Geology and Earthquake Hazards

Planning Guide to the Seismic Safety
Elements of Kern County, California 1975
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Kern County is one of the more seismically active areas on the west coast of the United States. Two major earthquakes have taken place in the County in historic time. Your local government has prepared this Seismic Safety Element of the General Plan to help the citizens of this county protect themselves from man-made and natural hazards caused by earthquakes and other geologic causes. It is an attempt to identify, appraise and call out the seismic and geologic hazards in the county so that mitigating actions may be taken to minimize the damage, loss of life and confusion that results from major earthquakes.

The nature of earthquakes and the causes of their destructiveness are discussed. The seismicity of the county is described in detail. A collection of maps has been compiled showing the faults in the county that may if movement occurs cause earthquakes. The known hazards from this source may therefore be considered during the planning stage before construction is undertaken. One the physical conditions of the land are understood, it is usually possible to build if suitable precautions are taken. Assessments are made of the magnitudes of earthquakes, the degree of shaking to be expected and the recurrence interval of earthquakes for various places in the county. Landslides that could be detered are shown on the fault maps and areas prone to sliding are identified. Information as to the location of soils likely to liquify during severe shaking is given. Areas of shallow water table in which seismic shaking and lurching is likely to be severe are outlined.

This report is not complete, because all sources of seismic activity are not yet identified. As more information becomes available, it will be added to the Seismic Safety Element. Nonetheless, the information contained herein furnishes a sound basis for decision making and if used wisely, can be of enormous help in preventing damage from earthquakes, landslides and similar disasters.
FOREWORD

The Seismic Safety Element is concerned with the various geological phenomena that influence man's use of the land. It is to be used as the basis for developing and implementing programs to protect the health and welfare of the people in this area.

This section of the general plan is designed to fulfill the requirements established by the California legislators under Section 65302 (F) of the Government Code of California.

It is not intended to be a comprehensive assessment of all geology and geologic hazards; rather it identifies the major geologic land use concerns, notes where further study is needed and recommends certain policies that are consistent with the following two factors: 1) the degree of seismic risk this community is willing to support and 2) the known geologic conditions.

Technical investigations in the fields of geology and seismology were accomplished under contract with Dr. Pierre Saint-Amand, Dr. René Engel, and Mr. William Park, working in concert with Kern County Council of Governments and assisted by the Kern County Planning Department. Mr. Brad Williams was project coordinator for the Council of Governments.

An atlas of quadrangle maps showing the geologic features was prepared for use in conjunction with this text. These maps will enable the planner, developer, and responsible governmental agency to identify zones of known seismic risk, so that adequate safeguards can be taken to protect the general public. The original 138 USGS quadrangles used in this study were provided by Honorable Robert Mathias, United States Congressman from California. Many other U.S. Government publications were also made available through this office.

The information provided by the consultants was transferred to the chronic bases by the Kern County Planning Department, Jack L. Dalton, Director; blue line paper for working prints was contributed by the Kern County Public Works and County Surveyors Department, L. Dale Mills, Director.

This Seismic Safety Element consists of excerpts from a comprehensive study and evaluation of available seismic information entitled "Geology and Earthquake Hazards Planning Guide to the Seismic Safety Elements for Kern County." The comprehensive study is herein made a part of this element by reference. It should be used to obtain a more detailed coverage of the seismic safety program.
SEISMIC SAFETY ELEMENT

INTRODUCTORY REMARKS

Because California has some severe and costly geologic hazards, (Figure 1) the California State Legislature enacted in 1971, legislation recommended by the Joint Committee on Seismic Safety, requiring a seismic safety element as a part of the general plans of all cities and counties. Section 65302f* of the Government Code, makes mandatory the preparation of a seismic safety element consisting of "an identification and appraisal of seismic hazards, such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failure, or to the effects of seismically induced water waves such as tsunamis and seiches."

In July, 1972, the Governor’s Earthquake Council released interim guidelines for seismic safety elements. Revised guidelines were released August 20, 1973, and adopted September 20, 1973. These guidelines with some modifications due to local seismic conditions, have been used in preparation of this element. The reason for requiring a seismic safety element is to insure that every local government consider seismic hazards in the planning process.

Prior to this geologic study, some assumptions regarding seismicity were made, based on natural processes and on long term trends. These processes have now been documented, and under this plan community values, as expressed during public hearings and meetings, have been converted into preliminary community goals.

This study will assess the degree of risk associated with such man-made and natural hazards as were identified. The people of the community can then determine the degree of risk they are willing to assume. At some point the public is no longer willing to pay more in order to reduce the risk any further.

Uses and Limitations of this Report

This report, and the accompanying maps and data, should be used only with an understanding of the intended scope and limitations of the study. The results of the study provide knowledge on the type, location and extent of hazardous geologic conditions and permit comparisons of alternative land uses over large areas. However, this information alone is inadequate for specific site evaluations such as: an individual dwelling, subdivision development, road alignment, or dam. In the evaluation of these sites, detailed geologic mapping, subsurface exploration by drilling and trenching, soil sampling and laboratory testing may be required.

Limitations of the Basic Data

The completeness and accuracy of the basic geologic data are limited by several factors: the completeness with which the ground could be examined within the allotted time, the difficulty of aerial photographic observation of many terrain features in areas of extensive heavy forest cover and the lack of subsurface exploration to verify or extend the results of surface observations.

* See Appendix A.
Much of the knowledge of surface geologic features is based upon the recognition and interpretation of characteristic landforms. In some cases, these interpretations are unequivocal. However, many processes modify the landscape. The time span over which they operate is long, and all their mechanisms and interrelationships are not well understood. Therefore, the interpretation of some landforms as being suggestive of geologic hazards is equivocal.

Most bedrock and many geologic structures, including faults, are concealed by an extensive soil mantle. Information based upon the observation of features at a relatively limited number of points was extrapolated to larger areas on the basis of geologic principles. This suffices for broad scale scientific purposes but is inadequate for understanding of local areas.

The basic understanding of many geologic phenomena is not as great as would be useful for some practical planning purposes (for example, the prediction of the time, location and effects of future earthquakes). For these reasons, one cannot rule out the possible occurrence of seemingly anomalous, unanticipated phenomena.

Limitations of the Interpretations

Limitations in the reliability of the seismic risk and slope stability interpretations are a function of the completeness and accuracy of the basic data, and of the validity of the interpretative techniques. Seismic risk and slope stability interpretations have come into existence only within the past few years. They are now a common product of geologic studies for planning. The interpretations are expressed in maps which go beyond the conventional plotting of geologic data. In part, they are predictions of the future relative density and frequency of occurrence of geologic phenomena (such as landslides). These predictions are based upon geologic principles, the geologic data, and anticipated possible alterations of the natural environment. Because most geologic phenomena occur slowly or sporadically over long time intervals, it has been virtually impossible to test these interpretations by reference to subsequent events. The use of these maps must be qualified by the understanding of the judgmental, predictive and largely untested nature of the interpretations.

The geologic maps and interpretations are in a "plastic" form. They can and should be modified to include new facts and understanding that develop.
GEOLOGIC HAZARDS IN CALIFORNIA
TO THE YEAR 2000:
A $55 BILLION PROBLEM

LOSS OF
MINERAL RESOURCES
$17 Billion

LANDSLIDING
$9.9 Billion

EARTHQUAKE SHAKING
$21 Billion

FLOODING
$6.5 Billion

EROSION $600 Million
EXPANSIVE SOIL $150 Million
FAULT DISPLACEMENT $76 Million
VOLCANIC ERUPTION $49 Million
TSUNAMI $41 Million
SUBSIDENCE $26 Million

Geologic hazards in California to the year 2000: a $55 billion problem. Estimated magnitude of losses due to ten geologic problems in California projected from 1970 to the year 2000, if current loss-reduction practices continue unchanged. (Reference No. 21)
SEISMIC POLICY STATEMENTS

A. OBJECTIVE OF THE SEISMIC SAFETY ELEMENT

The objectives of this plan are to prevent or at least reduce the loss of life, injuries, property damage and social and economical dislocation resulting from future earthquakes. Due to the sudden and unpredictable nature of seismic events, it is imperative to adopt and implement policies which endeavor to secure the highest possible degree of public protection. Such policies must realistically consider all segments of the populace without socio-economic bias.

Certain activities can be undertaken to safeguard the public, such as educational programs and evacuation drills. It is the purpose of this element to examine the scientific data relevant to seismically induced hazards and to determine land use policies consistent with the evidence. Therefore, the following policy statements regarding seismic events were adopted:

1. The personal safety of the people must take precedence over all other factors.

2. Structures designated for command control of emergency/disaster services should be designed to withstand a "maximum probable seismic event" and to remain operational.

3. Structures utilized for emergency services, schools, and hospitals should be designed to protect human life to the highest degree possible during a "maximum probable seismic event."

4. The Conclusions and Recommendations included in this Seismic Safety Element should be accepted as guidance for the preparation of local ordinances.

5. The local legislative body should adopt specific ordinances aimed at protecting human life from the effects of a "maximum probable event" of seismic activity.

6. The legislative body should establish procedures for collecting additional data and periodically updating the ordinances.

B. SCOPE OF INVESTIGATION

This element includes:

1. A general policy statement that:
   a. Recognizes seismic hazards and their possible effect on the community.
   b. Identifies general goals for reducing seismic risk.
   c. Specifies the level or nature of acceptable risk to life and property.
   d. Specifies objectives for reducing seismic hazard as related to existing and to new structures.
2. **Identification, Delineation and Evaluation of Natural Seismic Hazards.**

An investigation was made in Kern County of natural hazards related to the following:

a. Analysis of regional seismicity and of the potential of seismic activity to disrupt the community.

b. Analysis of faults or breaks in the earth's crust where movement has taken place.

c. Analysis of geologic conditions in the county, with regard to the soil and rock, stability, depth of the water table, and soils susceptible to flood conditions.

d. Analysis of the probability of landslides, mudflows, areal subsidence and liquefaction of clays and soils.

e. Projection of development constraints imposed by the potential seismic hazards.

3. **Consideration of Existing Structural Hazards.**

In addition to natural hazards, potential man-made hazards such as the stability of building structures - public and private, public utilities, natural gas and oil pipelines, dams and canals were also investigated as to their degree of safety. This study relates them to type, number of people, and duration of occupancy.

4. **Evaluation of Disaster Planning Program.**

For near-term earthquakes, the most immediately useful thing a community can do is to plan and prepare to respond to and recover from an earthquake as quickly and effectively as possible, given the existing condition of the area. The seismic safety element can provide guidance in disaster planning. (See Appendix H and Continuing Plan Sect. II.)

Other actions to be undertaken to attain the objectives of the SSE are in the domain of public education toward an understanding of seismic hazards.

a. Earthquake risks and how to cope with them calmly.

b. Improve seismic consideration in building codes; include seismic considerations in zoning and subdivision ordinances which control structures.

c. Identify seismic related hazards.

d. Organize emergency services to cope with urgent problems of medical services, communications, transportation, food, water distribution, and temporary shelter in the event of evacuation.

These subjects are considered in greater detail in Part II of this element.
5. Determination of Specific Land Use Standards Related to Level of Hazard and Risk.

C. DEGREE OF EARTHQUAKE RISK ACCEPTABLE TO COMMUNITY.

A community will willingly accept a greater economic burden for the protection of hospitals, schools and other public buildings than for homes and private structures. Thus, construction and site requirements for the former type of buildings will be more exacting than in the latter case.

Conversely, excessive regulations stifle development, introduce an unwanted economic burden, and tend to confiscate property owners rights without proper compensation. An equitable balance between society's needs and the preservation of individual property rights is fundamental to our system of government.

D. PUBLIC INTEREST AND PARTICIPATION

The SSE informs the public regarding specific local seismic hazards. It identifies means available to reduce risk and damage. Through disaster preparedness plans, it enables the public to respond to emergencies. Public participation is necessary to help decision makers determine the most acceptable policies regarding risks in relation to classes of land use, building use, and occupancy factors.

As an essential part of the planning process, citizen participation is started early in the program for the purpose of developing basic community goals and objectives (Section 65304, Gov. Code). When alternative planning concepts have been developed, there should be public review of the options through public conferences or other appropriate forms. The possible impact of each option needs to be carefully examined. Prior to official public hearings, there need to be meetings with the public to explain the content of a proposed plan to enable the public to come to hearings with better knowledge of the plan and its contents. The press should be informed as to the content of a proposed plan and the status of the planning program. Finally, published materials on the general plan should be distributed as widely as possible before public meetings or public hearings are held.

Successful citizen participation will generate support for implementation of public plans and policies after official adoption. Technical committees can also be utilized where a community is faced with particular natural resource problems.

E. METHODOLOGY IN THE DEVELOPMENT OF THE SEISMIC SAFETY ELEMENT

Phase I

As an initial step, it is helpful to determine what aspects of the element need greater emphasis. If a community is already developed, emphasis should be on eliminating structural hazards, and disaster planning would be most appropriate. On the other hand, communities with extensive open areas, and areas subject to urbanization, will wish to focus on natural seismic hazards and on the development of regulations to insure that new development is not hazardous. The following steps are suggested:
1. Initial Organization
   
a. Focus on formulation and adopting interim policy based on evaluation of earth science information now readily available.

b. Evaluate the adequacy of existing information in relation to the identified range and severity of problems.

c. Define the specific nature and the magnitude of the work program needed to complete the element in a second stage.

2. Identification of Natural Seismic Hazards.
   
a. General structural geology and geologic history.

b. Location of all active or potentially active faults, with an evaluation of past displacement and the probability of future movement.

c. Evaluation of slope stability of those soils subject to liquefaction and to differential subsidence.

d. Assessment of the potential for the occurrence and the severity of damaging ground shaking and the possible intensifying effects of unconsolidated materials.

e. Identification of areas subject to seiches.

f. Maps identifying location of the above characteristics.

3. Identification and evaluation of structural hazards; relating structural characteristics, rate of occupancy and geologic characteristics in order to formulate policies and programs to reduce structural hazard.

4. Formulation of seismic safety policies and recommendations.

Phase II

This phase of the plan is to be undertaken subsequent to the adoption of the Seismic Safety Element. Implementation of the program is accomplished by the use of the Uniform Building Code, zoning and subdivision ordinances. It is only as good as the extent to which it is put into effect. Therefore, the planner must work within the political processes of his community where the political leaders possess the final decision making authority in the formulation of an implementation program.
F. RELATIONSHIPS TO OTHER ELEMENTS OF THE GENERAL PLAN

1. To Other Elements:

The Seismic Safety Element contributes information on the comparative safety of using lands for various purposes, types of structures and occupancies. It provides primary policy inputs to the land use, housing, open space, circulation and safety elements.

2. To Environmental Factors:

a. Physical: Geologic hazards can be a prime determinant of land use capability.

b. Social: Provides the basis for evaluating the costs of social disruptions, including the possible loss of life due to earthquakes and identifies means of mitigating social impact.

c. Economic: Cost and benefits of using, or of not using various areas as related to potential damage and to the cost of overcoming the hazards.

d. Environmental Impact Report: Provides basis for the evaluation of the environmental impact of proposed projects in relation to slope and soil stability, possible structural failure, erosion, water use and similar factors.

3. To Other Agencies:

The State Geologist is required in Chapter 7.5, Division 2 of the Public Resources Code to delineate by December 31, 1973, Special Studies Zones, encompassing certain areas of earthquake hazard on maps and to submit such maps to affected cities, counties, and state agencies for review and comments.

By December 31, 1973, the Division of Mines and Geology will have delineated the Special Studies Zones encompassing all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto faults. The Special Studies Zones will be delineated on U. S. Geological Survey quadrangle sheets. The quadrangles will be included in the initial distribution which began on or about October 1, 1973, and be completed by December 31, 1973. In addition to the faults named above, all active or potentially active faults within the quadrangles listed will be zoned. The zones are ordinarily about one-quarter mile in width. Zones designated on the Seismic Hazard Maps accompanying this report are equal to or greater than those shown on the Division of Geology and Mines.

The State Mining and Geology Board is required by Chapter 7.5, Division 2 of the Public Resources Code to develop policies and criteria by December 31, 1973, concerning real estate developments or structures to be built within the Special Studies Zones.
II.

DISASTER CONTINGENCY PLANS

A. GENERAL STATEMENT

Earthquake losses are largely avoidable. For this reason, the County of Kern and each city therein, is required by state law to have contingency plans for preparedness in the event of either natural or man-made disasters. Earthquakes should be specifically included and given special treatment in such plans. Earthquakes, because of their regional extent, are, of all natural disasters, capable of inflicting the greatest loss of life and property. They may happen, without warning.

In addition to the hazards already mentioned in Part I, earthquakes may trigger events which result in disastrous fires, floods and the displacement of people. As an example: The 1906 San Francisco earthquake was, for many years, referred to as the "San Francisco Fire," because of the holocaust that was triggered by the earthquake. Virtually all of the damage was due to the fire. As recently as February 1971, about 80,000 residents were evacuated because of a flood danger that would have resulted from the possible collapse of the Van Norman Dam, damaged during the San Fernando earthquake. Fortunately, the reservoir was successfully drained without catastrophic dam failure.

When lack of reliable warning is coupled with multiple hazards, such as earth shaking, flooding, and fire, preparedness measures must take into account the particular vulnerability of the community that is at risk. Such measures must consider the population, buildings, roads, utility networks, and emergency services. (Ref. #1, page 73; see appendix #2.)

B. KERN COUNTY EMERGENCY PLANS (Ref. #2)

1. Authority and Elements

The Kern County Emergency Plan and those for each of the eleven cities were developed in accordance with the California Emergency Act (Government Code, Article 10, Chapter 7, Division 1 of Title 2) and Kern County Ordinance No. A-257 of October 3, 1972, to serve as a guide for the coordination of emergency preparedness and operations, before, during, and after a nuclear attack, other types of warfare or a natural disaster.

Act No. A-257 was implemented by resolution 72-723 and 72-795 of the Board of Supervisors of Kern County, to provide for the organization of emergency services in the unincorporated area of the county. Each city has taken or will take similar action.

These Emergency Services are derived from, and require, close cooperation between the operating departments and the branches of the Kern County government and of the eleven cities. They form an organization adaptable to all possible types of emergencies.
Essential Elements of the Emergency Services that contribute their cooperation and expertise to such an adaptation are:

a. Coordinating Center for:
   1. Direction and Control
   2. Public Information
   3. Communications
   4. Transportation and Evacuation

b. Medical Care, Ambulance Service

c. Welfare and Shelter

d. Law Enforcement

e. Fire Protection and Rescue

f. Engineering:

These involve the cooperation of the Public Works, the Building Inspection, and the Roads and Bridges Departments; of private engineers; and of engineering societies.

g. Public Utilities Operation Maintenance and Repair

h. Commerce and Industry:

Involving essential operational maintenance such as food distribution, shelter, availability of heavy construction equipment for clearing debris etc.

i. Economic Stabilization

Price control, consumer rationing, insurance and loans, etc.

2. Earthquake Emergency Planning

a. General Statement

The Emergency Services Divisions of County and City Government are well organized to develop a specially trained group to handle the urgent pre-earthquake preparedness problems. These groups should develop plans to mitigate the disruptive and destructive effects of earthquakes, before they happen. They should be ready to direct the operations needed to save life and property during an earthquake, and to help reestablish normal living trends and in ensuring safety. They should facilitate the operations of scientific groups (state, federal, academic, etc.) in the installation of instruments to collect seismic data, and in the conduct of field examinations.

During the immediate post-earthquake period, when the most urgent operations are completed, and earthquake tremors have subsided, the Emergency
services are to coordinate and help the engineering group, as defined above (Paragraph f). The objective is to complete an inventory of structural damage to buildings in the affected communities. The emergency preparedness plans of the county and city are herein adopted by reference as part of this jurisdictions' comprehensive plan.

b. Pre-Earthquake Mitigation Measures

The measures taken to render less severe the effects of an earthquake are of great importance to this part of the Seismic Safety Plan and should be implemented by the governing body in order to further establish those plans that have already been accomplished. This includes classifying buildings in Kern County and in the cities, according to their degree of safety in the event of an earthquake. To get this information, the Kern County Council of Governments sent a questionnaire to Kern County and city administrative offices. A review of the information provided by their engineering departments indicated that virtually no remedial plans have been made by any jurisdiction. Therefore, additional work is necessary in all communities in order to complete the program outlined in Part III of the SSE under the title "Existing Structural Hazards Evaluation."

The program must be comprehensive and include:

(1) Emergency Services Preparedness. The following implementation should be established:

(a) Control centers to be installed in earthquake resistant structures (possibly in sheriff or fire stations if adequate space is available or can be added).

(b) Personnel be designated and trained to perform specific tasks both within the control center and the affected area.

(c) Continuity of communications with all operating field forces, and with all echelons of government, to exchange operational information. Augment the capability of communication operations by planning contacts with standard and amateur radio stations and volunteer radio capability.

(d) Staff to prepare and to disseminate essential public information through local newspapers, television, and radio.

(e) Conduct exercises to test plans and procedures for training and to develop improvements to the plans.

(f) List the most vulnerable structures within each jurisdiction with relationship to their effect on emergency operations. (see Part III.)

(g) A fire fighting and life saving program with the county and city fire departments including maintenance of water supply, transportation and food supplies.

II-3
(2) Establishment of Health Department Policies about preparedness:
   (a) To care for a large influx of injured people.
   (b) To detect and prevent pollution of water supply by rupture of sewers.

(3) Designation on Maps of areas subject to:
   (a) Flooding due to failure of dams and irrigation canals.
   (b) Soil failure and liquefaction.
   (c) Landslides and mudflows (see Part IV, Natural Seismic Hazards).
   (d) Subsidence (see Part IV, Natural Seismic Hazards).

(4) Develop Plans and Procedures for rapid evacuation of people from the areas mentioned above.

(5) Identify and inventory of available essential materials and resources needed in each area.

(6) Establish procedures for obtaining mutual aid with the help of community groups and organizations, utilities and industrial corporations and professional associations, along with that from nearby towns and cities, counties, state, and federal governments.

c. Emergency Operations Immediately After the First Damaging Shock

The Emergency Services Division is responsible for administration of the following:

(1) Activate the control centers located in the areas affected by the earthquake. Check communications and liaison with sheriff and fire departments and public utilities. Start log of operations.

(2) Search out, and rescue, people trapped in damaged structures or isolated danger areas.

(3) Provide first-aid to and transport the injured to emergency medical facilities. Provide for water, food and clothing.

(4) Rapidly examine and delineate danger areas, evacuate or direct people to locations providing relative safety, shelter, and sustenance.

(5) Provide help to public utilities for maintenance and repair of services.

(6) Coordinate clearing and repair of roads, supervise traffic, provide security for evacuated areas; prevent access to dangerous buildings; and prevent unforeseen emergencies – all through mutual aid with official and private cooperation.
(7) Prepare information to be furnished to news media.

(8) Provide help to qualified earthquake investigators.

d. Post Earthquake Operations

After the major shock or shocks have subsided into a series of less severe or non-damaging after-shocks, the post-earthquake operations should commence under the direction of the Emergency Services Division. Operations listed under c above are either started during this phase or, depending upon the intensity and duration of major shocks, suspended and then continued to completion when it is safe to do so. The start of this phase is contingent on safe working conditions for Emergency Services personnel.

Additional tasks to be performed are:

(1) Social Disruption Abatement. As an aftermath of a serious disaster local government functions may become inoperative and have to be replaced by temporary personnel during the emergency. As far as feasible, essential public social activities should be reestablished through mutual aid and cooperation.

(2) Removal, identification and preservation, of dead persons and the notification of relatives should be done expeditiously.

(3) Provide for reuniting families dispersed by disaster. Maintain lists of dead and injured and of temporary addresses of survivors.

(4) Provide help in the assessment of damage by the engineering group (as defined in paragraph B.1.f) to structures, utilities (water, electricity, gas), highways, railroads, and airports. Hazardous structures should be identified as rapidly as possible. Warning signs should be posted before shoring work is started. In order to decrease the danger of collapse, shoring work should be completed in accordance to the sequence shown on a priority list. Such a list should be compiled by the inspection team.

(5) Following each earthquake, a serious field investigation of the phenomena produced by the earthquake is carried out by structural engineers, geologists, seismologists, geophysicists, sociologists and others. This group has as its primary objective, the goal of learning as much as possible about the earthquake so that future earthquakes can be better dealt with. The work done by these persons is of inestimable value to the various levels of government and to individuals in planning for actions to alleviate the effects of future earthquakes. While on the scene, these people can be of great help to the Emergency Services and to the local governments in assessing the most effective way to proceed with emergency measures, and in planning reconstruction. They are usually willing to give freely of their time and advice and are a real resource of knowledge in that their experience in assessing previous earthquakes and disasters can be of great help. Unfortunately, their work must be done as soon as possible after the earthquake, or other disaster,
and frequently they find themselves at odds with the police and military who wish to keep people out of the affected area.

The County should grant in advance, credentials and other distinguishing insignia to qualified individuals, who solicit them so that they can, at their own risk, pass freely and accomplish their necessary work. While these people are usually self-sufficient, it would be helpful if the county could aid them in obtaining access to private property for the purpose of setting up portable seismograph stations in order to record aftershocks and for making geologic investigations.
A. PRESENTLY EXISTING

1. Pre-Earthquake Planning by Public

Much of the damage produced by an earthquake can be avoided if care is taken, during routine fire and other building inspections, to call attention to items that could be an earthquake hazard. Many fires are caused by improper storage of chemicals and solvents. Considerable injury results from fall of unstable objects such as bookcases, filing cabinets, pictures and fluorescent light fixtures. Corrective measures are simple and cheap. A public awareness of such problems should be created by working with property owners and by appropriate publicity given to identification of such situations.

2. General Statement

The most urgent priority in the Hazard Abatement Plan of the SSE is the inspection and evaluation by the Engineering Group (see Chapter II, Section B-1.f), of structural damage that may result from future seismic activity. A priority listing should be made of structures after a critical examination to determine whether they meet community standards, whether they must be repaired, or whether they should be demolished because reconstruction cost exceeds a predetermined percentage of the value of the building.*

On the same priority list, identify and cause to be removed from buildings all non-structural parts deemed to be hazardous. This includes but is not limited to features such as cornices, parapets, unsafely anchored signs, etc.

The public should have explicit notice of buildings that constitute potential seismic induced structural hazards. This could be accomplished by requiring all potentially dangerous structures to be posted with signs indicating that their seismic safety is suspect.

Generally, existing substandard structures of all kinds constitute the greatest hazard to a community and mitigation processes described should be immediately activated.** There should be a continual on-going program to reach a status of economically acceptable safety, commensurate to the degree of structural soundness the community is willing to support.

Examination of structures should be scheduled according to a priority list and simplified guidelines. A procedure such as the age date base used in the Field Act of 1933 and giving two classes-pre-reference date and post-reference date structure could be used. It should include the type of control (community, state, federal, or private), and type and duration of occupancy (man-hours per day), physical condition and location. Each community should have a dangerous building ordinance to cover existing structural and non-structural hazards, similar to the 1973 Dangerous Buildings Code (Volume IV of the Uniform Building Code), modified to specifically treat earthquake risk.

* International Conference of Building Officials' "Dangerous Building Act."

** "Geology and Earthquake Hazards," Planning Guide to the Seismic Safety Element, Kern County, California.
It is recommended that the seismic safety condition of existing structures be a major factor in the selection of urban areas for redevelopment.

3. **Suggested Priority Action Schedule**

   a. Post signs in dangerous structures to warn the public.

   b. Remove all dangerous, outer, non-structural parts of buildings.

   c. Warn building occupants of inside dangerous hazards such as: partitions, glass, elevator counterweights, poorly anchored library stacks and shelves, improperly placed bottles in chemical laboratories, etc. Routine fire inspection prior to earthquakes can identify, and cause to be corrected, such hazards.

   d. Safety inspection of public and community buildings and the evaluation of degree of risk with recommendation when necessary for repair, demolition or replacement.

**B. POST EARTHQUAKE—STRUCTURAL DAMAGE AND HAZARD EVALUATION**

Damages to structures are surveyed and then evaluated and placed on a priority basis by the Engineering Group. From this investigation will emanate decisions relating to the degree of risk most acceptable to the community—either to repair or to demolish the damaged buildings. This group will decide on the action to be taken. In addition to the buildings, this survey is to include damages to public utilities, roads and highways, railroads, airports, dams and canals, agricultural and industrial plants and to the land. All hazardous and potentially hazardous conditions caused by ground movement and rupture should be listed. This also includes the damages which may result from mass movements such as mudflows and landslides.

The Kern County Building Inspection Department has established standard procedures for inspection and reporting of damage as a result of earthquakes and other disasters (Administrative Bulletin #1 of August, 1972).

For the sake of uniformity, each city should adopt this procedure. The county is divided into three areas with command posts in Bakersfield, Shafter, and Ridgecrest.
IV.

NATURAL SEISMIC HAZARDS

A. GENERAL STATEMENT

A list of natural seismic hazards investigated and analyzed in the SSE is given on page I-2 under paragraph B-2.* An overview of the environment in which seismic hazards develop under the influence of natural forces is presented in Appendix G, under the title "Outline of the Geology of Kern County."

Seismic and geologic hazards in Kern County were identified and delineated by compilation and critical study of all available published data, supplemented by field work in selected areas. This information was transferred to 7½" min. USGS topographic quadrangle maps (the largest published scale - 1:24,000 or about 1 inch = 2,000 ft.) so as to be clearly understandable by anyone concerned with land development or construction. In the eastern part of the county, where large scale maps are not yet completed, 15 min. quadrangles (the next smaller scale - 1:62,500 or 1 inch per mile) were used.

B. SEISMIC HAZARD ATLAS — Detailed Maps

The Seismic Hazard Atlas accompanying this study is intended to draw the attention of builders, developers and planners to areas of possible geologic and seismic hazards to existing and future structures. It includes 138 quadrangles listed on tables 1 and 2*.

The information shown has been collected from a wide variety of sources. Liberal reference has been made to published and unpublished data from the United States Geological Survey, California State Division of Mines and Geology and the California State Division of Oil and Gas. Because of the generous cooperation of oil and gas companies and consulting geologists in the Kern County area, some of the information shown in this study has come from confidential files not previously published. Many years of experience, in the Kern County area by the authors, have been drawn upon in data collection, collation and interpretation of a large volume of information.

The reader is cautioned that most of the source data is of a regional nature and the science of geology is often highly interpretative, particularly in the subsurface. Because of the breadth of this study and time limitations, a thorough check of source data and field investigation was impossible. Even though a great deal of information may be shown in some areas this should not be considered as a detailed study of any particular parcel of land. Nor should it be concluded that no hazards exist in a particular area simply because no data were available.

The basic data presented in this portion of the Seismic Safety Element are as follows: (1) Rock Types, (2) Rock Structure, (3) Landslide Data, (4) Shallow Water Tables, (5) Earthquake Epicenters, (6) Fault Characteristics and (7) Subsidence.

*"Geology and Earthquake Hazards; Planning Guide to the SSE for Kern County"
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QUADRANGLES - Kern County (Alphabetically)

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**TABLE 1**

**QUADRANGLES**

**List by Map Index Number of Quadrangles**

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1. **Rock Types**

Rock types were divided into three broad categories in an attempt to indicate to some extent the degree of consolidation. For the most part they consist of material at the surface or immediately beneath the soil cover. They represent varying degrees of competency in their ability to support foundations.

These groups are as follows:

a. Crystalline Rocks (Cr)

   This group includes all igneous and metamorphic rocks. Because of their crystalline structure they generally constitute the most consolidated rocks. This group does, however, include some rocks that are not well consolidated such as volcanic tuffs and contains zones of cataclastic material and badly fractured rocks, usually adjacent to major faults. Site evaluation is necessary at these locations to insure proper foundation design.

b. Older Sediments (Os)

   This group is made up entirely of sedimentary rocks. They are generally Pliocene Age and older and are for the most part moderately to well consolidated. In some cases the Pliocene and Pleistocene sediments are in gradational contact and are undifferentiated. In these cases the contact line as shown on the maps for Older Sediments may include some sediments of Pleistocene age.

c. Younger Sediments (Ys)

   These sediments are generally the least consolidated of the three groups and consist of alluvium, river terraces, and dune sands. They are Quaternary in age, deposited during Pleistocene and Holocene (Recent) time.

2. **Rock Structure**

The contact between different rock types is represented by a solid line where observed at the surface and a broken line where inferred. Uncertain contacts are emphasized by the addition of question marks.

The structure of the rocks in Kern County is shown on the maps as faults and folds.

**Strike and Dip**

Strike is the direction or bearing of a horizontal line in the plane of an inclined stratum, joint, fault, cleavage plane or other structural plane that would be displayed if topographic irregularities were removed.

Strike direction is written as the azimuth of the line, expressed in degrees of bearing east or west of a north-south line. Thus, a feature which strikes
$40^\circ$ west of north would be described as \( N 40^\circ \) W or \( S 40^\circ \) E.

Dip is measured in a vertical plane which is always at right angles to the strike. It is a measurement of the number of degrees the features deviates from the horizontal. Horizontal or flat features are designated as having zero degrees of dip while vertical features are designated as having $90^\circ$ of dip.

Strike and dip are represented on a map by a symbol having a line oriented in the direction of strike that is bisected by a short line indicating the direction of dip. The amount of dip is listed in degrees near the dip bar.

**Faults**

Faults are ruptures in rocks, either surface or subsurface, in which one side has moved past the other. An attempt has been made in this study to show, by the use of different symbols, all that is known about each individual fault represented. These data include the approximate width of the fault zone (shaded area), length of the fault, last known movement, amount of movement, sense of movement, whether the evidence for the fault is at the surface or in the subsurface only and the quality of the evidence.

**Types of Faults:**

**Strike Slip Faults:** In this type of faulting, the relative movement of the blocks of land in either side of the fault surface is predominately horizontal. The sense of movement is defined as sinistral, or left handed, if the left side of the fault as observed from a point on the fault has moved towards an observer. If the right side has moved toward the observer astride the fault, it is said to be dextral, or right handed. (see Fig. 2)

One finds in common use, terms such as lateral fault, longitudinal fault, wrench fault, transcurrent fault etc., often used to describe strike slip faults. These terms do not necessarily mean quite the same thing and such usage should be observed with caution.

**Dip Slip Faults:** In dip slip faults, movement is predominately vertical—parallel to the dip of the fault plane. These faults are of two types: normal and reverse.

**Normal Faults:** If the fault plane dips beneath the downdropped block, the fault is called a normal fault. These faults are usually associated with an extension of the terrain at right angles to the fault. They are sometimes called gravity faults.

**Reverse Faults:** If the fault plane dips under the upthrown block, the fault is called a reverse fault. Reverse faults that dip less than $45^\circ$ are often called thrust faults. Reverse faults are usually caused by compression of the earth's crust.
Oblique Faults: Virtually no fault is exactly a reverse fault, a strike-slip fault or a normal fault, because some combination of horizontal and vertical movement is usually present. If enough of both horizontal and vertical movement is present to be easily detected, the faults are referred to as oblique faults. Thus the White Wolf Fault, at the foot of Bear Mountain is a "left handed-steep reverse-oblique" fault.

Causative forces: Normal faults are usually caused by an extension of the crust. Reverse and thrust faults are produced by compression. Strike slip faults are usually related to a shearing movement. All three types can be caused by shear or by compression and it is often difficult to tell the nature of the deformation because all three types may be found in the same locality. Because of differences in orientation of the fracture with respect to the direction of the causative forces, or because of changes in direction of compressional axes in the geologic past, the problem of unravelling the causative mechanism may require extensive study.

Designation of Faulting: A fault is represented by a single solid line if evident at the surface.

Fault Zones: If the fault is more than a single rupture and has a scaleable width which has been measured or estimated it is shown as a fault zone ( ).

Moving Faults: In those few known cases where a fault is creeping or is indicating present continuous movement diamonds have been added to the fault symbol ( ).

Recently Active Faults: In the event there is evidence that a fault has moved in geologically recent time and/or has displaced Younger Sediments (Ys) circles have been placed on the single line ( ).

Inferred Surface Faults: Where evidence of a less precise nature is present, such as the probable extension of a known fault, geomorphic indications such as lineaments, alignments of cols, butts and topographic irregularities etc. and it can be inferred that a partially or completely hidden fault exists, but the exact location can not be pinpointed, the fault is shown by a broad, broken line ( ).

Subsurface Faults: Faults whose presence is established from geophysical information, such as well logs, seismic surveys and similar data are indicated by a line consisting of alternate dashes and dots ( ).

Inferred Subsurface Faults: Where the only data available is derived from subsurface information and it has been inferred that a fault must exist, but that its location is not precise, the fault is shown by a narrow dashed line ( ).
Figure 2. Fault types common in California:
A. Incipient fault, before movement; B. Normal fault; fault surface dips toward down-dropped block; similar to Kern River fault; C. Reverse fault; fault surface dips away from down-dropped block; similar to Pismo thrust fault; D. Horizontal, strike-slip fault; left lateral movement (block opposite observer has moved to left); similar to Garlock fault (San Andreas fault is horizontal, but with right lateral movement); E. Left lateral reverse fault (combination of movements of C and D); similar to White Wolf fault.
Sense of Fault Movement

The sense of movement of one side of a fault in relation to the other side is shown by the addition of another array of symbols added to those above. These data give the amount and direction of the relative movements that have occurred along a particular fault, if known. The side of the fault that has moved upward in relation to the opposite side is shown by a U. The side that moved downward is indicated by a D. If the distance of movement is known it is indicated by the distance in feet near these symbols. The dip of the fault contact surface is shown by a short line at a right angle to the fault indicating the direction of dip. The angle of dip measured from a horizontal plane is given at the end of that line. A normal fault, at a known location, having a total vertical displacement of 400 feet along a contact surface which dips at 70 degrees from horizontal is shown as follows: \[ \text{D} \text{400 feet} \text{70} \].

The relative movement of the opposite sides of faults may be vertical, horizontal, or oblique. If the movement is predominately in a horizontal direction the direction and distance are shown by arrows and the number of feet of movement ( \[ \text{D} \text{400} \]).

Folds

Folds are bends or flexures in rock strata. These structural features have been indicated in this study by a set of symbols independent of those used for faulting and it is important not to confuse the two.

Folds are evidence of a shortening of the crust caused by compression or by shear. They may also be produced by the action of gravity upon incompetent beds and may occur at, or shortly after, the time of deposition or over a long period of geologic time.

Homocline: A homocline is a section of rock in which the dip is uniform in one direction. A homocline may be a local or regional affair and may result from original deposition on a slanted surface or from subsequent tilting without much internal deformation in the rock.

Monocline: A monocline is a local steepening in an otherwise uniform dip. It is formed where the dip changes from gentle to steeper and back to gentle again. Monoclines often mask faults that occur at depth and which have not yet moved enough to rupture the softer surficial beds.

Anticline: An anticline is a fold that is arched upward or has such an attitude at the first stage of development. Anticlines are indicated on the maps by a line representing the outcrop of the axial plane of the fold; two arrows pointing away from the axis represent the direction of dip of the limbs of the fold. If the axis of the anticline is known to dip or to plunge in a particular direction it is so noted by an arrow at the end of the line which represents the axis. A normal anticline with a known direction of axial dip is presented as follows: \[ \text{A} \text{D} \text{90} \].

Deformation may have been so intense in a particular area that the present attitude of the anticline is such that instead of being arched upward it is turned...
on its side. In this event the fold is referred to as an overturned anticline. Such a structure is indicated by the following symbol: 

**Syncline:** A syncline is a structure, opposite to an anticline, in which the fold is concave upwards or had such an attitude in the initial stages of development. Synclines are indicated by a line representing the axis of the fold as is used for an anticline but with this difference – the arrows point toward the axis, representing the dip of the limbs of the syncline.

As in the case of anticlines, synclines may be in an overturned attitude and are so indicated by the symbol ( ).

In the event that anticlines and synclines are concealed and determined by subsurface data only, the above symbols are used but the axis is shown by a dashed line as follows for a subsurface anticline: 

In areas of tight folding, strong forces have been acting on the formations. Surface material may have been weakened so it is no longer competent. Special engineering and geological considerations should be required in such areas.

3. **Landslide Data**

Areas of known landslides have been noted on the maps by a symbol that outlines the boundary of the slide area with arrows showing the direction of movement. The toe or lower extremity of the slide is shown by small squares superimposed on the boundary line as follows: 

No attempt has been made in this study to determine the age of the slides nor the degree of stability. It is also recognized that many areas of unstable slope conditions exist that are not identified. Unstable slope conditions are prevalent in some areas of Kern County and careful attention should be given to this hazard prior to any development work. Landslides that appear to be stable may become active again following earthquakes or following additional loading such as construction on their surfaces. Excavation from the toes of landslides may reactivate the slides. Prolonged periods of wet weather or agricultural watering may aggravate the condition. Areas near to, but not involved, in landsliding may develop slides if something is done to disturb the equilibrium. Areas in or near landsliding should have special geologic studies before being used for construction.

