's recommendations. Seven broad tasks must be completed to achieve those goals:

- *Define acceptable risk.* State laws and policies have attempted to define acceptable earthquake damage levels for schools, hospitals, and emergency services buildings. Similar policies are needed to define what damage is acceptable for the rest of the building stock, or it will be difficult or impossible to define, let alone achieve, goals of reducing structural and nonstructural damage. Performance objectives over and above the basic goal of life safety are needed; they should reflect the importance of the functions and economic roles of many classes of buildings, and building codes should be revised—and, optimally, simplified—to achieve these objectives. A "California Earthquake Risk Colloquium," an ad hoc task force representing the various business, government, emergency management, health and social services, and public safety interests that could contribute should be convened by the Commission and charged with recommending an appropriate state policy on acceptable earthquake risk.
- *Provide incentives for risk reduction.* Interest in improving earthquake risk-reduction efforts—and the willingness to spend money on them—disappears quickly after each damaging earthquake. Permanent financial and other incentives need to be developed that will keep the level of interest high enough to make sure that risk reduction is carried out over the long term. Such risk reduction helps more people than just the building owners; the whole community benefits from a more predictable business climate, quicker earthquake recovery, and enhanced public safety.

  Even if building owners are aware of the seismic hazards of their buildings and want to address them, they are often hard pressed to obtain the resources needed. And it is difficult, whether at the state or local-government level, to provide financial incentives. The private sector can help by adjusting interest rates and insurance premiums and deductibles to reflect seismic risks; government can supply the information needed to develop these tools as well as providing grants, loans, and other incentives for risk reduction.
- *Improve the use of earth science knowledge to reduce risk.* The earth sciences have developed a great deal of information about California geology, but much of it is not in a form that can be used by builders, local government planners, or state lawmakers. Accelerating the progress of the state's Seismic Hazards Mapping Program would go a long way toward filling this gap. Improvements in how Uniform Building Code land-excavation and grading requirements are enforced and in continuing education for earth science professionals are also needed. Building designers must do more to take the effects of geologic conditions and the unique shaking characteristics near faults into account.
- *Improve the use of land use planning to manage seismic risk.* General plans, zoning and subdivision regulations, and environmental reviews can provide powerful tools for reducing and avoiding earthquake risk. Some relatively minor changes to existing laws and practices would make these tools more usable, such as requiring general plans to incorporate a description of the building stock and mitigation measures or incentives to reduce risk from vulnerable buildings.
- *Improve the code development process.* The current method of developing building codes with volunteer efforts has worked well in the past but has resulted in long, complicated regulations that are often slow to recognize new advances. Moreover, no single organization is accountable for substantiating the basis underlying the

code provisions. The California Building Standards Commission should be empowered to make improvements in the codes and in the code development process to make sure that code assumptions are valid and that design guidelines will meet performance objectives. More active state government support for developing building codes will have long-term impacts on the earthquake resistance of California buildings.

- *Support focused research.* The more California learns about earthquake mechanisms and damage, the better prepared we become. However, there are many critical aspects as yet unanswered. Where are the buried faults, and what kinds of earthquakes will they cause? How can damaged steel-frame buildings be repaired, and how can that kind of damage be prevented? What are appropriate guidelines for evaluating seismic performance? What are the true strengths of commonly used building hardware? Without focused research California will continue to invest billions in improvements that are not necessarily reliable during earthquakes. California needs answers to these questions more urgently than any other state. The state should amend existing statutes to create and fund the Center for Earthquake Risk Reduction, an entity to plan for and fund focused research to develop answers to such practical questions so they can be applied to reduce earthquake risks. The center would emphasize measures to ensure that research results are actually put to use by practitioners.
- *Improve state-level programs.* Resources, authority, responsibility—these are the key elements for making state seismic safety activities effective. State agencies that have seismic safety responsibilities must make them an important part of their mission, not just an afterthought; plans and schedules for implementation of these responsibilities should be a part of every budget request. State agencies and California's university systems must forecast the damage and disruption that will be caused by likely earthquake events and plan to reduce these effects.

The Commission believes that its role in carrying out California's earthquake risk-reduction programs should continue to be independent and advisory. Its unique perspective in considering all aspects of earthquake risk reduction, response, and recovery will help it identify those actions most likely to be effective in turning the lessons from earthquake losses to California's gain.

The Northridge earthquake lends new urgency to the need to carry out the initiatives in *California at Risk*, the outline of the California Earthquake Hazard Reduction Program. It is imperative that adequate funding be provided to meet the state's goal of reducing earthquake risk significantly by the end of this century.

Summary of Recommendations

Geologic and Geotechnical Aspects of the Northridge Earthquake

Using Geologic Information

- California Division of Mines and Geology (CDMG) use independent peer review by acknowledged experts representing scientists, hazard analysts, and users throughout the hazard mapping program.
- CDMG draw on resources outside state government to conduct the mapping program.

Strong-Motion Instrumentation

- The state continue its strong support of Strong Motion Instrumentation Program (SMIP) as a valuable part of California's effort to reduce the risk from earthquakes.
- SMIP exert leadership by organizing a workshop involving the other operators of strong-motion instrument networks in California to coordinate the deployment and operation of these networks.
- Public funds not be used for the purchase, deployment, or upgrading of strong-motion instrument networks operated by private organizations unless there is a plan for the maintenance of the instruments and an agreement for the timely release of data to the public.
- SMIP give high priority to establishing a network of reference stations to measure ground motions in major urban areas of California.

Buried Faults

- CDMG identify areas where active buried faults exist that may cause serious damage and loss of life. By December 31, 1995, CDMG should conduct short-term, focused studies including:
  - Mapping of geologic and geomorphic indicators of buried faults (for example, pressure ridges and sag ponds).
  - Compiling subsurface geologic, geophysical, seismological, and geodetic data and analyzing these data and knowledge of active tectonics.
- CDMG form an advisory working group of knowledgeable earth scientists to develop cost-effective methods for assessing the locations as well as the significance of buried faults, the potential for earthquakes of various magnitudes, and motion parameters.

Site Conditions

- Building codes, standards for design and retrofit of lifelines, and land use planning incorporate measures to identify and set priorities to reflect adverse seismic effects of local site conditions.

Ground Deformation

- CDMG, as part of its Seismic Hazards Mapping Act (SHMA) program, evaluate the level of hazard presented by possible subtle faults, buried faults, and incipient faulting in alluvial basins in active tectonic environments and zones of compression.
- CDMG, as part of its SHMA program, and under the policies of the State Mining and Geology Board, expand the categories of seismic hazards to create a new hazard zone to address ground deformation and amplified shaking associated with folding and faulting.

