In compliance with AB 2140 (2006), the 2025 Siskiyou County Local Hazard Mitigation Plan (LHMP) is herein incorporated and made a part of the Seismic Safety and Safety Element of the Siskiyou County General Plan.

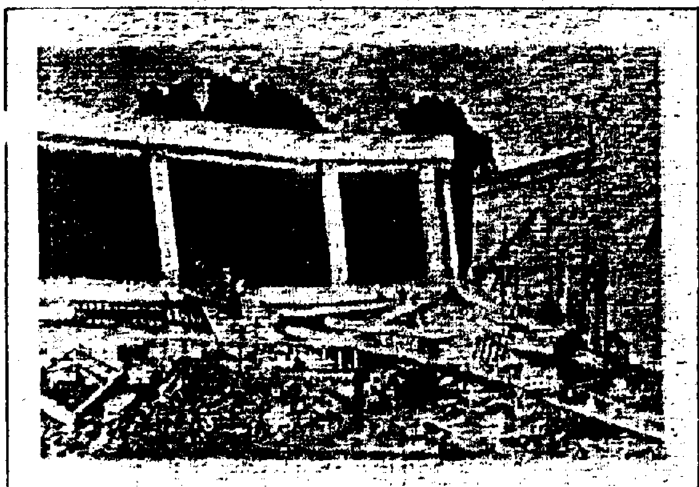
2025 LOCAL HAZARD MITIGATION PLAN

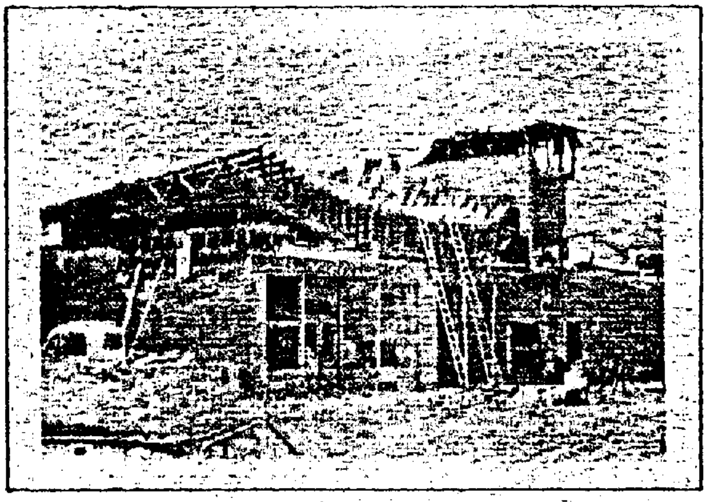
The 2025 Local Hazard Mitigation Plan (LHMP) for the Siskiyou County planning area was developed in accordance with the Disaster Mitigation Act of 2000 (DMA 2000) and followed FEMA's Local Hazard Mitigation Plan guidance. The LHMP incorporates a process where hazards are identified and profiled, the people and facilities at risk are analyzed, and mitigation actions are developed to reduce or eliminate hazard risk. The implementation of these mitigation actions, which include both short and long-term strategies, involve planning, policy changes, programs, projects, and other activities.

To view the 2025 LHMP in its entirety please visit:

https://www.siskiyoucounty.gov/emergencyservices/page/local-hazard-mitigation-plan

SEISMIC SAFETY AND SAFETY





SISKIYOU COUNTY GENERAL PLAN

Prepared by Siskiyou County Planning Department, June 1975

RESOLUTION

RESOLUTION OF THE BOARD OF SUPERVISORS OF THE COUNTY OF SISKIYOU, STATE OF CALIFORNIA ADOPTING THE SEISMIC SAFETY AND SAFETY ELEMENT OF THE SISKIYOU COUNTY GENERAL PLAN FOR SAID COUNTY

WHEREAS the Siskiyou County Planning Commission by its Resolution 1976-1 did on the 21st day of January 1976 adopt the proposed Seismic Safety and Safety Element for the Siskiyou County General Plan, and

WHEREAS, a Negative Declaration was prepared, reviewed and certified as complete, and

WHEREAS, this Board of Supervisors did on the 24th day of February 1976 hold a Public Hearing thereon, notice thereof having been given as prescribed by law, and at which time all interested persons were afforded opportunity to be heard thereon, and

WHEREAS, all comments, requests and suggestions received at said hearing were given due and deliberate consideration in connection with the objectives and purposes of the proposed element, now

THEREFORE BE IT RESOLVED by the Board of Supervisors of County of Siskiyou, State of California in regular session assembled this 24 day of February, 1976 that the Seismic Safety and Safety Element of of the Siskiyou County General Plan be and is hereby adopted as part of the General Plan for Siskiyou County, and

BE IT FURTHER RESOLVED, that the Planning Director is directed and authorized to certify the Seismic Safety and Safety Element to any concerned agencies.

The foregoing Resolution was introduced by Supervisor Hayden who moved it adoption, seconded by Supervisor Porterfield and adopted by the following vote:

AYES: Supervisors Hayden, Porterfield, Wacker and Torrey.

NOES: None.

ABSENT: Supervisor Belcastro

There upon the Chairman declared the above and foregoing Resolution duly adopted and so ordered.

[signature]

Chairman, Siskiyou County Board of Supervisors

ATTEST: NORMA FRICE, CLERK BOARD OF SUPERVISORS

[signature] Deputy

Clerk, Siskiyou County Board of Supervisors

RESOLUTION 1976-1

RESOLUTION OF THE PLANNING COMMISSION OF THE COUNTY OF SISKIYOU ADOPTING THE SEISMIC SAFETY AND SAFETY ELEMENT OF THE SISKIYOU COUNTY GENERAL PLAN FOR SISKIYOU COUNTY, STATE OF CALIFORNIA

WHEREAS, this Commission did cause to be prepared a Seismic Safety and Safety Element of the General Plan for Siskiyou County and,

WHEREAS, in accordance with the provisions of law a public hearing was held on the 21st day of January 1976, notice having been given in the time and manner specified by law in which all interested persons were afforded opportunity to be heard thereon, and

WHEREAS, a Negative Declaration was approved by the Planning Commission on January 7, 1976, certifying that the adoption of this element would not have a significant effect on the environment, and

WHEREAS, all comments received at the aforesaid hearing were duly considered, now

THEREFORE be it resolved by the Siskiyou County Planning Commission in regular session this 21st day of January 1976 this document entitled Seismic Safety and Safety Element of the Siskiyou County General Plan be and is here adopted and be it further resolved, that this Commission recommends that the Board of Supervisors of the County of Siskiyou hold a Public Hearing thereon in the manner prescribed by law and do adopt said Seismic Safety and Safety Element of the Siskiyou County General Plan.

The foregoing resolution was introduced by Commissioner Steinhaus who moved its adoption, seconded by Commissioner Radcliffe and adopted by the following roll call vote:

AYES: Lange, Nilsson, Martin, Radcliffe, Steinhaus, Cedros,

NOES:

ABSENT: Cannon, Hillery

So ordered,

[signature]

Chairman, Siskiyou County Planning Commission

ATTEST:

[signature]

Secretary, Siskiyou County Planning Commission

SISKIYOU COUNTY

SEISMIC SAFETY AND SAFETY ELEMENT

TABLE OF CONTENTS

THE SISKIYOU COUNTY SAFETY AND SEISMIC SAFETY ELEMENT TO THE GENERAL PLAN

INTRODUCTION

The Safety Element and the Seismic-Safety Element to the county's General Plan are required by the Government Code, Section 65302. The purpose of these elements is to examine the particular, physical needs of a county in relation to safety and seismic-safety, and to establish procedures for the orderly development of the county relative to physical problems. Because of the similarity in the requirements of these two elements, and to avoid duplication of effort, the county has chosen to write these two elements into a single document. As with each of the other elements to the county's General Plan, one must bear in mind that these elements while individually separate all interact and form the total development program for the county.

Many of the recommendations that are listed in the seismic-safety portion of this element will not be repeated in the safety portion. The purpose of this is for simplicity only and the recommendation which apply to seismic-safety would, of course, apply to the Safety Element.

The Seismic Safety Element is required and defined in Section 65303 (f) of the Government Code. This Element is mandated to be a part of the general plan of all cities and counties, and reads 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.

The effect of this section is to require cities and counties to take seismic hazards into account in their planning programs. All seismic hazards need 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.