4. **Shallow Water Table**

Areas in which earthquake vibrations may produce liquefaction of soils and endanger foundations are shown on the quadrangle maps and on the map that delineates shallow water table 5 to 15 feet below the ground surface. (Map No. 2) It is recognized that not all areas subject to liquefaction have been identified. Liquefaction may occur in areas having water tables at depths in excess of 15 to 70 feet.
5. Clay Soils

Areas are identified that may swell by water adsorption and through earthquake vibration become less viscous or thixotropic. These materials could cause mudflows or impair the ability of the soil to support foundations of structures. (Maps 2 and 3)

6. Earthquake Epicenters And Strain Release

Epicenter locations were plotted from data furnished by the Seismological Laboratory, California Institute of Technology, Pasadena. They include the years 1932-1971. Each epicenter is marked by a magnitude symbol indicating the total strain released at that location by one or more earthquakes during the 39 year period for which data are available. This magnitude symbol represents an earthquake equal to the sum of the individual strain releases expressed in units based on the strain release of one Earthquake Magnitude 3 (Richter Scale) taken as a unit. The number of earthquakes is indicated by a subscript (see Table 1 of Fig. 3 and Map No. 2)

Statistical analysis of the magnitude, frequency, sequence of occurrence and exact location of past earthquakes is one method used to predict future earthquake activity. The epicenter map of Kern County is a beginning in such an analytical approach.

A study of the distribution by location, frequency and magnitude of past earthquake epicenters in Kern County may give a first approximation of the magnitude and the location of future epicenters. Forces producing past earthquakes will continue to build up. When the structural strength of the rock is surpassed, earth movement which produces earthquakes will occur in the same or nearby location. Most earth scientists agree with this assumption in its most general terms, but there is no agreed way in the present state of the art to refine this concept and to predict when or where or how powerful the next earthquake -- or next 100 earthquakes -- will be.

The length of time for which earthquake epicenter and magnitude determination is available is short compared to geologic time, and patterns of occurrence may change. As time goes on, more precise ideas as to where earthquakes occur will certainly be developed. The locations of the epicenters is made as carefully as possible, given the information available for a particular earthquake. Some of the larger shocks are located to less than a kilometer, some of the smaller and older shocks have errors of location of as much as 10 kilometers. Therefore, one should not over interpret the fact that an earthquake of no great size is located at any one point on a map.

An epicenter map, even if it could overcome the time-base and location-accuracy limitations inherent in the current state of the art, represents raw data for use in seismic safety planning. The epicenter map must be interpreted along with the other data to be useful in local planning.

Other data that should be used in conjunction with the epicenter map in efforts to plan for future earthquakes include:

a. Damage actually caused by past earthquakes: the "Earthquake Intensity" map gives a start on this. (Map 5)
<table>
<thead>
<tr>
<th>N3</th>
<th>.0</th>
<th>.1</th>
<th>.2</th>
<th>.3</th>
<th>.4</th>
<th>.5</th>
<th>.6</th>
<th>.7</th>
<th>.8</th>
<th>.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3.00</td>
<td>1.21</td>
<td>1.52</td>
<td>1.87</td>
<td>2.30</td>
<td>2.83</td>
<td>3.47</td>
<td>4.23</td>
<td>5.23</td>
<td>6.50</td>
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<td>7.95</td>
<td>9.76</td>
<td>12.0</td>
<td>14.8</td>
<td>18.2</td>
<td>22.4</td>
<td>27.6</td>
<td>33.9</td>
<td>41.7</td>
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</tr>
<tr>
<td>5</td>
<td>53.1</td>
<td>77.7</td>
<td>95.5</td>
<td>120</td>
<td>145</td>
<td>178</td>
<td>219</td>
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<td>332</td>
<td>408</td>
</tr>
<tr>
<td>6</td>
<td>502</td>
<td>617</td>
<td>759</td>
<td>934</td>
<td>1,150</td>
<td>1,420</td>
<td>1,740</td>
<td>2,140</td>
<td>2,640</td>
<td>3,240</td>
</tr>
<tr>
<td>7</td>
<td>3,990</td>
<td>4,960</td>
<td>6,030</td>
<td>7,420</td>
<td>9,130</td>
<td>11,300</td>
<td>13,900</td>
<td>17,000</td>
<td>20,900</td>
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<td>39,000</td>
<td>47,900</td>
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<td>89,200</td>
<td>100,000</td>
<td>135,000</td>
<td>166,000</td>
<td>200,000</td>
</tr>
<tr>
<td>9</td>
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<td>310,000</td>
<td>380,000</td>
<td>468,000</td>
<td>576,000</td>
<td>708,000</td>
<td></td>
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</tr>
</tbody>
</table>

**Strain Release**

Each earthquake is assigned a strain-release figure based on the simplified magnitude-energy relation.

\[
\log E = 11.8 + 1.8M
\]

\[E = \text{Energy (ergs)} \quad M = \text{Richter Magnitude}\]

To avoid using a strain-release figure that involves the elastic constants, the strain-release is represented in terms of the equivalent number of magnitude 3.0 earthquakes, N3, so that:

\[N3 = 10^{0.90(M-3)}\]

Thus, two earthquakes differing by one unit in magnitude (M = 4 vs. M = 5) will differ by a factor of about 8 in strain-release. Therefore, a magnitude 7.0 shock will be equivalent to 3990 magnitude 3.0 earthquake.

When, during the study period (1932-1972), two or more earthquakes occurred at the same general location (epicenter) only one symbol was plotted on the map. It represents the conversion of summation of the individual strain-release's effective magnitude, as shown on the above chart. A subscript adjacent to the symbol represents the number of individual earthquakes for which summations were made.
Smoothed strain-release map of southern California region after ten iterations. The contours connect points having the same values of strain-release. Note that Kern County has had a strain-release history, most of it caused by the 1952 earthquake, at least as impressive as any other part of southern California. Ref. #3, pg. 771

IV-12

Figure 3
b. The specific types of ground motion involved in each earthquake; for example, duration, character of wave motion, etc. - the state of development of earthquake-recording instruments and interpretive skill is just beginning to meet this need.

c. Geologic factors - locations of known faults, especially those recently active ones marked by recorded epicenters: the "Provisional Fault Map of California," although subject to severe limitations, is a start toward accumulating this information.

d. Geologic factors - locations and characteristics of surficial rock, alluvial fill, and soil units: the art of defining and evaluating the seismic properties of specific geologic materials and formational units - the properties that enable prediction of their behavior under a given type and degree of earthquake shaking - is in its infancy.

C. GENERALIZED MAPS

These Kern County maps at a scale of about 1/3 inch to the mile show broad relationships that quadrangles at a larger scale are unable to express clearly.

Map 1 is an index map of the Seismic Safety Atlas showing the positions of the quadrangles and supplemented by the lists on tables 2 and 3.

Map 2 shows the location of the earthquake epicenters with their respective strain release, the areas covered by clay bearing soils capable of expanding the areas of shallow water and the major faults. These data were transferred from the quadrangle maps. It shows the amount of convergence and overlap of clays and water table at various locations. It also shows the northeasterly trend of the strain release axis, which is nearly parallel to the White Wolf Fault and the western part of the Garlock Fault. It confirms the trend shown on Fig. 3.

Map 3 depicts the subsurface limits of clay beds A, C and E. from the surface to depths of 300 feet and capable of creating hazards in the event of an earthquake.

Map 4 shows the area of land subsidence affecting the San Joaquin Valley between Delano and Wasco and South of Bakersfield as far as Wheeler Ridge.

Map 5 gives the Earthquake Intensity distribution by means of contours passing through points of equal intensity (Modified Mercali Scale) determined by the U.S. Coast and Geodetic Survey after the Kern County earthquake of July 21, 1952. (Ref. 5, page 208)
D. DISCUSSION OF SPECIFIC NATURAL HAZARD

1. Earthquakes and Seismicity

a. History of Major Shocks in Kern County.

Kern County has had but few seriously damaging earthquakes in historic time, but historic time is short in this area. In the distant past, many earthquakes have occurred and their history is written eloquently in the complex geology of the area. There is every reason to expect that they will continue to happen. Before the advent of seismology as a science, and the development of instrumental recording, information on earthquakes was limited to newspaper accounts of disasters, diaries, letters, journals, church records and official reports. These were sometimes written with care and insight, but more often than not are fanciful accounts of limited use.

San Joaquin Valley, June 1853, is the first earthquake noted, but no details are available.

Fort Tejon Earthquake, 1857: This very large earthquake took place on January 9, at 1813 San Francisco local time. The intensity approached Rossi Forrel X or a Modified Mercalli XII. The magnitude is unknown, but probably exceeded a value of Richter 8.

H. O. Wood (Ref. 24) considered this earthquake to be the greatest in California History. It was severe from north of Cuddy Valley to San Bernardino. Damage at Fort Tejon near the curve in the San Andreas Fault, was total. Collapse of adobe houses was widespread. An intensity of Rossi Forrel IX to X was estimated for Cuddy Valley, and RP VII to IX for inhabited parts of the southern San Joaquin Valley. The intensity in the Los Angeles area was surprisingly high. Lurching of the ground was reported along the Santa Clara and San Gabriel Rivers and damage was noted at Temple Ranch, now Temple City. It is likely that some of these effects were due to movements on faults other than the San Andreas.

This shock was accompanied by displacement along the San Andreas Fault. The descriptions published in the Visalia Iron Age by Stephen Barton (1879), 19 years later are clear and unmistakable accounts of strike and slip faulting. The northern end of the slippage was reported as "70 miles west of Visalia."

The southern extent was at least to Lake Elizabeth and probably to San Bernardino. Levi Noble (1953) states that some of the displacements seen along the fault in the Palmdale-Pearblossom region may well have been made in 1857. Barton states that the breakage extended into the Colorado Desert. Recent work by Clarence R. Allen (1957 a and b) shows that the San Andreas is overlain, or cut off, by the Banning Fault and hence it is difficult to see how the crack as described by Barton and as proposed by Wood could have reached into the Colorado Desert, if the fault itself did not do so directly. Fairbanks (1908) gives circumstantial evidence that it probably broke as far as Patton, near San Bernardino.
The amount of movement has been variously estimated on the basis of reports of observers who, although clearly stating that what is now called strike slip movement took place, recorded neither the magnitude nor the sense of displacement. A frequently repeated story, confirmed by Wood, is that a circular sheep corral constructed of wooden poles, had been located across the fault and that after the displacement of the earthquake, it had been converted into a rude letter "S". The story is told with variations of detail and no one seems to know just how rude the "S" was nor how large the corral was. Such corrals are still in use and are usually between 10 and 15 meters in diameter. Hence it seems reasonable to guess that at least 6 meters of displacement occurred. Very little vertical displacement, if any, was reported.

The main shock was preceded by some strong foreshocks, and aftershocks were noted over a wide area. The effects of long period waves of great amplitude were pronounced as can be deduced from the behavior of water in rivers and lakes as far away as Bensons Ferry. Some idea of the severity of shaking may be had from graphic descriptions of broken trees, fallen houses and disturbed animals.

One of the more fascinating accounts was given by J.M. Barker to the Bakersfield Women's Club and recounted in California Geology, August 1972 by Donald B. Eisman. Barker told of his experience on the shores of Tulare Lake between Cross Creek and Kings River. He was watering his horse at a small water hole near the edge of the lake when the earthquake struck. He had dismounted, and just as he reached the edge "the ground seemed to be violently swaying from east to west. The water splashed up to my knees; the tree whipped about, and limbs fell on and all around me. I was affected by a fearful nausea, my horse snorted and in terror struggled violently to get away from me, but I hung on to him, having as great a fear as he had himself. Of course, all this occupied but a few seconds, but it seemed a long time to me. The lake commenced to roar like the ocean in a storm, and, staggering and bewildered, I vaulted into the saddle and my terrified horse started, as eager as I was to get out of the vicinity. I found my friend, who had not dismounted, almost in a state of collapse. He eagerly inquired, while our horses were on the run and the lake was roaring behind us, 'What is this?' I replied, 'An earthquake - -.'"

They rode off about 5 miles and upon returning to the lake the next day noted that it had run up on the land for about three miles. Stranded fish were everywhere. Barker could not help but wonder what would have happened had a great city stood on the shores of the lake.

This effect was observed about 40 or 50 miles from the San Andreas fault and well over 100 miles from the Tejon area.

Kern River, September 4, 1868: This little known earthquake caused a rock slide just below Upper Kern Lake, damming the Kern River. The natural dam eventually broke and the Kern River Valley was flooded. Boulders were carried downstream as far as Bakersfield. It is thought that the earthquake occurred on the Kern Canyon Fault.

Owens Valley Earthquake of 1872: This monstrous earthquake was not in Kern County, but its effects were felt all over the region and it is
typical of the sort of earthquake that can occur along the southern exten-
tension of Owens Valley into Kern County. The disaster took place at
0230 Local time on the 26th of March, 1872. The magnitude is unknown,
but it probably reached 8.5. The earthquake was felt as far as Arizona
and Utah. At Lone Pine, 27 people were killed out of a population of
250. Fifty-two of the fifty-nine houses in the town were destroyed,
as were most of the houses between Owen's Lake and Bishop. Death and
injury were due mainly to collapse of adobe buildings. Severe damage
occurred as far away as Visalia and Grassy Valley. Rock falls were
widespread. The air was filled with dust until noon.

The geologic effects of this earthquake may be seen to this day. A
dextral, horizontal displacement of some 5 meters, took place on a fault
just to the west of Lone Pine. On another fault about one kilometer to
the west, the Alabama Hills were uplifted about 7 meters. The block
upon which Owens Lake lies was tilted down on the northwesterly corner
as evidenced by increased height of the water at that place.

Mojave, July 29, 1894: Moderate shock with minor damage. Felt from
Bakersfield to San Diego.

Bakersfield, December 23, 1905: Local shock with some damage to a num-
ber of buildings. Felt at Wasco and Tejon Ranch.

Tejon Pass, October 22, 1916: An earthquake of magnitude 6 and intensity
VII MM damaged the highway near Gorman and was felt over a wide area.

South of Maricopa, February 16, 1919: A shock of probable magnitude 6
and intensity VII MM damaged Maricopa, Belridge and Grapevine station;
there were landslides at Lebec.

Kernville, June 20th 1926: An earthquake of perhaps magnitude 6 damaged
Old Kernville, reaching an intensity of MM, VII to VIII.

Walkers Pass, March 15, 1946: An earthquake of magnitude 6.2 took place
in the unpopulated Walkers Pass region. It caused some landslides and
produced damage to some weak structures in Onyx and Weldon.

Kern County, July 21, 1952, 0452 PDT: This shock of magnitude 7.7 and
its accompanying aftershocks affected all Kern County and parts of Los
Angeles and Santa Barbara Counties as well. The earthquake took place
on the White Wolf Fault. Destruction in Arvin and Tehachapi was exten-
sive. The quake caused many landslides and damaged highways, bridges
and railroads. Crops suffered from the loss of irrigation water in the
heat of summer owing to loss of electrical power caused by the fall of
transformers from poles. Oil and water tanks were pulled from their
foundations. The Paloma Refinery was destroyed by fire.

Damage to Bakersfield from the main shock was slight, but on July 29,
and on August 5, aftershocks located just east of Bakersfield produced
a great deal of damage to older buildings, some of which had been weak-
ened by the main shock. The total damage reached a value of $12,600,000
(Ref. 4 and 5). Had the area been as highly developed as it is now, dam-
age would have been much more severe. This is graphically illustrated by
the San Fernando earthquake magnitude 6.6, which produced $553,000,000
damage. (Ref. 6)
b. **Epicenters and Seismicity (Clusters and Hazards)**

The term seismicity means the seismic or earthquake activity of a definite region of the earth. Activity for a given area may be expressed by the number of earthquakes and their respective strain release during a definite period of time. It was stated above that a map showing the seismicity zone oriented in a NE-SW trend, extending from Walker Pass east of Lake Isabella in the NE part of the county to Wheeler Ridge in the SW. This area is the place where the aftershocks of the Kern County earthquakes of 1952 were concentrated. The zone consists of an alignment of four distinct regions of high seismicity separated by areas of somewhat lower activity. A grouping of the highest strain release values, having a magnitude of 7 and above, are located five miles west of the community of Wheeler Ridge in a cluster of epicenters about 20 miles diameter. The second group, with values 5 to 6.9 is found in the Caliente, Loraine, and Harper Peak area. The third cluster, somewhat smaller and having the lowest values (3 to 4.9) is located near Piute Peak along the same strain release alignment, or strain release axis, generally parallel to the White Wolf and Garlock Faults. The center of the fourth cluster is located north of Walker Pass near Owens Peak and is about 10 miles in diameter. It exhibits a large amount of strain release from 3.0 to 6.9.

The theory of strain accumulation or earth deformation, the converse of strain release, is another way of attempting to evaluate the probability of earthquake recurrence. Deformations are measured by means of precise surveys at regular time intervals across fault zones. These observations are supplemented by creep and tilt observations. Unfortunately, such studies in Kern County are still so limited in number and duration that data interpretation is conjectural. Work is proceeding on this program.

c. **Type of Movements and Hazards.**

Seismic waves produce horizontal and vertical or rolling movements which affect people, the ground and structures in various ways, depending upon the amount of energy transmitted.

Ground shaking is the most widespread effect and often the greatest cause of structural failure, thereby producing deaths and damage. Loose or poorly attached objects inside and outside a building generally fall. (Transformers, air conditioners, etc.) Old or inadequately constructed or designed structures may suffer severe damage to failure.

Observations made during the San Fernando earthquake of February 9, 1971 show that hazards due to the intensity of ground shaking vary from point to point and in some cases, less than half a mile apart without any discernible change in geological conditions. Moreover, the instrumental data do not support the assumption that the intensity of ground shaking decreases from a soft to a hard ground and it does not appear safe to use the so-called "average ground-shaking factor" to calculate structural stresses in buildings. (Refs. 7 and 8)

In strong earthquakes a low rumbling sound, associated with the primary (P) wave is usually heard before ground shaking is felt. Ordinarily
with shaking of earth and buildings squeaking, rattling and other noises are heard. Although disturbing, these preceding events are harmless if adequate precautions are observed. To protect oneself when indoors, it is advisable to take refuge under the strongest part of the building where nothing will fall. If outdoors, stay out and away from any building or object which may fall or roll.

Ground failure with repeated shaking appears in the form of fractures, slumps, lurches, rock falls, and landslides. Close to faults, tension cracks, pressure ridges, mole tracks, and scarps may develop. In case of damp soils and particularly clay bearing soils, liquefaction may take place. Foundation failure, mass movement of soil and earthflows frequently occur when these conditions prevail.

Ground displacement along faults, either horizontal, vertical or both, is another source of damage. However, because of the localized nature of the displacement, the total damage it causes is usually small.

Fault zones are best avoided in construction since it is not economically feasible to design and build foundations of structures such as dams, bridges, buildings, etc., to remain intact across such zones of movement. Construction of major developments in the medial trough of the major fault zone should be avoided.

Ground movements also produce oscillations in lakes (seiches) and in other liquid bodies such as rivers, tanks, and reservoirs. In such cases, possible damaging effects are caused by splashing and pounding on sides or banks. Consideration should be given to the potential failure of dikes and dams due to the following four main causes: shaking, fault displacement, splashing or overtopping, and massive landsliding into the reservoir. Any one of these could lead to a disastrous flood, with subsequent levee failure.

Stability of slopes along flowing waterways and adjacent to reservoirs is of major importance and requires frequent observation. When potential hazards are observed they should be eliminated. Damming caused by landslides across a water course has been the cause of widespread destruction in many regions.

d. Recurrence Probability of Damaging Earthquakes

The probability of recurrence of earthquakes of various magnitudes in Kern County was established from the seismic data covering the period 1934-1963 by C.R. Allen, et al. (Ref. 3). From the recurrence curves given in that paper and reproduced as Figure 4, the average number of earthquakes per year, per thousand square kilometers corresponding to M=5 is 0.14 or about one or two per decade. This recurrence rate appears to correspond to the highest probable value, in view of the location of the area investigated in that paper which includes the regions of maximum seismicity in Southern California and covers only about 10% of the total area of Kern County or about 8,400 square kilometers. For the same area, the recurrence rate for a shock M=6 is about 2 every 10 years and for M=7.7, equal to the 1952 earthquake, is estimated at one every 100 years. At present, the short time interval for which reliable seismic data are available does not permit more accurate approximation of a recurrence analysis.
While it is not possible now to predict earthquakes in advance, or even to give rigorous figures for the recurrence intervals, it is not important for the purposes of good planning to know such information more accurately. The fact that they will take place in the future as they have done in the past is quite enough to justify the use of rigorous earthquake and construction codes and to conduct zoning in such a way as to preclude damage from major earthquakes.

e. **Intensity and Magnitude**

It is worthwhile here to draw a distinction between the terms "intensity" and "magnitude."

The oldest measure of earthquake severity is called "intensity." This is determined by observation of the physical effects produced by the earthquake, from interrogation of the sensations noted by the populace and from the behavior of animals. The system is largely subjective but it is good enough to obtain very valuable information of the amount of shaking at a given point and from this, an estimate of the accelerations can be deduced—useful but crude. The system uses the so-called Modified Mercalli Scale adumbrated by Wood and Neuman in 1933. (see Table 4) It is derived from earlier scales, such as the Rossi Forreel Scale, developed in the Mediterranean countries and other areas of high seismic activity. Unfortunately, the accurate use of this system depends to a large extent of the constructional practices used in those days in Italy, Spain, Central America, and to a lesser extent, in California. California, especially that part in which the building practices were derived from Mexico, used to abound in structures that could be expected to fail at precise points on the scale. Modern construction, all over the world, is so earthquake resistant, if built well, that it is no longer possible to use these criteria in estimating earthquake intensity and so persons skilled in the use of the Mercalli Scale will rely more upon other factors that are not peculiar to types of construction. The Mercalli Scale is reproduced herein and it may be used to calibrate the shaking of earthquakes felt in one's locality. The Mercalli Scale is divided into twelve units, the weakest has a value of one, the highest twelve. Common practice is to express Mercalli Intensity in Roman Numerals to make it clear that one is not talking about magnitude. There are as many values of the MM intensity for an earthquake as one may care to record. Magnitude is quite another matter. There is only one magnitude for each earthquake.

The magnitude of an earthquake is a measure of the total energy radiated by the earthquake. The concept of magnitude was first set forth by Dr. Charles Richter of the California Institute of Technology. It was originally given as the logarithm of the amplitude of the ground movement in microns (millionths of a meter) as recorded by a standard Wood-Anderson seismograph at a distance of 100 Kilometers. There are today many methods of measuring magnitudes and these are sometimes referred to in publications as slightly different magnitudes. These differences are of academic interest and do not need to concern us. The formula by which the magnitude has been related to energy in an earthquake is usually given as:

\[
\log_{10} J = 11.0 + 1.6M
\]
This diagram shows the observed recurrence rates for earthquake of a given magnitude in southern California as deduced from the Cal Tech data. (Ref. 3, p. 781) For example, an area of 1000 square kilometers has had one magnitude 5.2 earthquake every ten years in Kern County.
TABLE 4

MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

[From Barosh (1969, Table 1)]

| I. | Not felt except by a very few under especially favorable circumstances. |
| II. | Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. |
| III. | Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration can be estimated in some cases. |
| IV. | During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. |
| V. | Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned; disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop. |
| VI. | Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. |
| VII. | General alarm; all are frightened and run outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars. |
| VIII. | Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected from ground in small amounts. Changes in flow of springs and wells. Steering of motor cars affected. |
| IX. | Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. |
| X. | Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Sand and mud shifted horizontally on beaches and flat land. Water splashed (slopped) over banks. |
| XI. | Few, if any, masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly. |
| XII. | Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air. |
where $J$ is the energy in ergs and $M$ is the magnitude. For an increase of one whole magnitude, the total energy radiated is increased by a factor of about 10. Hence, although two earthquakes may have magnitudes that are about equal, the difference in amount of shaking and in the area shaken may be quite large. Nonetheless, given the magnitude and the depth of an earthquake it is quite possible to predict very closely the area and the degree of damage to be expected.

Earthquake magnitudes run from low values such as 1.0 to values of about 8.5. The nature of the scale is such that regardless of how much bigger an earthquake is that the values top out at about 8.8.

Magnitude 2 earthquakes are barely perceptible, even at the epicenter. Magnitude 3 earthquakes, at the depths usually in California, cause a good deal of excitement but little or no damage. Magnitude 4 earthquakes are usually noted over a ten mile radius and can cause loose objects to move about. Magnitude 5 earthquakes usually do little damage but can cause a veritable scandal over an area of a few tens of miles and may be felt for a hundred or so if they happen at a time of day when people are not too active. Magnitude 6 earthquakes can cause a great deal of damage to poorly built structures over an area up to ten miles in radius. The earthquake that destroyed the city of Managua, Nicaragua in 1972 was only of magnitude 6. Earthquakes of magnitude 7 get to be a very serious problem. By the time magnitude 8 is reached, the area affected and the total damage to poor construction, highways, electrical systems, water and sewage systems and all human activities is enormous.

f. **Acceleration, Velocity and Frequency**

The movement of the ground subjects buildings and other structures to induced movement and to the forces resulting from such movement. These movements are measured by the so called strong motion seismometers. The instruments are set up around the country in various places where earthquakes may be expected to occur and in many taller buildings of different heights. They measure the actual movement undergone by the structure as a function of time. The operation of the instruments is triggered by the first movements of the support on which the instrument is resting. They run for a minute or so and record the subsequent action. From the records made by these devices it is possible to obtain not only the accelerations to which the building was subjected but the frequency of oscillation as well. From these may be calculated, the velocity and displacement and the period of the waves. This latter is important in that, if the natural period of vibration of the structure approaches that of the earthquake, large oscillations, perhaps of a destructive nature may result. Thus, a knowledge of the sort of accelerations and the period (or frequency) of the oscillation will permit the earthquake engineer to design buildings such that the natural period of oscillation of the building is quite different from that of the earthquakes to be expected in the area and hence will not react strongly to such shaking.
**Title and Subtitle**

Geology and Earthquake Hazards—Planning Guide to the Seismic Safety Elements of Kern County, California

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Mr. William H. Park and Mr. Bradley F. Williams

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**Abstract**

The Seismic Safety Plan consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to effects of seismically induced waves.

The text identifies general goals, standards, policies, and outlines a course of action for implementing the plan. The ability of the jurisdiction to respond to an earthquake calamity as well as preparations taken before the earthquake are emphasized.

**Key Words and Document Analysis**

- Geology and Earthquake Hazards in Kern County, California
- Geological Risk
- Earthquakes
- Landslides
- Subsidence
- Emergency Preparedness
- Fault Identification
- Shallow Water
- Environmental Hazards
- Disaster Preparedness

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at cost
At the present time, a large number of records are available from small earthquakes and from a few larger earthquakes. This backlog of information gives the engineers something to design against. However, no records are available for large earthquakes close to the causative fault. Hence it is difficult in our present state of knowledge to give assurance that a given design will respond well in a large earthquake at a short distance from the causative fault.

g. Fling

Near to a fault, a permanent displacement of the ground may take place. This is called fling. It produces an added burden upon structures located close to such a fault and special care must be taken in such a locality to assure that the structures are capable of withstanding this type of permanent offset. Because this displacement is often distributed over a wide area in the fault zone, it is difficult to be sure that any structure placed in the medial zone of the large faults, such as the San Andreas and Garlock will not be subjected to such activity.

2. Faults (types of activity and movement)

FAULT CATALOG

In addition to the quadrangle maps a Fault Catalog for Kern County has been included in this section for the convenience of the reader. Known faults with a length of six miles, or ten kilometers, have been included. These faults have been categorized as:

a. Faults that have been historically active, as defined by the California Division of Mines and Geology. These faults are associated with one or more of the following:

1. Recorded earthquake with surface rupture.
2. Tectonic creep: slow ground displacement usually without accompanying earthquakes.
3. Seismic activity: alignment of earthquake epicenters including microearthquakes, related to a fault mapped at the surface.

b. Faults that indicate Quaternary displacement, without historical record. These faults that have been recognized by displaced alluvium, terraces, or other geomorphic features, such as offset streams, alignment of sag ponds, fault trenches, coals and concealed, fault-controlled, ground water barriers of cascades in Quaternary sediments as indicated by well data.

c. Faults that displace only pre-Quaternary rocks and the last movement is unknown.
# Historically Active Faults

<table>
<thead>
<tr>
<th>Name of Fault</th>
<th>Location by Index Map No.</th>
<th>Last Known Movement</th>
<th>Fault Type</th>
<th>Evidence of Existence</th>
<th>Length (Miles)</th>
<th>Possible Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Pine</td>
<td>5E3, 5E4</td>
<td>1852</td>
<td>Normal?</td>
<td>Surface</td>
<td>50⁺</td>
<td>7.0 to 8.0</td>
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<td>Buena Vista Hills Thrust</td>
<td>4D2</td>
<td>Creeping</td>
<td>Overthrust</td>
<td>Surface</td>
<td>1 3/4</td>
<td>-</td>
</tr>
<tr>
<td>Kern Canyon</td>
<td>7B, 7C, 8A, 8B</td>
<td>1868</td>
<td>Reverse &amp; Left Strike-Slip</td>
<td>Surface</td>
<td>85⁺</td>
<td>7.0 to 8.0</td>
</tr>
<tr>
<td>Kern Front</td>
<td>5B4, 5C1</td>
<td>Creeping</td>
<td>Normal?</td>
<td>Surface</td>
<td>6⁺</td>
<td>-</td>
</tr>
<tr>
<td>New Hope</td>
<td>5B4</td>
<td>Creeping</td>
<td>Normal?</td>
<td>Surface</td>
<td>2⁺</td>
<td>-</td>
</tr>
<tr>
<td>San Andreas</td>
<td>1B2, 1B3, 1B4, 1C1, 2C2, 2C3, 2C4, 3D2, 3D4, 4E1, 4E2, 4E4, 5E3, 5E4, 6E3, 6E4</td>
<td>1857</td>
<td>Right Strike-Slip</td>
<td>Surface</td>
<td>600⁺</td>
<td>8.0+</td>
</tr>
<tr>
<td>White Wolf</td>
<td>5D4, 5E1, 6D1, 6D3, 6D4, 7C3, 7C4, 7D2</td>
<td>1952</td>
<td>Left Strike-Slip &amp; Reverse</td>
<td>Surface</td>
<td>33⁺</td>
<td>7.5 to 8.0</td>
</tr>
</tbody>
</table>

*Historically active faults having one or more of the following features:
  a. Surface rupture -- with recorded earthquake.
  b. Tectonic creep--slow ground displacement usually without accompanying earthquakes.
  c. Seismic activity--alignment of earthquake epicenters including microearthquakes, related to a fault mapped at the surface.

Historical records of earthquakes in California begin with the year 1769.
<table>
<thead>
<tr>
<th>Name of Fault</th>
<th>Location (Index Map No.)</th>
<th>Fault Type</th>
<th>Evidence of Existence</th>
<th>Length (Miles)</th>
<th>Possible Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantil Valley</td>
<td>10C1, 10C3, 10C4, 11C2</td>
<td>Normal</td>
<td>Surface</td>
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</tr>
<tr>
<td>China Lake</td>
<td>11B</td>
<td>Normal</td>
<td>Surface</td>
<td>15‡</td>
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</tr>
<tr>
<td>Cottonwood</td>
<td>8B2</td>
<td>Right Strike-Slip</td>
<td>Surface</td>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td>Cummings Valley</td>
<td>7D1, 7D2, 7D3</td>
<td>Normal</td>
<td>Surface</td>
<td>10‡</td>
<td>6.5</td>
</tr>
<tr>
<td>Deepwell</td>
<td>5B1</td>
<td>Normal</td>
<td>Surface</td>
<td>10‡</td>
<td>6.5</td>
</tr>
<tr>
<td>Edison East</td>
<td>6C4, 7C3</td>
<td>Normal</td>
<td>Surface</td>
<td>6†</td>
<td>6.0</td>
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<tr>
<td>Edison West</td>
<td>6C4</td>
<td>Normal</td>
<td>Surface</td>
<td>6†</td>
<td>6.0</td>
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<tr>
<td>Elk Hills</td>
<td>3C4</td>
<td>Normal</td>
<td>Surface</td>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td>Elling Springs</td>
<td>1B1, 1B2</td>
<td>Normal?</td>
<td>Surface</td>
<td>7‡</td>
<td>6.0</td>
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<tr>
<td>Fremont Valley</td>
<td>9C, 9D, 10C3, 10C4</td>
<td>Left S/S</td>
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<td>6.0</td>
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<tr>
<td>Garlock</td>
<td>6E3, 6E4, 7E1, 7E2, 7E3, 8D1, 8D3, 8L4, 8B2, 9C, 9D, 9D1, 10C1, 10D3, 10D4, 11C2</td>
<td>Strike-Slip</td>
<td>Surface</td>
<td>150‡</td>
<td>8.0</td>
</tr>
<tr>
<td>Hodgesman Ranch</td>
<td>5A4, 5B1, 5B4</td>
<td>Normal</td>
<td>Surface</td>
<td>20‡</td>
<td>6.5</td>
</tr>
<tr>
<td>Indian Wells Valley</td>
<td>10B</td>
<td>Normal</td>
<td>Surface</td>
<td>9‡</td>
<td>6.5</td>
</tr>
<tr>
<td>Jasmin</td>
<td>5B1, 5B4</td>
<td>Normal</td>
<td>Surface</td>
<td>9‡</td>
<td>6.5</td>
</tr>
<tr>
<td>Little Oak Canyon</td>
<td>7E1, 8E2</td>
<td>Normal</td>
<td>Surface</td>
<td>7‡</td>
<td>6.0</td>
</tr>
<tr>
<td>Lockhart</td>
<td>10B, 10D1, 10D2</td>
<td>Normal</td>
<td>Surface</td>
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<td>7.5</td>
</tr>
<tr>
<td>Lockhart, South</td>
<td>10D1, 10D2</td>
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<td>Surface</td>
<td>15‡</td>
<td>7.0</td>
</tr>
<tr>
<td>Mt. Poso</td>
<td>6B3, 6C2</td>
<td>Normal</td>
<td>Surface</td>
<td>9‡</td>
<td>6.5</td>
</tr>
<tr>
<td>McVan</td>
<td>5B4, 5B6</td>
<td>Normal</td>
<td>Surface</td>
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<td>6.5</td>
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<tr>
<td>Pinyon Hill</td>
<td>7E1, 7E2, 7E3</td>
<td>Left Strike-Slip</td>
<td>Surface</td>
<td>12‡</td>
<td>6.5</td>
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<tr>
<td>Pleito Thrust</td>
<td>4E2, 5E4, 5E5, 5E6, 6E2, 6E2</td>
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<td>Surface</td>
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<tr>
<td>Premier</td>
<td>5A4, 5B4, 5C1</td>
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<td>Surface</td>
<td>26‡</td>
<td>6.6</td>
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<tr>
<td>Rodesmacher</td>
<td>10B, 11B</td>
<td>Normal</td>
<td>Surface</td>
<td>15‡</td>
<td>6.5</td>
</tr>
<tr>
<td>Ridgcrest</td>
<td>11B</td>
<td>Normal</td>
<td>Surface</td>
<td>11‡</td>
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<td>Sierra Nevada</td>
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<tr>
<td>Spring</td>
<td>11E2</td>
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<td>Surface</td>
<td>15‡</td>
<td>6.5</td>
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</tbody>
</table>

*Length in Kern County.
**Recognized by Surface evidence such as: displaced alluvium, terraces, or other Geomorphic features; offset streams, alignment of sag ponds, fault trenches. Includes concealed fault-controlled ground water barriers or discharge in Quaternary sediments as indicated by water well data.

Table 6  

IV-25
<table>
<thead>
<tr>
<th>Name of Fault</th>
<th>Location (Index Map No.)</th>
<th>Last Known Movement</th>
<th>Fault Type</th>
<th>Evidence of Existence</th>
<th>Length (Miles)</th>
<th>Possible Magnitude</th>
</tr>
</thead>
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<td>Aliso</td>
<td>B2, B2</td>
<td>Cretaceous</td>
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<td>Bear Hills</td>
<td>2C1, 2C2, 3C2</td>
<td>U. Miocene</td>
<td>Normal?</td>
<td>Surface &amp; Subsurface</td>
<td>9</td>
<td>6.5</td>
</tr>
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<td>Bear Flat</td>
<td>1D3</td>
<td>Miocene</td>
<td>Normal?</td>
<td>Surface</td>
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<td>6.0</td>
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<td>Bear Mountain</td>
<td>7D1, 7D2</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Surface</td>
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<td>6.5</td>
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<tr>
<td>Blake Ranch</td>
<td>1L3</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Surface</td>
<td>15</td>
<td>6.5 to 7.0</td>
</tr>
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<td>Breckenridge East</td>
<td>7B, 7C</td>
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<td>Normal</td>
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<td>6.5</td>
</tr>
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<td>Breckenridge West</td>
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<td>Normal</td>
<td>Surface</td>
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</tr>
<tr>
<td>Bull Run</td>
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<tr>
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<td>Miocene</td>
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<td>6.0</td>
</tr>
<tr>
<td>Campbell Mountain</td>
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<td>6.5</td>
</tr>
<tr>
<td>Cook Peak</td>
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<td>Normal</td>
<td>Surface</td>
<td>15</td>
<td>6.5 to 7.0</td>
</tr>
<tr>
<td>Deep Creek</td>
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<td>Normal</td>
<td>Surface &amp; Subsurface</td>
<td>15</td>
<td>6.5</td>
</tr>
<tr>
<td>Dougherty</td>
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<td>Normal</td>
<td>Surface</td>
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</tr>
<tr>
<td>El Paso</td>
<td>10C1, 10C2, 10C3, 11C2</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Surface</td>
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<td>6.5 to 7.0</td>
</tr>
<tr>
<td>Erkine Creek</td>
<td>8H</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Right Strike-Slip ?</td>
<td>5</td>
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<tr>
<td>Goat Ranch</td>
<td>6B</td>
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<td>6.5</td>
</tr>
<tr>
<td>Greeley-Ric Bravo</td>
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<td>6.0</td>
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<tr>
<td>Jawbone</td>
<td>1C1, 1C2</td>
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<td>Normal</td>
<td>Surface</td>
<td>12</td>
<td>6.5</td>
</tr>
<tr>
<td>Jewett</td>
<td>1C1, 1C2</td>
<td>Miocene</td>
<td>Normal</td>
<td>Surface &amp; Subsurface</td>
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<td>1C1, 1B3, 1B4, 1B5, 1B6, 1C1, 7C, 7D</td>
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<td>6.5 to 7.0</td>
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<td>Lasman</td>
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<td>6.5</td>
</tr>
<tr>
<td>Lone Tree</td>
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<td>Strike-Slip</td>
<td>Surface</td>
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<td>6.5</td>
</tr>
<tr>
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<td>1D1, 1D2, 1D3</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Strike-Slip</td>
<td>15</td>
<td>6.5 to 7.0</td>
</tr>
<tr>
<td>Moro</td>
<td>9A, 9B, 10D3</td>
<td>Mesozoic</td>
<td>Normal</td>
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<td>Pastoria Thrust</td>
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<td>Mesozoic</td>
<td>Thrust</td>
<td>Surface</td>
<td>7</td>
<td>6.0</td>
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<tr>
<td>Phillips Ranch</td>
<td>8D1, 8D2</td>
<td>Miocene</td>
<td>Normal</td>
<td>Right Strike-Slip</td>
<td>10</td>
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<tr>
<td>Pincon Pass</td>
<td>8A, 8B, 8C</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Surface</td>
<td>20</td>
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<tr>
<td>Plute</td>
<td>8B, 8C</td>
<td>Mesozoic</td>
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<td>Surface</td>
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<tr>
<td>Polanco</td>
<td>1B1, 1B2, 2B3</td>
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<td>Overthrust ?</td>
<td>Surface &amp; Geophysical</td>
<td>15</td>
<td>6.5</td>
</tr>
<tr>
<td>Pond-Poso</td>
<td>6A3, 6A4, 6A5, 6A6, 6A7, 5B1, 5B2</td>
<td>Plisoeic ?</td>
<td>Normal</td>
<td>Surface &amp; Subsurface</td>
<td>15</td>
<td>6.5</td>
</tr>
<tr>
<td>Poso Creek</td>
<td>6B1, 6B2, 5B4</td>
<td>Plisoeic ?</td>
<td>Normal</td>
<td>Surface &amp; Subsurface</td>
<td>15</td>
<td>6.5</td>
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<td>Pyramid Hills</td>
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<td>Reverses</td>
<td>Normal</td>
<td>Surface</td>
<td>12</td>
<td>6.0</td>
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<tr>
<td>Ravena Pass</td>
<td>1B1, 1B2</td>
<td>Miocene</td>
<td>Normal</td>
<td>Surface</td>
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<td>6.0</td>
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<tr>
<td>Recruit Pass</td>
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<td>Miocene</td>
<td>Normal</td>
<td>Right Strike-Slip</td>
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<td>Round Mtn.</td>
<td>6C1, 6C2</td>
<td>Miocene</td>
<td>Normal</td>
<td>Surface</td>
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<td>9D</td>
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<td>Normal</td>
<td>Left Strike-Slip</td>
<td>7</td>
<td>6.0</td>
</tr>
<tr>
<td>Split Mountain</td>
<td>8A, 8B</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Surface</td>
<td>6</td>
<td>6.0</td>
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<tr>
<td>Springs</td>
<td>6A1</td>
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<td>Normal</td>
<td>Surface</td>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td>Tyson Canyon</td>
<td>7D1, 7D2, 7D3</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Surface</td>
<td>7</td>
<td>6.0</td>
</tr>
<tr>
<td>Tillie Creek</td>
<td>7B, 7B</td>
<td>Mesozoic</td>
<td>Normal</td>
<td>Surface</td>
<td>6</td>
<td>6.0</td>
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<tr>
<td>Trico</td>
<td>4A1, 4A2, 4A3</td>
<td>Miocene</td>
<td>Normal</td>
<td>Geophysical</td>
<td>10</td>
<td>6.5</td>
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<tr>
<td>Name of Fault</td>
<td>Location</td>
<td>Last Known Movement</td>
<td>Fault Type</td>
<td>Evidence of Existence</td>
<td>Length (Miles)</td>
<td>Possible Magnitude</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------</td>
<td>---------------------</td>
<td>------------</td>
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<tr>
<td>Baker Ranch</td>
<td>6G1</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>3</td>
<td></td>
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<tr>
<td>Canal Spring</td>
<td>6E4</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pabncoy</td>
<td>3G3, 3A4</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>3</td>
<td></td>
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<tr>
<td>Dark Canyon</td>
<td>2G4</td>
<td></td>
<td>Reversal</td>
<td>Surface</td>
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<td>Marijuanas</td>
<td>2D4</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>3</td>
<td></td>
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<tr>
<td>Mesquite</td>
<td>6D4</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>2</td>
<td></td>
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<td>Midway Fault</td>
<td>3D1</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Midway McKittrick</td>
<td>3G3, 3C4</td>
<td></td>
<td>Reverse</td>
<td>Surface</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Mon Bluff</td>
<td>6B3</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Salt Creek Thrust</td>
<td>2D4</td>
<td></td>
<td>Thrust</td>
<td>Surface</td>
<td>1</td>
<td></td>
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<tr>
<td>Stenderup</td>
<td>6D1</td>
<td></td>
<td>Normal</td>
<td>Subsurface</td>
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<td>Sycamore</td>
<td>6D4</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>2</td>
<td></td>
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<tr>
<td>Telephone Hills</td>
<td>3G3</td>
<td></td>
<td>Reverse</td>
<td>Surface</td>
<td>4</td>
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<tr>
<td>Tyler Horse</td>
<td>8B2</td>
<td></td>
<td>Right 3/3</td>
<td>Surface</td>
<td>4</td>
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<tr>
<td>Wheeler Ridge Thrust</td>
<td>6D3</td>
<td></td>
<td>Thrust</td>
<td>Surface</td>
<td>2 1/2</td>
<td></td>
</tr>
<tr>
<td>Willow</td>
<td>6D4</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>2</td>
<td></td>
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<tr>
<td>Willow Spring</td>
<td>8E1</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Ybarra</td>
<td>2C4</td>
<td></td>
<td>Normal</td>
<td>Surface</td>
<td>3</td>
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</table>
It must be emphasized that dating the age of fault movement is one of the more difficult tasks a geologist encounters. The method used in this study was to determine the last movement in the youngest rocks that are known to have been displaced. Obviously, if a fault is present in an area where only older rocks exist it can only be determined that the movement occurred sometime subsequent to the emplacement of those rocks. For example, if a fault exists in Cretaceous Rocks of Cretaceous age and no younger rocks are present the last actual movement could have been a few hundred years ago, however, the last known movement would be Cretaceous. Although a great deal of subsurface geological work on faulting has been done in the sedimentary basin of the Southern San Joaquin Valley, very little attention has been given to this problem until the last few years. Some studies for example, show faulting extending into Pliocene and Pleistocene sediments when in fact the youngest evidence is the top of the Miocene beds. On the other hand if the primary objective was a study of the Lower Miocene, little or no attention was given to how much higher in the stratigraphic section faulting extends. This is not intended as a criticism of previous studies but merely to point out the limitations of source data available for this study.