Engineered Fill

- State and local jurisdictions enforce provisions in Appendix Chapter 70 of the 1991 Uniform Building Code (Appendix Chapter 33 of the 1994 UBC) as a minimum code for excavations and fills.
- Fills intended to support structures be designed and inspected by qualified professionals to ensure conformance with the current code and engineering practice; qualified technicians with proper certification inspect construction; the engineer of record certify that fill placement is in

Engineered Fill (continued)

conformance with plan design; and when the fill is to be placed on bedrock, an engineering geologist inspect the geologic conditions before placement.

- Seismically induced deformation caused by seismic compaction of fill and underlying alluvium be considered in the design and construction of residential fills.

Continuing Education of Geosciences Professionals

- The Department of Consumer Affairs' licensing renewal process require continuing education for geologists, geophysicists, engineering geologists, and geotechnical engineers.
- Licensing boards for geologists, engineers, and architects be required to hold hearings after each earthquake in the affected area to learn how their requirements can be improved.

Achieving Seismic Safety in Buildings

Owners' Responsibilities

- Appropriate state agencies develop a strategy to make owners aware that:
  - They are responsible for seeing that reasonable and appropriate care is taken to hire qualified designers, inspectors, independent reviewers, and contractors and for clearly delineating the lines of responsibility for their functions in appropriate contract documents.
  - The building system with the lowest initial construction cost may actually have a shorter useful life and be significantly less resistant to earthquakes than a slightly more expensive system or a building of higher quality.
  - They are responsible for taking reasonable and appropriate precautions to protect building contents.
- Legislation be enacted to direct California Occupational Safety and Health Administration (CalOSHA) to adopt standards for bracing building contents and to promulgate and enforce regulations to require employers to include this information in their workplace safety and emergency plans.

Designers' Responsibilities

- The California Building Standards Commission (CBSC) change the state's building standards to require that every building project have a single line of responsibility for the entire lateral force resisting system and vertical load carrying system assigned to the engineer or architect of record.
- CBSC amend the California Building Code (CBC) to require designers of record to be responsible for a quality assurance program for structural and nonstructural elements for each project and, through personal knowledge, for the general compliance of construction with the contract documents.
- Legislation be enacted to hold designers harmless from claims, other than those claims specifically involved with observation of the work designed by the designer, when present at construction job sites.
- The Legislature periodically review licensing board activities to ensure that they are administering effective licensing examinations, requiring continuing education to maintain competency, and enforcing registration rules.
- The boards of registration for architects, engineers, and geologists hold hearings at the site of each damaging earthquake to determine the effectiveness of the boards in providing the necessary enforcement to ensure consumer protection and quality control over professional workmanship.
- The Board of Registration for Professional Engineers and Land Surveyors and the Board of Architectural Examiners raise the level of awareness of board rules that limit professional practice to areas of competency and the level of enforcement of those rules.

Designers' Responsibilities (continued)

- Legislation be enacted to amend the title act for structural engineering to define the minimum level of seismic design expertise required of title holders.

Contractors' Responsibilities

- Legislation be enacted to require the Contractor's State Licensing Board (CSLB) to test candidates for a working knowledge of practical seismic safety principles in their contracting disciplines as part of the normal examination process and to require continuing education to ensure that contractors maintain competency in this area.
- The CSLB hold hearings at the site of each damaging earthquake to determine the effectiveness of the board's efforts to ensure consumer protection and quality control.

Building Code Enforcement Agencies' Responsibilities

- Legislation be enacted to make structural plan checking of engineered buildings an act requiring professional licensing.
- CBSC amend the CBC to require all building code enforcement agencies to require owners of important, irregular, complex, or special-occupancy buildings to hire, as part of the permit process, independent peer reviewers whose involvement starts with schematic design phases and continues through construction.
- Legislation be enacted to require building inspectors and public and private plan checkers to be trained and certified by nationally recognized organizations and subject to continuing education requirements by recognized organizations in their areas of competence. Inspectors and plan checkers should be restricted from inspecting and checking plans beyond their areas of certification and competency.
- CBSC amplify what is already allowed by state law and amend the CBC to empower building departments to reject incomplete plans and collect additional fees for reconsideration of incomplete plans. Building code enforcement agencies should file complaints against designers and contractors who violate the building code or approved construction documents, and such complaints should receive priority over other complaints.
- CBSC—with the assistance of boards of professional registration, CSLB, and inspection and plan check certification organizations—develop a standard method for filing complaints on repeat code violators and preparers of incomplete plans.
- Building code enforcement officials and professional associations work together to develop timely changes to the UBC and California amendments to the code to incorporate the changes recommended above.
- Legislation be enacted to require all state, local, and special agencies, including University of California (UC) and California State University (CSU), to have a formal and independent building code enforcement entity with clear and appropriate enforcement, citation, and stop-work responsibilities and authority.

Improving Accountability in the Code Development Process

- Legislation be enacted to designate CBSC as the entity responsible for the adequacy of the seismic safety codes and standards for all buildings in California. CBSC should ensure that building codes and their administration meet the state's acceptable levels of seismic risk through various actions, including but not limited to:
  - Ensuring the adequacy of existing and future seismic safety requirements in the model codes and state amendments.
  - Developing and adopting new seismic safety requirements for amendments to the building code for statewide applications.
- Legislation be enacted to authorize CBSC to establish a task force including other affected and interested agencies and organizations to develop plans to fulfill this responsibility within one year of the above legislation.

Acceptable Seismic Risk

- The Governor support and participate in a special high-level task force, the "California Earthquake Risk Colloquium," a meeting convened by the Commission to recommend acceptable levels of earthquake risk and performance objectives consistent with those levels.

Testing and Research

- Legislation be enacted to authorize funds for a Center for Earthquake Risk Reduction with a sustained funding source to help achieve desired earthquake performance for new and existing buildings.

Need for Response Data

- The California Strong Motion Instrumentation Program (SMIP) develop a program to encourage all municipalities in Seismic Zone 4 to designate significant buildings in their jurisdictions and to adopt building instrumentation ordinances that require owners of these buildings to install and maintain at least three strong-motion instruments in each.
- SMIP develop and adopt standards for the installation and maintenance of building strong-motion instrumentation and provide for processing, archiving, and disseminating records obtained from buildings instrumented according to these standards.