It has been the policy of the Boards of Supervisors of this county throughout its history to assure the residents of the county a life of safety and prosperity in all aspects of living coming within their ability to control. This is a county of vast wealth: timber, agriculture, and mineral. This is, also, an area of vast geographic diversity. This is a part of her wealth. However, this geographic diversity is one of our greatest problems.

Man has learned, and is continuing to learn to harvest this county's wealths without destroying its resources. We have not, however, learned to control the natural hazards of the county. Since we cannot control hazards, our prime goal must be to learn to live with these hazards and minimize their effects.

Generally, Siskiyou County is an area of low seismic activity within recent times. Obviously, our county was at one time very active seismically. Numerous faults cross the landscape. Volcanos dot the countryside, but most show insignificant recent, if any, disturbance.

We must accept the fact that an earthquake can occur at any time and any place.

To assure common understanding and a reference for discussion, Section I is a summary and analysis of the basic language and processes involved in seismic activity.

House built across fault at Wright's Station. 1906 earthquake.

GENERAL INFORMATION AND GLOSSARY ON EARTHQUAKES AND SEISMIC HAZARDS

SECTION I

GENERAL INFORMATION ON EARTHQUAKES

Earthquakes are caused by the sudden rupturing of the earth along faults (weak portions of the earth's crust). It is believed that this rupturing relieves stress that has been building up in the earth's crust. It is also generally believed that this stress is caused by the movement of plates in the earth's crust. As these crustal plates move against or past one another, stress develops which causes the crust on the edge of each plate to become deformed. When too much deformation builds up, the rocks snap along a fault. This relieves the strain by allowing each side of the fault to move to a position of lower stress.

The mechanism of the movement of a fault is explained by the Elastic Rebound Theory. Robert J. Foster has described how this theory explains the 1906 San Francisco earthquake: "Accurate surveys, which had been made on both sides of the fault before the earthquake, show that a small amount of movement had occurred between the time of the surveys. Resurvey after the earthquake showed that about 20 feet of absolute horizontal movement occurred in the earthquake, in agreement with the 20 feet of relative movement measured by surface features. This led to the theory that earthquakes occur when the energy stored by elastic deformation in the rocks on both sides of the fault is enough to rupture the rocks or to overcome the friction on the existing plane. This elastic rebound theory process. . . . explains the surface deformation of most earthquakes. Friction on the fault plane may cause sticking after some movement has occurred, and so the total strain may not be relieved in a single earthquake." *(See Figure 1)

The type of stress build-up discussed above is common along the margins of moving plates in all the earth's earthquake belts. California is located in one of the belts of greatest stress development - the Circum-Pacific Seismic Belt.

The fault which separates two plates is not always perceivable on the earth's surface, but there are land forms, geologic criteria and instrumentation which can be used to map its location. The fault is not one solid, continuous line, but is composed of a system of splinter faults which appear periodically on the earth's surface. The term fault trace is used to describe a line on the surface of the earth formed by the intersection of the fault with the earth's surface.

Ground rupture and cracking are surface expressions of earthquakes which originate on subsurface faults. Earthquakes occur at various depths within the earth's crust. The point below the surface where the rupture first occurs is known as the focus and can be located with the help of seismic instruments. The news media usually use the term "epicenter" to describe the

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*Robert J. Foster, PHYSICAL GEOLOGY, Charles E. Merrill Publishing Co., Columbus, Ohio, 1971.

point of initial rupture. Used in this context, the term is a misnomer. The epicenter of an earthquake is measured in two ways. The instrumental epicenter is that point on the earth's surface directly above the focus but may not be the area of maximum damage.

For planning purposes there are two kinds of faults: (1) active faults which have experienced displacement in recent geologic time, suggesting that future displacement can be expected on these faults; and (2) inactive faults that have shown no evidence of movement in recent geologic time, suggesting that these faults are dormant. However, some faults labeled as inactive are so termed due to lack of knowledge. Increased research and monitoring of these faults could reveal some of them as active.

California is interlaced with hundreds of active faults. The most important fault system is the San Andreas fault, which extends from south of Los Angeles to north of San Francisco. The main branch of this fault runs through Hollister and up the San Francisco peninsula. It enters the ocean at Daly City and runs through the mouth of Tomales Bay to Marin County. A branch of the San Andreas fault is the Hayward fault, which extends from Fremont, through Hayward, San Leandro, Oakland, Berkeley, Richmond and San Pablo. This fault has been responsible for at least two major earthquakes. (See Figure 2)

Earthquakes are not all the same. They can range from a minor disturbance to a catastrophic event. How then can we tell the difference between quakes and compare then to each other?

Figure 1

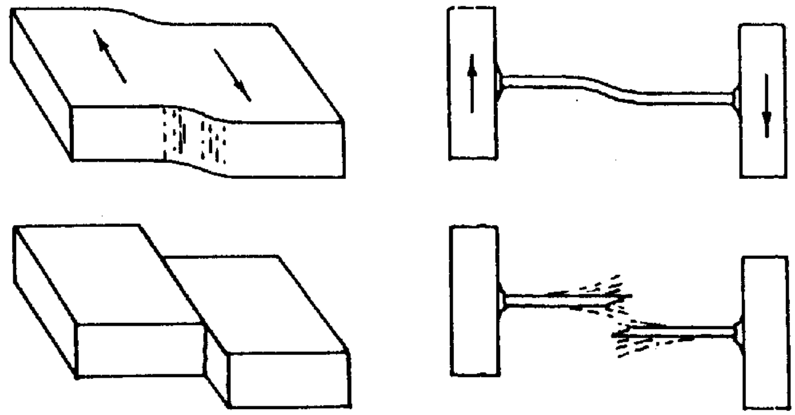
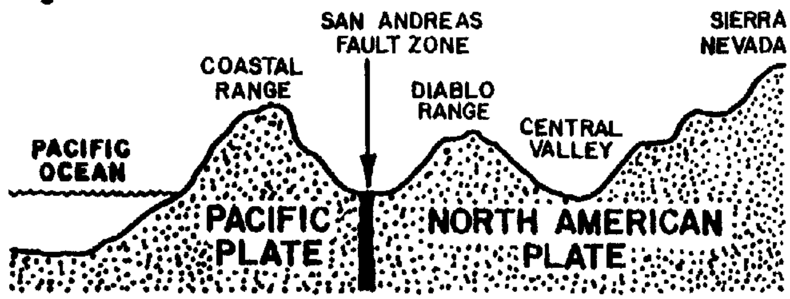


Figure 2



A Simplified Cross Section of San Andreas Fault Zone to Emphasize Location of Boundary Between Crustal Plates

Origin of earthquakes. A portion of the earth's crust is shown on the left and a limber stick on the right.

A. Slow deformation of the crust is caused by internal forces.

B. When the strength of the rocks is exceeded, they rupture or fault, producing earthquake vibrations. Earthquakes on old faults result when the friction along the plane of the old break is exceeded.

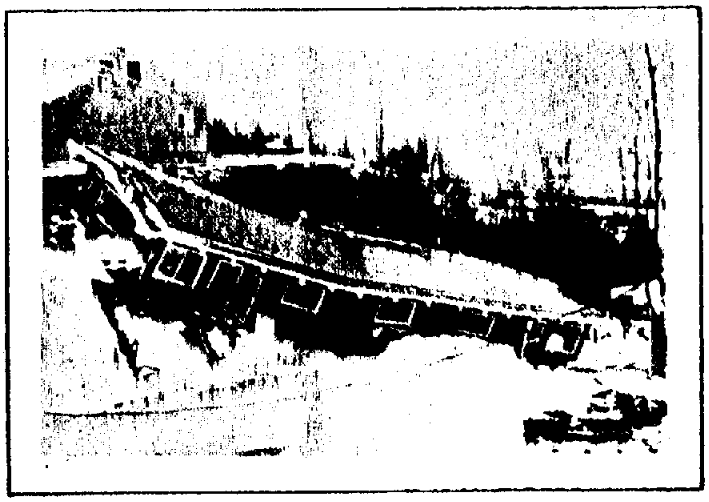
The first attempt to classify earthquakes involved a description of their intensity. The scale used to measure the intensity of a quake is the Modified Mercalli scale with intensities ranging from I to XII. (See Table I for the Modified Mercalli Scale with written descriptions of observations.)