A promising method for the determination of the recency of movement on a fault is by trenching along its trace to expose the fault surface for observation, possible displacement of young sediments and occurrence of wood or plant fragments which may be dated by Carbon 14 measurement.

The data shown for the faults in each of the three categories is as follows: (1) Name of fault (in some cases names have been coined for unnamed faults); (2) Location is shown by index numbers for the maps upon which each fault appears (see index map to Seismic Hazard Atlas and Appendix G); (3) Last known movement (creeping indicates current movement) (4) Type of predominate movement, sense of movement; (5) Evidence of the faults existence (surface observation, geophysical survey, well information etc.); (6) Approximate length; and (7) Possible magnitude of earthquakes that might be produced in the event of movement (Richter Scale) based on the relation between magnitude and the length of surface rupture. (Ref. 9, p. 66, Fig. 3-16)

3. Mass Movements and Subsidence

Under this title is meant movements under the influence of gravity, of masses of unstable soil and unconsolidated or loose rocks. Under normal conditions, without excessive rainfall, they remain in a fairly stable state. However, this condition may be disturbed by earthquake shock and by ground motion which produces a triggering action for mudflows, rock falls, rockslides, landslides, or regional subsidence.

a. Factors of Mass Movement.

Factors of major importance in the development of mass earth movements are water content, slope and soil composition. Increased amounts of water aggravate instability by lubricating the soil and producing creep, or in soils with greater capability for liquefaction, a simple landslide might become a mudflow. The amount and characteristics of the clay
fraction may play an important role in the stability of soil under the action of earthquake vibrations. Regions of frequent cloud-bursts and floods are particularly hazardous. Such regions susceptible to flooding are indicated on maps prepared by the Corps of Engineers. Seismic factors affecting mass movement are the earthquake wave acceleration and the duration of the tremor.

Regarding acceleration, it was generally admitted before the San Fernando earthquake of February 9, 1971, that the maximum possible value was equal to half that of the earth gravity acceleration or 0.5 g equal to 4.90.33 cm. per second, per second. Numerous measurements taken during the San Fernando earthquake completely changed this assumption by showing an average of 0.75 g for horizontal or lateral forces with a maximum of 1.05 g. These are the highest values ever observed in any earthquake. For the vertical forces' accelerations the measured values are smaller than the horizontal, but ground effects described as: "shattered or exploded ridge tops" suggest that values equal or even greater than g were possibly reached. (Ref. 10, pp. 67, 79) About the duration, the longer the shaking by the main earthquake shock the greater is the damage. As examples, the 1964 Alaska main shock (M=8.4) lasted at least 3 minutes and the 1906 San Francisco (M=8.3) major tremor duration was approximately 1 minute; both produced great damage. The July 21, 1952 Kern County (Wheeler Ridge) earthquake strong motion (M=7.7) lasted only about 12 seconds and major damages in Bakersfield were caused by the cumulative effects of several closer short aftershocks (M=3.8 to 6.1) spread during about one month. Conversely, some shocks are of very short duration (about 1 second) with their energy concentrated in a single pulse and although of low magnitude, are quite destructive. The 1957 Port Hueneme (M=4.7) and 1966 Parkfield (M=5,3) are examples of that type of earthquake. (Ref. #11, p. 170, and Ref. #5, p. 184,185)

b. Regional Subsidence

Subsidence may result from the compaction of alluvium and young sediments when the equilibrium between particles is disturbed either by fluid withdrawal or by earthquake shaking. In addition, movements due to tectonic stresses may also cause subsidence on the depressed side of a fault. On a relatively smaller scale, subsidence occurs when dry soils are saturated with water and become hydrocompacted. The southern and northcentral parts of Kern County already show relatively slow differential subsidence where fluid withdrawal by pumping - mostly water - has been very extensive. In event of an earthquake, the rate of subsidence would be likely be accelerated. Areas susceptible to these subsidence effects are delineated on the seismic hazard maps and designated as "Shallow Water Table Below Surface." (Maps No. 2 and 4) Unidentified areas outside of the designated shallow water area may also experience subsidence. Land subsidence in Kern County is shown on Map 4.

Water pumping in the San Joaquin Valley is the major cause of compaction and subsidence of an area estimated around 4,000 square miles which in 1969–70 reached locally in the Arvin-Maricopa region accumulative amount of 28 feet below the original surface. (Ref.#19) Recharging of the water table through spreading of imported water reduced the amount of subsidence by partial recovery of ground water level elevation and almost stopped it in some areas.
C. CAUSES OF SUBSIDENCE

Four types of subsidence are known to occur in the San Joaquin Valley. Listed in order of their magnitude, they are: (1) subsidence caused by water-level decline and the consequent compaction of aquifer systems, (2) subsidence related to the hydrocompaction of moisture-deficient deposits above the water table, (3) subsidence related to fluid withdrawal from oil and gas fields, and (4) deep-seated tectonic settlement. A fifth type, subsidence caused by the oxidation and compaction of peat soils, occurs mostly in the Sacramento-San Joaquin Delta area.

Map No. 4 (Seismic Hazard Atlas—Land Subsidence) shows the principal areas affected by subsidence caused by water-level decline and hydrocompaction. These areas are principally in the parts of the valley where runoff from surface streams is minimal. Subsidence due to hydrocompaction (also called near-surface or shallow subsidence) has occurred in five areas south and southwest of Bakersfield (California Department of Water Resources, 1964b, pl. 2; Lofgren, 1973, fig. 35). The total area susceptible to hydrocompaction is about 80 square miles.

Hydrocompaction—compaction due to application of water—has produced widespread subsidence in low density moisture-deficient deposits and is of serious concern in the design and construction of many engineering structures. In southern San Joaquin Valley irrigated farm land is subsiding due to the application of water and an area of several tens of square miles of susceptible land has not yet been irrigated. Preconsolidation before construction begins usually minimizes damage.

Significantly, most of the subsiding area in the San Joaquin Valley is underlain by a continuous and extensive confining bed (aquiclude). Most of the pumping overdraft and most of the compaction occurs in the artesian aquifer system beneath this confining bed. The boundary of this bed, where known, is shown on Maps No. 2 and 3.

North of the vicinity of Wasco the confining bed is the Corcoran Clay Member of the Tulare Formation, which also has been called the E clay by Croft (1972).

1. Wasco Area

Subsidence was first recognized in the Tulare-Wasco area in 1935. As of 1970 an estimated 1,420 square miles had been affected by subsidence; about 1,220 square miles had subsided more than 1 foot; and 300 square miles had subsided more than 5 feet. Lofgren and Klausing (1969) have described in considerable detail the pertinent geologic framework of the ground-water reservoir, the hydrologic units, and the history of water-level trends. They also described subsidence of the land surface and the measured compaction of the water-bearing deposits to the end of 1964.

The latest leveling of the bench-mark net in the Arvin-Maricopa area was in 1970. The maximum subsidence in the 5 years, centered 6 miles northwest of Mettler, was 2.2 feet. The average annual rate of subsidence in this 5 years was 0.44 foot at the center. From 1957 when the bench-mark net was established to 1970 subsidence exceeded 6 feet at the center. A small secondary center of 0.4 foot enclosed the town of Arvin.
2. Arvin-Maricopa Area

In the Arvin-Maricopa area the pumpage and subsidence were compared for the 3-year period March 1962 to March 1965. Pumpage estimates (Ogilbee and Rose, 1969b) are available for this exact period, and a subsidence map is available from leveling of the bench-mark net by the National Geodetic Survey in January 1962 and March 1965 (Lofgren, 1973, fig. 46). The subsidence/pumpage ratio was computed for all unit areas enclosed within or crossed by the 0.2 foot line of equal subsidence for the 1962-64 period. The ratio, which is the proportion of water pumped in the 3 years that was derived from compaction of the ground-water reservoir, ranges from 0.01 (1 percent) at several points around the perimeter of the subsiding area to more than 40 percent in the area of maximum subsidence.

D. ANALYSIS OF STRESSES CAUSING SUBSIDENCE

Increase in effective stress (grain-to-grain load) is the cause of compaction of sediments. Change in stress can be examined in terms of total, fluid, and effective stresses, the classical method, or solely in terms of effective stresses. There are advantages to each approach.

E. METHODS FOR STOPPING OR ALLEVIATING SUBSIDENCE

Studies of land subsidence in California and in other parts of the world furnish conclusive evidence that decrease in artesian head increases effective stress, causing compaction of sediments and correlative land subsidence (Poland and Davis, 1969). Conversely, increase in artesian head decreases effective stress and slows or stops land subsidence. In a compacting confined system, if fluid pressures in the aquifers are increased, the rate of subsidence will decrease; if fluid pressures in the aquifers are increased sufficiently to eliminate all excess pore pressures in the aquitards, subsidence will stop.

If artesian head declines for several years causing compaction, and subsequently the head fluctuates seasonally with about the same maximum stress application (depth to water) each year, compaction will continue but the annual rate of net compaction will gradually decrease until hydraulic equilibrium is reached—until pore pressures in the fine-grained beds attain steady state with pressures in adjacent aquifers. If the artesian head in the system then recovers to a higher level, it can subsequently be drawn down to the prior maximum effective-stress level without inducing appreciable compaction and subsidence. Effects of secondary consolidation due to internal processes that continue after pore pressures reach steady state are not considered in this discussion.

Remedial action to raise water levels can be accomplished by reducing ground-water pumpage, or by increasing recharge, or both. Intensively developed agricultural areas that have an overdraft of ground-water supply will continue to have an overdraft. For economic reasons, a reduction of pumping does not occur until pumping lifts become uneconomic, water quality becomes unusable, an adjudication of water rights is reached through legal procedures, or until water is imported.

As of 1972, surface water is being imported into subsiding areas in the San Joaquin Valley. These imports now constitute a large part of the applied
irrigation water and have replaced much of the ground-water withdrawal of prior years.

The importation of surface water to replace mining of ground water has two effects, not necessarily entirely beneficial, with respect to subsidence alleviation. The immediate effect is to reduce or eliminate pumping of ground water in the area of surface-water delivery, causing the artesian head to rise in the zones experiencing reduced pumping. This effect is wholly beneficial because it reduces seepage stresses and hence effective stresses.

The second effect of importation is to increase recharge, because any imported water that seeps through the soil zone and reaches the water table—whether from stream channels, canals, ditches, or field irrigation—is a net increase to the ground-water supply. This increase tends to raise the water table. If the recharge is accomplished in deposits in hydraulic continuity with a compacting confined system, such as the recharge (intake) area for that system, then buildup of the water table will be transmitted to the confined system as a pressure increase. This pressure increase will be beneficial in decreasing effective stress on the confined system. Also, if recharge can be accomplished by injection through wells directly in the confined system, the pressure buildup will be directly beneficial.

If the recharge from the imported water percolates down to a water table in unconfined or semiconfined deposits overlying a compacting confined aquifer system, as occurs in most of the principal subsiding areas in the San Joaquin Valley, any buildup of the overlying water table will be nonbeneficial with respect to the confined system. The water table rise will have the net effect of increasing stress applied to the confined system.

In much of the area now being supplied with imported water, the net change in effective stress on the confined aquifers is the result of two opposing components: (1) a recovery of artesian head in the confined system due to the decrease in pumping and (2) a rise in an overlying but hydraulically separate water table, due to recharge by imported water moving down through the unsaturated zone. Ground water recharge areas in the San Joaquin Valley are shown on Figure 5.

In the Tulare-Wasco area, recovery of artesian head northeast of Delano has been as much as 230 feet since 1954. At the same site, the rise in the water table has been about 50 feet. Thus, the effective stress on the confined aquifers decreased about 210 feet in twenty years. Even though 12 feet of subsidence occurred in this general area from 1926-54 (Lofgren and Klausing, 1968) and shows as a 12-foot subsidence hole on the long-term subsidence map of 1926-74, subsidence from 1962-70 was negligible.

P. OIL FIELD SUBSIDENCE

Oil field subsidence, the third type of subsidence in terms of magnitude, is known to occur in a few small areas south and west of Bakersfield (Lofgren, 1973). For the most part, this type of subsidence has been less than one foot during the period of leveling control and is restricted to local areas. Present subsidence rates are generally very low. During earlier periods of maximum production, however, subsidence rates in some oil fields undoubtedly were much greater. This type of subsidence has little effect on the long-term subsidence trends in the valley.
G. DEEP SEATED TECTONIC SETTLEMENT

The fourth type of subsidence and least significant in terms of magnitude is deep seated tectonic settlement. Rock structures and topographic features result from this type of deformation of the earth's crust. It is not considered in this element because the process extends over long periods of geological time and does not result in significant hazard.
h. Land slides and Slope Stability

In California, interest in slope stability has increased markedly because of the great influx of people and the accompanying expansion and development of new public facilities and enlarged areas of private housing. As flat land is used up, urban development is becoming more extensive in hilly and mountainous areas. Hillside development can "trigger" old landslides and initiate new ones, if the project is improperly managed or designed. Either natural or man-induced landslides can occur in areas where development is not properly controlled.

On the next page, table #8 outlines the different types of land instability in decreasing order toward stability, first in their natural geologic state then when acted upon either by earthquake shaking motion or by man's work.

The volume of material involved in individual landslides ranges from less than a cubic foot, such as a single falling rock, to 4 to 5 cubic miles. The causes of landsliding can be traced to the inherent properties of the rocks, and to external factors related to the geologic setting. External conditions that cause landslides range from gravity which is always present, through erosion and rainfall, which are commonly or periodically present, to earthquakes, which are infrequent.

Erosion is a factor which increases the development of landslides in addition to its destructive effect on soils. Relative degree of soil erosion in Kern County is represented on Figure #6.

Failures can occur either without additional external causes, or by the introduction of water which would expand and/or weaken the soil, or perhaps by shaking as a result of an earthquake.

Earthquakes are probably the most prominent mechanism that directly triggers landslides. Earthquakes and landslides go hand in hand in California, particularly near faults. The area of sliding is related to the magnitude of the earthquake, the distance from the causative fault, the state and kind of rock materials involved, and the angle of slope. On figure 7, generalized land slopes are shown within Kern County for the San Joaquin Valley and Mojave region.

The Kern County earthquake of 1952 resulted in the formation of many hundreds of large and small landslides. Most of them were near the White Wolf fault, which was responsible for the earthquake. Many other landslides occurred at distances of 50 to 60 miles from the fault. Rock falls partly blocked the Angeles Crest Highway between Pasadena and Vincent, in the San Gabriel Mountains. Near the White Wolf fault on Bear Mountain, landslides continued for at least two months after the main shock: "Whenever one of the numerous aftershocks was felt, clouds of dust from landslides would be seen rising out of the canyons shortly afterwards."
<table>
<thead>
<tr>
<th>SLOPE STABILITY CLASS</th>
<th>&quot;Normal&quot; Geologic</th>
<th>Earthquake Induced*</th>
<th>Man-induced*</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Presently unstable. Many landslides are undergoing slow, periodic downhill movement or will do so during the lifetime of a structure.</td>
<td>Movement generated or accelerated. Saturated shallow slides may liquefy and flow rapidly downhill. Possible massive, rapid movement in deep slides on steep coastal slopes.</td>
<td>Movement may be accelerated by cutting, loading or diverting water into slides. Stabilization of some areas may be possible with expensive remedial measures, such as removal of slide material, drainage, buttressing.</td>
</tr>
<tr>
<td>Q</td>
<td>Marginal stability indicates geologic evolution of slope will bring greatest development of new landslides in these areas.</td>
<td>Most likely areas for generation of new landslides, especially in saturated rock and soil. Old landslides may be reactivated.</td>
<td>Extensive failures of cuts likely. Generation of landslides and instability related foundation problems likely unless engineered works carefully planned, designed and constructed to avoid them. These problems may occur at construction or may develop with time.</td>
</tr>
<tr>
<td>'Q'</td>
<td>Evidence for the presence of old deep landslides is equivocal. Relative stability of these, if present, is uncertain. Therefore, more study of these areas is needed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Steep canyon slopes are of low stability. Portions may evolve to questionable stability. Bank erosion of streams may induce slides.</td>
<td>Landslides may be common, especially in areas, or at times of rock and soil saturation.</td>
<td>Logging, especially construction of logging trails, may precipitate slides. Engineered cuts and fills will be high and steep leading to stability problems.</td>
</tr>
<tr>
<td>D</td>
<td>Relatively stable. Landslides unlikely except on steepest slopes, moist areas or along stream banks. These probably will be shallow and small.</td>
<td>Small, shallow landslides may occur locally on steeper, moister slopes, and in seepage areas. In swales, marshes and similar areas containing deeper, moist soils there may be soil cracking accompanying differential settlement and lurching.</td>
<td>Cut failures likely in weak rocks and soils. Extent will depend on height, steepness and design of cuts. Weakness of some rocks and soils may result in foundation settlement, creep or sliding if sites not carefully engineered.</td>
</tr>
<tr>
<td>C</td>
<td>Same as above, but landslides are likely to occur less frequently.</td>
<td>Same as above but landslides are likely to be less numerous.</td>
<td>High, steep cuts feasible without significant failure in many areas. Firm rock and soil for most foundations.</td>
</tr>
<tr>
<td>B</td>
<td>Local bank slumps along gullies and streams.</td>
<td>Differential settlement, liquefaction and lurching may occur accompanied by sliding on gentle slopes, and soil cracking (see text — Slope Stability Evaluation).</td>
<td>Saturated weak materials may fail even in low cuts.</td>
</tr>
<tr>
<td>A</td>
<td>Landslides unlikely.</td>
<td>Minor differential settlement and lurching accompanied by soil cracking and shallow slides may occur locally in marshes, moist swales and similar areas of saturated deeper soils.</td>
<td>Significant problems unlikely in properly engineered construction.</td>
</tr>
</tbody>
</table>

*Rockfalls from man-made cuts probably will be common in earthquakes.
Rockfalls in mountainous areas are a particular hazard during earthquakes. This form of mass movement can be very dangerous as it was in the Hebgen Lake earthquake in Montana in which a public campground was completely covered. Another example was the debris avalanche that covered the town of Yungau in Peru during an earthquake. These rockfalls may not require an earthquake to trigger them and are a source of danger to those who build imprudently close to steep slopes and in the mouth of mountain canyons.

While landslides are not common in the desert regions, another phenomenon is of interest there. Mud and debris flows occur following heavy rains. Stream courses become clogged by debris that falls from the canyons sides and because there is not enough rain to keep it washed off it gradually accumulates, blocking stream channels. When a heavy rain, usually from a thunder shower, occurs upstream, the water infiltrates the rock mass and lubricates it. Eventually the whole mass becomes plastic enough to flow freely and it does so at surprisingly rapid rates. (see Figure 8, above) One such event in the Tehachapi Mountains swept a train off the track and buried it. Mudflows and debris masses that are not quite plastic enough to flow by themselves are often set off by earthquakes and a reasonably strong earthquake in mountainous terrain is often accompanied by numerous debris flows.

Man and his activities have influenced the triggering of landslides in many cases. Lawn water, sewage effluent, or street drainage into already "precarious" geologic situations are often the causes, or the renewing agents, of landsliding.
Careless construction practices can cause or aggravate landsliding. Removal of vegetation and top soil through excavation or by fire renders areas more susceptible to landsliding because the ability of the surface to control the penetration rate of water is altered and the cohesive effects of grasses and roots are reduced.

Landsliding in California is particularly severe in the areas near the larger faults, where the rocks have been ground to a cataclastic powder. Examples of this sort of maceration, with consequent landsliding are to be found on Bear Mountain, near the White Wolf fault, in the Gorman region where the San Andreas and Garlock faults are surrounded on all sides by zones of cataclastic material several miles wide. This soil is unstable with or without earthquakes.

4. Soils and Ground Motion

a. Ground Stability of Clay Soils

The soils of Kern County have diverse properties. The U.S. Department of Agriculture, Soil Conservation Service, divides the soils into 8 groups. There are further subdivided into a total of 50 types. For the purpose of this discussion, investigation was limited to surface exposed clay bearing soils of Group 3 and 7 (Map No. 2). During an earthquake they are most sensitive to movement and are susceptible to alterations that have proved to be hazardous. Group 3 includes areas of nearly level terrain, whereas Group 7 is found on slopes. The properties of these clayey soils are summarized in the following table 9.

<table>
<thead>
<tr>
<th>Group</th>
<th>Thickness Inches</th>
<th>Shrink-Swell Factor</th>
<th>Swelling Clay Mineral</th>
<th>Allowable Soil Pressure Lb/Sq.Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>40-60</td>
<td>High</td>
<td>Present</td>
<td>1000-2000</td>
</tr>
<tr>
<td>7</td>
<td>20-60</td>
<td>High</td>
<td>Present</td>
<td>1000-2000</td>
</tr>
</tbody>
</table>

1. Volume change by wetting and drying. 2. Presence or absence of montmorillonite. 3. Med = stiff or soft sandy clay, Uniform Building Code (1973) Volume 1, Section 2904, Table 29-c.
Clayey soils of the Nacimiento-Linne Association, located on some of the southwest slopes of the San Joaquin Valley, exhibit only a moderate shrink-swell behavior and contain little or no montmorillonite. This group is not considered in this discussion.

The regional surface distribution of each group is shown on a general map No. 2 of the Seismic Hazard Atlas. Group 3, clayey soils, when wet are potentially unstable for building foundations. In contrast, the clayey soils of Group 7, generally restricted to sloping ground, are located at a safe distance above the water table and would be relatively stable except in case of heavy rain or flood preceding an earthquake.

Non-clayey soils forming virtually all other soil groups in the county are, in general, alluvial sandy loams with coarse to moderately fine texture, variable alkalinity and moderate permeability. The few other soil groups are residual sand soils of variable coarseness on sloping ground which has been more or less eroded and has highly variable permeability. As a whole, none of these latter two groups of sandy soils appear to be associated with any particular hazard except that when subjected to wetting during heavy rains any soil might become saturated and, therefore, unstable, as mentioned above in the case of clayey soils of Group 7.

b. Effects of Water Table

Sub-Soil A potential source of instability in a soil is the shallow depth sub-surface "A" clay (Ref. #12, p. H-20). Its distribution is widespread in the central part of the San Joaquin Valley and occurs at a depth of 10 to 60 feet. Generally, it is found in the area of, and overlain, by the clayey soils found so abundantly in Buena Vista and Kern Lake beds. It is also present west of Wasco between the Semitropic Ridge and Kern River channel. It extends northeast and underlies the Kern National Wildlife Refuge and area to the east (most of T25S, R22 and 23E), below the clayey soils of Group 3 and the Tulare Lake beds. The "A" clay is dark green plastic, silty and sandy, gypsiferous, and highly organic. Its thickness varies from a few feet to about 60 feet. In many places "A" clay areas are associated with a high water table (see general map No. 3) and that situation contributes locally to an increase of seismic induced hazards.

The ground effects of earthquake motion appear to be most critical in the first 400 to 500 feet of alluvium beneath the surface. (Ref. 13 and 14) Within that depth interval of the San Joaquin Valley in Kern County four additional clay horizons - B to E - lie below and in the proximity of the "A" clay (Ref. 12). They are interbedded with silty sands and gravels; are relatively thin; and, except for the C and E clay, they are of limited lateral extent. The total combined thickness of A to E clays in the first 500 feet of alluvium is estimated at a maximum of 160 feet or about 32%. The lateral distribution of C clay is almost the same as that of A clay in the northern part of Kern County, northwest of Wasco; its southern limits are near Spicer City and Semitropic substation. In this region the thickness of C clay is from 10 to 25 feet and its depth below the surface varies between 30 feet and 40 feet.
On the other hand, the lateral distribution of the E clay is more extensive. It is warped into a gentle asymmetric northwesterly trending syncline whose steeper flank is on the west side. It underlies an elongated area from the King–Tulare boundary between Delano and the Lost Hills in the north to a region as far south as Kern Lake and Arvin, and follows the east side of the Elk Hills and Buena Vista Lake. The E clay easterly limit is about 7 miles west of Wasco along the Semitropic Ridge, and about 8 miles west of Shafter. Its extent is then undetermined for a distance of about 25 miles due to lack of data; this clay reappears about 5 miles southeast of Bakersfield. The E clay or "blue clay," well known to the water-well drillers, is more or less silty or sandy and may reach a thickness of about 50 feet in the Semitropic Ridge anticlinal area, 60 feet in the Buena Vista syncline and nearly 30 feet in the Arvin basin. Respective depths below the surface are approximately 180 feet, 80 feet and 300 feet.

From these data showing the distribution and multiple layering of unconsolidated sediments and intercalated clays in relation to the water table, it may be inferred that structural failure resulting from earthquake motion is likely to be more damaging on the west side of the San Joaquin Valley than on the east side.

Most of Bakersfield is relatively free from this hazardous soil condition. An exception to this is an area south of Brundage Lane in the vicinity of the City Municipal Sewer Farm, underlain by an old Kern River Channel that extends toward Kern Lake.

The deep water table and limited distribution of the clay belt continues south of Bakersfield as far as Arvin and northward to Delano through Shafter and Wasco.

So far, the preceding analysis of soil and subsoil stressed the most obvious earthquake related hazards which result in foundation failure and structural damage, i.e., the convergence effects of a shallow water table and multiple clay layers. Other conditions less obvious, but still factors affecting the amount of earthquake damage, are the physical properties of unconsolidated sediments. These include their thickness above basement layering, angle of slope, and moisture content.

c. Thickness and Amplitude

In general, as the sedimentary thickness above a crystalline basement (metamorphic or igneous rock) increases, a corresponding increase in amplitude of earthquake waves at the surface is accompanied by increased damage. It is assumed that sediments bulk properties and structure remain similar. This condition is apparent from observations made around Pasadena, California, in an area having more than 500' of fairly dry alluvium. An earthquake was studied which had a wave with a frequency near 1 Hz. The amplitude of the wave at the earth's surface was five times larger than that on the basement complex.

The amplification difference can be even greater in water-saturated soft (unconsolidated) sediments. At the surface the amplitude of the wave may exceed that at basement by a factor of ten (Ref. 13). Other examples of the amplification of the wave in the same order of magnitude are reported by authors in the U.S., Japan, Russia (Ref. 14 to 16).
These examples indicate the importance of considering physical factors which affect surface response to earthquake waves in one area and not in another. It also indicates how from year to year moisture can change the physical conditions at a given location. It explains in part why one area receives extensive damage while an adjacent area escapes with only minor shaking.

d. Layering

A layered sedimentary cover over bedrock is usually present in many areas.

For the purpose of stress computation of ground characteristics at a definite site, the information may be expressed in terms of layer thickness, velocities of transverse waves, material densities and visco-elastic properties (Ref. 14). These quantities are determined by field observations which include a combination of boring, sampling and testing of materials, seismic studies, static penetrometer logs with electric sensors, etc. (Ref. 17 and 18).

Another useful method is based on the relationship between amplitude and frequency of a seismic wave. This type of measurement is made by observing microseismic recordings of the earth movements (Ref. 1t and 16). This method of soil investigation is prescribed by the Japanese Building Code.

The determination of ground response to earthquake motion (seismic waves) and its relation to conditions hazardous to man requires a conjunction of all available methods, including those mentioned above and others specified in Section 2903 of the Uniform Building Code (1973).

E. COMBINED HAZARDS EVALUATION IN THE COUNTY, CITIES AND SOME COMMUNITIES

As complete as possible, a knowledge of geological conditions should be available to the people who already own properties or who may purchase land. This knowledge also enables communities to formulate long-range plans to regulate land use so future residents will be protected from imprudent public and private projects.

The data in the following pages provide some specific and general information that should assist in evaluating the hazards and the degree of risk for cities and certain population centers.

These data were obtained from various sources within the County of Kern Departments and from the eleven incorporated cities, regarding population, area, natural hazards from floods, soil failure, landslide and subsidence, structural hazards and pre-disaster planning. In addition geologic and seismic information, reference to the corresponding seismic hazard maps, were added by the authors of the S.S.E. and combined in the form of synoptic table 10 to 11. One of the objectives of that investigation was to find out the present status of pre-earthquake protection measures oriented toward: 1. pre-disaster planning as analyzed in Chapter II. 2. building inspection to list and evaluate existing structures as to their degree of seismic hazard.
The results of that inquiry are summarized in the tables under the title "Pre-Earthquake Planning." It is obvious that except in a few cases, that essential and urgent program is sadly neglected and lagging behind the recommendations of the Governor's Earthquake Council First Report of November 1972, (Ref. #20, pages 48-51) and those of the Urban Geology Master Plan for California (Ref. #21).

Future inspection of buildings may be served by the use of Table 14: Hazard Comparison of Non-Earthquake-Resistive Buildings, prepared by the Pacific Fire Rating Bureau (see page IV-31).

1. KERN COUNTY

   a. Ground Shaking

   The county is located in one of the more seismically active areas of California and may in the near future be subject to moderate or severe ground shaking (See Tables 10 to 13). This hazard exists because elastic strains that accumulate deep within the earth become so great the rock can no longer be contained as a single rock mass. When this happens, movement along a fracture zone occurs, releasing enormous amounts of energy creating two or more rock masses.

   At any given location the amount of the resulting shaking motion caused by the sudden movement depends to a large extent on local ground conditions, i.e. the degree of water saturation, etc., and may be as severe ten miles from a fault as immediately adjacent to it. In some instances the shock wave may actually increase in amplitude as it travels away from the source. It may cause greater damage at a location some distance from the actual rupture than at the point of surface displacement. (Refer to "Geologic and Earthquake Hazards – Planning Guide to the Seismic Safety Elements of Kern County."

   The surface material varies from crystalline rocks to the older and more consolidated sediments to the younger less consolidated sediments. No study has been made that relates the degree of surface response to shock waves having different periods (time from one crest of a wave to the next crest). The surface response will vary greatly in different locations and is a measurable factor that should be measured and shown as lines of equal response similar to the manner in which equal elevations are displayed on topographical maps.

In all areas but with special emphasis in high response areas a program should be initiated to inventory natural and structural hazards. These hazards should be reduced to a level the people are willing to accept.

Plans for new construction should be reviewed by the people in the Building Inspection Department to determine if minimum requirements of the Uniform Building Code are sufficiently restrictive to insure the degree of risk protection acceptable to the people. If the code is found deficient, the regulations should be raised to meet the need.

The determination of the various factors regarding fault activity and geologic hazards requires a specialist in this field, not just any geologist.
He must be able to make and interpret field studies. He must use all available methods of obtaining pertinent information such as trenching, core hole drilling, reflection and refraction seismograms, etc., in order to help define the geologic characteristics of a particular location.

Construction plans for structures other than single family dwellings should include geological information described in Sections 4 and 5, Page VI-7.

Underground utilities service are extremely vulnerable in areas of high surface response to seismic waves. Consideration should be given to their design and construction in order to provide installation that will remain functional after severe earthquakes.

b. Ground Failure

Landslides have been shown on the maps in the Seismic Hazard Atlas. Additional landslides may subsequently be identified and should be added to these maps. Development in landslide areas is an unwise practice that imposes an unnecessary risk on the people. The slide may have reached a state of equilibrium and become stable for a number of years, however, the factors that caused the original slide could reoccur and cause additional movement. The added moisture injected into the soil by water and sewer systems tend to be detrimental in unstable areas.

Flooding induced by seismic activity may be of significance in areas where earth movement dams drainage channels or streams and rivers, or downstream from dams. A flood management program should be initiated so mitigating action can be taken. The Corps of Engineers is preparing an inundation map for the Isabella Dam, California Aqueduct flood area designated on map. (Volume of water between raches of canal as water flooding at point when fault crosses canal.)

Land subsidence is occurring in that part of the county located in the San Joaquin Valley. (See Seismic Hazard Atlas, Map No. 4.)

This type of ground failure can be aggravated by ground shaking. It is often caused by the withdrawal of large volumes of fluids from underground reservoirs. However, it can also be caused by the addition of water at the surface to certain types of soils (hydrocompaction).

Subsidence may cause maintenance problems on roads, concrete-lined canals and underground utilities. All new installations in the area of subsidence should be engineered to withstand subsequent subsidence. The usual remedial action is that of raising the water table by injecting water or by reducing ground pumpage. This increases the fluid pressure in the aquifer and in most instances subsidence decreases or stops after a period of time.

Clay soils that expand when moisture is added, tend to lose their ability to support the foundation of structures located on them. The location of clay soils outcrop are shown on map No. 2 of the Seismic Hazard Atlas; Map No. 3 delineates the known limits of clay formations that are near enough to the surface to warrent consideration.
Development in these general areas should be preceded by soil analysis to determine the extent of these clay deposits. Foundation and septic tank designs should be modified if necessary in order to provide adequate support to the proposed structure.

Liquification can occur in certain types of soils that are associated with a shallow water table. It has been observed in many areas of the world that ground shaking produced by earthquakes tends to cause liquification to the extent that buildings have fallen over on their sides due to the lack of ground support. Some buildings especially designed to withstand earthquake shock waves have been made uninhabitable because they tipped but were structurally undamaged. The design was good all except for the foundation which failed because liquifaction occurred during an earthquake.

Development in the areas of shallow water (Map No. 2, Seismic Hazard Atlas) should be preceded by soil analysis to determine the extent of a potential liquifaction problem. The engineering design of the structure and foundation should be consistent with the most up-to-date technology as it relates to this problem.

Erosion induced by seismic activity occurs on the gentle to steep slopes covered by unconsolidated sediments. This geologic hazard is aggravated by landslides, fissures, tilting and offset along a fracture zone. It could become a significant hazard in many areas of the county. The flood management program should also provide protection against this type of geologic hazard.

c. **Surface Fault Rupture**

Surface fault ruptures are designated on the maps in the Seismic Hazard Atlas as well as some faults that do not come to the surface. It must be recognized that some faults may not have been recognized either because the evidence for detecting them has not been preserved, or there hasn’t been sufficient work in the area. Several maps in the atlas have a special note to this effect in order to call the users attention to this lack. It could be said that all maps need more work because all surface and subsurface information hasn’t been collected and analyzed. This statement of fact should not prevent the use of that information which is available. As new geological and geophysical data is collected and analyzed that is pertinent to this study becomes available it should be added to these maps. A special program administration by a planning commission subcommittee should have the responsibility and authority to perform this task.

All known faults deserve consideration when planning land uses. It is the fault identified as active that deserves special consideration. No structure should be built astride an active fault. Utilities that cross such faults both underground and surface must be designed to remain in operation after fault movement. The maps show the approximate location of these features. The building inspector and contractor must identify the exact location at each site.

Certain major fault systems such as the San Andreas, Garlock, and White Wolf are recognized as being more complex and hazardous than others. For this reason there has been a zone designated on the maps as deserving special consideration. Construction in these zones should be subjected to more rigid requirements than the minimum set forth in the adopted Uniform Building Code.
Special pre-development planning, engineering studies and design criteria must be employed in these areas in order to provide the degree of safety the community is willing to support.

Some of these areas will be found to be fractured and unsuitable for most types of development. In others the detailed geologic studies will identify splinter faults that must be avoided. In others a setback of 50 feet to 100 feet from the fracture might be the only requirement.
2. **ARVIN**

a. **Ground Shaking**

The city is in an area of the San Joaquin Valley subject to moderate to severe ground shaking. This hazard is produced by the buildup of potential energy along major fault systems that may suddenly be released.

Of the $6,700^\text{+}$ foot thickness of sedimentary cover over the crystalline basement complex, approximately $1,900$ feet is composed of younger sediment. This condition is conducive to the propagation of elastic seismic waves.

A program should be initiated to inventory and systematically eliminate existing structural hazards that could endanger people's lives and property in the event of an earthquake.

New construction proposals should be reviewed by the Building Inspection Department to determine if the minimum requirements of the Uniform Building Code are adequate for each particular site. Construction plans other than single family dwellings should be subjected to additional studies described on page VI-7, items 4 and 5.

Because it is difficult to predict strong motion characteristics and their effect quantitatively, high-rise structures that have a long fundamental period equivalent to that of the ground response should be analyzed by structural engineers.

Underground utilities, roads, and concrete lined canals are vulnerable to ground shaking. Consideration should be given to their design and construction in order to provide uninterrupted service.

b. **Ground Failure**

- **Landslides**

  The land within the city boundary is situated on a gentle southwest slope of the valley, not subject to significant landslides or soil creep.
- Flooding Induced by Seismic Activity
This hazard appears to be minimal from causes within the city, however, flooding within the city caused from conditions outside the city is possible. The damming by landslides of intermittent streams in the adjacent mountains and subsequent failure of the dam is a significant hazard.

A flood plain management program should be initiated in cooperation with the county to mitigate this hazard.

- Land Subsidence

This type of ground failure can be triggered by ground shaking; it can also be a condition related to normal differential compaction of unconsolidated sediments, it can be caused by the addition of water to certain soil types (hydro-compaction), or it can be caused by withdrawal of large volumes of fluid, either water or oil. Arvin has experienced some subsidence, approximately 1 to 2 feet in the past forty years (Map No. 4 of the Seismic Safety Atlas). This slow rate of subsidence may continue as oil and water are withdrawn from the underground reservoirs. Water recharge may slow or halt this subsidence. At present the center of subsiding area 12 miles to the southwest of Arvin has experienced 7 feet of subsidence since 1926. Subsidence may cause some maintenance problems of roads and underground facilities in the city. New installations of underground facilities should be engineered to withstand the continuation of subsidence.

- Clay Soil
No significant amount of clay soil, which expands when wet, thereby impairing the foundations of large structures, is recognized in this area.

- Liquefaction
Liquefaction does not appear to be a significant hazard at Arvin. No shallow perched water table is recognized; The water table is at a depth of approximately 210 feet.