Reducing Nonstructural Hazards

- The Division of the State Architect (DSA) draft nonstructural seismic standards for new construction and retrofits and submit them to the CBSC to be made mandatory by reference in the CBC.
- CBSC amend the CBC to require a quality assurance plan for all engineered buildings for the design and installation of nonstructural bracing.
- CBSC amend the CBC to require the design professional of record to delegate design, coordination, and field review responsibilities for nonstructural building components.
- The Public Utilities Commission (PUC) work with utilities to develop a program to allow gas utilities to include checks for water heater braces in their routine service calls, to notify building owners if water heaters are not properly braced or equipped with flexible gas lines, and to encourage or require retrofits of water heaters within a reasonable period of time.

Making Existing Buildings Safer

- Legislation be enacted to require that, by the year 2000, local general plan safety elements contain a generalized description of all typical building types and vintages in the community's neighborhoods, with a special emphasis on those vulnerable to collapse from seismic hazards, and a plan to mitigate the risk from these structures.
- Legislation be enacted to require state and local building code enforcement agencies to identify potentially hazardous buildings and to adopt mandatory mitigation programs by the year 2000 that will significantly reduce unacceptable hazards in buildings by the target year of 2020.
- The Seismic Safety Commission, in conjunction with the California Office of Planning and Research (COPR) and other interested organizations and agencies, develop guidelines for state and local governments to use to identify potentially hazardous buildings, amend safety elements, and prepare mitigation plans.

Effects of the URM Law

- The Legislature revisit the state's 1986 Unreinforced Masonry (URM) Law and consider appropriate actions to address the inequities and the public's continuing exposure to risk that have resulted from the failure of a significant number of local governments to comply with the intent of the law so that approximately half of the state's URM buildings remain unstrengthened.

Other Types of Retrofitted Buildings

- Legislation be enacted to require owners of potentially hazardous buildings to disclose seismic risk to potential buyers at the time of sale, to lenders, and to tenants on entering into or renewing leases, or when they relocate within a building.
- Legislation be enacted to allow the warning placards required by existing law to be removed from potentially hazardous buildings that have been retrofitted in substantial compliance with the Uniform Code for Building Conservation, Appendix Chapter 1, provided that the disclosures in the preceding recommendation take place.
- Legislation be enacted to require owners and business operators to include warning placards at the entrances to hazardous buildings of all types, as well as seismic risk management and response plans as part of in their overall emergency plans for safety in the workplace.
- The Governor direct CalOSHA to inspect, cite, and fine employers and operators when these earthquake warning placards and plans are not present during inspections of workplaces.

Single-Family Dwellings

- CBSC amend the administrative portions of the codes to require persons drawing plans for conventional light-frame construction to clearly identify on the building's plans all braced wall lines, wall panels, and their connections.
- Plan checkers be required to indicate that the braced wall lines and panels meet the requirements of the code, and construction inspectors be required to conduct an inspection to ensure that seismic elements are constructed in accordance with the plans and the building code.
- Inspectors receive special training, continuing education, and certification in the basic concepts of structural design in lowrise buildings, the identification and importance of key seismic elements, and the proper installation of materials, hardware, and devices used to provide seismic resistance.
- Banks and insurance companies create incentives to encourage seismic retrofit by offering lower rates on homes that have been retrofitted.

Other Wood-Frame Buildings

- CBSC amend the administrative portions of the codes in California to require professionals who are drawing plans for engineered portions of buildings to include and clearly identify on design plans all vertical and horizontal elements of lateral force resisting systems and their connections.
- Local governments initiate efforts to reduce the seismic risk in vulnerable wood-frame buildings such as collapse-risk apartment buildings with "soft" stories.

Manufactured Housing

- Legislation be enacted to require the installation of Housing and Community Development (HCD)-approved earthquake resistant bracing systems or other systems allowed by SB 750 (Roberti) on existing mobile homes when ownerships are changed or when homes are relocated.

Tilt-up and Reinforced Masonry Buildings

- The International Conference of Building Officials (ICBO) Evaluation Service review the building product evaluation and approval procedures used to establish allowable design values for earthquake resistance.

Concrete-Frame Buildings

- The state continue its support of the Seismic Retrofit Practices Improvement Program but recognize that the pace of this program is slow and is just a small step toward addressing the substantial risk posed by concrete-frame buildings.

Steel-Frame Buildings

- The state marshal its academic, technological, government, and industry resources to support the SAC Joint Venture to determine how to repair the steel moment-resisting frame connections damaged in the Northridge earthquake.

Hospitals

- Recently enacted legislation requiring the strengthening of nonstructural systems necessary for essential post-earthquake functions be carried out.
- The Office of Statewide Health Planning and Development (OSHPD), in consultation with the Hospital Building Safety Board, assign the highest priority to quickly retrofitting building components that have proven to be particularly vulnerable and disruptive—sprinkler and other water lines, emergency power, large oxygen tanks, and telephone and radio communications—before requiring retrofits for all the less critical nonstructural items in hospitals.
- OSHPD develop and adopt complete administrative regulations for hospitals, skilled nursing facilities, and intermediate-care facilities and develop and adopt regulations to allow OSHPD to issue minor citations or stop-work orders when violations are observed on construction projects under its jurisdiction.
- Legislation be enacted to require at least one go-slow elevator in each wing of all OSHPD-approved multistory healthcare facilities. This legislation should include the retrofitting of one elevator in all existing multistory healthcare facilities.
- Legislation be enacted to require hospitals to install, maintain, and periodically test in realistic exercises redundant emergency communications systems that do not rely on land lines. These systems must connect with emergency responders—police, fire, paramedics, and ambulances—and work within the hospital facility.
- The Department of Health Services (DHS) develop regulations in cooperation with Joint Council on Accreditation of Healthcare Organizations and OSHPD for recently enacted legislation to mandate that hospitals develop earthquake disaster plans that account for rapid execution of post-earthquake safety evaluations, realistic scenarios of the post-earthquake conditions of their specific buildings, and the availability and reliability of water, power, communication, and other lifeline services.
- OSHPD develop emergency regulations to establish and clarify its authority to post acute-care facilities after disasters and to prohibit the continued use of severely damaged facilities for acute-care purposes.