Intensity is a description of the physical effects of earthquakes. The lowest intensity ratings are based on human reactions, such as "felt indoors by few". The highest intensities are measured by geologic effects, such as "broad fissures in wet ground, numerous and extensive landslides, and major surface faulting". The middle intensity range is based largely on the degree of damage to buildings and other man-made structures. Intensity ratings are based on visual observation and are not measured with instruments. The degree of intensity varies from place to place during an earthquake. Specific locations in an area may have an intensity rating of VIII because of soil conditions and type of building structure, while other locations affected by the same earthquake may only have an intensity of IV. Therefore, a single earthquake can have different intensity ratings based on geologic conditions, structural design, or distance from field epicenter.

In 1932, Charles Richter developed a system of tables and charts to deduce from seismological instruments a method of measuring the magnitude of an earthquake. The magnitude assigns a number to the calculated energy release of the earthquake. Because numbers are assigned to the calculated energy release, this system can rank earthquakes and compare them one to another. By this method, an earthquake is rated independently of the place of observation.

The magnitude is the logarithm (base 10) of the maximum amplitude of a seismogram referred to a distance of 62 miles from the epicenter. Under this system, an increase of one degree in magnitude is equal to 32 times the previous energy release. Thus an earthquake of magnitude 7 represents about 32 times as much energy release as one of magnitude 6; magnitude 8 represents 32 times the energy of magnitude 7 and, therefore, about 1000 times the energy of magnitude 6.

Crustal movement and faulting are evolutionary processes in the earth's geologic history. These geologic processes have a direct impact on man and his activities when they occur in an urbanized area. Therefore, an understanding of the different types of seismic expression and their effect on development is necessary for an effective program of seismic risk reduction.



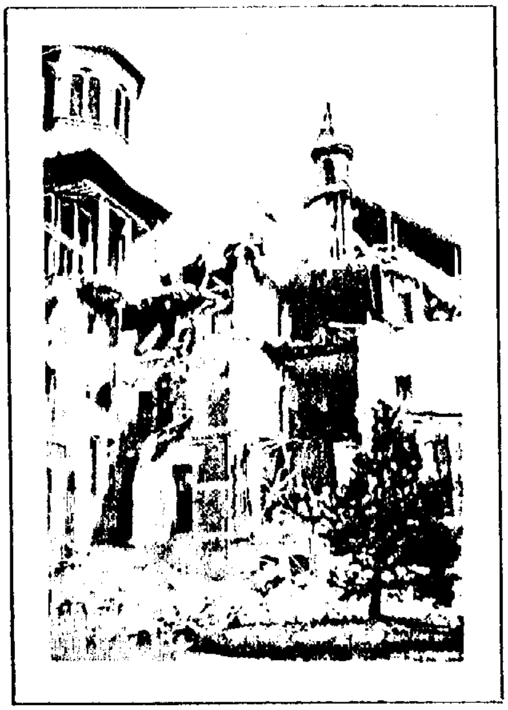
House in slide area, 1964 Alaska earthquake.

SECTION II

SEISMIC HAZARDS*

Donald R. Nichols
U. S. Geological Survey
Menlo Park, California

Earthquakes commonly give rise to various geologic processes that may cause severe damage to structures and loss of life to people in them. These processes include surface faulting, ground shaking, associated ground failure, generation of large waves in bodies of water, and regional subsidence or downwarping.



Effects of ground shaking.

Agnew State Hospital, 1906. 112 people killed.

*Excerpts from manuscript in preparation.

These seismic hazards vary widely from area to area, and the level of hazard depends on both geologic conditions and the extent and type of land use. This section concerns itself with a description of geologic conditions that may contribute to seismic risk, how to determine their significance in a given area, and the level of data desirable for land-use decisions.

Surface Faulting. The earth is laced with faults--planes or surfaces in earth materials along which failure has occurred and materials on opposite sides have moved relative to one another in response to the accumulation of stress. Most of these faults have not moved for hundreds of thousands or even millions of years and thus can be considered inactive. Others, however, show evidence of current activity or have moved sufficiently recently to be considered active; i.e., capable of displacement in the near future. Any fault movement beneath a building in excess of an inch or two could have catastrophic effects on the structure, depending upon its design and construction, and the shaking stresses it experiences at the same time. Therefore it is important to know not only which faults may move but how they might move.

The definition of what constitutes an "active fault" may vary greatly according to the type of land use contemplated or to the importance of the structure. For example, the Atomic Energy Commission regards a fault as active or "Capable" with respect to nuclear reactor sites if it has moved "at or near the ground surface at least once in the past 35,000 years", or "more than once in the past 500,000 years" (Atomic Energy Commission, 1974). A definition for purposes of town planning in New Zealand defines as active, any fault on which "movement has taken place at least once in the last 20,000 years", originally published as 1,000 years by typographical error (Town and Country Planning Branch, 1965). Commonly, faults are regarded as active and of concern to land-use planning when there is evidence that they have moved during historic time or, through geologic evidence there may be a significant likelihood that they will move during the projected use of a particular structure or piece of land. Because geologic evidence may be lacking, obscure, or ambiguous as to specific times of past movement, geologists may be able to estimate relative degree of activity only after a regional analysis that may extend far beyond the locality under consideration. Such analysis may be based on historic evidence of fault movement, seismic activity (occurrence of small to moderate earthquakes along the fault trace even though not accompanied by obvious fault movement), displacement of recent earth layers (those deposited during the past 10,000 years), and presence of topographically young fault-produced features (scarps, sag ponds, offset stream courses and disruption of man-made features such as fences, curbs, etc.) However, movement seldom is limited to a single fault surface throughout the lifetime of a fault system such as the San Andreas. In many places tens, or even hundreds, or thousands of individual fault surfaces made up the San Andreas in a zone varying in width from a few hundreds to many thousands of feet. Any individual fault surface may have ruptured at any time during the last 40 million years or so that the fault has been active. It is speculated, however, that most of these surfaces probably have not moved in millions of years, and only infrequently may a new rupture surface develop or is fault movement transferred from one part of the fault zone to another. Faults that commonly produce significant displacement (more than several inches at a time) often have related branches that diverge from the main fault but usually have less movement along them. They may also have secondary faults that are not directly or obviously connected physically to the main fault trace. Secondary faults are usually nearby (within hundreds of feet) of the main rupture, but they may extend as much as several miles away. As with branch faults, displacement along secondary faults is usually only a fraction of that along a main fault.

The amount of displacement that can occur during a single earthquake can be related in a general way to the total length of a fault. The longer the fault, the greater the potential for a great earthquake and the greater amount of displacement likely (Albee and Smith, 1967; Bonilla, 1970). The maximum displacement ever recorded during a single earthquake is about 42 feet of vertical displacement (Bonilla, 1970). Horizontal movement of as much as 20 feet occurred along the San Andreas fault in 1960 (Bonilla and Buchanan, 1970).

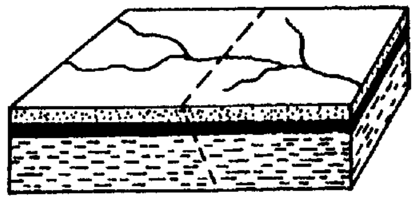
In addition to the location and amount of displacement, the sense of movement is extremely important in estimating the amount and type of damage that might be produced. This was evidenced by the great damage over faults during the moderate (magnitude 6.6) San Fernando earthquake, which produced a reverse or thrust fault movement. (See Figure 3b). Movement occurs along a similar plane, but in an opposite direction on the normal Wasatch fault in Utah. (See Figure 3c). Left-lateral movement (Figure 3d) and right-lateral movement, which is common to the San Andreas fault, probably are less potentially damaging to most structures than normal or thrust faulting.

Not all surface faulting need be rapid nor need it occur during major earthquakes. Imperceptibly slow movement, called "fault creep" occurs along the Hayward, Calaveras, and some other faults, and may be accompanied by microearthquakes. Similarly, not all deformation of the earth's surface produces fault displacements. Strains in the earth deform the rocks until their strength is exceeded and they rupture, producing the earthquake. Accompanying this bending, however, is a certain amount of plastic deformation. Both rupture and plastic deformation commonly occur along active fault zones and may be sufficient to damage or destroy structures over particularly strongly deformed rocks. Earthquakes deep within the earth may result from rupture of deeply buried rocks but without fault displacement at the ground surface, although the surface rocks may be deformed (See Figure 3e). This may have been the case along a part of the Newport-Inglewood fault zone where movement along the fault during the last 10,000 years or so has merely caused a permanent flexuring or bending of the surface rocks (Castle, 1966).