- Erosion
Soil erosion, a geologic hazard that can be aggravated by ground shaking and offset along a rupture, does not appear to be a significant factor in the city of Arvin.
c. Surface Fault Rupture

No active faults (i.e. fault having displaced quaternary rock of the Holocene Epoch) are recognized in the city boundaries.

The White Wolf and Edison faults near Arvin are recognized as being active faults in the vicinity. Two faults, Tejon Thrust and Jewett Canyon Fault, within the city were interpreted from subsurface data. There is no indication of recent movement along either fracture, so they are not considered as being hazardous at this time.
3. BAKERSFIELD

a. Ground Shaking

The city is in an area of the San Joaquin Valley that may be subject to moderate to severe ground shaking from the San Andreas, Sierra Nevada, White Wolf, or Garlock faults. This hazard exists because the elastic strain accumulated within the earth is released suddenly by movement along zones of weakness called faults. Shaking motion varies from one location to another and depends to a large extent on the amount of energy released, local ground conditions, degree of water saturation etc., and may be as severe ten to twenty miles from a fault as immediately adjacent to it.

The 7000± to 11,500± feet of sedimentary cover over the crystalline basement of which 14,000± to 3800± feet consist of younger sediments, is conducive to the propagation of elastic seismic waves.

The nearest fault displacing quaternary sediments or showing movement within historical time is approximately 6 miles north of the center of town. Destruction could be caused by some of the more distant faults in the county or even those located outside.

A program should be initiated to inventory and reduce existing structural hazards that, in the event of an earthquake, could endanger people's lives.

The Uniform Building Code should be reviewed to determine if the designs and regulations it imposes are sufficient to insure the degree of risk protection acceptable to the people. If found deficient the regulations can and should be revised to meet the need.

Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5, page VI-7, and should be engineered accordingly. This type of basic geological information is necessary for a response to development problems and must be the data on which action decisions are based.
Underground utilities and concrete lined canals are vulnerable in areas of severe ground shaking. Consideration should be given to their design construction in order to provide installations that will remain functional after an earthquake.

b. **Ground Failure**

   - **Landslides**
   For the most part the topography in the city consists of gentle slopes free from the hazards of landslides. The main exception to this is the bluff area north of Panorama Drive. Landslides in this area are possible if the soil accumulates too much moisture from lawn watering, surface runoff and other means. Constant monitoring of the bluffs in the area of residential development is necessary to evaluate this hazard.

   - **Flooding Induced by Seismic Activity**
   In October, 1969, the Department of the Army, Sacramento District, Corp. of Engineers, Sacramento, Calif. prepared a report entitled "Flood Plain Information, Kern River, Bakersfield, Calif." Areas of potential flooding in the city were delineated.

A more widespread area of destruction would result if the dam at Lake Isabella were to break due to seismic activity.

In order to mitigate this hazard, a flood management program should be initiated in cooperation with the county.

   - **Land Subsidence**
   Subsidence is not recognized as a significant problem in the developed part of the city. However, the fact that Bakersfield is between two subsiding areas, (see map No. 4 Seismic Hazard Atlas) and that the sewer farm southeast of town has been affected by subsidence is of concern.

This condition is the result of over producing ground water in the Delano and west Arvin areas. It is anticipated that water imported by the cross-valley canal and the recharge of the underground reservoir in the vicinity of
Bakersfield will prevent further subsidence in this area.

- Clay Soil

Clay soils that expand when wet thereby reducing the ground's ability to support foundations are found in the southeast part of Bakersfield in the vicinity of the sewer farm (Map No. 3 Seismic Safety Atlas). Development in this general area should be preceded by soil analysis to determine the extent of the clay deposit. Where it exists the design of foundations should be modified to provide adequate support to the proposed structure.

- Liquefaction

Ground shaking in areas of shallow watertable such as the sewer farm area in southeast Bakersfield can produce a soil condition that is termed liquefaction. In these areas the soil is not capable of supporting the foundation of a structure and in some instances the structure while perfectly intact has tilted or fallen over on its side thereby rendering it useless.

Development in the area of shallow water should be preceded by soil analysis to determine depths to water and if the area is subject to liquefaction. The design and foundation constructed in these areas should be done in a manner that would provide adequate support for the type of structure proposed.

- Erosion Induced by Seismic Activity

This type of geological hazard can be aggravated by landslides, tilting and offsets along a fault. It could become a significant hazard in this area and should be considered in development north of Panorama Drive and in the flood management program.

c. Surface Fault Rupture

No faults that displace younger sediments or show other evidence of recent movement are recognized within the city. Some recent faults may not be recognized because the evidence for determining them is not well preserved. Geophysical and other subsurface data that would enable faults to be detected should be collected and new data should be added to the appropriate maps in the Seismic Hazard Atlas. The faults shown on the atlas maps of the city are considered to be zones of weakness but not in danger of rupturing.
4. CALIFORNIA CITY

a. Ground Shaking.
The city is located in the Antelope Valley near the Garlock Fault. It may be subjected to severe ground shaking when elastic strains accumulated within the earth are suddenly released along the Garlock or other major faults. The Garlock Fault is considered active because in this area it displaces quaternary sediments.

Shaking motion depends to a large extent on local ground conditions, degree of water saturation etc., and may be as severe 10 miles from the fault as immediately adjacent to the fault.

The 1000 feet thickness of sedimentary cover over the crystalline basement is composed of 700 feet of younger less consolidated sediments. This thickness and composition is conducive to the propagation of destructive seismic waves.

A program should be initiated to inventory and systematically reduce existing structural hazards that, in the event of an earthquake, could endanger peoples' lives.

Plans for new construction should be reviewed to determine if the minimum requirements of the Uniform Building Code are sufficient to insure the degree of risk protection acceptable to the people. If found deficient the regulations can and should be revised to meet the need.

Construction plans for structures other than single family dwellings should contain the additional geological information described in item numbers 4 and 5, page VI-7 and should be engineered accordingly. The basic geological data are necessary so action decisions can be made in response to development problems.

Underground utility services are vulnerable in areas of severe ground shaking. Consideration should be given to their design and construction in order to provide installations that will remain functional after an earthquake.
b. **Ground Failure.**

- **Landslides**
The topography within the city varies from high rock buttes, often surrounded by relatively steep, slopes, to hilly sediment terrain patterned by dissecting drainage channels to areas that are virtually flat. No landslides are identified within the city; however, on the slopes, mud flow and soil creep may be precipitated by flash floods during years of high rainfall. The development of the slopes requires expert design by geologists and engineers plus study for documentation of the problems.

Failure of a builder or developer to investigate the slides potential, and to take precautions to prevent landslides, or to construct in such a way as to cause a slide, will subject them to liability. The jurisdiction issuing the construction permits may also assume a degree of liability.

- **Flooding Induced by Seismic Action**
Mudflows or landslides triggered by seismic action may dam drainage channels and subsequently break. Water trapped by such dam could be dangerous if released suddenly.

A flood management program should be initiated in cooperation with the county so provisions can be made to mitigate this hazard.

- **Land Subsidence**
This type of seismically induced hazard does not appear to be a problem in this area.

- **Clay Soil**
No deposits of clay soil which expand when saturated by water to the extent they impair foundations of large structures are recognized in this area.

- **Liquefaction**
No apparent problem in this area.
- Erosion Induced by Seismic Activity

Soil erosion, a geological hazard that can be aggravated by ground shaking, tilting and by offsets along ruptures, should be considered in a flood management program.

c. Surface Faulting

Several surface faults displacing younger sediments or showing other evidence of recent movement are identified within the city boundary. Additional unidentified faults may also exist. For this reason continued geological studies should accompany development within the city. The location of the faults and the potential hazard they represent should be explained to the people.

Earthquake zoning classifications should be used in the fault zones to ensure that development standards are consistent with the geologic hazard. In this way the community will be adequately informed of the conditions so they all share in the risk they accept.

New construction should not be located astride an active fault zone.

Underground utilities are vulnerable in the area because of possible movement along the zones of rupturing. Adequate engineering design should be employed so service will not be disrupted by ground rupturing. Particular attention must be given at points where utilities cross the active fault zones.
5. DELANO

a. Ground Shaking

The City is in an area of the San Joaquin Valley that may be subject to moderate to severe ground shaking from the San Andreas, Sierra Nevada, Poso Creek, White Wolf and Garlock Faults. This hazard exists because the elastic strain accumulated within the earth can suddenly be released by movement along major faults located within or near the county boundary. Shaking motion depends to a large extent on local ground conditions, degree of water saturation etc., and may be as severe ten miles from a fault as immediately adjacent to it.

The 7000+ foot thickness of sedimentary cover over the crystalline basement, of which 1500+ feet consists of younger sediment, is conducive to the propagation of elastic seismic waves.

A program should be initiated to inventory and reduce existing structural hazards that, in the event of an earthquake, could endanger peoples' lives.

The Uniform Building Code should be reviewed to determine if the designs and regulations it imposes are sufficient to insure the degree of risk protection acceptable to the people. If found deficient the regulations can and should be revised to meet the need.

Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5 page VI-7, and should be engineered accordingly. This type of basic geological information is necessary for a response to development problems and must be the data on which action decisions are based.

Underground utilities and concrete lined canals are vulnerable in areas of severe ground shaking. Consideration should be given to their design construction in order to provide installations that will remain functional after an earthquake.

b. Ground Failure

- Landslides

The City is situated on a gentle westerly slope not subject to significant landslides or soil creep.
- Flooding Induced by Seismic Activity

No apparent hazard from sources within the city were observed. Flooding may be caused from seismically induced factors outside the city by such features as landslides damming drainage channels and the subsequent breaching of the dam. Management program should be initiated in cooperation with the county in order to mitigate this hazard.

- Land Subsidence

This type of ground failure exists within the city and can be aggravated by ground shaking. It is caused by the withdrawal of large volumes of fluids.

This area has experienced subsidence of approximately 8 to 10 feet, in the past forty years (Map No. 4 - Seismic Hazard Atlas) essentially because of water withdrawal. A relatively slow rate of subsidence may continue as additional water is withdrawn from the underground reservoirs. To date twelve feet of subsidence has occurred since 1926 at a point ten miles north of the city.

Subsidence may cause maintenance problems on roads, concrete lined canals and underground utilities. New installations should be engineered to withstand subsequent subsidence. To mitigate this problem, remedial action of raising the water level should be accomplished by reducing ground pumping, and/or increase recharge. In most cases as the fluid pressure in the aquifer increases the rate of subsidence decreases.

- Clay Soil

The type of clay soil that expands when moisture is added, thereby reducing the structural support of building foundations, are not found in this area.

- Liquefaction

Liquefaction does not appear to be a hazard in this area.

- Erosion Induced by Seismic Action

This type of hazard appears to be minimal within the city boundary.
c. **Surface Fault Rupture**

No faults that displace younger sediments or show other evidence of recent movement are recognized within the city. This may not be indicative of the true hazard from surface ruptures because surface evidence of faulting is not preserved in the unconsolidated sediments of the central valley. A fault shown on the Seismic Hazard Atlas of the city was determined from subsurface data. As additional information becomes available, it should be added to this map.
6. MARICOPA

a. Ground Shaking

The city is located in a seismically active part of the San Joaquin Valley at the foot of a low range of hills which slope generally to the north and east. It is subject to moderate or severe ground shaking from the San Andreas Fault. This hazard exists because the elastic strain accumulated within the earth can suddenly be released by movement along major faults located within or near the county boundary. Shaking motion depends to a large extent on local ground conditions, degree of water saturation etc., and may be as severe ten miles from a fault as immediately adjacent to it.

The sedimentary cover over the crystalline basement includes 1,000± feet of younger sediments. This condition is conducive to the propagation of elastic seismic waves.

A program should be initiated to inventory and reduce existing structural hazards that, in the event of an earthquake could endanger peoples’ lives.

The Uniform Building Code should be reviewed to determine if the designs and regulations it imposes are sufficient to insure the degree of risk protection acceptable to the people. If found deficient the regulations can and should be revised to meet the need.

Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5, page VI-7, and should be engineered accordingly. This type of basic geological information is necessary for a response to development problems and must be the data on which action decisions are based.

Underground utilities and concrete lined canals are vulnerable in areas of severe ground shaking. Consideration should be given to their design construction in order to provide installations that will remain functional after an earthquake.
b. **Ground Failure**

- **Landslides**
  The city is situated on the relatively gentle easterly slope of the Temblor Mountains. The general area to the southwest is subject to landslides and soil creep. Within the city there are no known landslides, however, the steep slopes along the Bitterwater Creek may be subject to slumping that would be aggravated by ground shaking.

- **Flooding Induced by Seismic Activity**
  Two significant watersheds drain into the city area, Bitterwater Creek and Devils Gulch, along with two lesser drainage channels, Klipstein System and Welch System. The majority of the runoff from these channels passes through the city. No seismically induced flood hazard is foreseen from sources within the city, however, extensive flooding could result from seismically induced sources outside the city. Landslides that dam a drainage channel and the subsequent failure of the dam could result in widespread destruction within the city. In order to mitigate this hazard, a flood management program should be initiated in cooperation with the county.

- **Land Subsidence**
  Subsidence in the area can result from several causes. It can be a condition related to normal differential compaction of sediments, it can be caused by withdrawal of large volumes of fluid from the underground, or it can be caused by the addition of water to certain types of soils (hydrocompaction). The city is subject to subsidence hazards caused by the latter two causes, i.e., hydrocompaction and water withdrawal (Map No. 4). Of the two, hydrocompaction may be the most important at this time. Therefore, tests should be made prior to development of any property in the eastern part of the city in order to determine if the soil is subject to hydrocompaction. Severe ground shaking could aggravate this subsidence problem.

The imported water from the California Aqueduct should reduce the overdraft from ground water sources. As a result subsidence would be slowed or stopped in the large area east of the city where subsidence has occurred in the past.
- Clay Soil
The type of clay soil that expands when moisture is added, thereby reducing the structural support to a building's foundation, are not found in this area.

- Liquefaction
Liquefaction does not appear to be a hazard in this area.

- Erosion Induced by Seismic Action
Soil erosion, a geological hazard that can be aggravated by ground shaking, by tilting or by off-set along a rupture, should be considered in a flood management program.

c. Surface Faulting

No faults that displace younger sediments or show other evidence of recent movement are recognized within the city boundary. Such faults may exist so additional fault information should be added to the maps when it becomes available.
7. **McFarland**

a. **Ground Shaking**

The city is in an area of the San Joaquin Valley that may be subject to moderate to severe ground shaking (see chart on Table 10). This hazard exists because of the buildup of potential energy that may suddenly be released along a major fault system within and near to the county boundary. The nearest active fault is approximately 6 mile distance and could produce an earthquake of mag.6.5.

Of the 7000+ foot thickness of sedimentary cover over the crystalline basement, approximately 1500+ feet is composed of younger sediments. This condition is conducive to the propagation of destructive seismic waves.

A program should be initiated to inventory and systematically reduce existing structural hazards that could, in the event of an earthquake, endanger peoples' lives and property.

Plans for new construction should be reviewed to determine if the minimum requirements of the Uniform Building Code are sufficient to insure the degree of risk protection acceptable to the city. If found deficient the regulations can and should be revised to meet the need.

Construction plans for building other than single family dwellings, should contain additional information described in Item Numbers 4 and 5, page VI-7, and engineered accordingly.

Underground utility services and concrete lined canals are vulnerable in areas of severe ground shaking. Consideration should be given to the design and construction in order to provide for the reliable installations.

b. **Ground Failure**

- **Landslides**

The land within the city boundary is situated on a gentle northwest slope not subject to significant landslides or soil creep.
Flooding Induced by Seismic Activity
This type of hazard appears to be minimal from causes within the city, however, flooding may be caused by conditions outside the city. The damming of Poso Creek by a landslide and subsequent failure of the dam is a significant hazard.

A flood management program should be initiated in cooperation with the county in order to mitigate this hazard.

Land Subsidence
This type of ground failure can be triggered by ground shaking; in this area it can be a condition related to normal differential compaction of unconsolidated sediments, or it can be caused by the withdrawal of large volumes of fluid—either water or oil. This area has experienced subsidence, of approximately 2 to 3 feet, in the past forty years (Map No. 4 - Seismic Hazard Atlas) caused primarily by withdrawal of ground water.

A relatively slow rate of subsidence may continue as oil and water are withdrawn from the underground reservoirs. Twelve feet of subsidence has occurred since 1926, at a point ten miles north of the city.

Subsidence may cause maintenance problems on roads, concrete lined canals and underground utilities. New installations should be engineered to withstand subsequent subsidence. To mitigate this problem, the water levels should be raised by reducing ground pumpage, and/or increasing recharge. In most cases as the fluid pressure in the aquifer increases the rate of subsidence will decrease.

Clay Soil
Clay soils which expand when wet, thereby weakening the foundations are not found in this area.

Liquefaction
The city is not within the area that has a very shallow water table so liquefaction does not appear to be a significant hazard. The water table in this area is at a depth of approximately 150 feet.
- Erosion Induced by Seismic Activity
The probability of soil erosion, a geological hazard that can be aggravated by
ground shaking and by offset along a rupture in the earth, should be considered
in the flood management program.

c. Surface Fault Rupture
No faults that displace younger sediments or show other evidence of recent move-
ment are recognized within the city. This may not be indicative of the true
hazard because surface evidence of faulting is not well preserved in the central
valley. Therefore, some faults may not be recognized. Geophysical and subsur-
face data that would permit an accurate determination of active faulting is not
available at this time. Efforts should be made to obtain such information.

Nearest recognized active faulting is six miles northeast of the city.
8. RIDGECREST

a. Ground Shaking

The city is in an area of the Indian Wells Valley that may be subject to moderate or severe ground shaking (see Table #10) from the Garlock and Sierra Nevada Faults. This hazard exists because elastic strains accumulated within the earth are released along major faults located within or near the county boundary. The Ridgecrest and Rademaker Hills Fault displacing quaternary sediments or showing movement within historical time are within the city boundary. Shaking motion depends to a large extent on local ground conditions, degree of water saturation etc., and may be as severe ten miles from a fault as immediately adjacent to it.

The 1200 foot thickness of sedimentary cover over the crystalline basement is entirely composed of younger sediments. The thickness and composition is conducive to the propagation of destructive seismic waves.

A program should be initiated to inventory and reduce existing structural hazards that, in the event of an earthquake, could endanger peoples' lives.

Plans for new construction should be reviewed to determine if the minimum requirements of the Uniform Building Code are sufficient to insure the degree of risk protection acceptable to the people. If found deficient, the regulations should be revised to meet the need. The determination of fault activity requires an expert, not just any geologist, plus field study and documentation. All available methods of obtaining information such as trenching etc. should be used to help define the location and characteristics of faults.

Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5, page VI-7, and should be engineered accordingly. Necessary information for a response to development problems is basic geologic data on which action decisions can be formulated.

Underground utility services are vulnerable in areas of severe ground shaking. Consideration should be given to their design and construction in order to provide installations that will remain functional after an earthquake.
b. **Ground Failure**

- **Landslide**

The topography within the city consists of relatively gentle slopes at the south eastern end of a small valley which is a part of the main valley. Drainage from the south, southwest and east present some erosion problems, however, no significant landslides are observed.

- **Flooding Induced by Seismic Activity**

This type of hazard is minimal from causes within the city, however, flooding within the city may be caused by conditions in the unincorporated area.

A flood management program should be initiated in cooperation with the county so provisions can be made to mitigate this hazard.

- **Land Subsidence**

This type of seismically induced hazard does not appear to be a problem in this area.

- **Clay Soil**

No deposits of clay soil which expand when saturated by water to the extent they impaire foundations of large structures are recognized in the area.
- Liquefaction
This condition which can occur during a period of prolonged shaking in areas having a relative shallow water table does not appear to be a hazard in the city.

- Erosion Induced by Seismic Activity
This type of geological hazard can be aggravated by landslides, tilting and offsets along a fault. It could become a significant hazard in this area and should be considered in development and in the flood management programs.

c. Surface Fault Rupture
Several faults that displace younger sediments or show other evidence of recent movement are recognized within the city. Other such faults may not be recognized because the evidence for determining them is not well preserved. As additional fault information becomes available it should be added to the appropriate maps of the Seismic Hazard Atlas.

Land use zoning should include a fault hazard classification to regulate the location of structures and to insure that no structure is placed astride an active fault. The zoning will serve to give notice that movement in the earth's surface is probable at that location. The people should be made aware of the hazard and the risk to life and property.

Underground utilities are vulnerable in this area because of movement along the zone or rupturing. Adequate engineering design should be used so service will not be disrupted by ground rupturing.
9. SHAFTER

a. Ground Shaking

The city is in an area of the central San Joaquin Valley that is subject to moderate to severe ground shaking (chart page IV-6). The nearest fault displacing quaternary sediments or showing movement within historical time is approximately nine miles distance. This ground shaking type hazard exists because of the build-up of potential energy and the possibility that it may suddenly be released along a major fault system within or near the county boundary.

The severity of the shaking motion depends to a large extent on the local ground characteristics, degree of water saturation etc., and under certain stratigraphic conditions, may be as severe 10 miles from the fault as immediately adjacent to the fault.

The 13,500± feet of sedimentary cover over the crystalline basement is composed of 2,500± feet of younger, less consolidated sediments. This sedimentary thickness and composition is conducive to the propagation of destructive seismic waves.

A program should be initiated to inventory and evaluate those buildings and structures that represent an unacceptable risk to the people. Remedial programs that eliminate these unacceptable risks should be the responsibility of the building inspection department.

Plans for new construction should be reviewed to determine if the minimum requirements imposed by the Uniform Building Code are sufficient to insure the degree of risk protection acceptable to the people. If found deficient the regulations can and should be revised to meet the need.

Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5 page VI-7 and should be engineered accordingly. The basic geological data are necessary so action decisions can be made in response to development problems.
Underground utility services, canals and concrete water pipes are vulnerable in areas of severe ground shaking. Consideration should be given to their design and construction in order to provide installation that will remain functional after an earthquake.

b. Ground Failure

- Landslides
The gentle southwesterly slope on which the city is situated is not subject to landslides.

- Flooding Induced by Seismic Activity
This type of hazard appears to be minimal from causes within the city. However, the damming of Poso Creek by a seismically induced landslide and subsequent failure of the dam is a possible hazard. Several canals and highways act as a buffer to protect the city from much of the surface runoff. A flood management program should be initiated in cooperation with the county in order to mitigate this hazard.

- Land Subsidence
This type of ground failure can be accelerated by ground shaking in areas where subsidence is now present.

Shafter, Wasco and Delano areas have experienced subsidence caused by overproduction of the underground water reservoirs. The area north of Delano has subsided approximately 12 feet since 1926 (see Map No. 4 Seismic Hazard Atlas). The imported water from the California Aqueduct may tend to reduce the overdraft and thereby slow the rate of subsidence.

Subsidence may cause maintenance problems on roads, concrete lined canals, and underground utilities. New installations should be designed to withstand the effect of subsequent subsidence.

Subsidence can be decreased or stopped by increasing the fluid pressure in the underground aquifer. Reduced pumping and water recharge of the aquifer will usually accomplish this.
- Clay Soils

Clay soils that expand when wet, thereby reducing the ground's ability to support foundations are not found in this area.

- Liquefaction

The city is not within an area that has a very shallow water table so liquefaction does not appear to be a significant hazard.

- Erosion Induced by Seismic Activity

Soil erosion, a geological hazard that can be aggravated by ground shaking, landslides and by offset along a fault, is not a significant hazard.

c. Surface Fault Rupture

No faults that displace younger sediments or show other evidence of recent movement are recognized in this area. This may not be indicative of the true hazard in this area because surface evidence of faulting is not well preserved in the central valley. Therefore, some recent faults may not be recognized. Geophysical and other subsurface data that would permit an accurate determination of the fault problem is not available. Efforts should be made to obtain such information and add it to the maps in the Seismic Hazard Atlas.
10. **TAFT**

   a. **Ground Shaking**

   The amount of shaking or ground motion depends to a large extent on local ground conditions, degree of water saturation, etc., and may be as severe ten miles from the fault as immediately adjacent to it. The city is located within 2 miles (Buena Vista) and 8.5 miles (San Andreas) from two fault systems for which there is evidence of recent movement. Therefore, the city may be subjected to moderate to severe ground shaking from either source. There is approximately 2,000 feet of Pliocene or younger sediments and several thousands of feet of older sediments over a crystalline basement. The ground condition appears favorable for the propagation of destructive seismic waves.

   The ground shaking hazard exists because of the buildup of potential energy and the possibility that it may suddenly be released along the active faults.

   A program should be initiated to inventory and evaluate those buildings and structures that represent an unacceptable risk to the people. Remedial programs that eliminate these unacceptable risks should be the responsibility of the building inspection department.

   Plans for new construction should be reviewed to determine if the minimum requirements imposed by the Uniform Building Code are sufficient to insure the degree of risk protection acceptable to the people. If found deficient, the regulations can and should be revised to meet the need.

   Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5, page VI-7 and should be engineered accordingly. The basic geological data are necessary so action decisions can be made in response to development problems.

   Underground utility services, canals and concrete water pipes are vulnerable in areas of severe ground shaking. Consideration should be given to their design and construction in order to provide installation that will remain functional after an earthquake.
b. **Ground Failure**

- **Landslides**
The northeasterly and easterly slope on which Taft is located appear to be stable and not subject to landslides.

- **Flooding Induced by Seismic Activity**
This type of hazard appears to be minimal from causes within the city. However, the drainage from outside the city is a serious problem from Sandy Creek and several lesser drainage channels. Seismically induced landslides which dam and subsequently fill in these drainage channels with water could be a significant hazard.

A flood management program should be initiated in cooperation with the county in order to mitigate the hazard.

- **Land Subsidence**
Where it exists, this type of ground failure can be accelerated by ground shaking. Within the city there are two conditions which present a hazard. The first condition is the overproduction of the underground water reservoir which has affected a large area to the east of the city. (Map No. 4 Seismic Hazard Atlas) It is anticipated that water imported by the California Aqueduct can stop this subsidence by reducing the pumping and by recharging the underground reservoir.

The second condition is caused by the type of soil in parts of the area. When surface water is added the soil is compacted (hydrocompaction) and subsidence results. Soil analysis of the individual building site should be made to determine this condition.

Subsidence may cause maintenance problems on roads, concrete lined canals and underground utilities. New installations should be designed to withstand the effects of subsidence.

- **Clay Soils**
Clay soils that expand when wet thereby reducing the ground's ability to support foundations are not found in this area.
- Liquefaction
The city is not within an area that has a shallow watertable, so liquefaction does not appear to be a significant hazard.

- Erosion Induced by Seismic Activity
This type of geological hazard can be aggravated by landslides and offset along a fault and could be a significant hazard. This problem should be considered in the flood management program.

c. Surface Fault Rupture

No faults that displace younger sediments or show evidence of recent movement are recognized in this area. The hazard of new construction straddling an active fault are minimal.
11. TEHACHAPI

a. Ground Shaking

The city is in an area of the Tehachapi Valley, north of the Tehachapi Mountains that is subject to moderate to severe ground shaking (Table 10). The Destruct- ion occurring from the 1952 earthquake is indicative of the damage that future earthquakes could cause. The nearest faults displacing quaternary sediments are approximately 2.5 and 7.5 distance. Ground shaking hazard from these sources exists because of the build-up of potential energy and the possibility that it may suddenly be released along these or other major fault systems within or near the county border.

The severity of the shaking motion will depend to a large extent on local ground characteristics, degree of water saturation etc., and, under certain stratigraphic conditions may be as severe 10 miles from the fault as immediately adjacent to the fault.

The 400 feet of sedimentary cover over the crystalline basement is composed of younger sediments. This sedimentary thickness and composition is conducive to the propagation of destructive seismic waves.

A program should be initiated to inventory and evaluate those buildings and structures that represent an unacceptable risk to the people. Remedial programs that eliminate these unacceptable risks should be the responsibility of the building inspection department.

Plans for new construction should be reviewed to determine if the minimum requirements imposed by the Uniform Building Code are sufficient to insure the degree of risk protection acceptable to the people. If found deficient, the regulations can and should be revised to meet the need.

Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5, page VI-7 and should be engineered accordingly. The basic geological data are necessary so action decisions can be made in response to development problems.
Underground utility services, canals and concrete water pipes are vulnerable in areas of severe ground shaking. Consideration should be given to their design and construction in order to provide installation that will remain functional after an earthquake.

b. Ground Failure

- Landslides
The most highly developed part of the city is on a gentle north slope while the northern undeveloped part is located on a gentle to steep southwesterly slope. No landslides are recognized within the city, however, development of the steep slopes should be in accordance with grading regulations.

- Flooding Induced by Seismic Activity
Mountains to the south drain toward Tehachapi and vary in slope from 10% to 45%. The run off water from the mountains lying 2½ miles south of the city is diverted into several natural channels to the west. A concrete lined channel north of Highline Road has been constructed to divert water from the new subdivision south of the city to a 45 acre-foot flood control reservoir northwest of the city. Under normal conditions, Tehachapi experiences no major problems nor are any anticipated.

The flood control reservoir referred to above is considered adequate under existing conditions to handle a 100-year frequency flood. It would cause considerable loss of property and possibly life if it failed.

Extensive flooding could result from seismically induced sources outside the city. Landslides that dam a drainage channel and the subsequent failure of the dam could result in wide spread destruction within the city. Seismically induced failure of the 45 acre-foot flood control reservoir or the concrete lined channel north of Highline Road could be hazardous.

In order to mitigate these hazards a flood management program should be initiated in cooperation with the county.
- Land Subsidence
This type of geologic hazard is not recognized in the vicinity of Tehachapi.

- Clay Soil
The type of clay soil that expands when moisture is added, thereby reducing the structural support to a building's foundation, are not found in the city area.

- Liquefaction
Liquefaction does not appear to be a hazard in this area.

- Erosion Induced by Seismic Activity.
Soil erosion, a geologic hazard that can be aggravated by ground shaking, by tilting or by offset along a rupture, should be considered in a flood management program. Improper development of the steep hill north of the city could increase the erosion in this area.

c. Surface Faulting

The Tehachapi Creek Fault is designated on the Seismic Safety Atlas Quadrangle "Tehachapi North," as a fault that displaces younger sediments or shows other evidence of recent movement. This fault and several splinter branches cut through the north east part of the city. Movement has taken place in recent geological time and it is considered to be the most likely location for subsequent movement. If a structure is astride an active fault such as this when movement occurs it will be subjected to great stresses which will tend to tear the structures apart. This should be avoided by requiring detailed geological investigation such as trenching etc. prior to approving the building permit. The determination of the activity of a fault requires an expert plus field study and documentation. Not just any geologist will qualify as an expert for this specialized type of work.

There may be similiar faults within the city that have not been identified because distinctive features have either not developed or have been removed by erosion or by activities of man. The possibility of unidentified faults and new breaks developing at places other than exactly on old breaks is speculative. Therefore,
zoning classifications restricting certain high density uses cannot be expected to eliminate the hazard entirely. Nevertheless, adjusting land use through techniques of zoning can greatly reduce the hazard and should be included in the zoning of this area.

Failure of a builder or developer to use special foundation design and to take special precautions to prevent damage to structures in this area will impose absolute liability on them.
12. **WASCO**

a. **Ground Shaking**

The city is in an area of the central San Joaquin Valley that is subject to moderate to severe ground shaking (Table 10). The nearest fault displacing quaternary sediments or showing movement within historical time is approximately nine miles distance. This ground shaking type hazard exists because of the build-up of potential energy and the possibility that it may suddenly be released along a major fault system within or near the county boundary.

The severity of the shaking motion depends to a large extent on the local ground characteristics, degree of water saturation etc., and under certain stratigraphic conditions, may be as severe 10 miles from the fault as immediately adjacent to the fault.

The 13,000 feet of sedimentary cover over the crystalline basement is composed of 2,100 feet of younger, less consolidated sediments. This sedimentary thickness and composition is conducive to the propagation of destructive seismic waves.

A program should be initiated to inventory and evaluate those buildings and structures that represent an unacceptable risk to the people. Remedial programs that eliminate these unacceptable risks should be the responsibility of the building inspection department.

Plans for new construction should be reviewed to determine if the minimum requirements imposed by the Uniform Building Code are sufficient to insure the degree of risk protection acceptable to the people. If found deficient the regulations can and should be revised to meet the need.

Construction plans for structures other than single family dwellings should contain the additional geological information described in items 4 and 5, page VI-7 and should be engineered accordingly. The basic geological data are necessary so action decisions can be made in response to development problems.
Underground utility services, canals and concrete water pipes are vulnerable in areas of severe ground shaking. Consideration should be given to their design and construction in order to provide installations that will remedy functional after an earthquake.

b. Ground Failure

- Landslides
The gentle southwesterly slope on which the city is situated is not subject to landslides.

- Flooding Induced by Seismic Activity
This type of hazard appears to be minimal from causes within the city. However, the damming of Poso Creek by a seismically induced landslide and subsequent failure of the dam is a possible hazard. Several canals and highways act as a buffer to protect the city from much of the surface runoff. A flood management program should be initiated in cooperation with the county in order to mitigate this hazard.

- Land Subsidence
This type of ground failure can be accelerated by ground shaking in areas where subsidence is now present.

Shafter, Wasco and Delano areas have experienced subsidence caused by over production of the underground water reservoirs. The area north of Delano has subsided approximately 12 feet since 1926 (see Map No. 4 Seismic Hazard Atlas). The imported water from the California Aqueduct may tend to reduce the overdraft and thereby slow the rate of subsidence.

Subsidence may cause maintenance problems on roads, concrete lined canals, and underground utilities. New installations should be designed to withstand the effect of subsequent subsidence.

Subsidence can be decreased or stopped by increasing the fluid pressure in the underground aquifer. Reduced pumping and water recharge of the aquifer will usually accomplish this.
- **Clay Soils**
Clay soils that expand when wet, thereby reducing the ground's ability to support foundations are not found in this area.

- **Liquefaction**
The city is not within an area that has a very shallow water table so liquefaction does not appear to be a significant hazard.

- **Erosion Induced by Seismic Activity**
Soil erosion, a geological hazard that can be aggravated by ground shaking, landslides and by offset along a fault, is not a significant hazard.

c. **Surface Fault Rupture**

No faults that displace younger sediments or show other evidence of recent movement are recognized in this area. This may not be indicative of the true hazard in this area because surface evidence of faulting is not well preserved in the central valley. Therefore, some recent faults may not be recognized. Geophysical and other subsurface data that would permit an accurate determination of the fault problem is not available. Efforts should be made to obtain such information and add it to the maps in the Seismic Hazard Atlas.
**EVALUATION CHART**

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<tr>
<th>CITY</th>
<th>POPULATION</th>
<th>AREA WITHIN CITY BOUNDARY (Acres)</th>
<th>DENSITY</th>
<th>SEISMOIC HAZARD MAP</th>
<th>DEPTH TO WATER (Pt.)</th>
<th>THICKNESS YOUNGER SEDIMENTS (Pl.)</th>
<th>DEPTH TO INSECTANT COMPLEX (Pt.)</th>
<th>EXPOSURE DISTANCES (2)</th>
<th>NO. OF EPI-CENTERS WITHIN 5 MI RADIUS (3)</th>
<th>POTENTIAL HAZARDS (5)</th>
<th>PRE-CATASTROPHE</th>
<th>TYPES OF LAND USE</th>
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<td>In Process</td>
<td>None</td>
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<tr>
<td>McFarland</td>
<td>6,300</td>
<td>160 Total 160 350</td>
<td>3.4</td>
<td>McFarland 601</td>
<td>1,500 ± 7,600</td>
<td>0 500 ± 700</td>
<td>0 1,000 32 10 1</td>
<td>2 2 1 1 1</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Agriculture Oil</td>
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<tr>
<td>Ridgecrest</td>
<td>10,375</td>
<td>354</td>
<td>1.9</td>
<td>Ridgecrest 601</td>
<td>1,500 ± 7,600</td>
<td>0 500 ± 700</td>
<td>0 1,000 32 10 1</td>
<td>2 2 1 1 1</td>
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<td>None</td>
<td>None</td>
<td>Light Mfg. Navy Weapon Center</td>
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<td>4,285</td>
<td>1200 Total 1200 100 ± 200 ± 1000</td>
<td>3.4</td>
<td>Taft 601 100</td>
<td>2,000 ± 13,000</td>
<td>0 500 ± 700</td>
<td>0 1,000 32 10 1</td>
<td>2 2 1 1 1</td>
<td>None</td>
<td>In Process</td>
<td>In Part</td>
<td>Oil It., Mfg. Agriculture</td>
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<tr>
<td>Tehachapi</td>
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<td>2400 Total 2400 200 ± 200 ± 2000</td>
<td>1.0</td>
<td>Tehachapi North 601</td>
<td>1,500 ± 7,600</td>
<td>0 500 ± 700</td>
<td>0 1,000 32 10 1</td>
<td>2 2 1 1</td>
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<td>None</td>
<td>None</td>
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<tr>
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<td>6,550</td>
<td>400 Total 400 400 ± 200 ± 2000</td>
<td>1.7</td>
<td>Taft 601 100</td>
<td>2,000 ± 13,000</td>
<td>0 500 ± 700</td>
<td>0 1,000 32 10 1</td>
<td>2 2 1 1 1</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Agriculture Oil</td>
</tr>
</tbody>
</table>

**Notes:**
1. Distance to Epicenter magnitude 5 or greater.
2. Distance from approximate center of a community to nearest fault or subsurface activity, or showing movement within historical lines.
3. Within 5 mile Radius of approximate community center between the years 1952 to 1971.
4. Soil that may experience foundation failure, and flow or liquefaction.
5. Severity Scale: 1-Low 2-Moderate 3-High.
| COMMUNITY  | POPULATION | AREA (ACRES) | DENSITY | SEISMIC HAZARD MAP | DEPTH TO WATER (FT.) | FLOOR HEIGHT (FT.) | EFFECTIVE DEPTH (FT.) | EARTHQUAKE TYPE | SHELTER REQUIREMENT | NO. OF EPI-CENTERS WITHIN 5 MILE RADIUS | POTENTIAL HAZARDS | PRE-EARTHQUAKE | TYPES OF LAND USE |
|-----------|------------|--------------|---------|--------------------|----------------------|-------------------|---------------------|----------------|-------------------|----------------------------------------|----------------|---------------|----------------|-------------------------------------------------|
| Sunfish   | 710        | 5,760        | .1      | Isabella           | 89                   | 19                | 0.25                | 3              | 2                | 1                             | 3 2 1 3 5 2 3 1 | None None | Resident |
| Lake Isabella | 1,660    | 2,150        | .7      | Isabella           | 88                   | 21                | 0.4                | 1              | 2                | 2 1 3 3 5 3 1 | None None | Resident |
| Lennsville | 977        | 4,480        | .2      | Lennsville         | Isabella            | 88                | 0.3                | 3              | 2                | 1 3 2 3 1 | None None | Resident |
| Opons     | 100        | 640          | .08     | Opons              | 98                   | 31                | 0.3                | 3              | 2                | 2 1 3 2 3 1 | None None | Resident |
| So. Lake  | 1,000      | 1,280        | .06     | Isabella           | 88                   | 17                | 0.3                | 3              | 2                | 1 3 2 1 1 | None None | Residential |
| Squirrel Valley | 300     | 1,280        | .2      | Isabella           | 88                   | 21                | 0.3                | 3              | 2                | 1 3 2 1 1 | None None | Resident |
| Woodford Heights | 38        | 2,340        | .3      | Isabella           | 88                   | 20                | 0.3                | 3              | 2                | 1 3 2 1 1 | None None | Resident |
| Lemont    | 8,913      | 3,800        | 1.2     | Lemont             | 6C3                  | 20                | 6 9 9              | 2 1 1 1 1 1 1 | None None | Resident |
| Lorel    | 40         | 660          | .06     | Lorel              | 8C3                  | 4                 | 6 7 1             | 1 3 2 1 1 1 1 | None None | Resident |
| Hall Prov. | 10         | 10           | 1       | Hall Prov.         | 10                   | 10                | 10                 | 1 3 2 1 1 1 1 | None None | Resident |
| Mogra    | 2,725      | 8,320        | .3      | Mogra              | 903                  | 300               | 800                | 2              | 1                | 1 1 1 1 1 1 1 2 | None None | Residential |
| North Edwards | 800     | 1,280        | .1      | North Edwards      | 80                   | 1,825             | 39 8 16           | 1              | 1                | 1 1 1 1 1 1 1 1 | None None | Residential |
| New Mill, Chico Lake | 11,105  | 11,105       | .1      | New Mill, Chico Lake | 118                  | 100               | 1,355              | 22 1 1 1 1 1 1 1 | None None | Residential |
| Old River | 200        | 2,500        | .08     | Old River          | 504                  | 110               | 3,500              | 17 000         | 13 17            | 1 1 4 1 3 1 1 1 1 1 | None None | Agricultural Residential |
| Pampa    | 300        | 1,280        | .2      | Pampa              | 504                  | 120               | 3,500              | 17 000         | 9 14 3 1 1 1 1 1 1 1 | None None | Agricultural Residential |
| Pumpkin Center | 100    | 2,500        | .02     | Pumpkin Center     | 504                  | 115               | 3,500              | 17 000         | 6 15 1 1 1 1 1 1 1 1 | None None | Agricultural Residential |
| Sandberg, Johannesburg | 300   | 1,280        | .2      | Sandberg, Johannesburg | 1100                 | 0                 | 0 1 1 1 1 1 1 1 1 1 | None None | Agricultural Residential |
| Rosewood | 2,397      | 5,450        | .4      | Rosewood           | 9E3                  | 902               | 1,555              | 28 1 2 1 1 1 1 1 1 1 | None None | Agricultural Residential |
| Willow   | 12         | 20           | 1       | Willow             | Isabella            | 88                | 12                 | 20 1 2 1 1 1 1 1 1 | None None | Agricultural Residential |