Essential Services Buildings

- Legislation be enacted to require state and local agencies to review all pre-1986 essential services facilities for their ability to function after earthquakes and that those found deficient be retrofitted.
- Owners and operators of essential services facilities evaluate and make their emergency communication systems, including their power supplies, earthquake-resistant so that they are not lost during periods of most critical need following earthquakes.
- All new and existing multistory buildings with essential services facilities in upper floors be retrofitted or equipped with at least one go-slow elevator.
- A general obligation bond measure be placed on the 1996 ballot to fund a state and local matching grant program or other funding mechanisms to carry out the recommendations in this section.
- The Essential Services Act (ESA) be amended to require buildings designated as community shelters and those buildings that serve as the place of business for local governments, such as city halls, be placed within the definition of “essential services buildings.”

K-14 Schools

- Legislation be enacted to amend the Field Act to require DSA to prepare guidelines and procedures for identifying public-school and community college buildings that have potential collapse risks and to require public-school and community college districts to evaluate the seismic vulnerability of buildings and school structures built prior to 1976, correct all defects resulting from design, construction, deferred maintenance, or inflexible utility connections during repairs, alterations or additions and retrofit, replace, or phase out of use structures that pose significant risks to life.
- Legislation be enacted to amend the Field Act to authorize DSA to issue minor citations or stop-work orders when violations are observed on public-school construction projects.
- Legislation be enacted to direct DSA and the California Department of Education to determine whether contract bid evaluations and management of school building construction projects are typically executed by properly trained, licensed (where necessary), and qualified personnel within school districts and determine whether the state needs to establish minimum guidelines and personnel qualifications.
- Legislation be enacted to consider the appropriateness and feasibility of requiring prequalification of potential contractors before the submission of bids.

Portable Classroom Buildings

- Legislation be enacted to require public school districts and community colleges to attach portable classrooms to foundations and abate life-threatening nonstructural hazards as proposed by DSA.
- The DSA Field Act Advisory Board work with DSA to develop appropriate legislative language and implementing regulations.

Covered Walkways, Lunch Shelters, and Canopies

- The Legislature develop an adequate funding source for addressing deferred maintenance in public schools.
- Legislation be enacted to direct public schools to review walkways, shelters, and canopies to identify and retrofit those that might endanger students during earthquakes.

Nonstructural and Building Contents Hazards

- All public-school and community college districts evaluate nonstructural elements and abate unacceptable hazards. The Field Act should be amended to require DSA to adopt retroactive, mandatory retrofit standards regarding nonstructural hazards. Public-school and community college districts should be required to abate nonstructural and building contents hazards when undertaking major alterations, additions, renovations, or repairs. In any event, retrofits should be completed no later than 2010.
- A percentage of future school bond proceeds be used to abate life-threatening nonstructural and building contents deficiencies in public schools by 2010.
- Legislation be enacted to require personnel at every school district facilities office to be trained to recognize nonstructural hazards and the effective installation of restraints and anchorages and to require an annual refresher briefing on emergency plans for every administrator and teacher.

Private Schools

- Legislation be enacted requiring that at the time of sale or renewal of leases, private-school and preschool building housing 25 or more students and constructed before 1986 be evaluated by a structural engineer and that life-threatening earthquake risks, both structural and nonstructural, be mitigated.
- Legislation be enacted to require private schools to identify and abate nonstructural and building contents hazards in buildings housing students and in classrooms.

School Emergency Plans

- Legislation be enacted to clarify that laws requiring school emergency plans are mandatory and that public-school administrators, boards, and private schools are accountable for compliance.
- Legislation be enacted to direct the California Department of Education to provide up-to-date guidelines specifying the minimal requirements for these plans, including equipment, tools, supplies, and frequency of exercises.

Higher Education Facilities

- The Governor direct the University of California (UC) and California State University (CSU) to require each campus facilities manager to determine key buildings and academic functions needed to restore key educational and research programs after earthquakes in addition to life safety concerns that must continue to be the first priority of campus retrofit programs. Earthquake response plans should be established to redirect or restore such critical academic and research functions in a timely manner for realistic earthquake scenarios. The UC and CSU systems must review the pacing and priorities of their seismic retrofit programs, including nonstructural risk-reduction efforts, to ensure that they will be capable of resuming critical educational and research programs after major earthquakes in a timely manner.
- The Governor direct UC and CSU to establish the goal that all life-threatening structural and nonstructural seismic hazards in UC and CSU buildings be retrofitted by the year 2005.
- UC and CSU prepare a capital budget plan that would allow completion of seismic retrofitting of all university buildings that pose unacceptably high seismic life safety risks by the year 2005.
- Legislation be enacted to require UC and CSU to adopt guidelines that trigger the seismic retrofit of all hazardous, life-threatening university buildings upon major alterations, reoccupancies, additions, renovations, or repairs.
- DSA complete its effort to develop building seismic retrofit guidelines in cooperation and concurrence with UC, CSU, and other interested organizations by May 1995.
- The Governor direct the UC Board of Regents and the Legislature enact new laws to ensure that UC and CSU abide by the minimum seismic design standards and enforcement practices of Title 24, including independent peer review, thorough plan checking, field inspection, and the monitoring of construction by designers for all new, remodel, and retrofit projects.
- The university systems adopt stop-work and citation authority for their code enforcement personnel to reduce minor violations of and enhance compliance with Title 24.
- The Legislature provide sufficient funds for the seismic retrofit of UC and CSU buildings by the year 2005.
- Legislation be enacted to approve the use of program-based budgeting for state seismic retrofit programs as opposed to the current project-phased budgeting that requires delays and added costs due to multiple legislative approvals of each project.

Achieving Seismic Safety in Lifelines

Pace of Caltrans Retrofit Programs

- The toll bridge retrofit program be accelerated because of the critical importance of those structures and that Caltrans' efforts to do so be supported.

Steel or Concrete Girders

- Caltrans perform seismic performance probabilistic risk assessments of both concrete and steel designs as part of its continuing program of evaluation and improving the seismic safety of bridges.

New Technologies

- Caltrans study different types of seismic isolation and damping systems to protect bridge girders and columns from earthquake damage and take into consideration the effects of local soil conditions and near-source ground motion.

Use of Seismic (Base) Isolation

- Caltrans undertake a study of the effects of near-source motion on seismic-isolated bridges before building or retrofitting any seismic-isolated bridges.

Strong-Motion Instrumentation

- The bridge instrumentation program be expanded to install strong-motion instruments, including dynamic strain gauges and load cells on selected strategic bridges.
- Caltrans continue to tie seismic research funding to its capital outlay program rather than the Transportation Planning and Research Act.

Multimodal Transportation Systems

- Multimodal transportation and emergency rerouting issues be considered by Caltrans in all seismic design, planning, and policy decisions.