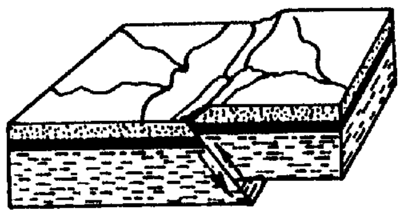
<u>Ground Shaking</u>. Probably the most difficult task today, in terms of the predictive capability of the geologist and seismologist, is devising a reasonably reliable method of predicting "ground shaking" effects--what most people and structures react to during an earthquake. Examination of damage from numerous past earthquakes, in lieu of conclusive strong-motion seismograph records, has suggested to geologists and engineers that the greatest damage to tall structures results where they are built over thick,

relatively soft, water-saturated sediments and that the least damage occurs where they are built on very firm bedrock (Wallace, 1968b, P. 67). Although engineers have shown that while great thicknesses of wet unconsolidated sediments may amplify the ground motion, perhaps a more critical measure of damage is a determination of the "predominant period" of the building and of the ground on which it rests. The predominant period of a building can be related in a very general way to its height or number of stories. Taller buildings have a longer predominant period (2 seconds or more). Therefore, they are subject to greater damage where they occur on ground with a longer predominant period (thick, saturated sediments). Conversely, one or two-story buildings with a short predominant period may be in trouble on firmer ground. Further complicating this very generalized picture are a wide variety of other factors that may contribute significantly to a damage potential: magnitude of a particular earthquake, distance and direction from the epicenter and causative fault, duration of shaking, and the structural integrity of buildings before the earthquake, and many others. The greatest damage is likely to occur where the predominant ground period is coincident with that of the greatest number of high-rise buildings. However, a prediction of ground shaking at a particular spot or point is subject to a great variety of conditions, only some of which are predictable with confidence. For example, a magnitude 5 earthquake on the San Andreas fault at Hollister may have the same damage pattern at a particular locality as a more distant 7.5 magnitude earthquake on the Hayward or Calaveras fault.

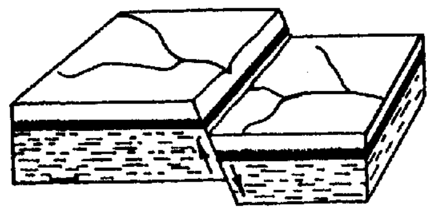
Figure 3



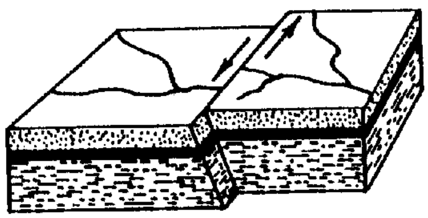
Earth block before movement
Fig. 3a



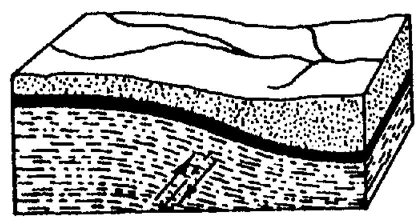
Thrust or Reverse fault
Fig. 3b



Normal fault
Fig. 3c



Left lateral fault
Fig. 3d



Monoclinal fold caused by faulting at depth
Fig. 3e

EXAMPLES OF SOME TYPES OF FAULT DISPLACEMENT AND EARTH FLEXURE

Ground Failure. Earth materials in a natural condition tend to reach equilibrium over a long period of time. In geologically active areas such as California and Alaska, there are many regions where earth materials have not yet reached a natural state of stability. For example, most of the valleys and bay margins are underlain by recent loose materials that have not been compacted and hardened by long-term natural processes. Landslides are common on most of the hills and mountains as loose material moves downslope. In addition, many activities of man tend to make the earth materials less stable and hence to increase the chance of ground failure. Some of the natural causes of instability are earthquakes, weak materials, stream and coastal erosion, and heavy rainfall. Human activities that contribute to instability include oversteepening of slopes by undercutting them or overloading them with artificial fill, extensive irrigation, poor drainage or even groundwater withdrawal, and removal of stabilizing vegetation. These causes of failure, which normally produce landslides and differential settlement, are augmented during earthquakes by strong ground motions that result in rapid changes in the state of earth materials. It is these changes, by means of liquefaction and loss of strength in fine-grained materials, that result in so many landslides during earthquakes as well as differential settlement, subsidence, ground cracking, ground lurching, and a variety of transient and permanent changes in the ground surface.

Mechanisms of Failure. Liquefaction is a common mechanism causing many types of ground failure. It occurs when strength of saturated, loose, granular materials (silt, sand, or gravel) is drastically reduced, such as may occur during an earthquake. The earthquake-induced deformation transforms a stable granular material into a fluidlike state in which the solid particles are virtually in suspension, similar to quicksand. The result, where the liquefied materials are in a broad buried layer, may be likened to the action of ball bearings in reducing friction in the movement of one material past another. The Juvenile Hall landslide during the 1971 San Fernando earthquake resulted from liquefaction of a shallow sand layer and involved an area almost a mile long and a failure surface that had a slope of only 2-1/2 percent (Youd, 1971, p. 107, 108). Where the liquefied granular layer is thick and occurs at the surface, structures may gradually sink downward. The tilting and sinking of building during the Niigata earthquake illustrate this phenomenon.

Loss of strength in fine-grained cohesive materials is another mechanism of ground or foundation failure, and might manifest itself in squeezing or "lateral spreading" of soft, saturated clays such as San Francisco Bay mud. It can result in rapid or gradual loss of strength in the foundation materials so that structures built upon them gradually settle or break up as foundation soils move laterally by flowage.

Other causes for loss of resistance include raising the ground water to reduce frictional resistance along a potential failure surface and removal of water or earth masses that may be serving as a buttress to prevent downslope movement.

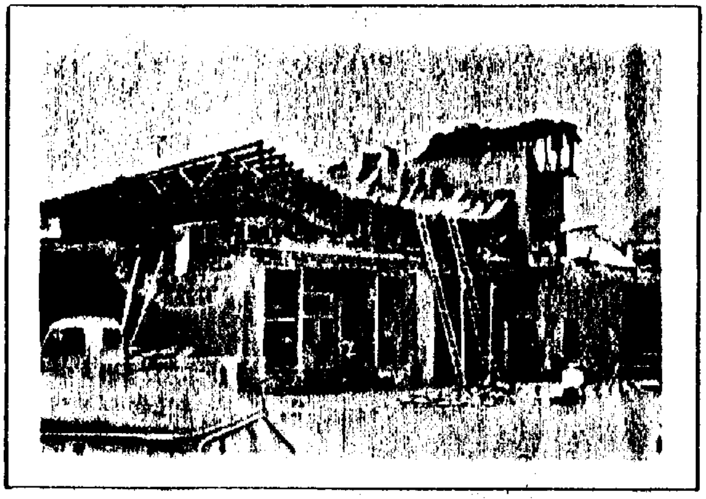
Results of Ground Failure. Although the basic causes of ground instability are simple in concept, the consequences are often complex and highly variable. They include numerous varieties of landslides, ground cracking, lurching, subsidence, and differential settlement. Moreover, these types of ground failure occur on a wide variety of ground conditions. Landslides, for example, do not require a steep slope on which to form, particularly during earthquakes. Many occur on slopes that are virtually flat, and the surface on which they fail may be very shallow (1 to 2 feet deep) or as much as hundreds of feet below the ground surface. The type of ground failure that develops in a given area is determined by the nature of the natural or man-made disturbance that occurs and partly by the topographic, geologic, hydrologic, and geotechnical characteristics of the ground.

Ground cracking usually occurs in stiff surface materials and is associated with changes in surface topography or materials. For example, during the 1964 Alaskan earthquake, much of the ground cracking that occurred along river flood plains adjacent and parallel to stream channels and along road and railroad embankments resulted from differential movement owing either to liquefaction or to lateral spreading of a relatively soft, deeper layer under a stiffer surface layer. Cracks may be only hairline or several feet wide and from a few feet to hundreds of feet long.