(1) Distance in miles to epicenter magnitude 5 or greater.
(2) Distance in miles from approximate center of a community to nearest fault rupturing earthquake analysis or seismic source within historical time.
(3) Within 5 mile radius of approximate community center between the years 1902 to 1971.
(4) All that any experience foundation failure, and flow or liquefaction.
### EVALUATION CHART

<table>
<thead>
<tr>
<th>COMMUNITY</th>
<th>POPULATION</th>
<th>AREA WITHIN BOUNDARY (Acres)</th>
<th>GEODATA</th>
<th>SECOND HAZARD MAP</th>
<th>DEPTH TO WATER (ft.)</th>
<th>RISK TO UPPER EMBANKMENT (ft.)</th>
<th>DEPTH TO EMBANKMENT COPPER (ft.)</th>
<th>NO. OF EPI CENTER WITHIN 5 MG RD. (1)</th>
<th>POTENTIAL HAZARDS (5)</th>
<th>PRE-PARTICIPATION PLANNING</th>
<th>TYPES OF LAND USE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belridge No.</td>
<td>100</td>
<td>640</td>
<td>.2</td>
<td>Blackwell Corner</td>
<td>288</td>
<td>350</td>
<td>50</td>
<td>60 13 1 1 1 1 1 1 1 1 1 1</td>
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<td>None None</td>
<td>Oilfield Residential</td>
</tr>
<tr>
<td>Belridge Sw.</td>
<td>200</td>
<td>1,380</td>
<td>.2</td>
<td>Belridge</td>
<td>322</td>
<td>1,500</td>
<td>55 33</td>
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<td>None None</td>
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</tr>
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<td>Buttonwillow</td>
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<td>1,280</td>
<td>.9</td>
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<td>422</td>
<td>2,000</td>
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<td>None None</td>
<td>Agriculture Residential</td>
</tr>
<tr>
<td>Derby Acres</td>
<td>300</td>
<td>640</td>
<td>.5</td>
<td>Fallow</td>
<td>322</td>
<td>1,300</td>
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<td>None None</td>
<td>Agriculture Residential</td>
</tr>
<tr>
<td>Dustin Acres</td>
<td>200</td>
<td>640</td>
<td>.3</td>
<td>Taft</td>
<td>422</td>
<td>2,600</td>
<td>23 4</td>
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<td>None None</td>
<td>Residential</td>
</tr>
<tr>
<td>Fallow</td>
<td>550</td>
<td>800</td>
<td>.7</td>
<td>Fallow</td>
<td>322</td>
<td>1,300</td>
<td>30 7</td>
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<td>None None</td>
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</tr>
<tr>
<td>Frazier Mtn.</td>
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<td>2,240</td>
<td>.5</td>
<td>Frazier Mtn.</td>
<td>623</td>
<td>0 - 300</td>
<td>3 0</td>
<td>31 3 3 1 2 1 2 1 1 1 1 1</td>
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<td>None None</td>
<td>Residential Recreation</td>
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<tr>
<td>Lake of the Woods</td>
<td>350</td>
<td>640</td>
<td>.5</td>
<td>Cuddy Valley</td>
<td>548</td>
<td>500</td>
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<td>26 3 3 1 2 1 2 1 1 1 1 1</td>
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<td>Residential</td>
</tr>
<tr>
<td>Lake</td>
<td>1,50</td>
<td>6,480</td>
<td>.1</td>
<td>Lebec</td>
<td>623</td>
<td>5 - 150</td>
<td>6 0</td>
<td>26 3 3 1 2 1 2 1 1 1 1 1</td>
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<td>None None</td>
<td>Residential</td>
</tr>
<tr>
<td>Lost Hills</td>
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<td>Lost Hills</td>
<td>323</td>
<td>600</td>
<td>40 21</td>
<td>0 1 1 2 1 1 1 1 1 1 1 1</td>
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<td>None None</td>
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</tr>
<tr>
<td>McElhiney</td>
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<td>West Elk Mtn.</td>
<td>323</td>
<td>230</td>
<td>37 10.5</td>
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<td>None None</td>
<td>Service Agriculture</td>
</tr>
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<td>1,280</td>
<td>.1</td>
<td>Mettler</td>
<td>429</td>
<td>250</td>
<td>5 10</td>
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<td>None None</td>
<td>Service Agriculture</td>
</tr>
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<td>.7</td>
<td>Rosedale</td>
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</tr>
<tr>
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<td>6 0</td>
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<td>None None</td>
<td>Agriculture Resident</td>
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<td>Taft</td>
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<td>None None</td>
<td>None None</td>
<td>Resident</td>
</tr>
</tbody>
</table>

(1) Distance in miles to Epicenter magnitude 5 or greater.
(2) Distance in miles from approximate center of a community to nearest fault.
(3) Displacing quaternary aquifer or similar movement within historical time.
(4) Within 5 mile radius of approximate community center between 1972 and 1971.
(5) Soil that may experience foundation failure, and flow or liquefaction.
(6) Security Scale: 1-Low 2-Moderate 3-High.
## EVALUATION CHART

<table>
<thead>
<tr>
<th>COMMUNITY</th>
<th>POPULATION</th>
<th>AREA WITHIN BOUNDARY (ACRES)</th>
<th>DENSITY</th>
<th>SEDIMENT HAZARD MAP</th>
<th>DEPTH TO WATER (Ft.)</th>
<th>THICKNESS YOUKER SEDMENTS (Ft.)</th>
<th>DEPTH TO MAINSTAY COMPLEX (Ft.)</th>
<th>MAXIMUM FLOODING (Ft.)</th>
<th>MAXIMUM FAULT (Ft.)</th>
<th>NO. OF ZI-71 CENTERS WITHIN 5 Mi RADIUS</th>
<th>POTENTIAL HAZARDS (S)</th>
<th>STRUCTURAL</th>
<th>PRE-LA-TROUQUAKE</th>
<th>TYPES OF LAND USE</th>
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<tbody>
<tr>
<td>Aerial Acres</td>
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<td>77</td>
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<td>1</td>
<td>2</td>
</tr>
<tr>
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<td>50</td>
<td>700x²</td>
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<td>1</td>
</tr>
<tr>
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<td>1,280</td>
<td>.2</td>
<td>Rana S. 1044</td>
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<td>10</td>
<td>3,865</td>
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<td>104</td>
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<td>3</td>
<td>2</td>
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</tr>
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<td>7</td>
<td>6</td>
<td>12</td>
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<td>1</td>
<td>1</td>
<td>1</td>
</tr>
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<td>10,333</td>
<td>.98</td>
<td>Fulmor Dr. 1044</td>
<td>60</td>
<td>100</td>
<td>98</td>
<td>98</td>
<td>18</td>
<td>14</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
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<td>1,280</td>
<td>.12</td>
<td>Glendora Ave. 1044</td>
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<td>1</td>
<td>44</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Greenfield</td>
<td>2,323</td>
<td>5,750</td>
<td>.4</td>
<td>Lassen St. 504</td>
<td>100</td>
<td>2,000x²</td>
<td>17,000</td>
<td>6</td>
<td>14</td>
<td>9</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
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<td>Havelock</td>
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<td>2,560</td>
<td>.01</td>
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<td>1</td>
<td>13</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
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</tr>
<tr>
<td>Ingolstadt</td>
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<td>Ingolstadt Dr. 1040</td>
<td>215</td>
<td>500x²</td>
<td>3,500x²</td>
<td>11</td>
<td>3.5</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Loma</td>
<td>100</td>
<td>1,280</td>
<td>.08</td>
<td>Rana St. 751</td>
<td>1.5</td>
<td>4.5</td>
<td>130</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

(1) Distance in miles to Epicenter magnitude 5 or greater.
(2) Distance in miles from approximate center of a community to nearest fault displacing quaternary sediment or showing movement within historical time.
(3) Within 5 mile radius of approximate community center between the years 1952 to 1972.
(4) Soil that may experience foundation failure, mudflow or liquefaction.
(5) Severity Scale: 1-Low 2-Moderate 3-High.
# HAZARD COMPARISON OF NON-EARTHQUAKE-RESISTIVE BUILDINGS

This table is intended for buildings not containing earthquake-resistant construction, and in general, is applicable to most older construction. Unfavorable foundation conditions and/or dangerous roof tanks can increase the earthquake hazard greatly.

<table>
<thead>
<tr>
<th>SIMPLIFIED DESCRIPTION OF STRUCTURAL TYPE</th>
<th>RELATIVE DAMAGE ABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small wood-frame structures, i.e. dwellings not over 3,000 sq. feet and not over 3 stories</td>
<td>1</td>
</tr>
<tr>
<td>Single or multistory steel-frame buildings with concrete exterior walls, concrete floors, and concrete roof. Moderate wall openings</td>
<td>1.5</td>
</tr>
<tr>
<td>Single or multistory reinforced-concrete buildings with concrete exterior walls, concrete walls, and concrete roof. Moderate wall openings</td>
<td>2</td>
</tr>
<tr>
<td>Large area wood-frame buildings and other wood frame buildings</td>
<td>3 to 4</td>
</tr>
<tr>
<td>Single or multistory steel-frame buildings with unreinforced masonry exterior wall panels; concrete floors and concrete roof</td>
<td>4</td>
</tr>
<tr>
<td>Single or multistory reinforced-concrete frame buildings with unreinforced masonry exterior wall panels, concrete floors and concrete roof</td>
<td>5</td>
</tr>
<tr>
<td>Reinforced concrete bearing walls with supported floors and roof of any material (usually wood)</td>
<td>5</td>
</tr>
<tr>
<td>Buildings with unreinforced brick masonry having sand-line mortar; and with supported floors and roof of any material (usually wood)</td>
<td>7 up</td>
</tr>
<tr>
<td>Bearing walls of unreinforced adobe, unreinforced hollow concrete block, or unreinforced hollow clay tile</td>
<td>Collapse hazard in moderate shocks</td>
</tr>
</tbody>
</table>

Source: Abridged from Pacific Fire Rating Bureau Tariff Rules

Mobile homes?
V.

HAZARD AND RISK ANALYSIS

A. General Statement.

The words hazard and risk are often used indiscriminately with the same intended meaning and connotation thus causing a lack of precise understanding and at times some confusion.

In this report, hazard is defined as an event happening unexpectedly such as an unforeseen accident or disaster due to a cause either natural or man-made. Consequently, hazard is a random event, unpredictable and only evaluated on a relative severity scale established on our present knowledge of facts pertaining to a specific hazard.

In this report, risk is defined as the value of a possible loss resulting from the effect of a certain hazard occurring at a definite location at an indefinite time. A risk is thus a quantity expressed as a monetary loss which may happen any time but varies in amount with the change of location.

The purpose of this chapter is to review the methods of regional seismic hazard analysis leading to corresponding risk evaluation. Discussions of potential hazards are presented in Chapters III and IV and their areal distribution is shown on the quadrangles of the Seismic Hazard Atlas. On the basis of those data the following principles may be formulated:

1. The relative severity of a definite hazard in a given area may be expressed by a scale: Low - 1; Moderate - 2; High - 3. These factors are used on charts -- Combined Hazards Evaluation -- Tables 10-13.

2. Convergence of superposition of several hazards in one area tend to increase the severity factor.

3. Increased distance from faults or epicenters tend to decrease the severity factor; the converse is also true. For instance in the tables mentioned above the shaking severity factor expresses the result of the composite analysis of seismicity represented by the number of epicenters within a five mile radius, the distance to the nearest "young" fault and the probable shaking by a past earthquake of magnitude equal or greater than 5 when damage begins. Similarly, other severity factors are estimated by analyzing all available data for each problem. For example, the failure of foundations is related to clay soils and subsidence. Extensive damage to communities and highways even near moderate slopes are caused by landslides and mud-flows. Building resistance to seismic stresses generally decreases with age increase, etc.

B. Conversion of Hazards into Risks.

The earliest method is based on the attempt to relate specific losses to the earthquake intensity (Mercali scale, Table 1) in the area of greatest damage and intensity (mezosismic zone). Variability of earthquake characteristics, environment, as well as uncertainty inherent to the intensity scale and poor records, prevented that method from giving reliable data generally applicable to risk evaluation. Only in the cases of thoroughly investigated earthquakes with their respective estimated losses should there be enough actuarial data
to establish some regional risk value for different types of damage and hazards. However, that material is apparently lacking even in the most recent publications on earthquake damages.

In older publications such as that on the Earthquakes in Kern County during 1952 (Ref. #5) although very detailed in many respects, the separate damage costs to buildings in Arvin and in Tehachapi are not given. For Bakersfield, the combined damages caused by the main shock of July 21 and the aftershock of August 22 are estimated at $23 millions. Assuming that this total loss is amortized by taxation by the population of the incorporated city in one hundred years, the annual tax burden would progressively decline with increased population from about $5. to $1.70 per person.

Another approach to the evaluation of risks to buildings is to calculate the probability of collapse of a structure for the maximum ground wave velocity during an earthquake at a given location. (Ref. #22.) That method assumes a complete destruction of a structure and seems to be unadapted to cases where salvage and repairs are considered.

C. Acceptable Risk.

The acceptable risk is the dollar amount society is willing to pay for the prevention and partial compensation for the losses caused by a disaster or several hazards. That acceptability depends upon the value of the savings or benefit (B) realized by decreasing the amount of probable loss through the expenditure of the acceptable risk or cost (C). The estimated values of cost ratio (Benefit-Cost) for the following hazards are:

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Cost Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansive soils</td>
<td>20:1</td>
</tr>
<tr>
<td>Landslides</td>
<td>9:1</td>
</tr>
<tr>
<td>Earthquake shaking</td>
<td>5:1</td>
</tr>
<tr>
<td>Fault displacement</td>
<td>1:7:1</td>
</tr>
<tr>
<td>Subsidence</td>
<td>1:5:1</td>
</tr>
<tr>
<td>Floods</td>
<td>1:3:1</td>
</tr>
</tbody>
</table>

The order of potential risks listed above reflects the relative efficiency of loss-reduction methods when applied to these problems. (Ref. #21, p.84)

D. Balanced Risk.

This concept of acceptable risk to a community is based on the design of earthquake resisting structures, which having a safety probability against death, equal to the risk of getting killed in an automobile accident (about one person in one million per year). Earthquake lateral forces are predetermined by that risk and increase with the life of the building. The average number of persons exposed daily and the type of occupancy in the building also enter into the design as importance factors in determining the balanced risk.

The balanced risk concept was developed by John H. Wiggins, Jr. for the new building inspection code accepted by the City Council of Long Beach in 1971. It serves as a basis for the evaluation of earthquake hazards of existing structures and for reducing this hazard. Buildings are rated on a priority basis for inspection which mainly depends upon the type of construction, physical state, degree of occupancy, nature of soil and foundation. When a building gets a high

V-2
priority rating, a serious hazard to life exists and it calls either for demoli-
tion or major strengthening. (Ref. #23)

E. Anticipated Risk.

The Anticipated Risk approach to risk analysis is presented in Urban Geology-
Master Plan for California (Ref. #21) and has for its major objective the re-
duction of losses caused by geological hazards in California. In order to
provide a common basis for comparative evaluation of hazards, a hypotheti-
cal "Urban Unit: having a population of 3,000 and a total value of $90 million
is used to measure the simulated impact of each of three severity levels or
zones for every hazard. By 1.) moving the "Urban Unit: in each severity
zone and hazard, 2.) calculating the costs of anticipated damage and consi-
dering the loss per event, 3.) estimating the average recurrence period be-
tween events and 4.) evaluating the life loss potential at $360,000 per life
lost; the anticipated average annual loss per capita can be obtained for each
security level and hazard.

The revised values of these annual losses, called geological points (GP), ob-
tained by applying the disaster factors listed on page 80 of reference 21, are
as follows:

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earthquake shaking</td>
<td>$21.0</td>
<td>$54.0</td>
<td>$93.0</td>
</tr>
<tr>
<td>Fault Displacement</td>
<td>0.06</td>
<td>0.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Landsliding</td>
<td>1.0</td>
<td>35.0</td>
<td>58.3</td>
</tr>
<tr>
<td>Flooding</td>
<td>0</td>
<td>96.0</td>
<td>290.0</td>
</tr>
<tr>
<td>Erosion activity</td>
<td>1.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Expansive soils</td>
<td>0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Subsidence</td>
<td>0</td>
<td>0.02</td>
<td>0.34</td>
</tr>
</tbody>
</table>

The anticipated losses caused by the occurrence of several hazards in a definite
predefined area, such as a 7½ minute quadrangle, is equal to the sum of geolo-
gic points of all individual losses for each hazard affecting that area at a
certain severity level.

The priority assigned a given locality scheduled to receive geologic loss-
reduction work or financial assistance from the state could be expressed
by the formula: \[ PP = S(GP) \times PY \times IF \]

When:
- \( PP \) = Priority Points Factor
- \( S(GP) \) = Summation of geological points of all individual losses
  for each hazard and severity level
- \( PY \) = Person-Year Exposure expresses the average number of
  residents in the given area until the year 2000
- \( IF \) = Immediacy Factor expresses the rate of projected growth
  until the year 2000

Application of this method of determining a priority factor to Kern County
areas around cities and regions of high development potential may have a
distinct usefulness in orienting future loss-reduction policies.

It is worth noting that in 1952 the annual loss per capita for structural
damage in Bakersfield is estimated above at $5.00 (see p. V-4). The figure
does not include the value of lives lost, but in this instance inclusion of
the dollar valuation that would be ascribed to the two fatalities is small
relative to the total dollar loss and would not change the figures above.

By contrast, the last computation method for earthquake shaking of medium
severity which applies to Bakersfield, gives an annual loss per capita fig-
ure about ten times that of 1952. It may indicate that additional scrutiny
of methods used to establish anticipated risk and priority factors is in order.
F. Expectable Earthquakes

The geologic and historic record clearly indicate that earthquakes are certain to happen in California. This is bolstered by evidence from geodesy on the rate at which strain is accumulating in the rock. The pattern of earthquake occurrence in California is of help to us in estimating seismic risk.

In Southern California, at least, large earthquakes do not as a rule have identifiable foreshock sequences. Most come without any noticeable preamble. They are followed by aftershocks that gradually spread out from the area in which the main shock took place. Elsewhere, foreshocks may signal a coming event by occurring for a week or more beforehand. It is uncommon for small earthquakes to take place on or along large faults in our area. Many of the small shocks are part of an aftershock series and most of them occur in the regions between major faults systems.

A lack of seismic activity in an area may not mean that the area is safe. Perhaps the largest earthquake in the United States in historic time took place in the Mississippi Valley in 1812. There has been almost no activity in the area since. The southern part of the region affected by the Chilean earthquake of 1960 had felt no important earthquakes since 1835 and many of the older residents could not remember having felt an earthquake in their lifetimes. Of the recent earthquakes that befell California, the faults involved were not thought to have been active or not regarded as likely to produce important earthquakes. This may of course be due to a lack of appreciation of the criteria for fault activity, but it serves to point up the problem.

The largest expectable earthquake anywhere, based on the Richter Scale is about magnitude 8.6. The reason for this is that the scale is so compressed at the upper end that no matter how much larger an earthquake may be, it is not likely to be interpreted as being much larger. In California, we experienced earthquakes approaching this size. The Owen's Valley earthquake, the San Francisco earthquakes and the Ft. Tejon earthquake were all in excess of magnitude 8. Even large as these were, there exists no basis for believing that Los Angeles will fall into the sea or for predicting catastrophes of the sort that one hears about on the television and in the popular press.

On the basis of recurrence rates of smaller earthquakes, on the basis of geodetic measurements of strain accumulation and the amount of strain released by earthquakes; various estimates have been made for the recurrence rates of large earthquakes. It is generally thought that the San Andreas fault will yield an earthquake approaching or exceeding magnitude 8, somewhere along its length at least once or perhaps twice a century.

It is not important to know the exact recurrence interval. If it were only of concern that property might be damaged, it would be more economical and even practical to ignore the earthquake situation. However, a number of economic interests such as public safety and the preservation of life are involved. A large earthquake taking place now in California would be capable of causing an economic disaster of such proportions that it would bankrupt the state and have a severe effect on the whole of the United States. It is therefore imperative that, even with the low recurrence interval, that construction be built to withstand earthquakes of at least magnitude 8.5.
The area affected by a large earthquake is so great that destructive effects would be felt in Kern County from one taking place say in the Imperial Valley, or near San Francisco. The long period waves from the larger earthquakes are capable of doing damage to flexible structures at a great distance. We must therefore consider the possibility of an earthquake in a neighboring county severity affecting Kern County.

There is little reason to feel that any part of the county is especially favored in being free of the effects of earthquakes. It is true that some parts are more certain to be severely shaken than others. Thus the immediate area along the San Andreas and Garlock Faults might require more attention to earthquake codes, or more rigorous codes, than the rest of the county.

The design earthquake for Kern County should be thought of as perhaps two design earthquakes. Magnitude 8.5 as the upper limit, with consideration for the effects of long duration of shaking and the effects of long period waves. Magnitude 6 as a lower limit, with consideration for the effects of high frequency shaking of short duration.
VI.

LAND USE PLANNING

A. General Statement

In attempting to decide the best approach to minimize potential earthquake damage at a specific site, it is essential to distinguish between problems that can be compensated for in design, those that cannot, and those economically unfeasible. Seismic problems that cannot be compensated for or which result in prohibitive expense for most uses are: (1) ground rupture or vertical and horizontal offset along a fracture, (2) soil liquefaction at substantial depths, and (3) landslides of regional extent.

Basically, there are two ways to respond to any problem: either remove the cause of the problem or accommodate to the problem situation. Generally speaking, it is impossible to remove the cause of the earthquake. It is technically possible under some circumstances to accommodate to the problem situation. However, in this category it is rarely economically feasible to design structures against ground ruptures which produce significant vertical or horizontal offset along a fault. The area of the rupture is relatively small, so the total extent of damage due to this feature is somewhat less than that caused by ground motion, either acting directly on the building or indirectly by triggering the mechanism that produces mechanical failure of the ground structure, such as soil liquefaction and landslides. Construction in any area affected by fractures, liquefaction and landslides should be avoided. However, if construction is proposed it should be preceded by a thorough engineering study to delineate the dangers and to identify corrective measures.

The consequence of strong shaking are of greater significance over a far wider area than are those of local ground rupture due to fault movement. However, the seismic shaking and most of the indirect effects can usually be compensated for by adequate design.

The previous sections have described the earthquake problem and have geologic information that can provide valuable data regarding the possibility of ground rupture, landslides and earthquakes shaking. However, this information is of no great value if steps are not taken to utilize it and alleviate the consequences of earthquakes and related seismic events. An inventory of existing physical hazards is essential and has been compiled graphically on maps of the community. Implementation of a plan within the hazardous zone is accomplished by the application of zone classifications and building codes.

* The outline in Appendix H can be used as a guide in the preparation of engineering geology reports when it is determined by the Public Works Department that such a report is necessary.

* "Geology and Earthquake Hazards", planners guide to the Seismic Safety Element Kern County, California.
1. **Utilities Highways and Dams**

The data available to us concerning the various utilities, including water, power, gas, telephone, fuel lines, and the highways are generally shown on the Quadrangle Maps included with this report. Not shown thereon are the many feeder lines and minor distribution systems which naturally must be located wherever service is needed. Many of these services are underground, and are highly susceptible to either subsidence or liquefaction. Aside from damage related to ground shaking which may be prevalent over the entire area, it is obvious in comparing the physical layout of the services with data presented on the geological sheets, that there are major problem areas where the services cross active faults.

2. **Freeways**

North-south highways include Interstate 5, State Route 99, and 14-395. The main east-west highways that traverse the county are Highways 58 and 178. There are many overpasses and freeway structures in the study area. Considering ground shaking alone, the San Fernando 1971 Earthquake has indicated that these structures as built in California will be subject to damage. Because of the type of seated connections at the abutments, it must be expected that many of these structures will fail. Even without that hazard, the highway in the Grapevine area will be subject to the effects of landslide. These highways also traverse zones of liquefaction as well as crossing the Garlock and Whitewolf faults. It must be expected that not only the overpass structures, but the highways between these structures are vulnerable to damage. Highway approach fills—especially at low elevations—are subject to damage. In disaster planning for any major earthquake, it must be expected that the freeways will be closed for an appreciable period of time and that alternate routes will be necessary.

3. **Sewers**

The main lines, connecting developed areas with the treatment plants, are underground. The major danger to these lines is from shaking while in some areas they may be sheared by fault movement. It must be expected that these will all be damaged severely. This loss of sewer capability is always a serious problem.

4. **Fuel Lines**

The petroleum tank farms, in some producing areas, are connected by fuel lines to the refinery and/or other portions of the county by lines which cross the fault. It is probable that ground displacement and shaking in an earthquake will cause these lines to rupture, even if the lines are well designed to resist ground motion. We understand that these lines are valved to limit damage in the event of breakage, but it must be expected that there will be loss of service. Since the liquefaction potential has only rather recently been recognized by many engineers, it is suggested that the valve locations and operations be reviewed. Steps should be taken to reduce the fire hazard and contamination from oil spills.
5. Water

Water for the study area is supplied by several Municipal Water Companies from underground sources. It must be expected that major conduits will be damaged and out of service following a major earthquake.

It is our understanding that all water pipelines of welded steel construction are the best and most ductile form of construction when unknown earthquake deformations must be accommodated. If ground deformation is nominal, it is most probable that few if any ruptures will occur. However, it is inevitable that with large motions some breakage will occur. If this occurs to the lines leading from the storage tanks, it is probable that the contents may not be available for use in some of the project area. The main water lines in some cases go roughly parallel to some of the main sewer supply lines. When breaks occur on both systems there is a major possibility of contamination of the water supply as happened in Anchorage in 1964.

Because of this probability, emergency plans should be developed to determine the potability of the water supply immediately after earthquakes of significant intensity and to proceed with the repair.

6. Dams

There is only one major dam that affects the study area, the Lake Isabella Reservoir. The dam that creates this reservoir was built to the best standards of its day, and its subsequent operation has been supervised closely. Until the 1971 San Fernando Earthquake, there was no question as to its safety in even major earthquakes. However, because of the near failure of the old hydraulic filled lower San Fernando Dam, the State Division of Safety of Dams has required that all hydraulic fill dams in the state be re-examined as to their safety. The Lake Isabella Dam is a rolled earth-fill dam. However, the Kern Canyon Fault passes along the west abutment of the auxiliary dam and is a major seismic hazard for the Hot Springs Valley communities.

In the last legislature, a requirement was initiated as a precautionary measure, that the State Department of Emergency Services map the downstream areas of all dams that might be inundated in case of dam failure. Such a map is in the process of being prepared at this time and should be available this fall. It will probably show that some of the San Joaquin Valley area will be included, although the actual area is indeterminate at this time.

7. Telephone

Many of the telephone conduit lines connecting with areas outside the study area can be expected to be damaged. However, the telephone system uses various routes and types of transmissions, and it can be expected that alternate routes, microwave pathways, etc., will be available. Past earthquakes have indicated two greater hazards - overloading of lines due to too much use and equipment or power failure.
We understand that methods are being investigated to attempt to limit user loads on the system so that critical or emergency calls can go through. We do not know the status of such investigations, nor their probabilities of success. Regarding equipment, the Pacific Telephone and Telegraph Company, the utility serving the project area, has had extensive successful experience in the Kern County and Eureka Earthquakes and a forerunner of the company served San Francisco in the 1906 earthquake. Their equipment bracing practices are quite different and more substantial than in other areas of the country or in other systems. However, the newer equipment is much more complex and sophisticated and with complexity there are greater opportunities to overlook critical details, so any reliance on telephones in the first few hours after an earthquake must be minimal. The record of the various telephone companies in assembling emergency equipment and providing communication has been excellent in even the worst disasters.

8. **Gas**

Gas lines cross some of the faults and some areas subject to liquefaction and/or landslide. Service can be expected to be disrupted and valves will need to be closed or will automatically close in order to isolate damaged lines.

9. **Power**

The main power supply lines serving the area cross some of the faults and unstable ground. Overhead structures will be less damaged than underground installations. However, there will be damage to substations, etc., as well as to certain overhead lines. The distribution systems with their transformers will be substantially damaged and could cause fires.
B. POLICIES

The following policies are suggested to assist the decision-maker in evaluating proposed projects in hazardous seismic zones.

- Obtain adequate data so hazardous areas can be identified.

- Plan appropriately in high risk areas — those with possibility of ground rupture or offset, shaking, landslides, and liquefaction — under strict design requirements and for low density use.

- Adequate grading and building code restrictions shall be applied in the design and construction so that damage is minimized.

- Enforcement of building codes is essential. Most failures of structures in earthquakes are related to a lack of inspection during the construction phase, to unauthorized changes following construction or to a failure to follow existing codes. This phase of the work requires less study than does the identification of hazards, the planning, design and the construction. Neglect of this phase can easily cancel all the good effects of the other work.

The benefits derived from the policies stated above do not just happen. They are the result of action authorized or required by legislation at the federal, state, and local level. A comprehensive zoning ordinance is essential in order to implement these policies; however, the building codes are the primary tools government possesses to reduce seismic risk in structures.

C. STANDARDS FOR DIFFERENT LAND USES AND ZONES

Differing degrees of acceptable risks should be assigned to various types of structures.

1. Emergency Operation Centers and Other Essential Facilities

Critical. Public facility uses, such as hospitals, fire stations, police stations, emergency operation and communication centers, and major power complexes are essential to post-earthquake disaster operations. These vital facilities must be designed and constructed to remain functional after a severe earthquake. Therefore, the level of earthquake risk for these important facilities must be low. Through adequate earthquake-resistant designs based upon a detailed geologic-seismologic investigation for each site, provisions can be established for obtaining this basic requirement of highest level of protection.

Local government will formulate, and the public works department implement, special seismic design and site location criteria to be integrated with the following classifications of critical-use buildings and structures:

a. Critical Occupancies — Complexes that are essential to disaster operations during and after an earthquake.

b. High Cost Facilities — Construction of certain public facilities involving expenditures of large sums of money (total building expenditures of $500,000 or more require detailed investigations, regardless of location).
c. High Occupancy Facilities – Occupancy levels that are considered critical from the standpoint of seismic safety are structures that have a tentatively established occupancy level in excess of 100 persons.

Comprehensive geologic-seismologic-foundation engineering investigations should be obtained for all vital public facilities. Minimum requirements for those coordinated and detailed investigations should include consideration of items D-1 through 5, page VI-7 no construction without detailed evaluation by public works of these facilities should be permitted within the zone of fracture shown as a shaded area on the quadrangle maps.

2. Community Facilities

A lower level of protection than that of Emergency Operation Center can, in general, be tolerated for community facilities. Such buildings may be asked to accommodate earthquake victims from outside the immediate area. The extent of this possibility should be determined on an area-wide basis by the local jurisdiction.

Because of the relative high level of occupancy at community centers they should have a higher level of protection than other community facilities. Some structural damage can be tolerated, but the facility must be designed and constructed to remain intact and not endanger the lives of its occupants.

Minimum requirements for coordinated and detailed investigation should include consideration of items 1 through 5, page VI-7.

3. Open Space Uses

This classification includes agricultural, recreational, and conservational uses. Unless a high occupancy or a large structure is involved, a low level of protection is acceptable. Items 1 and 3, page VI-7 should be considered prior to approving construction.

4. Industrial Uses

Moderately heavy to light occupancy is usual for industrial uses. Because of the wide latitude in the weight and size of equipment, it is impossible to state the degree of risk that is involved. The Public Works Department must use their own knowledge, based on experience, in determining the extent of site evaluation acceptable. Items 1 through 5, page VI-7 should be required as necessary.

5. Commercial Uses

The acceptable level of risk must be low for most commercial uses, because of the unrestricted access to the public and the high occupancy factor. In general, the Public Works Department, through experience, is familiar with the general geological conditions in most commercial areas. However, for large structures or areas where the geological characteristics are in question, items 1 through 5, page VI-7 should be evaluated.

6. Housing Uses

This use traditionally has a low degree of risk because most dwellings are
relatively small, one or two stories in height, and have a minimal occupancy factor. Items 2 and 3, page VI-6 should be evaluated.

Where the occupancy factor is high, such as in multiple wall apartment build-
ings, motels and hotels, a lower risk should prevail and items 1 through 5, page VI-7 should be considered.

D. SITE EVALUATION FACTORS

The following factors apply to site evaluation. Different land uses accommodate varying degrees of acceptable risk, so factors in this list are applied in accordance with standards for land uses 1 through 6 above.

1. Fault Proximity - Defined as an evaluation of all the active and poten-
tially active faults which have the capability of generating a moderate or
greater (magnitude 2.5) earthquake during the lifetime of the proposed struc-
tures. Additional data needed are distance to active faults, seismic history
of the area, and potential for surface ground rupture due to faulting.

2. Characteristics of the Foundation Materials - Defined as an evaluation
of the foundation materials on the basis of detailed subsurface exploration,
laboratory testing, and geophysical studies. A determination of the static
and dynamic physical properties of these underlying materials, their extent,
depth to groundwater, and depth to crystalline basement are parameters need-
ed to assess the site's seismicity. All other things being equal, these local characteristics will greatly modify the effects of earthquakes on
structures.

3. Ground Failure Potential - Defined as an evaluation of the site's sus-
ceptibility to failure of the ground surface due to landsliding, liquefaction,
differential dynamic settlement, and ground lurching.

4. Estimated Earthquake Parameters of Basement Motion - Basement motion par-

tameters for the site can be estimated from empirical methods. Some important
earthquake parameters are:

   a. Maximum probable earthquake or design earthquake (Richter magnitude).

   b. Average maximum basement acceleration (g).

   c. Duration of shaking.

   d. Predominant period of basement motion.

5. Ground Motion Spectrum - The influence of ground shaking on engineering
structures is customarily portrayed by means of response spectrum curve.
Response spectra curves are derived by a seismologist utilizing geodynamic
earthquake parameters characteristic of the basement underlying the site.
Basement seismic characteristics are determined by a geologist. The response
spectra are then computed over a range of periods, and for a number of dif-
ferent values of structural damping. A quantified description of the vibra-
tory effect of the ground acceleration on buildings is obtained by such re-
ponse spectra curves.
E. CONCLUSIONS

Implementation of zoning ordinances and these guidelines in the seismic design and construction represents additional forward steps toward effective seismic safety for the future. Because of California's relatively high susceptibility to earthquakes, public-use facilities intended to provide vital public service must be capable of functioning both during and after a high-energy earthquake. Structures should be constructed to provide a degree of risk commensurate with the occupancy rule, assessibility to the general public, and the size. Requirements must be adopted to better provide for uninterrupted public service and for post-earthquake operations.
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VIII.

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

SEISMICITY AND GEOLOGY

1. Earthquakes have been and will continue to be a major hazard in Kern County. While major earthquakes are infrequent, they are disastrous. Smaller earthquakes are now recognized as a real danger because the area is becoming built up and events as small as magnitude 6 can cause severe problems over a small area.

2. Based upon records of seismic activity of the past it is anticipated that once or twice a century earthquakes originating within or adjacent to the county boundary having a magnitude of 8 to 8.5 will affect residences of Kern County. Earthquakes of magnitude 6 originating within the same general area can be expected to affect some locations within the county every ten years or so. In most instances the ground shaking and rupturing they produce will affect unpopulated areas resulting in little destruction. However, occasionally densely populated areas will be affected. As areas of development expand the frequency with which people are affected and the amount of disruption will increase.

3. It may be reasonably assumed that all of the faults in the county, with few exceptions, are capable of further movement. The most important faults are: San Andreas, Garlock, Sierra Nevada, White Wolf, Big Pine, Kern Canyon, Bear Mountain, and perhaps some large faults buried under the alluvium of the San Joaquin Valley.

4. The Breckenridge fault system and the east and west branches of the Edison fault located in the central part of the county may be expected to generate earthquakes of magnitude 6 or greater.

5. The determination of the relative degrees of activity of different faults and of the degree of severity of other geological hazards are still uncertain and require more study before it becomes possible to delineate meaningful hazard zones.

6. The intensity of shaking from an earthquake on any fault decreases with distance from the fault, except in areas where deep, saturated alluvium can augment the ground motion. A large part of the San Joaquin Valley is subject to this effect.

7. The most serious threats are confined to the valley areas, where in addition to aggravated shaking, the possibility of liquefaction and failure of clay horizons adds to the difficulty by creation of differential settlement.

8. Areal subsidence, both tectonic and artificially induced, is an important problem in the southern and western San Joaquin Valley. A large earthquake will aggravate this situation.

9. Seismic activity, such as a large earthquake, will cause problems related to landsliding and other forms of mass movement over most of the county. Rock falls, avalanches, soil creep and mudflows are a problem in the mountains. Landslides, soil creep, soil flows, failure of clay rich formations and similar types of mass movement are to be expected in the San Joaquin Valley. Failure of dikes, canals, levee systems and irrigation ponds are to be expected over most of the agricultural parts of the county.
10. There is no probability that Kern County will be affected by tsunamis originating in the Pacific Ocean.

11. Seiches in lakes are a real possibility. Lake Isabella, Kern Lake and Buena Vista Lake are likely candidates and real estate lakes should be examined to be certain that seiches therein will not cause trouble to construction on the edges of the lakes.

12. Displacements along faults and creep along faults are likely to affect those areas in the immediate vicinity of the larger faults. Construction of pipelines, aqueducts and similar works across or along fault zones should be done so as to minimize the likelihood of damage from this source and should be so arranged that repair is easy.

13. While a number of Pleistocene and Recent volcanoes have been active in and around the county, none are at present active. Volcanism is therefore not a serious threat.

14. Flooding as a result of failure of levees, dams and similar structures for retaining water is a real possibility. As an example, the dam at Lake Isabella is situated near an important fault in such a way that movement on this fault could endanger the dam.

**Emergency Services**

1. The Kern County and the city emergency services are organized to respond to emergencies and disasters caused by natural or wartime conditions. This division of the General Services Department in the County and the Public Works Departments for the cities, has assigned emergency operating functions to specific agencies and has designated personnel to serve in the command and control role in a widespread emergency.

2. An inventory of vulnerable structures which could endanger public safety during a seismic event, and a plan for mitigating hazardous conditions must be promulgated soon.

3. The Emergency Services are organized to respond rapidly to a seismic disaster by providing emergency medical treatment for the injured, operating as part of a regional communications network, instituting emergency law enforcement deployment to protect public safety, and restoring to operation those municipal facilities which have suffered damage.

4. A study should be made which assesses the hazard to life and the economic loss that would result from failure to the dam at Lake Isabella and of the canals.

**Recommendations for Abatement of Seismic and Geologic Hazards**

1. Before engineers will be able to make the best possible recommendations and calculations as to the types and methods of construction it will be necessary to know more about the intensity of shaking of earthquakes. To this end then, State, County and Local governments should continue to support research on geologic hazards and to encourage the Federal Government to do the
same. Of utmost importance is the program of installing and maintaining strong motion seismographs throughout the country. This program should be continued and expanded. Following a few more strong earthquakes, with instruments at a variety of distances from the causative fault and on a variety of soil and rock types, it will be possible to set down realistic standards so that the intensity, duration and frequency of shaking can be specified for the type of earthquake likely in a given locality. Without this information, it is difficult to design correctly and the only assurance of safety lies in an uneconomical overdesign. With this information in hand, and with further study into the techniques of earthquake resistant design for buildings of various types and sizes, it will be possible to prepare, enact and enforce earthquake codes that do not depend upon building lore, but which will be able to take advantage of the latest state of the art in construction. Further work on the earthquake resistance of dams is also needed.

2. The fault zones, designated on the maps in the Atlas as shaded areas should be declared Geologic Hazard Areas. Wherever possible, these areas should be zoned for use as open space with such agricultural and recreational uses as are consistent with the hazards involved. Minimum lot sizes for future subdivisions should be set at 10 or 20 acres depending upon the circumstances. High density land use should not be prescribed in this area because the cost to the county in the event of a calamity could easily outweigh the benefits of such land use.

Before any construction permits are granted in these areas, Environmental Hazard Reports should be prepared by a registered geologist and checked by a geologist retained by the local government agency having jurisdiction in the area. The planning agency should then use the report to determine if the proposed construction is suited to the type of land use designated for the area and if the risks involved are adequately met by sound construction practice.

3. Special structures that house numerous people, or incapacitated people, such as hospitals, sanitoriums, health care units, schools, colleges and auditoriums, should not be constructed in Geologic Hazard Zones. Police and Fire stations and other structures used by the Emergency Services, should not be constructed in such zones, but if they must be placed there for good reason, then special care must be taken in the construction to assure that they will not fail during the maximum expectable earthquake.

4. Buildings such as specified in Paragraph 3 above should be built to more than ordinary standards and must not collapse during the maximum expectable earthquake. The California Field Act, adopted after the 1933 earthquake in Long Beach sets the highest standards ever specified for the construction of school houses. It does not apply to other structures. All schools built in the state must conform to the Field Act.