Railroads

- The PUC review the earthquake response and risk-reduction programs of California's railroads and adopt regulations, including deadlines, for such programs by December 31, 1995.

Natural-Gas Transmission and Distribution Lines

- California utilities accelerate their upgrade and replacement programs to improve the performance of seismically vulnerable gas transmission and distribution lines. Priority should be given to those pipelines in the vicinity of essential facilities, special occupancies, and dense population, and in areas of potential ground deformation.
- Emergency response procedures be improved and valves installed in areas where ruptures are more likely so that breaks can be rapidly detected and lines depressurized to reduce the potential for explosions or gas-fed fires.
- The PUC issue recommendations and regulations to ensure improvement in the safety and seismic performance of gas transmission and distribution lines, including implementation schedules and priorities and the use of automatic shut-off valves, as appropriate, by June 30, 1996.

Mobile Home Gas Service

- Automatic gas shut-off valves be mandatory at the service entry point at all mobile home parks in California.
- The PUC conduct hearings and workshops to determine the best method for providing shut-off valves for mobile home parks and appropriate performance standards for such valves and to prepare draft legislation mandating shut-off valves for mobile home parks by September 1, 1995.
- The Department of Housing and Community Development develop and institute an education program for mobile home owners and park managers to encourage and guide installation of seismic bracing for mobile homes, proper bracing for water heaters in mobile homes, and measures to reduce the risk of gas-fed fires in mobile homes and mobile home parks.

Residential Gas Service

- The PUC sponsor a task force of representatives from the California Utilities Emergency Association (a division of the Office of Emergency Services), utilities, construction, manufacturing, emergency and fire services, and local governments to evaluate the damage data from the Northridge earthquake and other recent earthquakes, define the risks of fire and potential for damage and injury, and review alternative mitigation methods, including the use of earthquake-activated shut-off valves.
- DSA review the adequacy of its criteria for earthquake-activated gas shut-off valves and revise them to improve reliability.
- The PUC use the task force results to adopt requirements by June 30, 1996, to reduce natural-gas earthquake risks to an acceptable level and recommend actions for utilities outside the PUC jurisdiction.

Electric Utilities

- Measures be taken by investor-owned and municipal utilities to improve the performance of substations and transmission lines.
- The PUC investigate and evaluate the causes of substation equipment damage and transmission tower failures; the actions utilities are taking to identify the potential for similar failures and improve substation equipment and transmission tower performance; the use of site-specific geologic and geotechnical information for locating and designing utility facilities; and the adequacy of current utility risk-mitigation programs.
- The PUC determine whether mandatory regulations are required for design and location of substation equipment and transmission towers to ensure adequate component and system performance. If regulations are deemed necessary, the PUC should issue such regulations by July 1, 1996.
- Electric utilities not under the jurisdiction of the PUC, such as municipal utilities, cooperate with the PUC and other utilities in reviewing their seismic mitigation programs and the governing boards of those utilities adopt regulations and practices at least as stringent as those mandated by the PUC for private utilities.

Emergency Power

- Legislation be enacted to require those who own essential communications and emergency services facilities or hospitals to provide for reliable backup power in conjunction with utilities.
- The Air Resources Board investigate claims that local air quality maintenance district restrictions prevent regular testing of emergency generators and resolve any conflicts to allow testing.

Water Supply

- The Department of Water Resources issue a report to all water utilities describing the reasons behind the failures of large-diameter piping, distribution piping, water tanks, and other system components and providing representative risk-mitigation programs to identify and address seismic vulnerabilities.
- Legislation be enacted to require each water utility within California to prepare a seismic mitigation program consisting of a seismic policy and a statement of acceptable levels of risk; a description of potential earthquake damage and system impacts based on likely earthquake scenarios; a priority-based long-term risk-mitigation program; and a commitment to fund the program.

Communications

- The owners of essential services facilities ensure the adequacy of backup power generation systems and assess whether these systems can resist earthquakes.
- The agencies that rely on communication systems during emergency response have reliable redundant backup systems.
- The Office of Emergency Services (OES) explore the possibility of identifying and licensing additional mutual-aid channels in both the VHF and UHF bands for police and fire service use statewide.
- OES continue to place high priority on working with the Federal Communications Commission (FCC) to address standards for radio equipment that will enhance direct communications between police and fire agencies, including those assigned through mutual aid.
- The PUC work with the cellular industry to facilitate limiting access to cellular phones to essential services after declared disasters.
- The Emergency Medical Services Authority investigate problems with emergency medical communication systems and specify measures to correct inadequacies, including requiring testing of emergency communication systems and training personnel.
- The ESA be amended to require that switch facilities for land lines and cellular communications be located only in buildings constructed or retrofitted to seismic requirements at least as stringent as those found under the Essential Services Buildings Act.

Communications (continued)

- The Governor petition the FCC to:
  - Provide additional frequency spectra for public safety services and expedite the development of appropriate standards and protocols to facilitate direct communications between systems.
  - Limit access to cellular phone service to essential services after a declared disaster.

Dams

- The owners of dams be required to fund a dam instrumentation program carried out by the Strong Motion Instrumentation Program at the direction of the Division of Safety of Dams (DSOD).
- DSOD review its current assessment procedures in light of the strong-motion data obtained from the Northridge, Loma Prieta, and Landers earthquakes and assess concrete dams in areas having a likelihood of intense shaking and where the release of water would have significant public safety consequences.
- DSOD be directed to conduct seismic reevaluations and to increase inspection frequency of high-risk dams in zones of high seismic hazard.
- Legislation be enacted to allow DSOD to establish a research program directed towards improving and verifying methods of analyzing the seismic performance of dams.
- The Governor petition the federal government to ensure that all federal dams in California are designed, built, inspected, and repaired to state requirements.

Achieving Seismic Safety Through Land Use Planning

General Plans and Safety Elements

- CDMG complete the Seismic Hazards Mapping Act program by 2005.
- Legislation be enacted requiring review of the safety element of general plans every five years to incorporate new information; the information in maps prepared under the SHMA should be incorporated within one year of the date final maps are provided to local jurisdictions.
- Legislation be enacted to make the existing optional CDMG review of safety elements mandatory for CDMG.
- Legislation be enacted to require that the safety elements of general plans address seismic vulnerability of existing building stock, or inventory, and contain risk-mitigation strategies. Description of the building stock should be included in enough detail to support the risk-mitigation strategy.
- Legislation be enacted to require CDMG to convene a high-level independent review board for the preparation and review of guidelines and maps prepared under the SHMA.
- CDMG work with local governments to establish a systematic program to ensure that the information provided by the SHMA program can be easily incorporated into general plans and zoning, subdivision, and environmental quality decisions.
- CDMG work with the Insurance Commissioner and representatives of the insurance industry to ensure that mapped hazard areas are not misinterpreted and used incorrectly in issuing insurance policies.
- CDMG and OES support the preparation of damage scenarios, including localized scenarios and scenarios for areas of the state not presently covered.