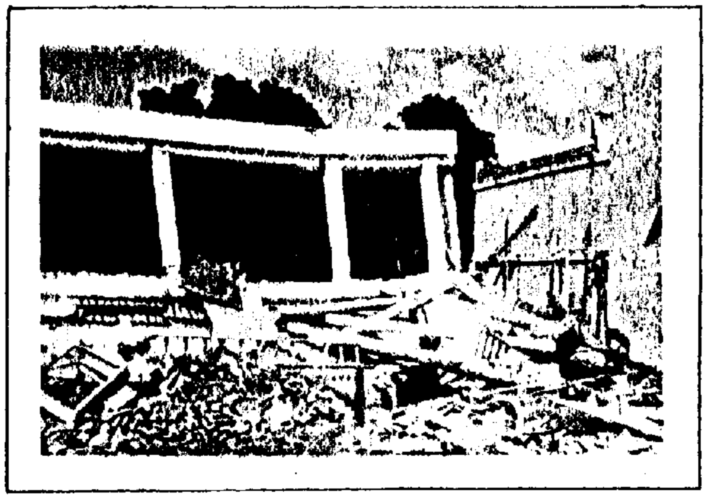
Ground lurching may be both a transitory and permanent phenomenon. During earthquakes, soft saturated ground may be thrown into undulating waves that may or may not remain when the ground motion ceases. The same or similar ground surface appearance may also result from permanent differential settlement of the ground, which can be caused by loss of soil strength or by liquefaction. Commonly, the water freed by liquefaction of buried and confined granular layers is forced to the ground surface, moving laterally toward steep slopes or vertically along the planes of weakness in the overlying layers. As the water moves toward the surface or "free face", it often carries with it some of the sand. Thus, "sand boils," "sand volcanoes," "sand ridges," and similar anomalous features attest to the occurrence of liquefaction. As sand and water are removed from the subsurface, the ground settles, often differentially because the sand and water are seldom removed evenly over broad areas. The resulting effects on buildings can be catastrophic. Subsidence of as much as several feet may occur over a broad area underlain by a thick sequence of sedimentary deposits. For example, after the 1906 earthquake, a well casing was reported to have "risen" two feet out of the ground, when in fact, the ground around it probably liquefied or compacted as a result of the shaking. Subsidence is likely to be greatest in areas where there has been withdrawal of fluids (ground water or oil) over a long period of time. Lesser amounts of subsidence can occur even where fluid withdrawal has not taken place, as in the Homer area of Alaska in 1964. Compaction effects may be predicted with some degree of assurance over fairly broad areas (up to 1 or 2 miles) and even on a site basis, especially when the cause may be liquefaction.

Tectonic Deformation. Earthquakes may produce major differential vertical and horizontal movements over broad parts of the earth's crust. For example, as a result of the 1964 Alaskan earthquake, between 70,000 and 110,000 square miles of both the sea floor and land in Southern Alaska were warped, elevating or depressing them as much as 6 feet; elevation changes locally exceeded 50 feet (Hansen and others, 1966, p. 17). While the effect of compaction and tectonic subsidence may appear the same locally, the mechanisms differ greatly and the total area affected will be much greater where tectonic deformation occurs. Tectonic land changes result from major movements in the earth's crust, and neither their location nor their magnitude is predictable. Therefore, little can be done to minimize the effects of these changes before they occur.

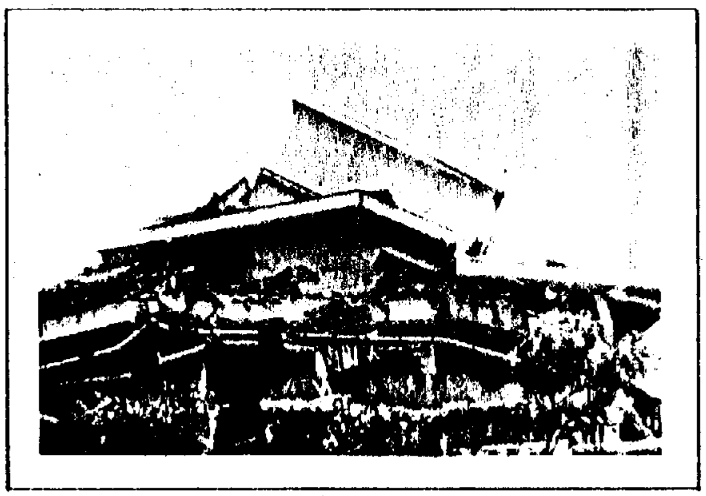
Tsunami and Seiche Effects. Tsunamis are large ocean waves generated by rapid changes in elevation of large masses of earth and ocean. They are commonly caused by vertical faulting beneath the ocean that rapidly moves a large volume of earth and water. Such rapid movement may generate huge waves of destructive force that can travel thousands of miles. During the 1964 Alaskan earthquake, for example, faulting and crustal warping created tsunamis, or sea waves, tens of feet high that spread more than 1,500 miles from the source area and caused devastation to many coastal communities within their reach. The effects of tsunamis can be greatly amplified by the configuration of the local shoreline and the sea bottom. Since a precise methodology does not exist to define these effects it becomes important, through examination of the historic record, to what elevation they have reached. It is also desirable to attempt to assess what amplifying effect a local coastal topographic configuration might have on uniquely directional incoming waves.



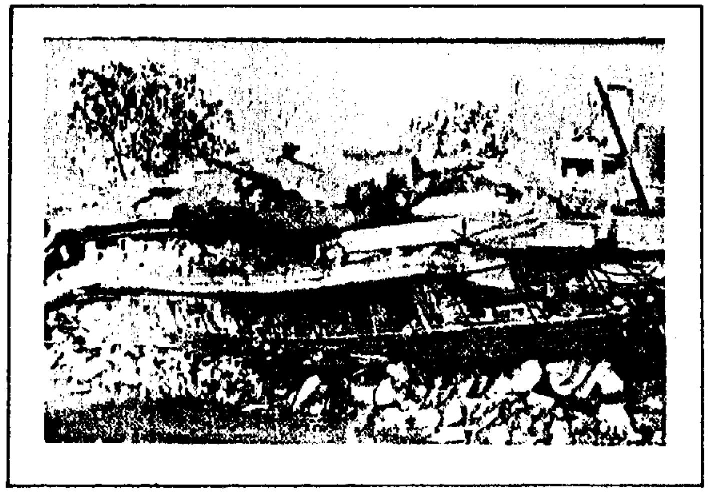
Lodge Hall in Tehachapi in 1952 earthquake. The ceiling over the 2nd floor auditorium now rests on the piano.



Three story school in Managua is now one story. 1972 earthquake - effects of groundshaking.

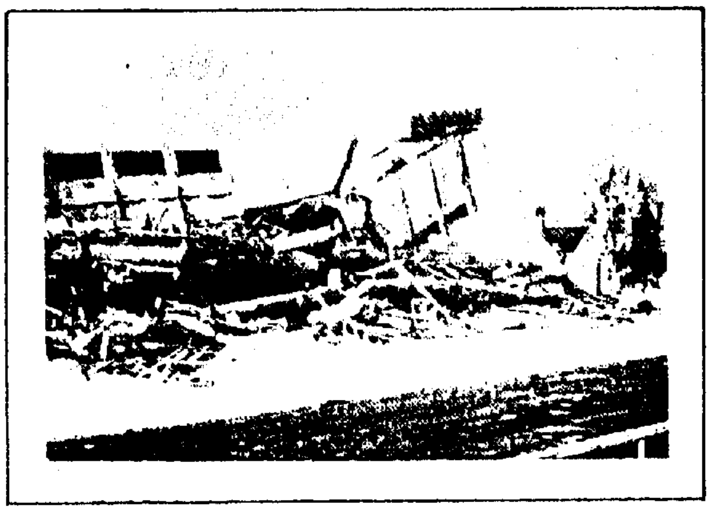


Three story office for the Custom House in Managua. Effects of groundshaking. 1972 earthquake.



Picture No. 19: Four story office in the Building Commission in Managua, 1972. Groundshaking effect.

Five story Penney Store in Anchorage, Alaska collapsed causing some deaths in 1964 earthquake.



Six story Four Seasons Apartment Building in Anchorage collapsed in 1964.

Seiches are earthquake-generated waves within enclosed or restricted bodies of water (lakes, reservoirs, and bays). They can be likened to the sloshing of water in a bowl or bucket when it is shaken or jarred. The waves can be tens of feet high or more and have devastating effects on people and property within their reach. Dams and reservoirs can be overtopped and large volumes of water released to inundate downstream development.