5. The Uniform Building Code of 1973, designating Kern County as within Seismic Zone 3, should be adopted by all local jurisdictions. The new earthquake code for taller buildings in Los Angeles City (See Appendix F) should also be adopted. (For information and comparison with other codes the earthquake regulations of the 1968 Los Angeles County Building Code are attached as Appendix E.) These should be regarded as interim measures to be amended, supplemented or replaced at a later date as more progress is made in this field.
6. A long range building inspection program, to identify dangerous structures should be drawn up and executed as rapidly as possible by the several cities and by the county. Once a dangerous structure has been identified, no further enlargement or improvement thereto, except as necessary to make the structure safe, should be permitted. The use of such buildings as are uncorrectable, should be phased out as rapidly as possible and the worst of them taken out of service and removed.

An ordinance to deal with seismically unsafe buildings and with unsafe architectural appendages should be promulgated. This should call for inspection, repair or demolition, either before or after an earthquake. Provision should be made however for preservation of architecturally or historically significant structures.

7. Where important, the effects of liquefaction, or failure of clay rich or saturated soils should be taken into account in construction and special consideration should be given to the possibility of landsliding in those areas where it is an identifiable problem.

8. The threat of flooding of large areas of the San Joaquin Valley following a major earthquake are important enough to require a special study of the hazard as related to dam and levee stability and recommendations for positive action to correct such situations as may be identified should be made.

9. A Seismic Safety Commission should be established with responsibility for implementing the Seismic Safety Element. This commission should periodically update the element, make suggestions for changes in codes and design requirements, as well as supervise necessary drills and tests that are conducted by the Emergency Services at regular intervals.

10. The Seismic Safety Element should be reviewed on a yearly basis and be comprehensively revised at least every five years or sooner, whenever substantial new scientific information becomes available.

11. Work by professional structural engineers has resulted in the development of techniques by which dynamic analysis of structures can be performed by high speed computers. It is recommended that the use of such calculations be, in the future, made the basis of the county code for the construction of large buildings. It will thus be possible to economically design such structures with little possibility of failure and to take advantage of the latest constructional techniques as they become available. It would be wise to tryout this system on some of the larger county buildings to see if they are earthquake safe.

12. Instability of slopes along highways, canals, river banks, in the foothills and mountain areas should be investigated in the near future.

13. Protection zones against seiches should be established after investigation, along residential and recreational areas around Lake Isabella, Buena Vista Lake and others, and enforced by an appropriate ordinance.

14. The Federal Emergency Services Administration should be requested to provide on-site assistance to local agencies through the State Office of Emergency Services, as necessary when asked by the commission.
REFERENCES


10. California Division of Mines and Geology (several authors), The San Fernando earthquake, 1971, California Geology, April-May 1971.


References (contd.)


APPENDIX A

SEISMIC SAFETY ELEMENT

AUTHORITY

Section 65302(f) of the Government Code of the State of California requires a seismic safety element of all city and county general plans, as follows:

A seismic safety element consisting of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunamis and seiches.

The seismic safety element shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure and seismically induced waves.

Section 65700 of the Government Code, effective March 5, 1972 extends the law to include charter cities.

The effect of this section is to require cities and counties to take seismic hazards into account in their planning programs. The intent is that all seismic hazards are to be considered, even though only ground and water effects are given as specific examples. The basic objective is to reduce loss of life, injuries, damage to property, and economic and social dislocations resulting from future earthquakes.
APPENDIX B

REVISION OF THE SEISMIC SAFETY ELEMENT

PERIODIC UPDATING OF COMPONENTS OF THE SEISMIC SAFETY ELEMENT

A. GENERAL PLAN AMENDMENT

Although the general plan, composed of various elements, is a long-range, comprehensive policy document, it must be periodically updated to meet new conditions and from time to time revised or amplified to respond to unforeseen changes or needs. The plan is, therefore, subject to amendment to reflect changes in goals, policies and physical, social or economic conditions. Some changes may be minor and not require changes in other parts of the plan. All proposed changes, however, should be evaluated in regard to environmental impact and consistency with the balance of the document.

The procedure for amending the general plan is the same followed in the adoption of the plan. Notice of public hearing before the Planning Commission and the legislative body must be given at least 10 days prior to the hearing. Approval of the plan by both the planning agency and the legislative body must be by resolution and must be endorsed by each.

Section 65361* restricts the number of times per year that the mandatory elements of the general plan can be amended. "No mandatory element of a general plan shall be amended more frequently than three times during any calendar year..." This provision does not apply to adding new elements to the general plan. Local agencies can amend the general plan by adding new plan elements as often as desired. For example, noise, seismic safety and other safety elements may be adopted during the calendar year and this will not constitute an action under Section 65361.* Plan elements which are not required in the planning law (e.g., urban design, specific area plans, public buildings, etc.) but may be of community interest can be amended to the general plan as often as desired. This procedure only affects proposals to change existing mandatory general plan elements. This requirement becomes effective on January 1, 1974.

Section 65362* requires that a two-week period of time be provided between the adoption or amendment of the general plan or element thereof and proposal for a rezoning for the purpose of bringing zoning into consistency with the general plan. This prohibits concurrent action to amend the general plan and the zoning ordinance at the same meeting. The two processes have been separated in order to strengthen the general plan as a policy document and the zoning ordinance as an implementing device. This requirement became effective on January 1, 1973.

B. ZONING ORDINANCES

Zoning ordinances are adopted and amended by a procedure somewhat similar to that described for adoption of the general plan (Section 65850*).

Chapter 4 of the planning act enables cities and counties to regulate the use of land in order to protect the public health, safety and general welfare. Recent amendments to the zoning law require a closer relationship between the objectives, policies, and land uses of the general plan and regulatory devices provided for in the zoning ordinance.

Section 65860 of the Govt. Code requires a consistency of zoning with the general plan. Updating of the ordinance is a continuing process because there must be consistency between the zoning ordinance and the general plan. This emphasizes the importance of clearly defining the purpose and nature of the zoning ordinance as a short range implementing device and the general plan as a body of long range public policy. Although many general plans are becoming more comprehensive and at the same time more detailed, the plan is intended to provide a broad base of policy for guiding decisions. On the other hand, the zoning ordinance is a set of specific legal regulations which prescribe the various uses allowed within the jurisdiction. The range of uses allowed and the standards related to each use are applied with the short range expectation that the land will be used for a particular purpose.

For this reason there will be differences of specificity between the zoning map and the general plan diagram. In addition, there will very likely be land use differences between the two in cases where the general plan includes only a single diagram indicating the intended land use pattern some years in the future. Determination of consistency, thus, is not a simple matter. It requires more than superficial comparison of the zoning map and the general plan diagram. In addition to a review of the map and diagram, it is necessary to review the text of the general plan to determine if the land uses authorized by the zoning ordinance are compatible with the objectives, policies, general land uses and programs specified in the general plan. Compatibility of the policies in the general plan and the text of the zoning ordinance should be clearly described.

Questions of type of use, intensity of use, characteristics of uses in relation to environmental values expressed in the plan should also be evaluated. Also requiring evaluation is the timing and sequence of change in use, particularly where the change is from a lower intensity to a higher intensity use. The sequence of change is particularly important and may be either covered in specific terms in the general plan or inferred.

The zoning ordinances, being current and precise, reflect the existing phase of land development, but should gradually follow the general plan into the future as appropriate in relation to timing and sequence of uses. Thus it may be inconsistent with the plan to rezone a large, low intensity use area to a more intensive use as shown in the general plan, when the transition to the more intensive use will occur so gradually that scattered uses will result and contravene a general plan policy calling for compact urban development. Even though the zoning ordinance may indicate uses different from those shown in the general plan, the zoning in this case will carry out general plan policies as to orderly development, and thus is consistent with the general plan.

The zoning ordinance should be considered consistent with the general plan when the allowable uses and standards contained in the text of the zoning ordinance tend to further the policies and designated uses in the general plan and do not inhibit or obstruct the attainment of those articulated policies.
The local jurisdiction should adopt an ordinance providing for establishment of a Seismic Safety Commission which would initially be mainly advisory. This commission would not be required if the city had taken action to transfer its building inspection function to the county. The commission would be responsible for the implementation of this plan by devising local earthquake and geological hazard safety standards, encourage research, provide technical assistance and oversee other recommendations in this report.

As advisory to the local planning commission the Seismic Safety Commission should include in their recommendations to the planning and building inspection departments, ground stability tests, recording seismic hazards on subdivision maps, and making geological "blighting conditions" in terms of possible redevelopment projects. In addition they should insure that new information related to the Seismic Hazard Element be added to the plan (text and maps).

This committee should make recommendations to the state and local legislators regarding revision to the building code, destruction of older hazardous buildings, removal of hazardous parapets and similar features from buildings, more stringent standards for emergency service centers, a review of construction standards for dams and implementation of the "Safety Element," an additional state mandated element to the general plan.

Locations for construction of emergency service buildings include fire stations, government buildings which house principal emergency operating centers or base radio stations, police stations, jails and other structures which house persons physically restrained, must receive review by this commission.

Local jurisdictions must adopt minimum earthquake design requirements no less stringent than those prepared and adopted by the state. The committee should make an annual review of the Seismic Safety Plan, the zoning ordinance and the subdivision ordinance in order to insure the conformity of the plan with state law and the communities' needs.
APPENDIX C

IMPLEMENTATION

Implementation is the administrative process by which the citizens of the jurisdictions and all its component communities are brought together in a cooperative effort to institute and maintain the design.

PHASE I

The preparation of the Seismic Hazard Atlas and adoption of this text constitutes phase I of the Seismic Safety Plan.

PHASE II

This phase of the Seismic Safety Program is to be undertaken by the Planning Commission subsequent to the adoption of this element by the decision-makers. The steps that are necessary for the implementation of the plan are outlined at the end of this section.

Any program is only as good as the extent to which it is put into effect. The planner cannot afford to develop his plans without due consideration of the political processes of his community. He must start with a careful and balanced design that will achieve the goals recognized as desirable within his community. But he must not think his job is complete once he is satisfied, professionally, that his design is sound. He must also explain and defend his plan to chief executives, legislative officials, heads of independent agencies, community groups, and interested citizens who individually and collectively are able to exert considerable influence on the implementation of plans. For their part, these groups should learn to appreciate the professional judgment of the planning agency staff.

The political leaders, not the planner, possess the final decision-making authority within the government. It is they who must reconcile the differences among competing groups and who are responsible for their actions directly to the people through normal democratic processes. The burden of cooperation between planner and political leader must fall principally on the planner.

The information system described should enable the planner to make rational decisions concerning the future growth and development of his community. But the planner works closely with his data and employs his professional judgment based on long experience with planning problems. Such a background is frequently denied the lay political leader.

The political leader addresses himself to a host of problems other than planning and commonly finds the atmosphere in which he operates more frenzied and harried than the surrounding work of the planning agency. Recognizing this, the planner must show to the political leader, in terms that hold his interest, just what a design will do for the area and its people.

The ideal situation would be one in which planners and political leaders and representatives from the community work together in establishing community planning goals. A joint effort to formulate explicit goals would have two desirable results:
A. The issues of planning would be better integrated into the political process and would therefore be elevated from the realm of local interest to the more critical realm of community interest. Most planning issues have an impact beyond the immediate community and should be of concern to the entire region.

B. Political leaders who control the implementation of plans will have taken part in the goal-formulation process and will therefore have subscribed to the plan. If they do not support its implementation, they run the risk of being inconsistent.

In short, cooperation between planner and political leader is essential if planning is to be successful in a democratic society. An information system should provide the data upon which sound planning is based and by which it is judged. But to make a plan a reality requires an understanding of the role that both the professional planner and the political leader play in the planning process.

**PLAN IMPLEMENTATION**

The following steps are necessary for the implementation of the plan.

1. Concurrent or subsequent revision of other general plan elements to give specific recognition to seismic safety policies and criteria.

2. Inclusion of appropriate requirements and procedures in zoning, subdivision and site development regulations and building codes. Designation of special zones with special land development regulations such as "seismic hazard management zones".

3. Preparation of renewal plans for areas where a change in use and development pattern is proposed because of major seismic damage or extreme hazard.

4. Building inspection program to identify unsafe structures and institute necessary corrective measures.

5. Inclusion of potential earthquake destruction in contingency plans for major disasters and emergencies. Review and liaison with Emergency Preparedness Organizations and Police Departments of overall plans and major public facilities proposals as to their adequacy in emergency situations.

6. Educational programs to develop community awareness of seismic hazards.

7. Implement recommendations proposed in Chapter IX.

**NOTE:** Implementation programs described above are consistent with the following:


Activities Following Adoption

Following adoption of the general plan, the planning agency is required to:
(Section 65400)*

a. Investigate and make recommendation regarding implementation.

b. Submit annual report to local legislative body on status of the general plan and its application.

c. Promote public interest in and understanding of plan and regulations.

d. Consult and advise (with others) on ways of carrying out the plan.

e. Review referrals as to conformity with the general plan (all real property acquisitions and dispositions, construction of buildings and other structures). Section 65402*.

f. Develop and adopt regulatory programs (zoning and subdivision ordinances, building and housing codes and other devices) which will implement the policies described in the general plan.

Following the adoption of the general plan, the local legislative body may designate an official agency to list and classify and coordinate a program of the public works proposed by all agencies with projects recommended for the ensuing year. Such a program is then submitted to the planning agency for review and report to the official agency as to conformity with the general plan. Section 65401*

The planning agency may, or if so directed the legislative body shall, prepare specific plans based on the general plan and drafts of such regulations, programs, and legislation as may, in its judgement, be required for the systematic execution of the general plan. The planning agency may recommend such plans and measures to the legislative body for adoption. Section 65450*

This directive provides the planning agency and the local legislative body broad authority to develop coordinated plans and programs to implement the general plan.

Dr. Engel is presently developing a method for evaluating areas according to the degree of hazard from seismic related events. It is anticipated that quantitative values representing seismic risk can be shown on maps. This type of information would assist planners in determining the appropriate land use construction method and engineering studies.

APPENDIX D

LEGAL BASIS AND GUIDELINES FOR DRAFTING LAND USE REGULATIONS

IN GEOLOGIC HAZARD AREAS

INTRODUCTION

The purpose of this chapter is to explore some of the legal questions involved in incorporating (or not incorporating) seismic hazard considerations into land use planning. The general conclusion is that communities throughout the State do have the legal power to impose substantial seismic hazard land regulations.

CONSTITUTIONAL LIMITATIONS ON REGULATIONS

In determining the legality of a land use regulation the courts will look at its reasonableness. It must be reasonable on its face and as applied in the situation before the court. There are several aspects of reasonableness which courts generally examine although these aspects are often not very explicit in the opinions.

1. Are the Objectives Within the Proper Scope of Legislative Action?

California courts in particular defer to legislative judgment and do not inquire into the scope of the action. Nevertheless, the objectives are important when the court must decide whether the imposition of strict regulations requires compensation for the landowner.

The obvious objective of regulation in seismic hazard areas is to minimize threats to public health and safety. This objective has enjoyed practically a special presumption of constitutionality in areas other than land use. There is every reason to believe that these objectives will present a very strong argument for upholding land use regulations.

The public health and safety objectives can be broken down into at least four parts:

a. Prevention of Direct Damage to Other Land.

Normally development on land in a seismic area would not affect other lands. However, there are at least two exceptions. One is where the earth movement along a fault would trigger landslides which would in turn affect property other than that being regulated. An extreme example would be permitting cutting and filling in a seismic area which bordered the reservoir in back of an earth-filled dam. An earthquake could cause a landslide into the reservoir causing the dam to fail which would result in damage to life and property located below the dam.

The second is where the disruption of utility services at the place where they cross the fault line would affect other lands. An example would be where sewage lines would break causing contamination of the water supply of another area. These and other nuisance-like effects of building on or near an area of seismic activity should be considered.
b. Reduction of Government Costs.

The first consideration is reduction of extraordinary costs to governments for the construction and maintenance of streets and utility services crossing or located within an area of seismic hazard. It seems clear that a city or county can refuse to extend services to areas where there are abnormal or extraordinary expenses involved. However, there is a question of whether the local government can prohibit development for this reason where the developer is willing to pay the cost of making the utility more earthquake resistant. Of course, the cost of doing this may make the development economically unfeasible.

The second consideration is reduction of costs to government for rescue operations and disaster relief. There is virtually no case law which would indicate how the court would react to this objective. One problem is that much of this aid comes from the state or federal government and is not an expense borne by the local government. It would appear that this objective, standing alone, would not be sufficient to justify severe regulations.

c. Prevention of Fraud and Victimization.

This type of objective has long been used as one reason to justify subdivision regulations. This use has been upheld by the California courts. However, while this objective could be used to justify regulations such as disclosure of seismic hazards, there is little precedent for using it to impose regulations which would restrict development.

d. Reduction of Risks to the Individual.

The extensive use of building codes is an example of where one of the purposes of the regulation is to protect the homeowner against possible injury to himself. Our society does not allow people to assume all the risks in many situations. An example is the cases upholding motorcycle crash helmet statutes. The U.S. Supreme Court, in a case involving a statute limiting working hours expressed this policy when it said: "The whole is no greater than the sum of all the parts, and when the individual health, safety and welfare are sacrificed or neglected, the State must suffer." There is little doubt that the objectives of reduction of risks would permit the imposition of more stringent building codes. It also seems certain that a reckless or careless activity such as constructing a building directly over an active fault could be prohibited.

It should be noted that regulation of lands subject to seismic hazards should not be concerned only with the public health and safety objective. These areas are often well suited to open space and recreational uses. Development may, depending upon the specific local conditions, cause landslides, restrict the flow of water to water recharge areas, cause loss of topsoil and siltation of streams and lakes, and disrupt plant and wildlife communities. A comprehensive regulatory system must consider all of the possible land use objectives.
2. Are the Means Proper?

Although this was formerly a matter which courts examined, the current trend is to defer to legislative judgment. However, if the court feels that the means do not in fact help achieve the stated objective, they will be much less inclined to uphold the regulation. The problem with seismic hazard regulation is the accuracy of the data and methodology. For example, if there is no reasonable basis for assuming that a fault is active, the courts will probably not uphold a prohibition of building around the fault.

3. Is the Effect of the Regulation too Harsh?

California courts are reluctant to enter this area, probably because they feel that the local planning process generally works well and that landowners have the opportunity to have their voice heard at the local political level. There is a feeling among some courts that if the regulation destroys all or substantially all of the value of the land then it is invalid. However, the California Supreme Court in the Consolidated Rock Products case upheld an ordinance after the trial court had found that the result was to leave the land with no appreciable economic value.(5)

4. Do Similarly Situated Landowners Receive Equal Treatment?

There are two broad questions which must be addressed in connection with this requirement. The first is what amount and accuracy of data is required while the second is to what extent standards should be set forth in the local ordinances. The first question can be broken into two parts - how exact must the regulatory boundary lines be drawn and how much data is needed to justify one type of development as opposed to another within the boundaries. All of these considerations are related. If the use of the land is by ordinance severely limited within a zone, then the boundary of the zone must be determined with some accuracy. If to be within a zone means only that a special permit is required, then the boundary need not be as exact but the criteria for approving a permit must provide enough accuracy to meet the constitutional requirements.

In conventional zoning the establishment of boundary lines is reviewable by the courts only for abuse of discretion. However, in contrast to these boundaries which reflect broad community land use goals, seismic hazard boundaries reflect physical conditions which can be defined with some precision by geologic and engineering techniques. This, of course, assumes that the necessary time and money are available. Courts are sensitive to the time and money problems and can be expected to require only that the boundaries be drawn using the available data and methodology. However, this would not include the use of techniques and equipment whose reliability is shown to be very doubtful.(6) In order to protect itself against errors, the local governmental agency should have provisions for changing the seismic hazard boundaries if a landowner can show that a mistake was made.
To the extent practical, regulations should specifically state what the owner of land within the seismic zones can or cannot do with his land. This approach gives the owner certainty in the use of his land and prevents arbitrary or discriminatory administrative action. In such a system there must be provisions for dealing with landowners who feel that they should be treated differently because their land is somehow unique or their proposed development would not contribute to the hazards being protected against. An administrative framework with specific standards should be set up for considering these special applications on a case-by-case basis.

5. Does Public Policy Dictate that Compensation should be Paid?

This question presents a difficult question for courts. In fact, many courts would claim that this is not a criteria which the court uses to reach its conclusion. However, it seems inescapable that whether a court considers a regulation to be a "taking" will largely depend upon whether public policy dictates that the cost incurred by the regulation should be imposed upon only the landowner or whether society should pay the cost through eminent domain proceedings. The taking question arises from the Fifth Amendment to the U. S. Constitution which states that no "private property be taken for public use, without just compensation."

One test which has been advanced is the harm-benefit analysis. This analysis begins by saying that regulations should only be used to prohibit land uses which would produce a nuisance-like or harmful effect on others' lands.(7) Courts holding this view could be expected to take a close look at the objectives of the regulations which were discussed earlier. Critics of the harm-benefit analysis argue that this test is virtually impossible to apply in practice since every regulation which inhibits a harm produces a public benefit and, more importantly, every regulation which produces a public benefit also inhibits a harm.(8) Fortunately, the California courts have not adhered to this conceptually difficult distinction.


It seems clear that earthquake standards can be incorporated into the construction of structures in an earthquake prone area. The establishment of a permit system within the special studies zones established pursuant to the Alquist-Priolo Geologic Hazards Zones Act also appears to be valid. The construction of certain types of buildings within the special studies zones probably can be prohibited if they present an "undue hazard." However it is not clear to what extent the construction of single family residences can be prohibited. If this construction could be shown to affect other lands and if the regulation were part of a comprehensive planning system then the prohibition might be upheld. A California court recently upheld a local floodplain ordinance which prohibited permanent residences and commercial or public buildings in a designated area which was subject to flooding.(9) However, construction on a parcel of land in a seismic area normally would not directly affect other parcels as would be the case with construction in a
floodplain which could very possibly increase the flood heights and velocities. Much of this discussion relates back to the earlier paragraphs on the goals of the public health and safety objectives. Also, it may very well be that a single family dwelling limited to two stories and having a wood frame is not particularly hazardous when located in an area near a fault unless in were built directly over the fault trace.

GOVERNMENTAL LIABILITY

Local governments should be cautious about approving development in areas of potential hazards. In addition to the increased cost of maintaining public improvements, the local government may be directly liable for property damage.

Liability is based on the theory of inverse condemnation based on Article I, Section 14, of the California Constitution which prohibits the damaging of property without just compensation. A property owner can allege inverse condemnation if the government, by its actions, causes direct damage to this land. Examples would be in diverting water or causing earth to slide onto the property.

Some California courts have required that the government need not even be negligent. The case of Albers vs Los Angeles County is the leading example of the latter. This case involved a landslide which was caused by earth fills deposited by the county. (10) Before conducting the filling operation the county had concluded, based on studies reasonably thought to be reliable, that the area was not hazardous. In litigation against the county after the slide, the California Supreme Court ruled that the county was liable even though there was no negligence or other wrongful conduct involved.

In the above case, the government entity itself dumped the earth which caused the slide. But if the government approves an action on one piece of land which affects a second parcel, the government may be liable to the owner of the second parcel. One court expressed this as follows: "The fact that the work is performed by a contractor, subdivider or a private owner of property does not necessarily exonerate a public agency, if such contractor, subdivider or owner follows the plans and specifications furnished or approved by the public agency. When the work thus planned, specified and authorized results in an injury to adjacent property the liability is upon the public agency under its obligation to compensate for the damages resulting from the exercise of its governmental power." (11)

The above cases should not be taken as authority that the local government will be liable for damages in the event of an earthquake. First, the type of harm which would make the government liable is very limited. The landowner must suffer direct physical damage to his land. The Albers opinion said that this meant "definite physical injury to land or an invasion of it cognizable to the senses, depreciating its market value." (12) This might occur in slides or the breaking of dams or utility lines. However, it would account for only a small portion of the probable damage in the event of an earthquake.

A second requirement is that the public action is the proximate cause of the damage. This brings up the involved legal question of what is a
proximate cause. An act of God (such as an earthquake), if unforeseeable, may break the chain running from the governmental act to the damage to the property.\(^{(13)}\) It must be remembered that an earthquake is reasonably unforeseeable on faults such as the San Andreas and the Hayward faults.

Perhaps the biggest question is the policy issue of who should bear the burden. Inverse condemnation is subject to a balancing test. This has been stated by one California court as follows: "The decisive consideration is whether the owner of the damaged property if uncompensated would contribute more than his proper share to the public undertaking."\(^{(14)}\)

A determination of governmental liability would mean that some of the cost of the damage from the earthquake would be spread among the community. In the event of an earthquake the damage may be widespread. It seems inconceivable that a court would impose liability without a showing of governmental negligence. The burden of the community would be staggering. There is also a question of equity. Why should people who suffered damage where no governmental action was involved have to compensate, through taxation, those who suffered damage where governmental action, even though not negligent, was involved? Governmental negligence would make for a stronger case but policy reasons may dictate limited liability. To impose liability at the time of a major disaster would be giving the local government an added financial burden just at the time when its expenses have unexpectedly increased and its property values fallen.

In summary, governmental liability without fault seems unlikely in the event of an earthquake. Liability with fault may be imposed. In any event, local governments have at least the moral responsibility to exercise care in approving projects in hazardous areas.

**NONCONFORMING USES**

A nonconforming use can generally be thought of as a building, structure, or land use which exists but which would not be permitted under the current building and land use regulations.

There are several methods of controlling nonconforming uses. One is to have a provision in the ordinance that nonconforming uses shall not be expanded or extended in any way, either on the same or any adjoining parcel. This ordinance should have a provision stating that repairs are allowed as long as they are part of nominal annual maintenance.

Many city or county ordinances provide that nonconforming uses should be terminated because of abandonment, obsolescence, or destruction. The latter is of particular interest in geologic hazard areas because if an earthquake occurs which destroys a building it would seem unwise to rebuild it if the same type of disaster might destroy it again. The ordinance should have language stating that if the building is damaged to the extent of more than a certain percentage of its value or if the cost of reconstruction exceeds a certain percentage of the value, the nonconforming use must be terminated. The ordinance should specify whether fair market value or assessed value is to be used.

Under certain circumstances the local government can require that uses be terminated immediately under a nuisance theory or be terminated at the end of a specified time period (amortization). The specified time period
for amortization must be reasonable. California courts will look at the cost, age, and remaining useful life of the building or structure. (15) California courts have seemed to suggest that requiring termination of a nonconforming building or structure because of its aesthetic impact or lack of conformity with the surrounding area will not be upheld if done before the end of its ordinary economic life. (16) This issue has not been directly faced by the California courts. However, a California court has upheld an ordinance that terminated the nonconforming use of a conforming building within five years of the enactment of the ordinance. (17)

It has been suggested that California courts have looked at the following factors in making their decisions: a) the extent of private investment in the nonconforming use, b) the degree to which that investment would be jeopardized by a termination of nonconformity, c) the age, condition, and physical characteristics of the nonconforming property and the practical possibility that it may be relocated at a legally permissible site without unreasonable expense, d) the range of alternative but legally permissible uses to which the property could be put if the existing nonconforming uses were terminated.

The case for terminating a use in a geologic hazard area is much stronger because of the threat to public health and safety. A fifth factor, that of the degree of risk to public health and safety, should be added to the above list. A balance would then be made by the court in each case between the public gain and the hardship to the individual.

As noted above, a nonconforming building or structure can be terminated immediately if it has been declared to be a nuisance. (19) The concern with requiring termination of non-nuisance buildings or structures before the end of their economic life is that this might be held as an unconstitutional taking of property because of the great diminution of value. However, California courts have permitted a great diminution of value in instances where more than aesthetics were involved. (20) This has long been true where there has been a threat to public health and safety in areas other than land use.

There are three types of nonconforming uses of concern in or near a seismic hazard area. The first is buildings located directly over the fault trace. Any such building presents a threat to public safety, and should not knowingly be constructed over a fault. It is questionable whether single family homes with wooden frames present a threat of such magnitude that they should be removed. There may be other types of buildings or structures in the same category. However, any building which is normally occupied by more than a few people would be a hazard if located over the fault. This would also be true of such structures as petroleum storage tanks. An ordinance requiring the immediate termination of the use might be held unconstitutional. The court would look at the potential for harm, the activeness of the fault, the type of construction, and the hardship to the property owner. It seems safe to assume that a relatively short period of time such as five years for a building or structure which presented a substantial risk to public safety would be upheld. A longer period might be used for those buildings or structures presenting a less substantial risk.

The second type of nonconforming use is that of a building being used for some purpose which involves a very high degree of risk even though the
building is not on the fault and is well constructed. An example is a hospital located very near an active fault. This use should be terminated (although the building might be used for something else) because of the uncertainty as to exactly where in the fault zone the next displacement will occur. Hospitals probably present the strongest case for a relatively short termination period because of the need to keep hospitals functioning as well as keeping the structure intact. The rapid termination of nonconforming schools would probably also be upheld. If a community drew up a list of types of critical and especially vulnerable facilities to be eliminated in the area immediately surrounding an active fault, the courts would probably allow an amortization period less than the remaining economic life if the community could show that they had a well thought out plan.

The most difficult type of use to handle is the building or structure which is not over the fault, does not contain a critical or especially vulnerable activity near the fault, but is unsafe because of its siting, construction, soil conditions, water table or thickness of sediment. This is difficult because it is virtually impossible to draw up general guidelines. It is also difficult because the political problems increase because the hazard is less apparent and the economic implications are much greater. The courts are likely to carefully balance the lessening of the risk to public safety with the economic impact, not only upon the individual landowner, but upon the community. It seems reasonable that facilities such as hospitals and schools which are unsafe could and should be terminated within a short time. Buildings presenting a relatively small hazard should be terminated at the end of their economic life. Buildings falling in between these extremes could be terminated somewhere before the end of their economic life but not so soon so as to impose an unjust burden upon the property owner. Each situation would have to be examined individually.

Many buildings could be modified so as to make them safe. The time period for the required modifications could be much less than for termination because the economic impact upon the property owner is less.

STATE LEGISLATION

California began to enact statutes aimed at reducing earthquake losses after the 1933 Long Beach earthquake. This quake, which resulted in 102 deaths, would probably have been much less damaging if buildings in the area had been designed to withstand a major earthquake. The result was the incorporation of seismic design requirements into the Uniform Building Code.

General state building standards have also been the subject of state statutes. (21) Special attention has long been given to the construction of school buildings. (22) Recent legislation strengthens these regulations by clarifying provisions requiring geological and engineering investigations of school sites as well as prohibiting any school building from being constructed or situated on an active fault. (23) The types of regulations which are applied to schools are now being extended to hospital construction.

Seismic concerns are also being incorporated into state requirements
for local planning. The Seismic Safety Element, a required element of the Local General Plan, now consists of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to effects of seismically induced waves such as tsunamis and seiches. The seismic safety element shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure and seismically induced waves. (25) The guidelines for the preparation of this element have been prepared.

The problems of seismic safety are also addressed in the legislation relating to the adoption of open space plans. One of the categories of open space is land kept open for reasons of public health and safety including earthquake fault zones. (27)

Legislation has also been adopted which deals with the possibility of dam failure due to earthquakes. This legislation requires the filing of inundation maps and the adoption of emergency procedures for evacuation and control of populated areas below dams. (28)

Probably the most significant legislation relating land use with seismic safety is the Alquist-Priolo Geologic Hazard Zones Act. (29) This act provides that the State Geologist shall prepare maps by December 31, 1973, showing "special studies zones" along active earthquake faults. (30) These maps will be provided to all cities and counties having jurisdiction over land within these zones. (31) The State Mining and Geology Board will develop criteria by December 31, 1973, for evaluating development within these zones. (32) Within the zones, every structure intended for human occupancy must get approval from the appropriate city or county; approval cannot be granted if the local government finds that an "undue hazard" would be created. (33) The act specifically states that cities and counties may adopt stricter policies and criteria than those established by the state. (34)

The effectiveness of this act will largely depend upon the evaluation criteria developed at the state level. It should be noted again that if an "undue hazard" is found to exist after applying these criteria, the local government has no choice but to disapprove the development. Perhaps the biggest benefit of the act will be to force the attention of local governments towards a system of development control based on the existence of earthquake faults.
FOOTNOTES


6. Anaconda V. Ruckelshaus, 4 ERC 1817, 1823.


10. Albers v. County of Los Angeles, 62 Cal. 2d 250, 42 Cal. Rptr. 89.


12. Albers, supra, 250.


20. See note 5 above.


22. Education Code #15451-56.

24. Stats. 1972, Ch. 1130.
26. See Nichols, "Guidelines for the Preparation of a Seismic Safety Element."
27. Government Code #65560 as added by Stats. 1972, Ch. 251.
31. Ibid.
32. Public Resources Code #2623.
33. Ibid.
34. Public Resources Code #2624.
APPENDIX E

Los Angeles County 1968 Building Code
Earthquake Regulations

SEC. 2314 — EARTHQUAKE REGULATIONS

(a) General. Every building or structure and every portion thereof shall be designed and constructed to resist stresses produced by lateral forces as provided in this Section. Stresses shall be calculated as the effect of a force applied horizontally at each floor or roof level above the foundation. The force shall be assumed to come from any horizontal direction.

The provisions of this Section apply to the structure as a unit and also to all parts thereof, including the structural frame or walls, floor and roof systems, and other structural features.

(b) Definitions. The following definitions apply only to the provisions of this Section.

SPACE FRAME is a three-dimensional structural system composed of interconnected members, other than bearing walls, laterally supported so as to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor bracing systems.

SPACE FRAME-MOMENT RESISTING is a vertical load carrying space frame in which the members and joints are capable of resisting design lateral forces by bending moments.

SPACE FRAME-DUCTILE MOMENT RESISTING is a space frame-moment resisting complying with the requirements for a ductile moment resisting space frame as given in Section 2314 (j).

LATERAL FORCE RESISTING SYSTEM is that part of the structural system to which the lateral forces prescribed in Section 2314 (d) 1 are assigned.

SPACE FRAME — VERTICAL LOAD-CARRYING is a space frame designed to carry all vertical loads.

BOX SYSTEM is a structural system without a complete vertical load-carrying space frame. In this system the required lateral forces are resisted by shear walls as hereinafter defined.

SHEAR WALL is a wall designed to resist lateral forces parallel to the wall. Braced frames subjected primarily to axial stresses shall be considered as shear walls for the purpose of this definition.

(c) Symbols and Notations. The following symbols and notations apply only to the provisions of this Section.

\[ C = \text{Numerical coefficient for base shear as specified in Section 2314 (d) 1.} \]

\[ C_s = \text{Numerical coefficient as specified in Section 2314 (d) 2 and as set forth in Table No. 23-I.} \]

\[ D = \text{The dimension of the building in feet in a direction parallel to the applied forces.} \]

\[ D_s = \text{The plan dimension of the vertical lateral force resisting system in feet.} \]

\[ F, F_s, F_v = \text{Lateral forces applied to a level "l", "n", or "s", respectively.} \]

\[ F_s = \text{Lateral forces on the part of the structure and in the direction under consideration.} \]

\[ F_t = \text{That portion of "V" considered concentrated at the top of the structure, at the level "m." The remaining portion of the total base shear "V" shall be distributed over the height of the structure including level "m" according to Formula (14-5).} \]

\[ H = \text{The height of the main portion of the building in feet above the base.} \]
The value of "K" shall be not less than that set forth in Table No. 23-I. The value of "C" shall be determined in accordance with the following formula:

\[ C = \frac{0.05}{\sqrt{T}} \]  

(14-2)

Except as provided in Table No. 23-I, the maximum value of "C" need not exceed 0.10. For all one- and two-story buildings, the value of "C" shall be considered as 0.10.

Where wind load as specified in Section 2307 would produce higher stresses, this load shall be used in lieu of the loads resulting from earthquake forces.

Footnote No. 2 is deleted.

The minimum value of "K" shall be 0.12, and the maximum value of "K" shall not exceed 0.25.

For overturning, the factor "J" as specified in Section 2314 (b) shall be 1.00.

The tower shall be designed for an accidental torsion of five per cent as specified in Section 2314 (g). Elevated tanks which are supported by buildings or do not conform to type or arrangement of supporting elements as described above shall be designed in accordance with Section 2314 (d) (2) using "C" = 2.

### Table No. 23-I — Horizontal Force Factor "K" for Buildings or Other Structures

<table>
<thead>
<tr>
<th>Type or Arrangement of Resisting Elements</th>
<th>Value of K</th>
</tr>
</thead>
<tbody>
<tr>
<td>All building framing systems except as hereinafter classified</td>
<td>1.00</td>
</tr>
<tr>
<td>Buildings with a box system as specified in Section 2314 (a)</td>
<td>1.25</td>
</tr>
<tr>
<td>Buildings with a dual bracing system consisting of a ductile moment-resisting space frame and shear walls using the following design criteria:</td>
<td>0.85</td>
</tr>
<tr>
<td>(1) The frames and shear walls shall resist the total lateral force in accordance with their relative stiffness, considering the interaction of the shear walls and frames.</td>
<td></td>
</tr>
<tr>
<td>(2) The shear walls acting independently of the ductile moment-resisting portions of the space frame shall resist the total required lateral forces.</td>
<td></td>
</tr>
<tr>
<td>(3) The ductile moment-resisting space frame shall have the capacity to resist not less than 25 per cent of the total required lateral forces.</td>
<td></td>
</tr>
<tr>
<td>Buildings with a ductile moment-resisting space frame designed in accordance with the following criteria:</td>
<td>0.67</td>
</tr>
<tr>
<td>(1) The ductile moment-resisting space frame shall have the capacity to resist the total required lateral forces.</td>
<td></td>
</tr>
<tr>
<td>(2) If major rigid elements are included in addition to the ductile moment-resisting space frame, the required lateral force shall be distributed to all resisting elements in accordance with their relative stiffnesses, considering the interaction of the frames and rigid elements.</td>
<td></td>
</tr>
<tr>
<td>Elevated tanks plus full contents on four or more cross-braced legs and not supported by a building.</td>
<td>3.00</td>
</tr>
<tr>
<td>Structures other than buildings and other than those set forth in Table No. 23-I</td>
<td>2.00</td>
</tr>
</tbody>
</table>

*Footnote: The value of "K" is based on the fundamental period of vibration of the structure in seconds in the direction under consideration. Properly substantiated technical data for establishing the period "T" may be submitted in the absence of such data, the value of "T" for buildings shall be determined by the following formula:

\[ T = \frac{0.05A}{\sqrt{D}} \]  

(14-3)

**EXCEPTION:** In all buildings in which the lateral resisting system consists of a moment-resisting space frame which resists 700 per cent of the required lateral forces and which frame is not enclosed by or adjoined by more rigid elements which would tend to prevent the frame from resisting lateral forces.

\[ T = 0.10W \]  

(14-3A)
The total internal force "V" shall be distributed in the height of the structure in the following manner:

\[ F_s = 0.04V \left( \frac{h_s}{D_s} \right)^2 \]  \hspace{2cm} (14-A)

\[ F_s = \frac{n \Sigma w \cdot h_s}{1 + \sum} \]  \hspace{2cm} (14-B)

**EXCEPTION.** One-and-two story buildings shall have uniform distribution.

At each level designated as "h,", the force "F" shall be applied over the area of the building in accordance with the mass distribution on that level.

3. Lateral force on parts or portions of buildings or other structures. Parts or portions of buildings or structures and their anchorage shall be designed for lateral forces in accordance with the following formula:

\[ F_s = \frac{V_s}{L_s} \]  \hspace{2cm} (14-C)

The values of "L" are set forth in Table No. 234. The distribution of these forces shall be according to the gravity loads pertaining thereto.

3. Pile foundations. Individual pile or caisson footings of every building or structure shall be interconnected by ties each of which can carry by tension and compression a horizontal force equal to 10 per cent of the larger pile cap loading unless it can be demonstrated that equivalent restraint can be provided by other approved methods.

**EXCEPTION.** Ties may be omitted for belled footings having a height not exceeding six feet not twice the diameter of the bell and for piles supporting one-story buildings of lightweight Type IV-N construction.

(c) Distribution of Horizontal Shear. Total shear in any horizontal plane shall be distributed to the various elements of the lateral force resisting system in proportion to their rigidities considering the rigidity of the horizontal bracing system or diaphragm.

Rigid elements that are assumed not to be part of the lateral force resisting system may be incorporated into buildings provided that their effect on the action of the system is considered and provided for in the design.

(d) Drift. Lateral deflections or drift of a story relative to its adjacent stories shall be considered in accordance with accepted engineering practice.

(e) Horizontal Torsional Moments. Provisions shall be made for the increase in shear resulting from the horizontal torsion due to an eccentricity between the center of mass and the center of rigidity. Negative torsional shear shall be neglected. Where the vertical resisting elements depend on diaphragm action for shear distribution at any level, the shear-resisting elements shall be capable of resisting a torsional moment assumed to be equivalent to the story shear acting with an eccentricity of not less than five per cent of the maximum building dimension at that level.