Zoning, Subdivision, and Environmental Reviews

- State California Environmental Quality Act guidelines be amended to require that EIRs address seismic hazards, and engineering geologists and civil engineers, practicing within their areas of competence, review the hazards and proposed mitigation measures.
- Legislation be enacted to amend the Subdivision Map Act to require that geologic and geotechnical reports addressing seismic hazards be required for all major (five lots or more) subdivisions unless information is already available or until superseded by SHMA maps and that reports be reviewed by local government staffs or consultants with appropriate credentials.

Alquist-Priolo Earthquake Fault Zoning Act

- Legislation be enacted to allow designation of active fault zones based on all viable geologic, geodetic, and tectonic evidence and provide for alternative mitigation measures to be defined by the Mining and Geology Board as appropriate to complex areas where the location of potential fault ruptures is uncertain.
- Legislation be enacted to apply the Alquist-Priolo Act to publicly owned facilities, critical facilities, and lifelines, including public utility pipelines and facilities in which hazardous materials are used or stored, and to provide for alternative mitigation measures appropriate to lifelines.

Inundation Mapping

- Legislation be enacted to impose sanctions on dam owners who fail to prepare and submit inundation maps by December 31, 1996.
- Legislation be enacted to require that inundation maps be reviewed and revised whenever downstream development could significantly change hydrologic patterns and to require that inundation maps be reviewed every ten years and revised when necessary to reflect new data and to incorporate new inundation mapping technology.
- Legislation be enacted to amend land use laws to require state and local agencies to make specific findings regarding the acceptability of inundation hazards before approving development of critical facilities (for example, hospitals, schools, emergency response facilities, hazardous material storage, and sewer treatment plants) within potential inundation areas.
- The Governor petition federal agencies responsible for dams in California to provide inundation maps for their facilities to the state and local agencies.
- Legislation be enacted to require owners to prepare inundation maps for low-lying areas protected from flooding by levees.

Hazardous Materials

- State general plan guidelines be revised to require safety elements to include maps that depict where acutely hazardous materials are stored, used, and transported and their relationship to seismic hazards and that circulation elements address the existing and proposed location of pipelines transporting hazardous materials.
- Legislation be enacted to amend the Alquist-Priolo Act and the SHMA so they apply to all facilities that produce or store reportable quantities of acutely hazardous materials.

Historic Buildings

- The State Historical Building Safety Board revise the State Historic Building Code to include minimum life safety standards and guidance on measures to control damage.
- The California Office of Planning and Research (COPR), in consultation with the Office of Historic Preservation, publish guidelines for adding optional historical resources elements to local general plans to address the seismic retrofit of historic buildings.

Redevelopment

- Legislation be enacted to allow redevelopment agencies to increase spending caps easily after a natural disaster to accommodate disaster-recovery activities, including repairs to appropriate standards.
- Legislation be enacted to add to the definition of "blight," when designating a redevelopment project area, those structures deemed by the local jurisdiction to pose an unacceptable risk of collapse in earthquakes.

Planning for Recovery

- The CBSC amend the CBC to include triggers to require that alterations, repair, retrofit, and reconstruction activities incorporate seismic upgrades to mitigate future earthquake damage. The code should allow setting aside mandated upgrades not related to life safety that may be triggered when elective remodeling projects are undertaken.
- Legislation be enacted to require local general plans and emergency plans to address post-earthquake recovery and rebuilding.

Training

- The American Planning Association, the League of California Cities, and the County Supervisors Association of California institute formal training on earthquake principles for their members.

Reducing Earthquake Risk in California

Most of the recommendations in this section are summaries of previous ones.

Making Seismic Safety a Priority

- The Governor direct agency secretaries to be responsible for the progress of every department, board, and commission under their jurisdiction in carrying out their seismic safety responsibilities.

Improving the Quality of Construction

- The Governor direct that California's codes and regulations be amended to:
  - Require that a single design professional be responsible for the complete seismic design of each engineered building, indicate earthquake bracing elements and connections on plans, specify quality assurance plans, and observe construction of critical elements.
  - Improve the way licensing boards test engineers, architects, and geologists on seismic principles and aggressively enforce licensing board rules regarding professional competence in seismic safety matters.
  - Require plan checkers to review the lateral force resisting elements and inspectors to inspect these elements thoroughly, require independent peer review of important or complex buildings and authorize state and local government building departments to reject incomplete or incompetent plans, collect additional fees when the poor quality of design creates additional review work, and file complaints with licensing boards.
- The Governor support legislation during the 1995 session of the Legislature to:
  - Amend the practice acts for professional engineers and architects to require continuing education and the title act for structural engineers to define the level of seismic expertise necessary to attain and keep the license and to require structural plan checking of engineered buildings by licensed professional engineers or architects.
  - Require testing of contractor license candidates on basic seismic safety principles in construction and continuing education of licensees.
  - Require building inspectors and plan checkers to be trained and certified under programs provided by recognized organizations.

Reducing the Risk from Seismically Vulnerable Structures

- The Governor require state agencies to carry out the recommendations in the report *Policy on Acceptable Levels of Earthquake Risk in State Buildings* (Seismic Safety Commission report SSC 91-01).
- The Governor require the University of California (UC) and the California State University (CSU) systems to prepare capital budget plans for seismic retrofitting of all university buildings that pose unacceptably high risks to life by the year 2005, to determine whether they have the ability to restore critical educational and research programs following damaging earthquakes, and to begin addressing this concern in retrofit programs.
- The Governor support legislation during the 1995 session of the Legislature to:
  - Amend planning laws to require general plan safety elements to include a generalized description of seismically vulnerable building types by neighborhood and a plan to mitigate the risk from these buildings.
  - Enact legislation to require state and local building code enforcement agencies to identify potentially hazardous buildings and to adopt mandatory mitigation programs by the year 2000 that will significantly reduce hazardous and unsafe buildings by the target year of 2020.