Large water waves causing catastrophic inundation can also result during an earthquake from a dam failure or from large-scale landsliding into a reservoir or bay. The near failure of the Van Norman reservoir during the 1971 San Fernando earthquake required the evacuation of 80,000 people that lived below it (Seed, 1974, p. 14). Although not the result of an earthquake, almost 3,000 lives were lost in Italy in 1963 when a huge landslide (more than 312 million cubic yards of material) suddenly fell into Vaiont Reservoir, sending up a wall of water and rocks 850 feet above reservoir level opposite the slide area and waves of water about 330 feet above the crest of the dam (Kiersch, 1964). Waves were more than 230 feet high in the narrow valley as far as 1 mile downstream from the dam. Earthquake-generated landslides of this magnitude are possible hazards to dams or reservoirs. The 1958 Alaskan earthquake produced a massive rock fall that plunged into an inlet at the head of Lituya Bay, causing water to surge against the opposite wall of the inlet and to wash out trees up to 1,720 feet above sea level (Miller, 1960, p. 51). It is extremely fortunate that the bay was uninhabited and that no more than two fishermen died when their boat was destroyed as the wave passed out of the mouth of the bay.

Methods for Assessing Wave and Flooding Hazards. Assessing the hazards from tsunamis and seiches is very difficult and subject to varying interpretations because of very limited historical data and theoretical knowledge. Nevertheless, wave run-up elevations could be predicted for most ocean and lake shorelines from examination of historic records. An attempt should be made to assess the amplifying effect of unique topographical coastal configurations even though the methodology may be very crude. Potential areas of catastrophic inundation from dam and reservoir failure or from landslide-generated waves that overtop dam crests, on the other hand, can be mapped for all large bodies of water perched above populated areas. Recently passed legislation in California now requires the dam owners to prepare maps showing areas of potential inundation for use in disaster and land-use planning.

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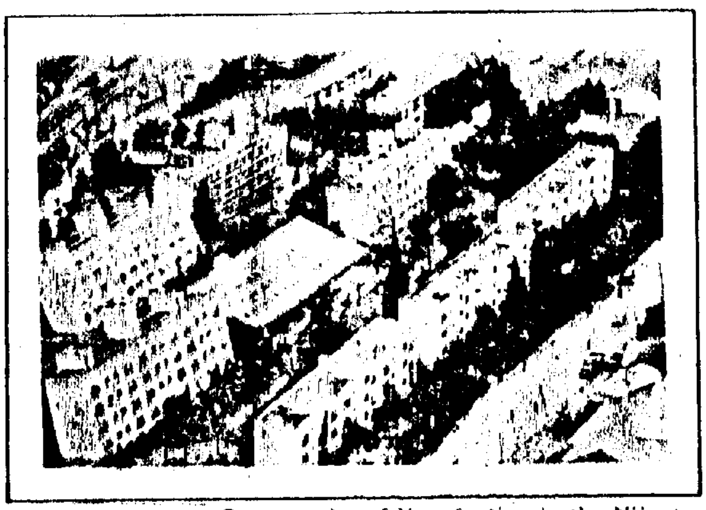
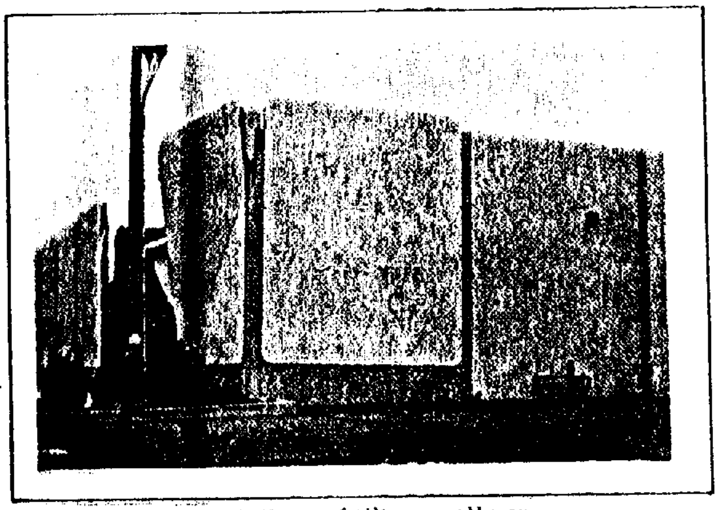


One results of liquefaction in the Niigata earthquake. These apartment houses which did not have basements overturned. The two buildings with basements were not damaged and remained vertical.

SECTION III

BUILDING CODES AND BUILDING PERFORMANCE IN EARTHQUAKES

The forces exerted on a building and its contests by shaking are often represented as fractions of the acceleration of gravity. Thus, an earthquake force of 0.3g would indicate that the maximum ground acceleration expected would be 30% of the acceleration of gravity. Ground acceleration from earthquakes can occur in both the horizontal (lateral) and vertical directions.



Failure of tilt-up walls on industrial structure in San Fernando earthquake, 1971.

Lateral forces are usually but not always randomly directed and a design for a 1g horizontal acceleration could be very roughly compared with a design which allowed the foundation of the building to be set on edge with the building cantilevered into space. A vertical acceleration of 1g would throw loose objects into the air. The design of a building for a 1g vertical acceleration could be roughly compared to designing the building to support double the weight of the structure and its contents. Total vertical design load of a building is the load resulting from the weight of the building itself (called the "dead load"), plus the estimated load to result from the contents, usage, wind, ground and other variable forces (called the "live load"). This would be equivalent to more than 1g acceleration in total.

HISTORY OF EARTHQUAKE CODES IN CALIFORNIA

Prior to 1933, the earthquake design standards contained in building codes in California specified only a single lateral force for both wind and earthquake resistance. For example, San Francisco was rebuilt after the 1906 earthquake and fire under a code which required strength enough for 30 pounds per square foot from either wind or earthquake forces.

Beginning with the Riley Act, adopted by the California State Legislature in 1933, earthquake codes have specified that buildings be designed for earthquake forces proportional to their masses. This initial act required all buildings except certain dwellings and farm buildings to be designed to resist a lateral force of 2% of the total vertical design load. In 1953, this requirement was revised to require 3%

for buildings less than 40 feet in height and 2% for those over 40 feet in height.

In 1948, a Joint Committee on Lateral Forces (of the San Francisco Section of the American Society of Civil Engineers and the Structural Engineers Association of Northern California) was formed, and after several years of study, it recommended a code in which the required percentages of load were related to the estimated or calculated fundamental period of the structure. This takes into consideration semi-dynamic loads. San Francisco adopted a version of this code in 1956 and the Uniform Building Code adopted it somewhat later.

Recently, some structural engineers have been working with an analytical method which takes into account the dynamic response of proposed buildings, through the use of computer analysis. This dynamic response method is likely to become part of the building codes in the future.

TYPES OF BUILDINGS AND PAST PERFORMANCE

Steel Frame Buildings. During the 1971 San Fernando earthquake, no significant structural damage was experienced by any completed earthquake resistive steel-frame buildings in the Los Angeles area. Many did suffer other kinds of damage resulting in a maximum loss, in one case, of $200,000, or about 1% of the value of the building.

Older steel frame non-earthquake resistive buildings performed much more poorly. While none sustained structural damage, many experienced non-structural losses amounting to over 5% of assessed market value and in one case over 25% of assessed market value.

Concrete Frame Buildings. The experience of the 1971 San Fernando quake showed that earthquake-resistive concrete frame buildings performed generally as well as steel frame buildings when located 15 to 25 miles from the epicenter. Of the high-rise buildings which suffered the highest amounts of damage, however, many more were to reinforced concrete than steel.

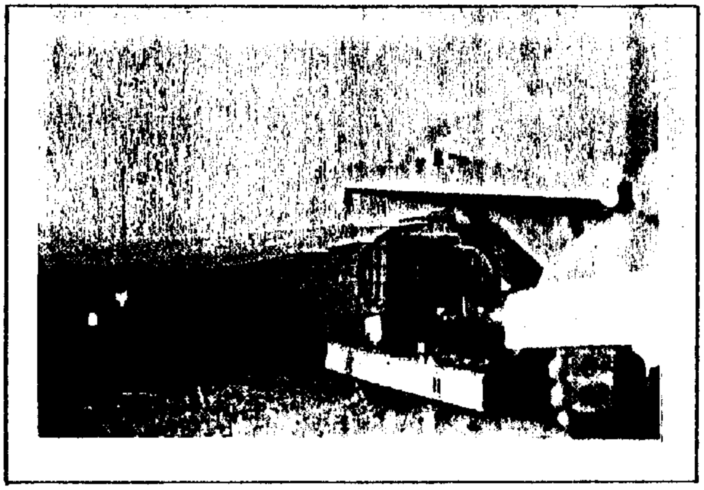
Unreinforced Concrete Block and Hollow Clay Tile Buildings. Older buildings of non-reinforced concrete block laid in sand-lime mortar are extremely vulnerable to earthquake damage. Many of this kind of building suffered slight and moderate damage in San Fernando, and a few experienced severe damage.