### Table No. 234 - Horizontal Force Factor C" for Parts of Portions of Buildings or Other Structures

<table>
<thead>
<tr>
<th>Part or Portion of Building</th>
<th>Direction of Force</th>
<th>Value of C&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior bearing and nonbearing walls, piers, columns, and cornices over six feet in height</td>
<td>Normal to flat surface</td>
<td>0.20</td>
</tr>
<tr>
<td>Concrete parapets and other concrete walls</td>
<td>Normal to flat surface</td>
<td>0.20</td>
</tr>
<tr>
<td>Exterior and interior ornamental and architectural details</td>
<td>Any direction</td>
<td>0.20</td>
</tr>
<tr>
<td>When connected to or part of a building, members, or structural elements, chimneys, smokestacks, and signal towers</td>
<td>Any direction</td>
<td>0.20</td>
</tr>
<tr>
<td>When resisting over one story, tanks plus effective mass of accessories</td>
<td>Any direction</td>
<td>0.10</td>
</tr>
<tr>
<td>Hinges and nodes acting as expansion joints</td>
<td>Any direction</td>
<td>0.10</td>
</tr>
<tr>
<td>Connections for exterior forces or for the forces, complying with Section 234.38, in the direction of the moment</td>
<td>Any direction</td>
<td>0.10</td>
</tr>
<tr>
<td>Connections for prefabricated structural elements</td>
<td>Any direction</td>
<td>0.10</td>
</tr>
</tbody>
</table>

*See also Section 2322 (b) for minimum load on foundations for exterior partitions.*

*When "h_s/D_s" of any building is equal to or greater than five, the increase value by 0.10 per cent.*

*Fours and roofs acting as diaphragms shall be designed for a minimum value of "C" of 0.10 per cent applied to loads tributary to that story unless a greater value of "C" is required by the basic seismic formula V = \( \frac{V_s}{L_s} \)."
WHERE

\[ J_1 = J + \left( J_1 \right)^2 \]

At any level the incremental changes of the design overturning moment, in the story under consideration, shall be distributed to the various resisting elements in the same proportion as the distribution of the shears in the resisting system. Where other vertical members are provided which are capable of partially resisting the overturning moments, a redistribution may be made to these members if framing members of sufficient strength and stiffness to transmit the required loads are provided.

Where a vertical resisting element is discontinuous, the overturning moment carried by the lowest story of that element shall be carried down as loads to the foundation.

(i) Set-backs. Buildings having set-backs wherein the plan dimension of the tower in each direction is at least 25 per cent of the corresponding plan dimension of the tower part may be considered as a uniform building without set-backs for the purpose of determining seismic forces. For other conditions of set-backs the tower shall be designed as a separate building using the larger of the seismic coefficients at the base of the tower determined by considering the tower as either a separate building for its own height or as part of the overall structure. The resulting total shear from the tower shall be applied at the top of the tower part of the building which shall be otherwise considered separately for its own height.

(ii) Structural Systems. 1. Design Requirements. Buildings designed with a horizontal force factor, \( K \), of 0.60 or 0.80 shall have a ductile moment-resisting space frame. Buildings more than one hundred and sixty feet in height shall have a ductile moment-resisting space frame capable of resisting not less than 25 per cent of the required seismic load for the structure as a whole.

Moment-resisting space frames and ductile moment-resisting space frames may be enclosed by or adjoined by rigid elements which would tend to prevent the space frame from resisting lateral forces, where it can be shown that the action of these rigid elements will not impair the vertical and lateral load resisting ability of the space frame.

2. Construction. The necessary ductility for a ductile moment-resisting space frame shall be provided by a frame of structural steel conforming to ASTM A 7, A 36 or A 441, with moment-resisting connections, or by reinforced concrete in accordance with Section 2602 of this Code.

Shear walls in buildings exceeding one hundred and sixty feet in height shall be composed of rolled or rolled shaped members of ASTM A 7, A 36 or A 441 structural steel, or reinforced concrete. Shear members or walls shall be supported by means of poured-in-place concrete or by mechanical fasteners in accordance with the following provisions:

A. Connections and panel joints shall allow for a relative movement between stories of not less than two times story drift caused by wind or seismic forces, or one-fourth inch whichever is greater.

B. Connections shall have sufficient ductility and rotation capacity to preclude fracture of the concrete or brittle failures at or near welds. Inserts in concrete shall be attached to, or hooked around reinforcing steel, or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

C. Connections to permit movement in the plane of the panel for story drift may be properly designed using slotted or oversized holes or may be connections which permit movement by bending of steel.

(ii) Design Requirements. 1. Building Separations. All portions of structures shall be designed and constructed to act as an integral unit in resisting horizontal forces unless separated structurally by a distance sufficient to avoid contact under deflection from seismic action or wind forces. Structural separations of at least one-inch, plus one-half inch for each ten feet of height above twenty feet are considered adequate to meet the requirements of this paragraph.

2. Minor alterations. Minor structural alterations may be made in existing buildings and other structures, but the resistance to lateral forces shall be not less than that before such alterations were made, unless the building as altered meets the requirements of this Section of the Code.

3. Reinforced masonry or concrete. All elements within the structure which are of masonry or concrete and which resist seismic forces or movement shall be reinforced so as to qualify as reinforced masonry or concrete under the provisions of Chapters 24 and 26. Principal reinforcement in masonry shall be spaced two feet maximum on center in buildings using a ductile moment resisting space frame.

4. Combined vertical and horizontal forces. In computing the effect of seismic force in combination with vertical loads, gravity load stresses induced in members by dead load plus design live load, except roof live load, shall be considered.

5. Exterior elements. Precast, non-bearing, non-shear wall panels or other elements which are attached to, or enclose the exterior, shall accommodate movements of the structure resulting from lateral forces or temperature changes. The concrete panels or other elements shall be supported by means of poured-in-place concrete or by mechanical fasteners in accordance with the following provisions:

A. Connections and panel joints shall allow for a relative movement between stories of not less than two times story drift caused by wind or seismic forces, or one-fourth inch whichever is greater.

B. Connections shall have sufficient ductility and rotation capacity to preclude fracture of the concrete or brittle failures at or near welds. Inserts in concrete shall be attached to, or hooked around reinforcing steel, or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

C. Connections to permit movement in the plane of the panel for story drift may be properly designed using slotted or oversized holes or may be connections which permit movement by bending of steel.

6. Minor rigid elements. Minor rigid elements within or attached to a structure may be assumed to be expendable and not part of the lateral force resisting system.
APPENDIX F

PROPOSED EARTHQUAKE CODE BY THE CITY OF LOS ANGELES
PROPOSED BUILDING CODE AMENDMENTS
(1972)

This earthquake resistance design code has been proposed for adoption by the City of Los Angeles. It is a code that would require a dynamic analysis for building construction.

It is of significant importance and cited in this report as reference material. Copies may be obtained from the Department of Building and Safety L02 City Hall, Los Angeles, California 90012.
APPENDIX G

OUTLINE OF THE GEOLOGY OF KERN COUNTY

Compiled by Rene L. Engel

Introduction

This summary includes some of the most important geological features presently observable in Kern County and how they lead into the aspects of the past. It is written principally for non-geologists and thus departs from the geological historical order usually considered by earth scientists. Instead of beginning at some time in the historical past and relating geological events in sequence as they occurred and ending with the present, it begins with the landscape we see in our surroundings today; i.e. our mountains, plains, and valleys. It then describes how those geomorphic features relate to other landforms in California and the rock formations that produce them. It progressively delves into successive stages of the past; into the less known; the inferred.

Geography

Kern County, the third largest county in California, comprises 8,172 square miles (21,165 square kilometers) of land located in the south-central part of the state. It is 66 miles wide from north to south and its length from east to west increases from about 91 miles in the south to 145 miles in the north. For purposes of land surveying the northern part of the county is included in the Mt. Diablo Base and Meridian system of townships and ranges and the southern part in the San Bernardino system.

The northern boundary of the county cuts across the high desert Sierra Nevada Mountains, the San Joaquin Valley, and the Coast Ranges along a parallel at about 35° 47.5' latitude north. This line also coincides with the northern limit of T25S, MDB&M, which separates Kern from King, Inyo and Tulare Counties.

The eastern boundary, separating Kern County from San Bernardino County, is defined by a geographic line, a meridian at the average 117° 38' longitude west, roughly corresponding to the eastern limits of RLOE, MDB&M, in the southeast.

The western boundary between Kern and San Luis Obispo Counties roughly coincides with the crest of the Temblor Ranges through a series of steps from about 34° 49.3' latitude north and 119° 15' longitude west at the southwest corner of the county, to 35° 47.5' latitude north and 120° 11.5' longitude west, at the northwest corner. The southern boundary with Los Angeles County in the east, Ventura and Santa Barbara Counties in the west, follows approximately the parallel 34° 49.3' latitude north, or close to the southern limit of T9N, SBB&M.

Geomorphology

The descriptive study of the sculpturing that has formed the earth's surface or landforms is called Physiography. Using the general context of the earth sciences, Geomorphology attempts to trace the origin of landforms through their successive stages of evolution.
For the purpose of such studies Kern County can be divided from east to west into five of the eleven geomorphic provinces that are present in California. These are broad regional classes characterized by similar aspects of landforms or relief, structural orientation and physical environment. To a large extent the local ecology is related to the geomorphology.

The geographic limits of the provinces are indicated on Figure 9. They are described as follows:

1. The southern part of the Basin Ranges Province represented by Indian Wells Valley, El Paso Mountains and Red Rock Canyon.

2. The northwestern portion of the Mojave Desert Province including the Rand Mountains, Freeman Valley, Soledad Mountain and the northern part of Antelope Valley.

3. The southern Sierra Nevada Province including the southern edge of the Kern Plateau, Kiavah, Plute, Breckenridge, Greenhorn and Tehachapi Mountains.

4. The Great Valley Province represented by the southern portion of the San Joaquin Valley enclosed by the Sierra Nevada to the east, the Tehachapi and San Emigdio Mountains to the south and the Temblor Range on the west side.

5. The Coast Ranges Province represented by the Temblor Range and San Emigdio Mountains.

In addition to these five provinces the northern limit of the Transverse Range Province represented by Frazier Mountain and Mt. Pinos, both in Ventura County, extends into the southwest corner of Kern County.

Elevations in the county range widely from 215 feet above sea level in San Joaquin Valley, west of Delano, to 8800 feet on Sawtooth Mountain near the southwest corner of the county and to 8475 feet on top of Owens Peak in the Sierra Nevada near the northeast corner of the county. Owens Peak is located at the apex of a roughly triangular shaped mountainous area which slopes easterly toward the Basin Range Province and the Mojave Desert, and westerly toward the Kern River Valley and San Joaquin Valley area. A line connecting Owens Peak and Mt. Pinos represents the approximate divide between the drainages into the San Joaquin Valley and to the southeast.

In Kern County most of the Mojave Desert lies at elevations above 2000 feet whereas most of the San Joaquin Valley lies below 1000 feet. Both the Mojave Desert and the San Joaquin Valley have arid climates with average annual rainfall of less than 10 inches. They are characterized by hot summers and mild to cool winters which vary with the elevation and protection from wind.

In the mountains, the climate is semi-arid with rainfall from 10 to 30 inches and generally lower temperatures.

A great variety of landforms in Kern County were developed by erosion. Changes occurred in varied climatic environment, and in rock masses of different hardness, compaction, alteration and structural conditions.
Some landforms were named after the Kern River where they were first observed. Such features are rock benches marked by ridges and saddles along upper Kern Canyon called "Kernbut" and "Kerncol."

Among some of the most remarkable regional geomorphic features in the county are Red Rock Canyon, Kern Canyon, the Walker Basin, San Joaquin Valley and its encircling mountain system from the Coast Ranges to the Sierra Nevada.

When a traveler enters Kern County from the south, through the narrow defile of Tejon Pass, the sudden opening of the vastness of the San Joaquin Valley is before him and he views one of the most beautiful sites in California.

Drainage

The drainage of Kern County is divided between two major collecting basins. The San Joaquin Valley which receives the waters from most of the western two-thirds of the county and the Mojave Desert which receives water from the eastern third. The line of separation between the two basins, or Eastern Divide, follows mountain crests and summit passes of the east side of the Sierra Nevada; it crosses Tehachapi Valley and follows the summits of the Tehachapi Mountains to end north of Castaic Lake where it joins the Western Divide, formed by the San Emigdio and T embrior Mountains of the Coast Ranges. The meeting of the two divides closes the southern end of the San Joaquin Valley basin. On the east side of the Western Divide, the runoff flows into the San Joaquin Valley and on the west side it flows toward the Pacific Ocean.

Of all streams that flow into the San Joaquin Valley, the Kern River is the largest. It has two branches that join at Lake Isabella: the North Fork, originates near Mt. Whitney and the South Fork has its source on the Kern Plateau near Trail Peak. The total area drained by the two branches covers about 2,420 square miles. The two rivers flow into Lake Isabella Reservoir which has a total impounding capacity of 550,000 acre-feet* controlled by two m.n.m.-made dams. The combined average annual runoff of the two rivers amounts to 760,000 acre-feet. Water leaving the lake is regulated by the dam and during periods of exceptionally high runoff, excess water is released into the Kern River. When all of this water is not needed for irrigation the section of the Kern River which is usually dry below Bakersfield has water flowing into Buena Vista Lake. This playa had a capacity of over 200,000 acre-feet.

* One acre-foot is equal to 325,851 gallons of water.
When filled to capacity the lake may overflow northward into Tulare Lake by way of the Kern River East and West flood canals. Facilities are being developed that will carry this water into the California Aqueduct. That system will prevent overflow and flooding and utilize the excess water for agricultural uses.

The next drainage channels of importance, also on the east side of the valley are Poso Creek, located North of Kern River and Caliente Creek to the South. They have lesser drainage areas than the Kern River but like it they play a big part in making agriculture possible by helping to recharge the ground water supply of the San Joaquin Valley.

The western Mojave Desert basin collects an average annual runoff of about 66,000 acre-feet. This runoff serves to recharge the ground water reservoir which is being depleted by pumping.

Among the more or less isolated valleys or drainage sub-basins, is the Indian Wells Valley which receives most of its water supply from the eastern slopes of the Sierra Nevada and has during years of abundant rainfall overflowed into a playa called Searles Lake.

Examples of greater confinement are the intermountain valleys near Tehachapi that receive the drainage from Cummings and Bear Mountains.

Their normal flow is westward, either directly from the mountain slopes facing the San Joaquin Valley or through Tehachapi Creek, a tributary of Caliente Creek. At times of high runoff, the low divide that separates the Tehachapi drainage basin from that of Monolith and Cache Creek, may be overrun and part of the flow runs eastward into Proctor Lake. Sometimes, after filling this dry lake, the excess water overflows eastward through Tehachapi Pass into the Mojave Desert.

Minerals and Rocks

Minerals are natural substances that have characteristic internal structures, chemical composition, and physical properties. Most of them are crystallized and their origin is usually inorganic.

Rocks are naturally found assemblages of one or more minerals in fairly large amounts, either unconsolidated or consolidated. Unconsolidated rocks of recent origin are transported either by running water (river alluvium, fan deposits, lake deposits), by the wind (sand dunes), or by volcanic explosions (ash, tuff). The first two rock types are produced by erosion of older rocks and are formed of rock and mineral particles derived from them. They are more or less rounded, sorted by size and weight according to the carrying capacity of the water or wind and deposited as successive layers. This process of depositing sedimentation produces rocks that have characteristics found only in sedimentary rocks. Most common sedimentary rocks are: Conglomerate (made up of pebbles or gravel), sandstone, shale (made principally of clay), and limestone (made from the shells of animals or by precipitation).

The third type of rock is the volcanic ash or tuff produced by molten magma of igneous origin. It exhibits hardly any sorting although it may be layered. Igneous rocks are transported as hot fluids (magnas) within the earth and may appear at the surface to form volcanic cones or flows that consolidate as sheets of extrusive rocks. Slow crystallization of the magma under a thick cover of older rocks produces large igneous rock masses called plutons. They are observable
at the surface of the earth as cutting or penetrating older rocks and are called intrusive rocks.

The most common examples of extrusive rocks listed in the order of high to low silica or quartz content are: rhyolite, andesite, and basalt. For the plutons and intrusives, in the same corresponding order of composition, are found: granite, diorite, and gabbro. The extrusive rocks are generally very finely grained and glassy at times, whereas the plutons and intrusives are coarse grained and completely crystallized.

Metamorphic rocks are rocks produced deep in the earth's crust. They can be derived from either igneous or sedimentary rocks by the effects of temperature, pressure, chemical reactions and shearing stress. Some types of metamorphic rocks (metasedimentary) are characteristically derived from sedimentary rocks mostly by recrystallization. The major types are: quartzite formed by recrystallization of quartz sandstone, slate derived from clay shale and marble from limestone. As the mineral composition of the original sedimentary rock increases in complexity, that of the metamorphic rock derivative also increases and the metasediment tends to resemble a metamorphic rock that was derived from igneous rocks. Of these more complex rock types, the most common are schists and gneisses of varied composition. All these types of rocks are found in Kern County.

In addition to the minerals which form the rocks a large number of mineral deposits or concentration of minerals in a small area are found here in Kern County. These deposits are made of either metallic or nonmetallic minerals that have varied degree of economic value according to their abundance and demand. The most important metallic mineral deposits are those of gold, silver, tungsten, molybdenum and copper, with smaller amounts of antimony, lead, tin, uranium and mercury.

In the early days of Kern County these metallic minerals were mined and produced the major source of activity and wealth; today, however, nonmetallic minerals such as borates, gypsum, salt, clay and lime minerals, along with the fuels such as petroleum and natural gas, dominate the county's mineral industry.

The "Kern County Mineral" named Kernite, found near Boron is associated with other borates and was named to indicate the site at which it was originally identified in 1926. It is nicely crystallized into long transparent prisms interstratified with shale beds. Kernite is one of the principal ore minerals of the borax deposit mined in one of the world's largest open pit mines located at Boron, California.

**Stratigraphy and Structure**

Relative age dating of different rocks are established by strata or bed superposition, induration, alteration, intrusive relations and fossil remains that reveal the life evolution of plants and animals throughout time.

Radiometric age dating of rocks is determined by relating the quantity of radioactive elements to the decay products that was produced in the time measured. Such dating is expressed by the number of millions of years before present time and is based on the known rate of decay for that element.

Other uses of stratigraphy are to assist in the correlation between similar strata and rocks observed at different locations and to relate the measurement of their thickness. The thickness may vary relative to the position and attitude of rock masses that indicate deformation expressed by folds, faults, igneous intrusions and exhumations and unconformities.
Geologic time is a subdivision of the earth's history that corresponds with geologic events which produced time stratigraphic units. The standard geologic-relative time scale is divided into eras, periods, and epochs. A further division into stages is based on life evolution. These divisions and corresponding radiometric ages and the major geologic events in western and eastern Kern County are shown in table form in the appendix.

The table starts on top left with the present time: The Holocene or Recent epoch which began about 10,000 years ago (0.01 million years before present). At this time the Cascadian orogenic movements (mountain building) ceased or became much smaller or localized. This was the end of a period of mountain building process that began at the end of the Pliocene epoch.

Most of the earth's surface is covered by the unconsolidated sediments. These sediments were deposited or eroded then redeposited, during the Holocene, by: 1) Rivers on their flood-plain and generally called: Alluvium, composed of principally sand, silt, clay and gravel of different sizes usually fairly well sorted; 2) torrents in steep canyons at the foot of mountains, named Fans, composed of coarse unsorted detritus varying in sizes from boulders to clay; 3) wind to form sand dunes; or 4) earth moved by gravity to form landslides composed of older rocks of various origins; and 5) deposited in lakes formed of fine sand, silts, and clay.

Although the sediments produced by these different modes of deposition are from different sources and materials and therefore vary in mineral composition, a common characteristic of all these deposits is that they have about the same degree of alteration and their bedding is nearly horizontal or untilted.

The exposure of deposits of gravels and sand that make up river banks, correspond to a relatively recent episode of flood-plain cutting by the rejuvenated stream that originally deposited those gravels and sands. These features are called river terraces. Deposits similar to those previously described but tilted and usually strongly altered, are classified into the next older epoch: the Pleistocene and referred to as "Older Alluvium." Their contact with the horizontally overlying Recent deposits is marked by a lack of parallelism between the beds of the older and younger formation or by what is termed an "Angular Unconformity."

On the west side of the San Joaquin Valley, below the Older Alluvium are found the tilted lake beds of the Tulare Formation. They consist of gravel, sand, silt, and clay, gysiferous at times and contain fresh water diatoms and snails. Their age determined by fossils is principally Pleistocene but toward the base of the formation the age is Upper Pliocene. This example illustrates the fact that some formation boundaries may overlap biostratigraphic zones, i.e., divisions between epochs and stages of the geologic time scale.

On the east side of the valley, the upper portion of the coarse fanglomerate deposits of the Kern River Formation have a similar position under the Older Alluvium. Both Tulare and Kern River formations were deposited under nonmarine conditions and contain characteristic fossilized remnants of terrestrial plants and animals.

During the entire Pleistocene epoch, strata previously deposited were strongly deformed by repeated movements of the Cascadian Orogeny. This deformation observable today as faults and folds (anticlines and synclines) contributed to the accumulation of petroleum.
The beginning of the Quaternary Period and the end of the Tertiary (3 million years ago) is indicated by a line that also marks the change on the west side of the San Joaquin Valley from a terrestrial to a marine environment. This is shown on the left hand side of the table, page XXII-7 by the appearance of marine foraminifers.

Subdivision of the Tertiary Period into epochs from Pliocene to Paleocene is based on time stages defined by characteristic foraminiferal assemblages listed under the names of the accepted California nomenclature. This differentiation of assemblages also marks the end of the Tertiary Period. It is shown in the table as well as the most important corresponding formations in the valley for each epoch and stage.

The terrestrial stage names defined by mammalian faunal assemblages and the corresponding principal formations are given for nonmarine strata intercalations into marine formations in the San Joaquin Valley and for major occurrences in the Western Mojave Desert and Tehachapi Valley. This is shown in the center of the table on page XXII-7.

In the table center right, some formations are listed in their natural sequence of deposition (for example the Ricardo and the Horned Toad-Witnet sequences); other formations are mentioned individually and their name is followed by the sign "/". All formation names on the chart are in a horizontal alignment with the corresponding stage to which they belong.

Toward the end of the Cretaceous the first movement on the San Andreas Fault is estimated to have taken place. (Wentworth, Carl M., 1968.)

During the Cretaceous and possibly part of the Jurassic, marine sediments were deposited in the San Joaquin Valley and Temblor Range region. Most of the pre-Cretaceous sediments through the process of burial, alteration, and metamorphism, as well as the effect of igneous intrusions, were changed in character so they are now non-datable.

In the western Mojave Desert the deposition of marine sediments was continued with the deposition of the Garlock Formation of estimated Permian Age.

Other rocks of sedimentary origin are metasediments included in the Kernville formation of probably Pennsylvanian age; possibly, the much older metamorphic rocks exposed in the Tehachapi Mountains (Pelona schist) and in the Mojave Desert (Mesquite and Rand schists) are pre-Cambrian. The considerable thickness of rocks of Paleozoic age exposed to the east of the Sierra Nevada but not found in the west suggest that during the Paleozoic era, the sea may have covered the Kern Region and deposited large amounts of sediments which were subsequently almost completely removed by erosion.

A considerable number of volcanic events are recorded by the formations deposited during the Pleistocene and the Tertiary. The volcanism appears in east central California as extrusive lava flows and beds of ash or tuff interstratified within sedimentary formations. Some extensive flows of known age in the Mojave Desert are listed on the table in the column under the heading: "Igneous and Metamorphic Rocks."

The five mesozoic plutons which formed the Sierra Nevada and ultimately the surrounding basement and mountains are shown in the same column. They represent
Figure 10.

Development of California Land
distinct magmatic intrusions and deformation periods which started in Middle Triassic and ended in Late Cretaceous. These intrusive and deformation periods are separated by intervals of about 30 million years.

Only the youngest two of these plutons are exposed at the surface in the Kern Region. They are the Huntington Lake Pluton of Early Cretaceous age, composed mainly of granodiorite and quartzdiorite and the Cathedral Range Pluton of Late Cretaceous age, composed principally of high potassium bearing rocks: quartz monzonite, granite and granodiorite.

Near the time the Cathedral Range Plutonic intrusion began in Late Cretaceous (about 90 million years ago), a period of strong regional deformation started to affect California. This was followed by periods of marine sea transgression into the Great Valley that reached its maximum extent toward the end of the plutonic intrusion (approximately 70 million years ago). (Evernden, J. F. and R. W. Kistler, 1970.)

Historical Geology and Paleogeography

In this chapter, the events listed in the geologic time scale are reviewed in the reverse order from that used previously, i.e. from the past to the present. The purpose is to outline the major disturbances that caused the variations in areas occupied by the sea and land.

The geologic history consists of a succession of cycles. In general, each one starts with a land subsidence followed by an invasion or transgression by the sea and deposition of sediments. This is followed by a structural deformation related to a new orogenic event which cases folding and faulting of the new and older sediments into mountains as the land emerged from the sea. The cycle is completed when this mountain building period is followed by erosion that reduces vast areas to a flat land surface. Every period or epoch of geologic history as shown on the time scale experienced one or more cycles during the geologic evolution of the region.

The older rocks have experienced several cycles and are therefore altered more than the younger. The older Pre-Cambrian and Paleozoic rocks although limited in the Kern Region, may be considered as small remnants of more extensive deposits exposed in the eastern part of California and in Nevada. The same concept may apply to some of the metamorphic rocks of undetermined age such as the Kernville metasediments which because of their analogy with other metamorphic rocks, for which the age is determined more accurately, may possibly by inferred to be of Pennsylvanian age. The Pampa schist that overlies the Kernville Formation is possibly Permian or older. Both formations were folded and partly metamorphosed during the early movements which uplifted the ancestral Sierra Nevada.

The Garlock Formation still younger than those mentioned is exposed in the El Paso Mountains and only slightly metamorphosed. In the middle of the 35,000 feet thick formation rare marine fossils of Permian age are found. Therefore, it is possible that the formation may include a mixture of both sediments from younger and older ages. The end of the Paleozoic in the Kern Region is more clearly defined than its beginning. This gives added support to other evidence that tends to indicate several geological cycles with associated marine transgressions occurred during most of the era.
The regional history of the Mesozoic Era starts with the development of the Franciscan Formation which probably began in Late Jurassic and continued until Late Cretaceous age. Its composition is a mixture of sedimentary and metamorphic rocks of marine and igneous origin. At about the same epoch renewed movements began in the Sierra Nevada ancestral region. Marine sediments deposited during the Cretaceous epoch are better preserved than in older rocks. It is so complete that the areas of deposition can be accurately represented on a paleographic map. (See Figure 10-a.) The black areas indicate submerged land covered by the sea and the cross hatched area represents emerged land surfaces. The Cretaceous sea invaded the Great Valley from the north and later from the south when a land barrier subsided. Sediments both Lower Cretaceous (Gravelly Flat and Hex Calystone Formation) and Upper Cretaceous (Panoche Formation) were deposited in the region which later became a part of the Temblor Range. To the east, in the Sierra, the first intrusive to appear was the Huntington Lake Pluton. It required 18 million years during Early Cretaceous time for the emplacement of these intrusions. They caused strong deformations in older rocks then invaded and separated them into large rock masses to form roof–ponds. Nearly 30 million years later, in Late Cretaceous, the Cathedral Range Pluton emplacement started. This continued during the next 20 million years and was accompanied by additional orogenic movements. About the end of that time (70 million years before present) the Cretaceous Sea in the west attained its greatest area wide extent. At the onset of the Tertiary Period it started to decrease in size.

In the San Joaquin Valley marine sedimentary deposition of the Tertiary Period is better preserved than in any previous period. Therefore paleographic maps showing the geographic area covered are more accurate. On Figure 10–b is shown the Lower Miocene sea ("Vaqueros" or approximately Saucian stage) that covers parts of the San Joaquin Valley. Mountains on the west formed islands and the main drainage lines on land to the east and in the valley are shown running southward into the sea. The Sierra and Mojave regions stood at a low elevation and were almost continuous. The whole area was covered by forests and grasses. Primitive horses, camels, rhinoceros and other mammals roamed the area.

The great expansion of the Middle Miocene sea (Relizian and Luisian stages) is generally depicted on Figure 10–c. The San Joaquin Valley was completely submerged during this time. The sea was deepest on the west and south sides where subsidence of the sea-floor was greater. On the East, depths are shallower, the sea overlaps the Sierra shores where sharks and ancestral dolphins played. Volcanism is active on both the land and under the sea.

Toward the end of the Miocene, the land area occupied by the sea in the San Joaquin Valley decreases. Land emergence from the sea in the west is caused by local movements. The Sierra Nevada is uplifted and tilted toward the west for the first time. Drainage to the west starts and new rivers capture some of the older streams that flowed south. Mount Whitney was a small hill 1500 feet above sea level and nearly 500 feet above the surrounding land surface that had low relief. These effects are sketched on the Pliocene sea diagram (Figure 10-d) where reduced coastal basins limited by the emergence of western land masses and a shallow eastern shore are shown. By contrast, marine sedimentation continues unimpaired in the Maricopa region of the San Joaquin southern basin. Terrestrial sediments deposited during interruptions of marine sedimentation in the valley (example: the Chanac beds deposited on Santa Margarita, M.) or on the western slopes of the Sierra (Kern River Fangoglomerate), in the Tehachapi region (Horned Toad section) and the Mojave, associated with
Figure 10.

Development of California Land
volcanic tuffs and extrusives (Ricardo section), are listed on the geologic time scale table.

Besides minor local movements, the Sierra Nevada was uplifted twice, elevating Mount Whitney to an altitude of 9000 feet above sea level.

At the beginning of the Pleistocene all the Kern Region including the San Joaquin Valley emerged above sea level and fresh water lake deposits occurred in place of the marine environment. The Sierra Nevada was again uplifted. Other deformations in the west originated the Coast Range Orogeny that rapidly increases in intensity with time. It culminates in Middle Pleistocene then decreases and terminates at the end of the epoch. Glaciation present in Northern California did not reach the Kern Region.

The mountains which encircle the Great San Joaquin Valley were all elevated to produce the general landscape that is almost the same as seen today. As the present time was approached general erosion was widespread, alluvial deposits were formed, some localized landslides occurred and deposition by the wind continued. Less and less tilting took place, as did less alteration and consolidation of the newly established soil. The more stable conditions were conducive to the growth of plants and animals as we see them today.
REFERENCES


8. Geologic Map of California, California Division of Mines & Geology, Sheets:

   Bakersfield, 1964, A. P. Smith.
   San Luis Obispo, 1958, C. W. Jennings.


APPENDIX H

A GUIDE TO A TYPICAL GEOLOGY REPORT

ABSTRACT

LOCATION OF PROPERTY AND TOPOGRAPHY

U.S.G.S. Topographic Quadrangles, preferably at the scale 1:24,000. If unavailable indicate topographic outline by approximate contours on the geologic map. Selected profiles will help to delineate the approximate topography.

Interpretation of the topography by discussion of land forms.

Recent changes in topography and their causes.

DRAINAGE (surface)

Main trunk and tributary streams and how controlled.

Erosional hazard.

Floods.

Evolution of drainage in time. Drainage damage caused by man's work.

DRAINAGE (Subsurface)

Zones of seasonal wetting and drying.

Water table and water bearing strata.

NATURAL VEGETATION

Types and density.

EARTH MATERIALS

Overburden

Fill Soil

Nature and Extent

Natural Soil

Type, classification, origin.

Geological features affecting suitability as a foundation material.

Difficulty of excavating.
A GUIDE TO A TYPICAL GEOLOGY REPORT (contd.)

Mass Movement

Type, cause and extent of.

Bedrock

Description.

Geologic structures.

Geological features affecting suitability as a foundation material.

GEOLOGICAL DISCUSSION

Consideration of geologic features of the general neighborhood which might affect this particular site.

ADJACENT PROPERTY

Where pertinent the report shall comment upon features evident in adjacent structures or public improvements in so far as they affect his evaluation of a particular site.

RECOMMENDATIONS

Opinion as to the soil stability and suitability of the property for its intended use with suitable warning regarding danger or potentially dangerous geological condition.

NOTE: SUFFICIENT COPIES OF THE GEOLOGICAL REPORT SHALL BE FURNISHED THE OWNER TO PROVIDE THREE COPIES TO THE PLANNING, PUBLIC WORKS AND BUILDING INSPECTION DEPARTMENTS.
APPENDIX H

DESIRED CONTENT OF GEOLOGICAL REPORTS

The purpose of this statement is to provide geologists who submit reports to the Public Works Department and Planning Department (EIR) with an understanding of what kinds of information, discussion, and recommendations are desired and/or required in order that such reports can be approved. It is recognized that certain geologic interpretations cannot be firm or complete, at least in advance of grading operations, but it is expected that all kinds of pertinent data will be presented fully and clearly, so that interpretations and recommendations can be critically reviewed by others. It also is recognized that different physical situations demand reports differing from one another in scope, length, and organization; most of the following comments are therefore intended to serve as a general guide and check list for those persons who prepare and use geological reports, rather than as a rigid framework of requirements.

GEOLOGICAL MAPPING

1. Each report must be a product of independent geologic mapping of the subject area at an appropriate scale and in sufficient detail to yield a maximum return of pertinent data. In connection with this objective, it may be necessary for the geologist to extend his mapping into adjacent areas.

2. All mapping should be done on a topographic base map with satisfactory horizontal and vertical control. The nature and source of the base map should be specifically indicated.

3. Mapping by the geologist should reflect careful attention to the lithology, structural elements, and three-dimensional distribution of the earth materials exposed or inferred within the area. In most hillside areas these materials will include both bedrock and surficial deposits. A clear distinction should be made between observed and inferred features and their relationships.

4. The nature and distribution of earth materials, faults, folds, landslides or other significant features should be shown on a geologic map to accompany the descriptive and analytical report. A detailed large-scale map will be required for a report on a tract or on a small area in which the geologic relationships are complex.

5. Where three-dimensional relationships are significant but cannot be described satisfactorily in words alone, the report should be accompanied by one or more appropriately positioned structure sections.

6. The locations of test holes and other specific sources of subsurface information should be indicated in the text of the report and if possible, on the map and any sections that are submitted with the report.

GENERAL INFORMATION

Each report should include definite statements concerning the following matters:

1. Location and size of subject area, and its general setting with respect to major geographic and/or geologic features.
2. Authorship of the geologic mapping upon which the report is based, and when it was done.

3. Amount of time spent in field work by the geologist.

4. Any other types of investigation made by the geologist; amount of time spent and, where pertinent, reasons for doing such work.

5. Topography and drainage in the subject area.

6. Abundance, distribution, and general nature of exposures of earth materials within the area.

7. Nature and source of available subsurface information. Suitable explanations should provide any technical reviewer with the means to assess the probable reliability of such data. (Subsurface relationships can be variously determined or inferred, for example, by projection of surface features from adjacent areas, by the use of test-hole logs, and by interpretation of geophysical data. Different sources of information can differ markedly from one another in degree of detail and reliability according to the methods used and the person or persons involved.)

GEOLOGIC DESCRIPTION

The report should contain brief but reasonably complete descriptions of all natural materials and structural features recognized or inferred within the subject area. Where interpretations are added to the recording of direct observations, the basis for such interpretations should be clearly stated.

The following check list may be useful as a general, though not necessarily complete, guide for descriptions:

1. Bedrock — igneous, sedimentary, metamorphic types.
   a. Identification as to rock type (e.g., granite, silty sandstone, mica schist).
   b. Relative age, and, where possible, correlation with named formations (e.g., Kern River formation, Round Mountain Silt and Kreyen Lagen Shale).
   c. Distribution.
   d. Dimensional features (e.g., thickness, outcrop length of exposure, vertical extent exposed or inferred).
   e. Physical characteristics (e.g., color, grain size, degree of sorting, texture, microstructure, hardness, compactness, coherence, or jointing).
   f. Special physical or chemical features (e.g., calcareous or siliceous cement, concretions, mineral deposits, alteration other than weathering).
   g. Distribution and extent of weathered zones; significant differences between fresh and weathered rock.
h. Response to natural surface and near-surface processes (e.g., raveling, gully ing, mass movement).

2. Structural features - stratification, foliation, schistocity, folds, zones of distortion or crushing, joints, shear zones, faults, etc.

a. Occurrence and distribution.

b. Dimensional characteristics.

c. Orientation, and shifts in orientation.

d. Relative ages (where pertinent).

e. Special effects upon the bedrock.

f. Specific features of faults (e.g., zones of gouge and breccia, nature of offsets, relative age of movements (historical record versus geological and seismological evidence).

3. Superficial (unconsolidated) deposits - artificial (man-made) fill, topsoil, subsoil, stream-laid alluvium, beach sands and gravels, residual debris lake and pond sediments, swamp accumulations, dune sands, marine and nonmarine terrace deposits, talus accumulations, creep and slope-wash materials, various kinds of slump and slide debris, etc.

a. Distribution, occurrence, and relative age; relationships with present topography.

b. Identification of materials as to general type.

c. Dimensional characteristics (e.g., thickness, variations in thickness, shape).

d. Surface expression and correlation with features such as terraces, dunes, undrained depressions, (sinks, sag-ponds) anomalous pretuberances (mounds, mogotes, inselberge, etc.).

e. Physical characteristics (e.g., color, grain size, hardness, compactness, coherence, cementation, permeability, porosity).

f. Special physical or chemical features (e.g., moisture content, mineral deposits, content of expandable clay minerals, alteration, cracks and fissures).

g. Distribution and extent of weathered zones; significant differences between fresh and weathered material.

h. Response to natural surface and near-surface processes (e.g., raveling, gullying, subsidence, creep, slope-washing, slumping and sliding).

4. Drainage - surface water and groundwater.

a. Distribution and occurrence (e.g., streams, ponds, swamps, springs, seeps, subsurface basins).
b. Relations to topography.

c. Relations to geologic features (e.g., pervious strata, fractures, faults).

d. Sources and permanence.

e. Variations in amounts of water (e.g., intermittent springs and seeps, floods).

f. Evidence of earlier occurrence of water at localities now dry (e.g., vegetation, mineral deposits, historic records).

g. The effect of water on the properties of the materials.

5. Features of special significance (if not already included in foregoing descriptions).

a. Features representing accelerated erosion (e.g., cliff reentrants, badlands, advancing gully heads).

b. Features indicating subsidence or settlement (e.g., fissures, scarp-lets, offset reference features, historic records and measurements).

c. Features indicating creep (e.g., fissures, scarp-lets, distinctive patterns of cracks and/or vegetation, topographic bulges, displaced or tilted reference features, historic records and measurements).

d. Slump and slide masses in bedrock and/or surficial deposits: distribution, geometric characteristics, correlation with topographic and geologic features, age and rates of movement.

e. Deposits related to recent floods (e.g., talus aprons, debris ridges, canyon-bottom trash).

f. Recent effects of faults upon topography and drainage.

THE BEARING OF GEOLOGIC FACTORS UPON LAND USE

Treatment of this general topic, whether presented as a separate section or integrated in some manner with the geologic descriptions, normally constitutes the principal contribution of the report. It involves both (1) the effects of geologic features upon the proposed grading, construction, and land use, and (2) the effects of the proposed modifications upon future geological processes in the area.

The geologist is in a better position than anyone else to correlate interpretations of natural processes in the historic and geologic past with the relationships between such processes and land use in the present and future. In doing this, he should make every effort to evaluate processes in terms of rate, distinguishing in this connection between geologic time and time in the engineering or human sense. Quantitative estimates concerning features such as natural compaction, bearing characteristics, and gross stability of earth materials, estimated rates of erosional processes and expected magnitude of ground movements, are highly desirable but should be offered only to an extent justified
by the geologist's normal area of competence and by the data at hand. Applied engineering procedures should be left within the purview of qualified engineers.

The following check list includes the topics that ordinarily should be considered in submitting discussions, conclusions, and recommendations in the geologic report:

1. General compatibility of natural features with proposed land use: Is it basically reasonable to develop the subject area?
   a. Topography.
   b. General bearing characteristics of earth materials.
   c. Lateral stability of earth materials.
   d. Problems of flood inundation, erosion, and depotism.
   e. Problems caused by features or conditions in adjacent properties.
   f. Problems related to:
      (1) Water pollution from waste disposal system.
      (2) Subsidence
   g. Other general problems.

2. Proposed cuts.
   a. Prediction of what materials and structural features will be encountered.
   b. Prediction of stability.
   c. Problems of excavation (e.g., unusually hard or massive rock, excessive flow of groundwater).
   d. Recommendations for reorientation or repositioning of cuts, reduction of cut slopes, development of compound cut slopes, special stripping above daylight lines, buttressing, protection against erosion, handling of seepage water, setbacks for structures above cuts, etc.

   a. General evaluation of planning with respect to canyon-filling side-hill masses of fill.
   b. Suitability of existing natural materials for fill placed under engineering control.
   c. Recommendations for positioning of fill masses, reduction in fill slopes, special preparation of ground to be loaded with fill, provision for underdrainage, buttressing, special protection against erosion, setbacks for structures near edges of fill prisms, etc.

4. Recommendations for subsurface testing and exploration.
   a. Cuts or trenches and test holes needed for additional geologic information.
b. Program of subsurface exploration and testing, based upon geologic considerations, that is most likely to provide data needed by the foundation engineer.