Reducing the Risk from Seismically Vulnerable Structures (continued)

- Require public-school and community college districts to evaluate the seismic vulnerability of school structures built before 1976 and retrofit structures with significant life safety risks and to evaluate and abate life-threatening nonstructural hazards.
- Require a portion of future school bond proceeds be used to abate life-threatening structural, nonstructural, and building contents seismic deficiencies.
- Require that private-school buildings, including preschool buildings housing more than 25 students be evaluated for structural, nonstructural, and building contents seismic hazards upon sale or lease renewal, and that life-threatening risks be mitigated.
- Require the UC and CSU systems to adopt guidelines that require seismic retrofit as a condition of carrying out major renovations, reoccupancies, additions, and repairs.
- Place a general obligation bond measure on the 1996 ballot to fund the retrofit of seismically vulnerable state-owned buildings and local government essential services buildings.

Improving the Performance of Lifelines

- The Governor direct Caltrans to revise its retrofit priorities to give more weight to the importance of structures, accelerate the toll bridge retrofit program, meet its stated project completion goals for retrofitting vulnerable structures, undertake a study of the effects of near-source ground motion on seismically isolated bridges, and continue support for research and instrumentation of bridges.
- The Governor direct the Public Utilities Commission (PUC) to take an active role in the seismic safety efforts of the utilities within its regulatory responsibilities. Specifically, the PUC should review the earthquake response and risk-reduction efforts of California's railroads and electric and gas utilities, adopt needed regulations, and draft legislation that will require an earthquake-activated natural-gas shut-off valve at each mobile home park.
- The Governor direct the Department of Water Resources to help water districts identify and address seismic vulnerabilities by disseminating a summary of the causes of earthquake failures in piping systems, tanks, and other system components, and a model risk-mitigation program.
- The Governor direct the Division of the Safety of Dams to review its current assessment procedures in light of data obtained from the Northridge earthquake and to conduct seismic reevaluations and increase inspection frequency of high-risk dams in zones of high seismic hazard.
- The Governor support legislation during the 1995 session of the Legislature to:
  - Require owners of essential communications and other essential facilities and hospitals to provide reliable backup power.
  - Require water utilities to adopt and carry out long-term seismic risk-mitigation efforts.
  - Require dam owners to place earthquake motion recording instruments on major dams.

Defining Acceptable Risk

- The Governor direct the Department of Finance and the California Office of Planning and Research and request the Joint Budget Committee to convene a panel of economists and other experts to estimate the economic impacts of likely earthquake events.
- The Governor support and participate in a special high-level task force meeting, the "California Earthquake Risk Colloquium," a meeting convened by the Commission to recommend acceptable levels of risk and performance objectives consistent with those levels.
- The Governor direct the California Building Standards Commission (CBSC) to work with representatives of the engineering professions, building code groups, building inspectors, and the building industry to implement the performance objectives once they are defined.

Providing Incentives for Risk Reduction

- The Governor convene an ad hoc task force of the agencies and people who can provide incentives to encourage earthquake risk-reduction efforts.

Providing Incentives for Risk Reduction (continued)

- The Governor support legislation to carry out the recommendations for incentives developed by the "Colloquium" during the 1996 session of the Legislature.

Improving the Use of Earth Science Knowledge to Reduce Risk

- The Governor direct the California Division of Mines and Geology to map areas where active buried faults exist, describe the level of hazard associated with these faults and other subtle faults, complete the Seismic Hazards Mapping Act (SHMA) by the year 2005, and use independent peer review to ensure consistency in all aspects of the SHMA program.
- The Governor support legislation during the 1995 session of the Legislature to:
  - Require that state and local jurisdictions enforce as a minimum the Uniform Building Code grading provisions, that fills be designed by qualified professionals considering seismic forces, and that fills be inspected by qualified professionals.
  - Require continuing education for geologists, geophysicists, engineering geologists, and geotechnical engineers as part of the professional license renewal process.

Improving the Use of Land Use Planning to Reduce Seismic Risk

- The Governor direct the California Office of Planning and Research to revise the State Planning Guidelines to address acutely hazardous materials and their relation to seismic hazards.
- The Governor direct the Resources Agency to amend the California Environmental Quality Act guidelines to improve the review of seismic hazards and risk-mitigation measures.
- The Governor support legislation during the 1995 session of the Legislature to:
  - Amend general plan laws to require that safety elements address the seismic vulnerability of the building stock, that elements be updated every five years, that they incorporate information published under the SHMA, and that the existing optional review of draft safety elements by the California Division of Mines and Geology be mandatory.
  - Amend the Alquist-Priolo Act and SHMA to allow designation of faults as active based on geologic, geodetic, and tectonic evidence: to apply the acts to all publicly owned buildings, other facilities, and lifelines; and provide for alternative mitigation measures for buildings in areas of complex faulting and for lifelines.
  - Amend the dam inundation mapping program to impose sanctions on dam owners who fail to prepare and submit maps by December 31, 1996, and to require updating of maps when downstream conditions change and review of maps every ten years.

Improving the Building Code Development Process

- The Governor support legislation during the 1995 session of the Legislature to designate the CBSC as the entity responsible to ensure that building codes and their administrative provisions meet the state's acceptable levels of seismic risk, ensure the adequacy of seismic safety requirements in the codes, and develop and adopt amendments for statewide application.

Supporting Focused Research

- Legislation be enacted to create and fund a state-level Center for Earthquake Risk Reduction to implement a seismic safety research program.

Improving State Seismic Programs

- The Governor direct each state agency with the authority to design, construct, and lease facilities and those with responsibility for seismic safety programs, to:
  - Report to him on how seismic safety will be afforded priority attention.
  - Incorporate ongoing independent peer review on all seismic matters, including planning and priorities.