Brick Buildings and Reinforced Brick Buildings. Brick and reinforced brick buildings also do very poorly in earthquakes. In the San Fernando quake, pre-1940 brick structures suffered much more severe and moderate damage than any other type.

Reinforced Masonry Buildings. Most of these buildings were built under modern building codes and can be considered generally safe. Their weakness in San Fernando was joint failure, leading occasionally to detachment of roof from walls.

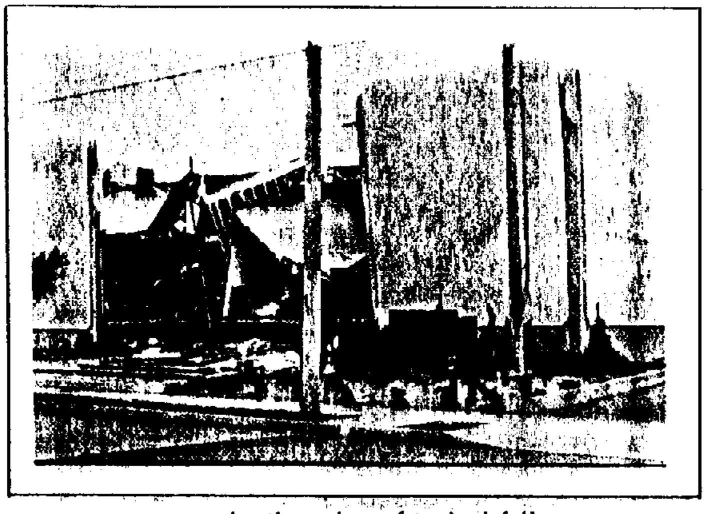
Steel and Sheet Metal Buildings. Metal-sided buildings, usually used for storage and factories, perform very well in earthquakes because of their light weight and flexibility.

Wood-Frame Buildings. Wood-frame structures have the best earthquake performance record of all older and smaller buildings. Their light mass accounts for much of their low susceptibility to damage.

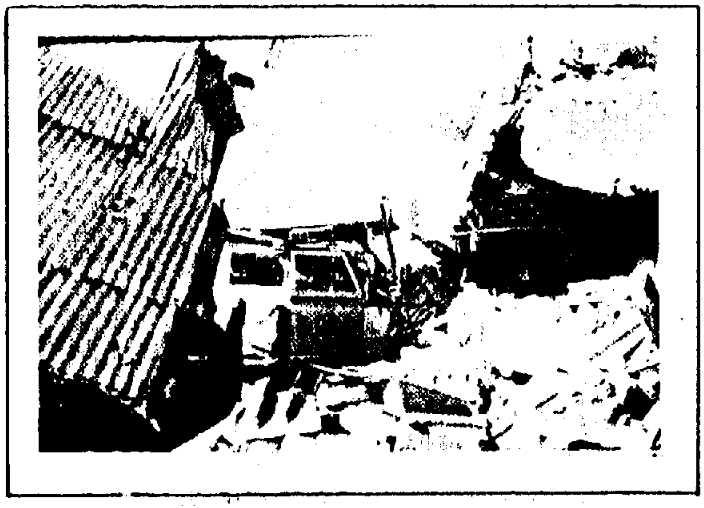


Managua, 1972. Eight modern firetrucks were of no use in fighting fires after the firehouse collapsed on them.

Even reinforced masonry failed similarly to tilt-up walls in the 1971 San Fernando earthquake in the industrial buildings.



Another view of typical failure 1971 San Fernando earthquake.



Managua, 1972 earthquake. The collapse of the Red Cross Building rendered the ambulances useless

BUILDING COMPONENTS AND PAST PERFORMANCE

Parapets and Chimneys. Probably the greatest loss of life from earthquakes has resulted from the failure of unreinforced unit masonry, particularly unreinforced brick parapets, on commercial buildings. Persons on the streets or inside buildings are often injured by such falling masonry. Chimneys can, also, be a great hazard in houses and small apartments.

Signs and Appendages. Signs, marquees, canopies, and general ornamentation extending out from buildings pose a great potential hazard in earthquakes if not adequately anchored to the building.

Facades. Two kinds of hazards can be caused by building facades. Masonry veneer facades, inadequately anchored, can be shaken loose by an earthquake, causing danger similar to parapets. On the other hand open glass facades, as on stores, can cause amplified twisting to the building and shattering of glass on the sidewalk.

Ceilings and Hanging Items. Plaster ceilings and ceiling tiles are often shaken loose during an earthquake, as are poorly-anchored hanging fixtures, resulting in human injury.

Building Contents. Heavy furniture, appliances, bookcases, machinery, etc. often are thrown about during earthquake shaking and can cause damage and injury.

Access Routes. Stairwells and doorways are often blocked after earthquakes. Doors and elevators are often inoperative.

BUILDING PERFORMANCE IN RELATION TO FAULTS

Straddling Fault. Buildings located upon a fault inevitably suffer damage in an earthquake as well as by fault creep. Any fault displacement will cause cracking of continuous foundations or shearing and twisting of pile foundations. This may result in failure of the structural frame.

Adjacent to Fault. While damage is insured to structures located on faults, it is much more variable for structures very near faults and depends a great deal on specific ground and building conditions. Buildings on solid ground near a fault often fare much better in an earthquake then buildings on softer ground miles away.

Some Distance from the Fault. Although the force of the earthquake is diminished as it moves away from the epicenter, it can still have considerable effect for miles. Buildings over five stories high are especially susceptible to damage from the diminishing gentler oscillations of an earthquake, which may travel as far as 100 to 200 miles from the epicenter.

Reference: Section I-III, Table I, Glossary Tri-Cities Citizens Advisory Committee, The Seismic Safety Study for the General Plan. California Council on Intergovernmental Relations, Sacramento, California 1973.

TABLE I

MODIFIED MERCALLI SCALE OF EARTHQUAKE INTENSITIES

(As modified by Charles F. Richter in 1956 and rearranged)

The intensity is:	If most of these effects are observed:
1	Earthquake shaking not felt, but people may observe marginal effects of large distance earthquakes without identifying these effects as earthquake caused. Among them: trees, structures, liquids, bodies of water sway slowly, or doors swing slowly.
2	Effect on people: Shaking felt by those at rest; especially if they are indoors and by those on upper floors.
3	Effect on people: Felt by most people indoors. Some can estimate duration of shaking. But many may not recognize shaking of building as caused by an earthquake; the shaking is like that caused by the passing of light trucks.
4	Other effect: Hanging objects swing. Structural effect: Windows or doors rattle. Wooden walls and frames creak.
5	Effect on people: Felt by everyone indoors. Many estimate duration of shaking. But they still may not recognize it as caused by an earthquake. The shaking is like that caused by the passing of heavy trucks, though sometimes, instead people may feel the sensation of a jolt, as if a heavy ball had struck the walls. Other effects: Hanging objects swing. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. Structural effects: Doors close, open or swing. Windows rattle.
6	Effect on people: Felt by everyone indoors and by most people outdoors. Many now estimate not only the duration of shaking but also its direction and have no doubt as to its cause. Sleepers wakened. Other effects: Hanging objects swing.

Shutters or pictures move. Pendulum clocks stop, start or change rate. Standing autos rock. Crockery clashes, dishes rattle or glasses clink. Liquids disturbed, some spilled. Small unstable objects displaced or upset.
Structural effects: Weak plaster and Masonry D* crack. Windows break. Doors close, open or swing.

7 Effect on people: Felt by everyone. Many are frightened and run outdoors. People walk unsteadily.
Other effects: Small church or school bells ring. Pictures thrown off walls, knicknacks and books off shelves. Dishes or glasses broken. Furniture moved or overturned. Trees, bushes shaken visibly, or heard to rustle.
Structural effects: Masonry D* damaged; some cracks in Masonry C*. Weak chimneys break at roof line. Plaster, loose bricks, stones, tiles, cornices, unbraced parapets and architectural ornaments fall. Concrete irrigation ditches damaged.

8 Effect on people: Difficult to stand. Shaking noticed by auto drivers.
Other effects: Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Furniture broken. Hanging objects quiver.
Structural effects: Masonry D* heavily damaged; Masonry C* damaged, partially collapses in some cases; some damage to Masonry B*; none to Masonry A*. Stucco and some masonry walls fall. Chimneys, factory stacks, monuments, towers, elevated tanks twist or fall. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off.