5. Special recommendations:
   a. Areas to be left as natural ground.
   b. Removal or buttressing of existing slide masses.
   c. Flood protection, erosion, landslides.
   d. Protection from wave erosion along shorelines.
   e. Problems of groundwater circulation (water quality control).
   f. Position of structures with respect to active faults.
   g. Suggestions for further work such as trenching drilling geophysical studies.
APPENDIX I

EARTHQUAKE SAFETY TIPS

Before
1. Store emergency supplies; food, water, first aid kit, flashlight and battery-powered radio.
2. Take a practical first aid course.
3. Locate main switches and valves that control the flow of water, gas, and electricity into your house. Know how to operate them.
4. Support community programs that inform the public and emergency personnel about earthquake preparedness.
5. Take action to help strengthen or eliminate structures that are not earthquake-resistant.
6. Support "parapet ordinances" that would remove dangerous, unreinforced overhangs and cornices from buildings.
7. Support building codes that require earthquake-resistant construction and careful foundation preparation and grading.
8. Support land use policies that recognize and allow for the potential dangers of active fault zones.
9. Heavy furniture above the fifth floor in tall buildings should be bolted to the floor.
10. Require guard rails across the inside of plate glass windows that extend to the floor.
11. Support basic research into the cause and mechanism of earthquakes and fault movement.

During
1. Don't panic even if you are frightened.
2. If you are indoors, stay there. Get under a desk, table, or doorway.
3. Do not rush outside. Falling debris has caused many deaths.
4. Watch for falling plaster, bricks, and other objects.
5. If you are outside, move away from buildings and power lines; stay in the open.
6. If you are in a moving car, stop as soon as it is safe. Remain in the car.

After
1. Check your family, or the people near you for injuries.
2. Inspect your utilities for damage to water, gas, or electrical conduits. If they are damaged, turn them off.
3. Extinguish open flames.
4. Do not use the telephone except to report an emergency.
5. Turn on your battery-powered radio for emergency information.
6. Don't go sightseeing.
7. Stay away from damaged structures; Aftershocks can cause the collapse of weakened structures.
8. Stay away from beaches and waterfront areas subject to seismic sea waves (commonly called "tidal waves").
APPENDIX J

YOU CAN REDUCE THE DANGER *

FOREWORD

Damaging earthquakes have been and will continue to occur in California.

How often can earthquakes be expected to occur in California? Dr. Robert Wallace, Assistant Chief Geologist, U.S. Geological Survey, Menlo Park, says, with regard to the San Andreas fault alone:

"At the present time we can make only generalized predictions about the occurrence of major earthquakes along the San Andreas fault zone based on past performances of the faults. For example, analysis of the record of seismic activity suggests that two successive magnitude 6 earthquakes somewhere along the San Andreas would occur every 5 years; that the interval for magnitude 7 quakes is 15 years; and that earthquakes of magnitude 8 might be expected at intervals of about 100 years."

And what might be the result of another great earthquake in the San Francisco Bay Area? The report of the California Legislature's Joint Committee for Seismic Safety contains the following scenario outlining the possibilities. "Casualties appear to be extremely heavy. Possibly several hundred have been killed and many thousands injured. The greatest concentration of casualties appears to be in the downtown areas. Medical facilities will face a tremendous overload."

Or in Southern California? C. Martin Duke, Professor of Engineering at the University of California at Los Angeles says, "It is distressingly easy to visualize 10,000 deaths."

While fires and floods may often be prevented or controlled, there is no feasible method yet known for heading off a major earthquake. Are we then helpless in the face of calamity? Not by a long shot! While we may not be able to prevent an earthquake, there are many positive things which all of us can do to prevent or reduce casualties and damages resulting from the quake.

Most earthquake casualties are inflicted in or below structures of one kind or another which are either designed, constructed, or located improperly with respect to the forces to which they are subjected. Anyone who would deliberately attempt to ride out an ocean storm in an improperly designed or constructed ship would be considered foolhardy. Yet here we sit, most of California's communities, in and below many tens of thousands of old structures designed and built with little or no knowledge of earthquake engineering or foundation geology, waiting to ride out a severe earthquake next year or in five years or, with great luck, in twenty years.

The following article outlines some of the things you can do as an individual, as a family, and as a part of your community to improve your odds of coming out of an earthquake intact.

... Wesley G. Bruer, State Geologist

* California Geol. November 1971

XIX-1
The circum-Pacific seismic belt follows the edge of the Pacific Ocean basin. It is along this belt that 80 percent of the world's earthquakes take place. The Alpide belt extends from Java to Sumatra, through the Himalayas, the Mediterranean, and out into the Atlantic. Seventeen percent of the world's earthquakes strike along the mid-Atlantic Ridge and elsewhere throughout the world.

INTRODUCTION

California often is referred to as earthquake country. Earthquakes are part of the state's heritage, and those who reside here must learn to live with them. The historical record of quakes in the state begins with 1769, when Gaspar de Portola's expedition was shaken by a large earthquake while camped on the Santa Ana River. Few detailed records were kept of earthquakes in California until after 1850 when the state's population began to grow rapidly. By 1900 studies were much more numerous and detailed, and the San Francisco earthquake of 1906 was one of the most widely documented of all. Unfortunately, community leaders attempted to suppress these studies believing that they would be "bad publicity for the community."

California is located on what is known as the "ring of fire," the volcanic belt which roughly coincides with the circum-Pacific seismic belt (see map). This belt curves around the basin occupied by the Pacific Ocean from the coast of Chile, northward along the Southern American coast through Central America, Mexico, and the west coast of the United States, and the southern part of Alaska, through the Aleutian Islands to Japan, the Philippine Islands, New Guinea, the Malanesian Islands, including the Solomons and the Fijis, to the islands of New Zealand. Eighty percent of the world's earthquakes occur along this belt, and all parts of this belt - including California - are jolted by numerous shocks. Other parts of the belt, such as the Aleutian Islands, Japan, and the Malanesian Islands, have more frequent earthquakes than California but, for the past 60
years, destructive earthquakes have occurred in California on the average of about once every two years.

At 0601 on the morning of 9 February 1971, millions of residents of California became acutely aware of the destructive forces of an earthquake. On that morning, the crust of the earth near San Fernando was relieved of some of the stresses that had built up in the rocks over a period of time. For 64 unlucky residents of the area, the ground shaking and subsequent damage to structures resulted in death. Luckier residents suffered no physical injury or only minor injury; however, subsequent events show that virtually everybody who experienced the quake will vividly recall the frightening feeling brought on by the sudden, unexpected, and violent movement of the ground. Aftershocks continued to alarm people for many days.

**CAUSES OF EARTHQUAKES**

Earthquakes are caused by movement of crustal material as the rocks of the earth adjust to tectonic forces. Recent conclusions derived from the synthesis of geologic data gathered primarily from the world’s ocean floors, indicate that the surface of the earth is composed of a number of more or less rigid plates. These plates are "floating" on a "plastic" zone of rock material. The frequency of earthquakes is highest where two plates are being pushed against each other or where one plate is overriding another, both of which occur in the circum-Pacific seismic belt.

The American plate includes both North and South America, and extends from the Mid-Atlantic ridge to the western coast of both of the continents. The San Andreas fault is a part of the western boundary of the American plate, according to some geologists. The crustal material west of the San Andreas fault is a part of the Pacific plate which is moving to the northwest. The stresses built up in the rocks as these plates are pushed into each other are released when the strength of the rock is exceeded, and the result is an earthquake.

In reality, most faults exhibit a combination of vertical and lateral movement, and are called oblique faults. The 1971 San Fernando earthquake, for example, resulted in measurable fault movement at the ground surface which consisted of a lateral component, during, which the rocks moved to the left, past each other, and a reverse vertical component. Such a combination of movements is called a "left oblique reverse fault." Thus, the San Gabriel Mountain block moved up, to the left, and out over the San Fernando Valley with a gross movement of as much as seven feet.

Even though many earthquakes are felt by the residents of California each year, they amount to only one one-hundredth of the many thousands of small quakes that are detected instrumentally in the state each year. One hundred thirty shocks were felt in California alone, while only one hundred ten were felt in all of the other states.

Fortunately, the potentially destructive earthquakes that occur in California do not always strike in areas inhabited by man or in which his structures are located. On 9 February 1971, when the earthquake hit the densely populated San Fernando area, we were unfortunate in the location; but had the quake struck at a different time of day, when schools, offices, and freeways were crowded, the death toll would have been much higher.
The San Fernando earthquake was one of the most devastating in the state's history. Although the magnitude of this temblor was 6.6 on the Richter scale, which ranks it as moderate to large but not great, a wide and heavily populated area was severely affected. In addition to the 64 deaths caused either directly or indirectly by the earthquake, the damage to property has been estimated to be over $500 million. Subsequent examination of the damage is revealing that the estimates of damage were low, indicating that the cost of the property damage may rise considerably higher.

**PREDICTION OF EARTHQUAKES**

By collecting data on earthquakes throughout the world, earth scientists are closer to being able to predict earthquakes accurately. Prediction has three parameters: 1) location, 2) magnitude, and 3) time. Crude estimates of the first two can now be made. We know, for example, that earthquakes are going to continue to occur throughout the world. We know that the frequency of earthquakes in the U.S. is going to be higher in the western states than elsewhere. Even more specifically, we know that the frequency of earthquakes in California is going to be highest along the faults that historically have been the most active. Therefore, it can be predicted that earthquakes will continue along the San Andreas fault, the San Jacinto fault, the Sierra Nevada fault, and the Hayward fault, among others. The San Fernando earthquake of 9 February 1971, however, was caused by crustal adjustments along a fault which was fairly well known but which was not considered to be particularly active. Obviously, then, accurate prediction of the location of future earthquakes is not yet possible.

We can also expect earthquakes to recur along these faults with at least the same magnitude that has been measured or estimated in the past, including earthquakes of both lesser and greater magnitude. The number of earthquakes for which the magnitude has been recorded is insufficient to allow reliable statistical determination of the probable maximum earthquake magnitude which can be expected along a given fault. To reiterate, then, we know we can expect large magnitude earthquakes where they have occurred before. Obviously, this is not an accurate prediction of magnitude.

The third parameter of prediction, the time of the earthquake is subject to even fewer deductions than are the first two parameters. Earthquakes have occurred in the past and, as State Geologist Wesley G. Bruer says in the foreword to this article: "Knowledgeable earth scientists unanimously agree that California will periodically experience severe earthquakes long into the future." Earthquakes will continue, but we don't have the ability to forecast the month, much less the day and the hour. Obviously, this is not an accurate prediction of the time of an earthquake.

It may eventually be possible to predict accurately the time, the place and the magnitude of an impending earthquake, and, in addition, to predict where the ground will rupture.

In summary, it is not yet possible to predict accurately the location, the magnitude, or the time of future earthquakes even though we can make some very general deductions. Basic research into the causes, frequency, and ground movement of earthquakes is necessary if we ever expect to understand these phenomena well.
enough to be able to predict them accurately. Basic research techniques include measurement of the rate of creep of two fault blocks past each other, measurement of the amount of tilt the earth's crust is undergoing, precise geodetic surveying and measurement of the amount of strain accumulating in the rocks of the crust, and measurement of vibratory ground motion during earthquakes. Laser beam ranging devices, tilt meters, strain meters, seismographs and accelerographs are some of the instruments used to measure these changes. Colleges and universities in California, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and the California Division of Mines and Geology all maintain active programs of basic earthquake research.

WHAT CAN BE DONE?

The accurate prediction of earthquakes may be far in the future, but we can take some immediate steps to reduce the loss of life caused by earthquakes. Constant improvement to the standards for the design and construction of structures is required. Most communities use the Uniform Building Code to guide them in requiring that certain standards be followed in construction practices. The Uniform Building Code is excellent for this purpose. Nevertheless, as new data are provided by basic earthquake research, even the Uniform Building Code must be modified so that recently acquired engineering data can be incorporated to increase the earthquake safety of construction practices required by the Code.

The accumulated knowledge concerning earth movement during an earthquake is presently adequate to design substantially earthquake-resistant structures that would appreciably reduce both injuries and deaths and would minimize the cost of quake-caused damage. Public schools in California built under the constraints of the Field Act of 1933 have borne this out.

Most deaths and injuries in earthquakes have been caused by falling debris or the collapse of structures. Other casualties have been caused by earthquake-triggered landslides, avalanches, fires, seismic sea waves (tsunamis), fallen power lines, and panic. Fault rupture or ground cracking itself seldom is the direct cause of death or injuries unless such ground cracking occurs under the foundation of a large building.

The initial damage to structures occurs during the first few seconds of the earthquake when the ground is accelerated suddenly. The frame of any building obviously must hold the roof and the floors of that building off the ground and must hold the walls of the building apart under normal conditions. Too many buildings, however, have been built without taking into account the additional strong horizontal and vertical forces likely to be exerted in a severe earthquake. This is particularly true of many older buildings but some changes in the Uniform Building Code are necessary to ensure the survival of new buildings subjected to the accelerations experienced during a moderate earthquake.

Even if the building survives the initial accelerations of the ground, sustained shaking may cause gradual disintegration of the building's components. The data gathered from many instruments that operated during the San Fernando earthquake will go far in helping to improve the design of buildings so that they can withstand both the initial accelerations and the sustained shaking.

Not so surprisingly, one-story wood-frame houses have performed well in many earthquakes throughout the world, even when they have been subjected to high
accelerations. This is because of the inherent flexibility of this type of structure.

Although there is no way to eliminate all earthquake dangers, injury and damage can be reduced substantially if the following steps are taken before, during, and after the quake.

**Before an Earthquake**

1. Potential earthquake hazards in the home should be removed or corrected. Top-heavy objects and furniture such as bookcases and storage cabinets, should be fastened to the wall and the largest and heaviest objects placed on lower shelves. Water heaters and other appliances should be firmly bolted down, and flexible connections should be used whenever possible.

2. Supplies of food and water, a flashlight, a first aid kit, and a battery-powered radio should be set aside for use in emergencies. Of course, this is advisable for other types of emergencies as well as for earthquakes.

3. One or more members of the family should have a knowledge of first aid procedures because medical facilities nearly always are overloaded during an emergency or disaster, or may themselves be damaged beyond use.

4. All responsible family members should know what to do to avoid injury and panic. They should know how to turn off the electricity, water, gas; and they should know the locations of the main switch and valves. This is particularly for teenagers who are likely to be alone with smaller children.

5. Programs that train policemen, firemen, and civil defense wardens how to perform effectively after an earthquake should be supported. One public agency should be designated as being responsible for organizing search-and-rescue activities. Studies of activity after the Good Friday earthquake in Alaska in 1964 concluded that people did what they had been trained to do. Firemen looked for fires to extinguish; policemen directed traffic and guarded against law violations; utility workers restored utilities; and administrators held meetings. A systematic search-and-rescue effort was not begun until a day and a half hours after the quake because no agency had immediate responsibility for this activity.

6. Pre-Field Act schools, older buildings, public facilities, and dams that are not earthquake resistant should be replaced or strengthened. As an example, the City of Long Beach, with a combination of foresight and fortitude, has enacted and is enforcing a very effective code dealing with structurally sub-standard buildings. Overhangs, cornices, and parapets on buildings pose an extreme hazard to public safety and should be securely fastened to the buildings or removed.

7. It is most important for a resident of California to be aware that this is "earthquake country" and that earthquakes are most likely to occur again where they have occurred before. Building codes that require earthquake-resistant construction should be vigorously supported and when enacted into law, should be vigorously enforced. It effective building codes and grading ordinances do not exist in your community, support their enactment.
8. Zoning ordinances should be enacted to limit the types of construction allowed in active fault zones.

9. Above the fourth and fifth floor in taller buildings, heavy objects such as desks, tables, and bookcases should be bolted or otherwise securely fastened to the floor or wall. Heavy furniture like this can become virtual battering rams under some conditions of earthquake shaking. Stout guard rails should be installed across windows which extend to the floor.

10. In new construction or in alterations of existing structures, building codes, if they exist, should be diligently followed to reduce and minimize potential hazards. Construction sites should be carefully selected, graded, and engineered to reduce all potential geologic hazards including landslides, subsidence, and the Effects of earthquakes.

11. Public safety agencies in your community should have reliable auxiliary communication equipment that can be operated during periods of emergency when regular power supplies may be interrupted.

12. Research to learn more about earthquakes, matching site selection to intended use, and construction of resistant structures should be strongly supported. In the home, at work, or at any other place, you should give some thought to what you would do in the event of an earthquake. Planning ahead may enable you to react effectively during such an emergency.

**During an Earthquake**

The most important thing to do during an earthquake is to remain calm. If you can do so, you are less likely to be injured. If you are calm, those around you will have a greater tendency to stay calm, too. Make no moves or take no action without thinking about the possible consequences. Motion during an earthquake is not constant; commonly, there are a few seconds between tremors.

1. If you are inside a building, stand in a strong doorway or get under a desk, table, or bed. Watch for falling plaster, bricks, light fixtures, and other objects. Stay away from tall furniture, such as china cabinets, bookcases, and shelves. Stay away from windows, mirrors, and chimneys. In tall buildings, it is best to get under a desk if it is securely fastened to the floor, and to stay away from windows or glass partitions.

2. Do not rush outside. Stairways and exits may be broken or may become jammed with people. Power for elevators and escalators may have failed. Many of the 115 persons who perished in Long Beach and Compton in 1933 ran outside only to be killed by falling debris and collapsing chimneys. If you are in a crowded place, such as a theater, athletic stadium, or store, do not rush for an exit because many others will do the same thing. If you must leave a building, choose your exit with care and, when going out, take care to avoid falling debris and collapsing walls or chimneys.

3. If you are outside when an earthquake strikes, try to stay away from high buildings, walls, power poles, lamp posts, or other structures that may fall. Falling or fallen electrical power lines must be avoided. If possible go to an open area away from all hazards but do not run through the streets. If you are in an automobile, stop in the safest possible place, which, of course, would be an open area, and remain in the car.
After an Earthquake

1. After an earthquake, the most important thing to do is to check for injuries in your family and in the neighborhood. Seriously injured persons should not be moved unless they are in immediate danger of further injury. First aid should be administered, but only by someone who is qualified.

2. Check for fires and fire hazards. If damage has been severe, water lines to hydrants, telephone lines, and fire alarm systems may have been broken; contacting the fire department may be difficult. Some cities such as San Francisco, have auxiliary water systems and large cisterns in addition to the regular system that supplies water to fire hydrants. Swimming pools, creeks, lakes, and fish ponds are possible emergency sources of water for fire fighting.

3. Utility lines to your house – gas, water, and electricity – and appliances should be checked for damage. If there are gas leaks, shut off the main valve which is usually at the gas meter. Do not use matches, lighters or open-flame appliances until you are sure there are no gas leaks. Do not use electrical switches or appliances if there are gas leaks, because they give off sparks which will ignite the gas. Shut off the electrical power if there is damage to the wiring; the main switch usually is in or next to the main fuse or circuit breaker box. Spilled flammable fluids, medicines, drugs, and other harmful substances should be cleaned up as soon as possible.

4. Water lines may be damaged to such an extent that the water may be off. Emergency drinking water can be obtained from water heaters, toilet tanks, canned fruits and vegetables, and melted ice cubes. Toilets should not be flushed until both the incoming water lines and outgoing sewer lines have been checked to see if they are open. If electrical power is off for any length of time, plan to use the foods in your refrigerator and freezer first before they are spoiled. Canned and dried foods should be saved until last.

5. There may be much shattered glass and other debris in the area, so it is advisable to wear shoes or boots and a hard hat if you own one. Broken glass may get into foods and drinks. Liquids can be either strained through a clean cloth such as a handkerchief or decanted. Fireplaces, portable stoves, or barbecues can be used for emergency cooking but the fireplace chimney should be carefully checked for cracks and other damages before being used. In checking the chimney for damage, is should be approached cautiously, because weakened chimneys may collapse with the slightest of aftershocks. Particular checks should be made of the roof line and in the attic because unnoticed damage can lead to a fire. Closets and other storage areas should be checked for objects that have been dislodged or have fallen, but the doors should be opened carefully because of objects that may have fallen against them.

6. Do not use the telephone unless there is a genuine emergency. Emergencies, and damage reports, alerts, and other information can be obtained by turning on your radio. Do not go sightseeing; Keep the streets open for the passage of emergency vehicles and equipment. Do not speculate or repeat the speculations of others – this is how rumors start.

7. Stay away from beaches and other waterfront areas where seismic sea waves (tsunamis), sometimes called "tidal waves," could strike. Again, your radio
is the best source of information concerning the likelihood that a seismic sea wave will occur. Also stay away from steep landslide-prone areas if possible, because aftershocks may trigger a landslide or avalanche, especially if there has been a lot of rain and the ground is nearly saturated. Also stay away from earthquake-damaged structures. Additional earthquake shocks known as "aftershocks" normally occur after the main shock, sometimes over a period of several months. These are usually smaller than the main shock but they can cause damage, too, particularly to damaged and already weakened structures.

8. Parents should stay with young children who may suffer psychological trauma if parents are absent during the occurrence of aftershocks.

9. Cooperate with all public safety and relief organizations. Do not go into damaged areas unless authorized; you are subject to arrest if you get in the way of, or otherwise hinder, rescue operations. Martial law has been declared in a number of earthquake disasters. In the 1906 disaster in San Francisco, several looters were shot.

10. Send information about the earthquake to the Seismological Field Survey to help earth scientists understand earthquakes better.
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APPENDIX L

GLOSSARY OF SELECTED TERMS

Alluvium  Fragmental rock material transported by flowing water and deposited in comparatively recent geological time. More or less sorted sediments, such as clay, silt, sand and gravel deposited in river beds, flood plains, estuaries, in lakes, on shores and in fans at the base of mountain slopes.

Amplification  Increase of the amplitude in an elastic wave which may occur at certain frequencies during an earthquake when the thickness of alluvium above bedrock reaches a certain value. (See Report page IV-37.)

Amplitude  The maximum displacement measured from a steady state point of reference, in the periodic motion of an elastic wave.

Anticline  An uparching fold in rocks in which the layers are inclined away from each other. The opposite of a syncline.

Bentonite  Soft, plastic, light colored rock capable of absorbing water and greatly increase its original volume (about 8 times). It is composed of colloidal silica and essentially clay minerals, chiefly montmorillonite. Also used for the preparation of drill muds in boring operations.

Bore hole  A hole drilled into the earth's crust to obtain subsurface information, extract petroleum, natural gas, soluble minerals and exploit geothermal resources.

Brecciated  Broken or crushed into angular fragments.

Cataclastic  Structure of a metamorphic rock produced by severe mechanical stresses and characterized by bending, breaking and granulation of the minerals.

Clay  A natural substance or soft rock made-up of the finest insoluble fraction of a soil or sediment and more or less plastic when mixed with water.

Cohesion  Shear strength of rock or sediment independent of interparticle friction. Particle capacity of sticking or adhearing together.

Colluvium  Loose rock fragments or soils deposited by landslides, mudflows, surface wash and soil creep.

Competent  Rock capable of withstanding an applied load under given conditions without failure or collapse. Capacity of rock to fold under pressure without flowage or change in original thickness.

Creep  (mass movement) Slow, gradual, more or less continuous, permanent deformation sustained by soil, rock material and ice under gravitational body stresses. In the case of landslides, it prepares the slope debris for more rapid mass movement by increasing permeability, decreasing shear strength and oversteepening slopes.

Creep  (tectonic) Continuously increasing, usually slow deformation of solid rock by a small, constant stress acting over a long period of time.

Deformation of Rock  A change in form or volume of the original rock produced by tectonic forces during faulting or folding.
Differential compaction (settlement) The compaction or settlement of soil and rock in different amounts in adjacent areas.

Dip The maximum measurable inclined angle of any planar geologic feature in rocks at a given point; denoted in degrees of downward from horizontal plane.

Displacement The amount of movement of one side of a fault relative to the other side.

Earthquake Sudden motion or trembling in the earth caused by the abrupt release of accumulated strain by faulting or by volcanic activity.

Epicenter Point on the earth's surface which is vertically above the focus or hypocenter from which elastic waves originate during an earthquake.

Fault A surface or zone of rock fracture in the earth along which one side has moved relatively to the other.

Active fault A fault that moved in recent geological time and which is likely to move again in the relatively near future. In the fault catalog (IV-page 25-26) this definition applies to classes: a. Historically active, and b. Quaternary Displacement.

Inactive fault A fault which shows no evidence of movement in recent geologic time and no evidence of potential movement in the relatively near future. These are the faults of class c. Such faults may eventually become again active when stresses in the earth change after a long period of time.

Fall (mass movement) A very rapid downward movement of a mass of rock or earth that travels mostly through the air by free fall, leaping, bounding or rolling; e.g. rockfall, debrisfall, soilfall.

Focus Hypocenter. The point which represents the position of initial rupture of the rocks where the first elastic waves originate at the outset of an earthquake.

Flow Mass movement of unconsolidated material that exhibits a continuity of motion and a plastic or semi-fluid behavior resembling that of a viscous fluid; e.g. creep, solifluxion, mudflow. No discrete slip or shear surfaces are discernible within the flow mass. Usually some water is required for most types of flow movement. It occurs on slopes which range from very gentle to steep.

Dry flow Rock, sand and silt gravity flow containing a minimum amount of water.

Wet flow Commonly results from torrential runoff following cloudbursts; e.g. mudflow.

Fold A bend or curve of a planar structure such as bedding planes in rock strata.

Footwall The underlying or lower side of a fault, dike or vein.

Ground failure The mechanical strength of the soil or rock has been exceeded so the particles are no longer held together. Ground failures include: landslides, subsidence, mudflow, liquefaction.
Ground response  The mechanical reaction of the soil and near surface layers to different amplitudes and frequencies of elastic waves in an earthquake.

Ground water  That part of the sub-surface water which forms the zone of saturation and includes underground streams.

Hangingwall  The overlying or upper side of a fault, dike or vein.

Hazard  An event happening unexpectedly, such as an unforeseen accident or disaster due to a cause either natural or man-made. (See Report, p. III-1 & IV-1.)

Hypocenter  See Focus.

Intensity  (seismic) The measurement at a given location of the physical effects produced by the energy released during an earthquake and expressed in degrees of severity on the Modified Mercalli Scale. (See Report, page IV-19.)

Inundation  Flooding caused by water.

Isoclinal fold  A fold in which the layers on each limb of the fold are inclined at the same angle.

Lurch  Earthquake warping movement of rock or soil at right angle to a cliff, a stream bank or an embankment that produces a series or more or less parallel fractures and steps along the unsupported direction.

Magnitude  (seismic) Measure of the total strain energy released by an earthquake as determined by seismographic observations made with standard instruments and expressed on a scale established by C.F. Richter. (See Report, page IV-19.)

Microseismic effect  Produced by low magnitude seismic waves and recorded on very sensitive instruments, usually not felt by people. Applied to the study of vibrations in soils and buildings.

Montmorrillonite  A clay forming mineral characterized by swelling in water due to its internal structure and chemical composition: Hydrous silicate of aluminum, magnesium and other elements in smaller amounts.

Mudflow  A flowing mass of predominantly fine-grained earth materials having a high degree of fluidity during movement. The fluidity varies with the proportion of water, clay and rock particles of various sizes. The velocity of mudflows has been recorded in some cases as being in excess of 50 miles per hour.

Pendant  Residual mass of older rocks surrounded, except at the top, by younger intrusive rocks.

Risk  Value of a possible loss resulting from the effect of a certain hazard or combination of several hazards occurring at a definite location at an indefinite time. (See Report, page V-17.)

Seiches  Earthquake-induced waves in lakes, ponds, reservoirs or tanks.

Seismic  Pertaining to the phenomena related to earthquakes or to manmade explosions.
Seismicity  Measure of the seismic activity of a definite region of the earth during a given historic time period. Usually expressed in strain-release energy units.

Shear  A strain resulting from forces which act to cause one part of a body to slide past the other when the mechanical strength of the body is exceeded and a fault develops as a result.

Slide  A mass movement resulting from the failure of earth materials under shear stresses along one or several surfaces that are either visible or easily inferred. The movement may be rotational or planar and the deformation of the mass may vary greatly. The velocity of movement is commonly rapid, but is usually inferior to that of mudflows and in particular that of rockfalls.

Stratigraphy  The branch of geology that deals with the definition and description of the natural divisions of rocks according to their chronological succession.

Strike  The bearing of a horizontal line in any planar geologic feature in rocks; denoted in degrees west or east or north.

Subsidence  A mass movement of the earth's surface that results in gradual downward settling or sinking with little or no horizontal motion and without the development of a free surface, as in sliding.

Syncline  A downmarching fold in rocks in which the layers are inclined toward each other. The opposite of an anticline.

Soil liquefaction  Change of a water saturated cohesionless soil to a liquid. Earthquake shaking accelerates this change.

Tectonics  A branch of geology that deals with the structural or deformational features of the earth, their origin and historical evolution.

Topographic map  Delineation of the physical features of the earth's surface which include in particular the elevation and contour of the land, rivers, lakes, seas and oceans.

Tsunami  An ocean wave produced by a large magnitude, shallow submarine earthquake, an earth movement or a volcanic eruption; sometime called erroneously a "tidal wave."

Unconformity  A substantial break or gap in the geological record where a rock unit is overlain by another that is not next in the stratigraphic succession, such as an interruption in the continuity of a depositional sequence of sedimentary rocks or a break between eroded igneous rocks and younger sedimentary strata. Correspond to a surface of erosion, or nondeposition or separating changes of dips between strata of different ages. (angular unconformity)

Unconsolidated material  Deposits consisting of uncemented or uncompacted particles. Alluvium, in general.

Water table  The upper surface of a body of unconfined ground-water at which the pressure is equal to that of the atmosphere. An "apparent water table" or perched water table is the upper surface of a body of unconfined ground-water separated by impervious rocks from an underlying main body of ground-water.
APPENDIX M

POLICIES AND CRITERIA OF THE STATE MINING AND GEOLOGY BOARD
WITH REFERENCE TO THE ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT
(CHAPTER 7.5, DIVISION 2, PUBLIC RESOURCES CODE, STATE OF CALIFORNIA)

(Adopted by State Mining and Geology Board November 21, 1973.)

The legislature has declared in the ALQUIST-PRIOLO GEOLOGIC
HAZARD ZONES ACT that the State Geologist and the State Mining and
Geology Board are charged under the Act with the responsibility of
assisting the Cities, Counties and State agencies in the exercise
of their responsibility to provide for the public safety in hazard-
ous fault zones. As designated by the Act, the policies and criteria
set forth hereinafter are limited to hazards resulting from surface
faulting or fault creep. This limitation does not imply that other
gologic hazards are not important and that such other hazards should
not be considered in the total evaluation of land safety.

Implementation of the ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT
by affected cities and counties fulfills only a portion of the
requirement for these counties and cities to prepare seismic safety
and safety elements of their general plans, pursuant to Section
65302 (F) and 65302.1 of the Government Code. The special study
zones, together with these policies and criteria, should be incorp-
orated into the local seismic safety and safety elements of the
general plan.

The State Geologist has compiled and is in the process of com-
piling maps delineating special studies zones pursuant to Section
2622 of the Public Resources Code. The special studies zones desig-
nated on the maps are based on fault data of varied quality. It
is expected that the maps will be revised as more complete geologi-
cal information becomes available. Also, additional special studies
zones may be delineated in the future. The Board has certain respon-
sibilities regarding review and consideration of those maps prior
to the time that they are finally determined. Cities, Counties
and State agencies have certain opportunities under the Act to
comment on the preliminary maps provided by the State Geologist
and these Policies and Criteria. Certain procedures are suggested
herein with regard to those responsibilities and comments.

Please note that the Act is not retroactive. Section 2623 of
the Public Resources Code provides that it applies to every pro-
posed new real estate development or structure for human occu-
pancy.

REVIEW OF PRELIMINARY MAPS

The State Mining and Geology Board suggests that each review-
ing governmental agency take the following steps in reviewing the
preliminary maps submitted for their consideration:
1. All property owners within the preliminary special studies zones mapped by the State Geologist should be notified by the Cities and Counties of the inclusion of their lands within said preliminary special studies zones by publication or other means designed to inform said property owners. Such notification shall not of necessity require notification by service or by mail. This notification will permit affected property owners to present geologic evidence they might have relative to the preliminary maps.

2. Cities and Counties are encouraged to examine the preliminary maps delineating special studies zones and to make recommendations, accompanied by supporting data and discussions, to the State Mining and Geology Board for modification of said zones in accordance with the statute and within the time period specified therein.

3. For purposes of the Act, the State Mining and Geology Board regards faults which have had surface displacement within Holocene time (about the last 11,000 years) as active and hence as constituting a potential hazard. Upon submission of satisfactory geologic evidence that a fault shown within a special studies zone has not had surface displacement within Holocene time, and thus is not deemed active, the Mining and Geology Board may recommend to the State Geologist that the boundaries of the special studies zone be appropriately modified.

The definition of active fault is intended to represent minimum criteria only for all structures. Cities and Counties may wish to impose more restrictive definitions requiring a longer time period of demonstrated absence of displacements for critical structures such as high-rise buildings, hospitals, and schools.

SPECIFIC CRITERIA

The following specific and detailed criteria shall apply within special studies zones and shall be included in any planning program, ordinance, rules and regulations adopted by Cities and Counties pursuant to said GEOLOGIC HAZARD ZONES ACT:

A. No structure for human occupancy shall be permitted to be placed across the trace of an active fault. Furthermore, the area within fifty (50) feet of an active fault shall be assumed to be underlain by active branches of that fault unless and until proven otherwise by an appropriate geologic investigation and submission of a report by a geologist registered in the State of California. This 50-foot standard is intended to represent minimum criteria only for all structures. It is the opinion of the Board that certain essential or critical structures, such as high-rise buildings, hospitals, and schools should be subject to more restrictive criteria at the discretion of cities and counties.

B. Applications for all real estate developments and structures
for human occupancy within special study zones shall be accompanied by a geologic report prepared by a geologist registered in the State of California, and directed to the problem of potential surface fault displacement through the site, unless such studies are waived pursuant to Section 2623.

C. One (1) copy of all such geologic reports shall be filed with the State Geologist by the public body having jurisdiction within thirty days of submission. The State Geologist shall place such reports on open file.

D. Requirements for geologic reports may be satisfied for a single 1 or 2 family residence if, in the judgment of technically qualified City and County personnel, sufficient information regarding the site is available from previous studies in the same area.

E. Technically qualified personnel within or retained by each City or County must evaluate the geologic and engineering reports required herein and advise the body having jurisdiction and authority.

F. Cities and Counties may establish policies and criteria which are more restrictive than those established herein. In particular, the Board believes that comprehensive geologic and engineering studies should be required for any "critical" or "essential" structure as previously defined whether or not it is located within a special studies zone.

G. In accordance with Section 2625 of the Public Resources Code each applicant for a building permit within a delineated special studies zone shall pay to the City or County administering and complying with the ALQUIST-PRIOLO GEOLOGIC HAZARD ZONES ACT a fee of one-tenth of one-percent of the total valuation of the proposed building construction for which the building permit is issued as determined by the local building official.

H. As used herein the following definitions apply:

1. A "structure for human occupancy" is one that is regularly, habitually or primarily occupied by humans.

2. A geologist registered in the State of California is deemed to be technically qualified to evaluate geologic reports.

3. Any engineer registered in the State of California in the appropriate specialty is deemed to be technically qualified to evaluate engineering reports in that specialty.
EXPLANATION OF SPECIAL STUDIES ZONES MAPS
COMPILED BY THE STATE GEOLOGIST

Requirements

Maps showing special studies zones were compiled in compliance with Chapter 7.5, Division 2, of the California Public Resources Code. This Chapter, which may be cited as the Alquist-Priolo Geologic Hazards Zones Act, requires the State Geologist to 1) "delineate, by December 31, 1973, appropriately wide special studies zones to encompass all potentially and recently active traces of the San Andreas, Calaveras, Hayward, and San Jacinto Faults..."and such other faults..."that"... constitute a potential hazard to structures from surface faulting or fault creep"; and 2) compile maps of special studies zones and submit such maps to affected cities, counties, and state agencies by December 31, 1973, for their review and comment. Following appropriate reviews, the State Geologist must provide "official maps" to the affected cities, counties, and state agencies.

The State Geologist also is required to "continually review new geologic and seismic data" in order to revise the special studies zones or delineate additional zones.

This chapter requires cities and counties to exercise specified approval authority with respect to real estate development or structures for human occupancy within the special studies zones. Specific Policies and Criteria to assist local jurisdictions are provided by the State Mining and Geology Board. Other requirements and guidelines are provided by the State Mining and Geology Board. Other requirements and guidelines are provided in the Alquist-Priolo Act.

Special Studies Zones

Special studies zones are delineated on topographic base maps at a scale of 1:24,000 (1 inch equals 2000 feet). The zone boundaries are straight-line segments defined by turning points. Each turning point is identified by a number on the map for reference.

The intent of the Alquist-Priolo Act is to provide for public safety from the hazard of fault rupture by avoiding, to the extent possible, the construction of structures for human occupancy astride hazardous
faults. The precise location and identification of hazardous faults within or near a zone of potentially active faults can be determined only through detailed geologic investigations. Thus, this Act establishes the concept of a Special Studies Zone — an area of limited extent centered on recognized faults. Faults other than those depicted on the maps may be present within the Special Studies Zones. The zone boundaries delimit the area that the State Geologist believes warrants special geologic investigations to detect the presence or absence of hazardous faults.

Locations of special studies zone boundaries are controlled by the traces of potentially active faults (defined below), which are based on the best data available at the time the map was compiled. However, the faults shown on the Special Studies Zones maps were not field checked during the compilation of these maps. Because available fault data are highly varied in quality and the locations of some faults are known imprecisely, the zone boundaries have positioned at a reasonable distance (about 660 feet or an eighth of a mile) from the trace of the nearest potentially active fault. However, zone boundaries generally are more or less than 660 feet away from mapped faults because of 1) curved or multiple fault traces, 2) of the need to keep the number of turning points to a reasonable minimum, or 3) the quality of the data dictates a narrower or wider zone.

Definitions of Fault Terms

Fault, fault zone

A fault is defined as a fracture or zone of closely associated fractures along which rocks on one side have been displaced with respect to those on the other side. Most faults are the result of repeated displacement which may have taken place suddenly and/or by slow creep. A fault zone is a zone of related faults which commonly are braided and subparallel, but may be branching and divergent. It has significant width (with respect to the scale at which the fault is being considered, portrayed, or investigated), ranging from a few feet to several miles.

Fault trace

A fault trace is the line formed by the intersection of a fault and the earth's surface. It is the representation of a fault as depicted on a map, including maps of the Special Studies Zones.
Potentially active faults

For the purposes of delineating Special Studies Zones, any fault considered to have been active during Quaternary time (last 3,000,000 years) — on the basis of evidence of surface displacement — is considered by the State Geologist to be potentially active. An exception is a Quaternary fault which is determined, from direct evidence, to have become inactive before Holocene time (last 11,000 years). Such a fault is presumed to be essentially inactive and has been omitted from the map in most cases. Although faults shown on the maps may have been active during any part of, or throughout, Quaternary time, evidence for the recency of displacement is incompletely preserved and often is equivocal. In contrast, the State Mining and Geology Board, in their Policies and Criteria (adopted November 21, 1973), has defined any fault which has had surface displacement within Holocene time as "active and hence as constituting a potential hazard."

The surface ruptures associated with historic earthquake and creep events are identified where known. No degree of relative potential for future surface displacement or degree of hazard is implied for the faults shown.

The following geologic time scale is provided for reference and perspective:
<table>
<thead>
<tr>
<th>Era</th>
<th>Epoch</th>
<th>Radiometric Age Million Years Before Present</th>
<th>Marine Formations</th>
<th>Terrestrial Formations</th>
<th>Eogeny</th>
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<td>Holocene</td>
<td></td>
<td></td>
<td></td>
<td>Sierra last uplift</td>
</tr>
</tbody>
</table>

**Formations:***
- Alluvium: River & Lake deposits; Untilled
- Alluvium: Melted
- Rancholabrean
- Irvingtonian 1.5
- McKinley tar sands
- Black Mt. basalt
- Andesite flows
- Basalt flows
- Tuffs
- Monterey
- Cretaceous
- Cenozoic
- Oligocene
- Miocene
- Pliocene
- Pleistocene
- Holocene

**Eogeny:**
- San Ardoan
- Tehachapi
- Sierra new mts.
USES AND LIMITATIONS OF SPECIAL STUDIES ZONES MAPS

Users of these maps should be fully aware that the zones are delineated to define those areas within which special studies may be required prior to building structures for human occupancy. Traces of potentially active faults are shown on the maps mainly to justify the locations of zone boundaries. These fault traces are plotted as accurately as the sources of data permit; yet the plots are not sufficiently accurate to be used as the bases for set-back requirements.

The State Geologist has identified potentially active faults in a broad sense, and the evidence for the potential activity of some faults may be only weak or indirect.

The fault information shown on the maps is not sufficient to meet the requirement for special studies. The onus is on the local governmental units to require the developer to evaluate specific sites within the special studies zones to determine if a potential hazard from any fault, whether heretofor recognized or not, exists with regard to proposed structures and their occupants.

Copies of the State maps are on file at the Kern County Planning Department, 1103 Golden State Highway, Bakersfield, California.