EXECUTIVE DEPARTMENT
STATE OF CALIFORNIA

Executive Order W-78-94

WHEREAS, I, PETE WILSON, Governor of the State of California, having declared a State of Emergency based on conditions of extreme peril to the safety of persons and property within the Counties of Los Angeles, Orange and Ventura, State of California, beginning on January 17, 1994; and

WHEREAS, building design and construction standards in California have consistently lead the world in seismic safety; and

WHEREAS, the January 17, 1994, Northridge earthquake was the first major earthquake in California to occur directly beneath a highly urbanized area; and

WHEREAS, the performance of buildings in events such as the Northridge earthquake need to be better understood; and

WHEREAS, these considerations have important implications for building design standards, and other seismic safety policy; and

WHEREAS, the public should benefit from the broad range of seismic knowledge and experience present within the Seismic Safety Commission, and throughout private industry and public institutions; and

WHEREAS, strict compliance with all statutes, rules and regulations prescribing procedures for the conduct of certain state business, specifically the award and administration of state contracts would hinder and delay the completion of this important study;

NOW, THEREFORE, I, PETE WILSON, Governor of the State of California, do hereby direct the California Seismic Safety Commission to review the effects of the Northridge earthquake and to coordinate a study of the specific policy implications arising from the Northridge earthquake, with particular attention to implications for seismic structural safety, and land-use planning:

IT IS FURTHER ORDERED that the Commission, in its work to examine the need for changes in seismic building standards, avail itself of the expertise available from building design and construction professionals; as well as academia, by creating a process for the inclusion of the following organizations in this study: the Associated General Contractors of California, the American Institute of Architects, California Chapter; California Building Industry Association, Consulting Engineers & Land Surveyors of California, Structural Engineers Association of California, Earthquake Engineering Research Institute, the Mayor of the City of Los Angeles, or his designee, California Fire Chiefs Association, California Building Officials, Southern California Earthquake Center, California Resources Agency, California State and Consumer Services Agency, California Business, Transportation, and Housing Agency, and the United States Geologic Survey, the University of California, the California Institute of Technology;

IT IS FURTHER ORDERED that the California Seismic Safety Commission present the recommendations resulting from this collaborative effort by September 1, 1994;

IT IS FURTHER ORDERED that, in accordance with the authority vested in me by the California Emergency Services Act, and in particular, Section 8571 of the California Government Code, HEREBY SUSPEND the operation of all such statutes, rules and regulation as they apply to California Seismic Safety Commission contracts for the investigation and technical analysis required in fulfillment of this order.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 9th day of February 1994.

ATTEST:

Governor of California

Secretary of State

Introduction

This report outlines affordable, common sense actions that can be taken to make our homes, schools, hospitals, places of work, freeways, and lifelines safer from earthquakes. It was developed in response to Governor Pete Wilson's Executive Order W-78-94 (Figure 1), issued after the Northridge earthquake struck the San Fernando Valley and surrounding areas. In issuing the order, Governor Wilson acknowledged that California has an opportunity to improve the policies, laws, programs, code enforcement, and professional practices across a broad front to manage our seismic risk. We should take full advantage of the time before the next destructive earthquake as a very brief window of opportunity to reduce our risk.

We cannot afford to rely on good fortune to minimize earthquake losses.

The magnitude 6.7 Northridge earthquake occurred at 4:31 on the morning of January 17, 1994, a national holiday, when most Californians were at home asleep (Figure 2 shows the epicenter and the affected area). Fifty-seven people lost their lives, nearly 9,000 were injured, and damage was in excess of $20 billion.

In many respects we were fortunate. The earthquake could have occurred during normal business hours, with freeways loaded to capacity, shopping centers crowded, people at work, and children in school. It also could have been larger; shaking could have lasted considerably longer and been felt over a much wider area. The number of injuries and deaths could have been much higher, and damage figures much greater. We cannot afford to rely on good fortune to minimize earthquake losses.

Figure 1. Executive Order W-78-94.

We must use the lessons from the Northridge earthquake to turn our losses to gains in seismic safety.

California is a world leader in reducing risks from earthquakes. We have a strong history of learning from earthquakes and building on that knowledge. We have developed a formidable technical expertise to design and build structures that withstand intense shaking, and we should be encouraged by the fact that the vast majority of structures did withstand this moderate earthquake and by the efficient response of the affected communities and agencies. Had such an event occurred in a similarly densely populated area outside California, the number of fatalities and injuries, as well as the amount of damage to structures, would have been immeasurably greater.

Nevertheless, California has not done all it can to reduce earthquake losses. The Northridge losses were enormous. Now we must use our knowledge and turn our losses from the Northridge earthquake to gains in seismic safety. We must vigorously pursue the actions recommended in this report. As Californians, we all share a critical responsibility to make our families, ourselves, and our surroundings safer from earthquakes. The vision and leadership necessary to provide an infrastructure that can withstand the forces of future earthquakes without unacceptable losses must be forged and carried out by our elected officials, policymakers, government agencies, professional organizations, and the professionals who deal with seismic matters on a daily basis.

Seismic issues must be placed in their proper economic, legal, and political context. There will always be risks from earthquakes. The Commission believes the keystone of a successful policy framework for mitigating seismic risk is to face the risk squarely, use available knowledge to the fullest possible extent, and to inaugurate common sense changes that will work in both the short and

DEVELOPING THE REPORT

Responding to the losses from the Northridge earthquake, Governor Pete Wilson issued Executive Order W-78-94 (Figure 1) instructing the Seismic Safety Commission to review the effects of the earthquake and to "coordinate a study of the specific policy implications . . . with particular attention to . . . seismic structural safety and land use planning." Furthermore, he directed the Commission to "avail itself of the expertise available from building design and construction professionals, as well as academia, by creating a process for the inclusion of . . . a number of public and private entities in the study." Governor Wilson emphasized how vital it is that we "learn all we can from this tragedy and, if possible, improve building seismic standards to protect life and property in future quakes."

In carrying out the Governor's mandate, the Commission used over three dozen background reports (published separately in the *Compendium of Background Reports on the Northridge Earthquake,* SSC 94-08) that describe the relevant laws, codes, regulations, and current practices in the fields of land use planning, structure and lifeline design, construction, and earth sciences. These reports were prepared by experts who reviewed the results of the Northridge earthquake and the legal, social, and physical environment in which they took place. The reports were also reviewed by over 60 stakeholders, from state agencies and professional organizations to private citizens. In addition, a number of detailed case studies were conducted on over two dozen buildings following the earthquake and published as *Northridge Buildings Case Studies,* SSC 94-06. The Commission also reviewed the effectiveness of the laws, codes, regulations, and programs dealing with seismic safety in California.

Figure 2. The triangle shows the epicenter of the January 17, 1994, Northridge earthquake.

long term. Solutions to reduce seismic risk must be both economically and technically feasible and be carried out by those with appropriate responsibility. Programs must have clearly defined objectives, clear lines of responsibility, adequate resources, solid plans of action, and external accountability.

This report calls for policy changes in land use planning and in the overall process by which we design and build structures and lifelines to resist earthquakes. Its recommendations call for high-priority actions by the Administration, the Legislature, government agencies, professional organizations, private business, academia, and individuals to reduce earthquake risk in California to acceptable levels.

Though most of these recommendations will be carried out by government agencies, earth scientists, and professionals in the building industry, every Californian should understand the importance of these measures and hold elected officials accountable for results.