9 Effect on people: General fright. People thrown to ground.
Other effects: Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes. Steering of autos affected. Branches broken from trees.
Structural effects: Masonry D* destroyed; Masonry C* heavily damaged, sometimes with complete collapse; Masonry B* is seriously damaged. General damage to foundations.

10	Effect on people: General Panic. Other effects: Conspicuous cracks in ground. In areas of soft ground, sand is ejected through holes and piles up into a small crater, and in muddy areas, water fountains are formed. Structural effects: Most masonry and frame structures destroyed along with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes and embankments. Railroads bent slightly.
11	Effect on people: General panic. Other effects: Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Structural effects: General destruction of buildings. Underground pipelines completely out of service. Railroads bent greatly.
12	Effect on people: General panic. Other effects: Same as for Intensity X. Structural effects: Damage nearly total, the ultimate catastrophe. Other effects: Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.

*Masonry A: Good workmanship and mortar, reinforced designed to resist lateral forces.

Masonry B: Good workmanship and mortar, reinforced.

Masonry C: Good workmanship and mortar, unreinforced.

Masonry D: Poor workmanship and mortar and weak materials, like adobe.

GLOSSARY

An attempt has been made to define all technical words contained in the text. If a technical word is not defined, often the word can be found in a standard dictionary. In using the glossary, the reader will note that many technical words appear within the definitions themselves. Definitions of these words can also be found in the glossary.

Active faults. Active faults are faults which show evidence of any or all of the following:
1. Topographic or physiographic expressions suggestive of geologically young fault movements.
2. Fault creep.
3. Records of surface rupture within or adjacent to the study area in historic time.

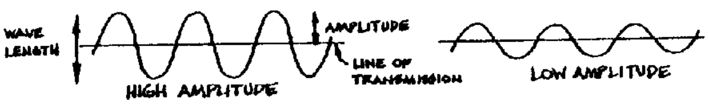
Aggregate. Materials such as sand, gravel, and crushed rock, with which cement or bituminous material is mixed to make concrete or asphalt.

Alluvial fans. Alluvial fans are built by rivers flowing from mountains onto lowlands. They are low cone-shaped heaps, steepest near the mouth of the valley, and sloping gently outward with ever decreasing slope.

Alluvium. A general term for the sediments laid down in river beds, flood plains, lakes, fans at the foot of the mountain slopes, and estuaries during relatively recent geologic times.

Amplification. The increase in earthquake ground motion that may occur to the principal components of seismic waves as they enter and pass through different earth materials.

Amplitude. One-half the elevation of the crest of a wave or ripple above the adjacent troughs:



Anomaly. A deviation or inconsistency of a specific land feature from uniformity with the larger area.

Anomalous features. See "anomaly".

Anticline. An upfold or arch of rock strata formed by internal earth pressure forming a shape like the roof of a house. Erosion could alter this shape leaving only the inclined strata.

Attitude (of rock structures). A term including the terms dip and strike. The attitude of the flat surface of a sedimentary bed, whether inclined or not, is referred to the horizontal plane. Dip is its slope inclination (in degrees) from this plane, and is measured with a clinometer. Strike is the compass bearing on the line of intersection of its surface with horizontal plane. The terms may also apply to faults, veins, and dikes.

Basalt. A dark-colored, fine-grained volcanic rock, composed essentially of the mineral plagioclase feldspar and one or more dark minerals such as pyroxene.

Bed. The smallest division of a stratified series, and marked by a more or less well-defined plane from its neighbors above and below.

Bedding plane. In sedimentary or stratified rocks, the division planes which separate the individual layers, beds or strata.

Bedrock. Any solid rock underlying soil, sand, clay, etc.

Berkeley hills. The hills on the immediate east side of San Francisco Bay contained within such cities as Oakland, Berkeley, El Cerrito and Richmond.

Bore hole. A hole drilled into the earth for exploratory purposes.

Breccia. A rock composed of angular coarse fragments, commonly cemented together.

Chert. A compact sedimentary rock containing abundant quartz of organic or precipitated origin.

Clastic rock or Clast. A rock which is composed principally of detritus transported mechanically into its place of deposition.

Cohesion, rock. The capacity of a rock to stick or adhere together. In effect the cohesion of soil or rock is that part of its shear strength which does not depend upon interparticle friction.

Cohesive materials. See "cohesion, rock".

Colluvium. Soil deposited by soil creep, landslides and surface wash.

Compaction. Decrease in volume of sediments, as a result of compression of sediments deposited above them.

Competent beds. Those beds or strata which, because of massiveness or inherent strength, are able to lift not only their own weight but also overlying rock. Therefore, such rock material is especially able to withstand failure such as landsliding.

Conglomerate. A rock composed of larger fragments (such as pebbles or cobbles) set in a matrix of finer material (such as sand, silt, and/or clay).

Consolidated material. Soft or hard rock which requires some medium of loosening at the excavation site before it can be handled. The more loosening required (i.e., blasting as opposed to bulldozing) the more consolidated the material.

Continental rock. A rock unit laid down on land as opposed to one laid down in marine water.

Contra Costa Group. The type of poorly consolidated young sedimentary rock found in the Tri-Cities Area east & north of the Berkeley hills ridgeline.

Creep, fault. See "fault creep".

Cross bedding. The arrangement of narrow layers of sedimentary rock such that layers are at angles to rather than parallel to the other layers.

Damping. A resistance to vibration that causes a progressive reduction of motion with time or distance.

Deformation of rocks. A change in the original form or volume of rock masses produced by faulting, folding or other tectonic forces.

Detritus. The materials that result from the breaking up, disintegration and wearing away of minerals and rocks resulting in alluvial deposits.

Diatomite. A light friable, siliceous material chiefly produced from the remains of minute forms of algae.

Differential Settlement. Loss of strength or the loss of water and sand through liquefaction often does not occur evenly over broad areas. Thus the ground settles different amounts in adjacent spots. Can be very destructive to buildings.

Dip. See "attitude".

Dip slip. Fault displacement parallel to the dip of the fault. See "attitude" and "slip".

Displacement. The dislocation of one side of a fault relative to the other side resulting from fault movement.

Earth-flow. A slow flow of earth lubricated with water. Earth-flows may be discriminated from earth-slumps by reason of their greater mobility.

Earthquake. Perceptible trembling to violent shaking of the ground, produced by sudden displacement of rocks below and at the earth's surface.

Earthquake focus. See "focus".

Earth-slump. See "earth-flow".

Elastic limit. The maximum stress that a material can withstand without undergoing permanent deformation either by solid flow or by rupture.

Elasticity. The property or quality of being elastic, that is, an elastic body returns to its original form or condition after a displacing force is removed.

Eocene. An epoch of the lower Tertiary period. It ranges from 37 to 38 million to 53 to 54 million years before the present.

Epicenter. The geographical location of the point on the surface of the earth that is vertically above the earthquake focus.

Fan, alluvial. See "alluvial fan".

Fault. An earth fracture or zone of fracture along which the rocks on one side have been displaced in relation to those of the other.

Fault block. A body of rock bounded by one or more faults.

Fault creep. Very slow periodic or episodic movement along a fault trace unaccompanied by quakes.

Fault-scarp. The cliff formed by a fault. Most fault scarps have been modified by erosion since faulting.

Fault set. Two or more parallel faults within an area.

Fault slip or slippage. The relative displacement of formerly adjacent points on opposite sides of a fault. Also known as fault creep.

Fault system. Two or more fault sets formed at the same time.

Fault surface. The surface along which dislocation has taken place.

Fault trace. The intersection of a fault and the earth's surface as revealed by dislocation of fences, roads, by ridges and furrows in the ground, etc.

Fault zone. A fault instead of being a single clean fracture, may be a zone hundreds or thousands of feet wide; the fault zone consists of numerous interlacing small faults or a confused zone of gouge, breccia or other material.

Fault, active. See "active fault".

Fault, inactive. See "inactive fault".

Fault, normal. See "normal fault".

Fault, reverse. See "reverse fault".

Fault, right-lateral. See "right-lateral fault".

Fault, thrust. See "thrust fault".

Faulting. The movement which produces relative displacement of adjacent rock masses along a fracture.

Fissure. An extensive crack, break, or fracture in the rocks.

Flexuring. Synonymous with folding.

Focal depth. Depth of an earthquake focus below the ground surface.

Focus. The point within the earth which marks the origin of the elastic waves of an earthquake.

Fold. A bend in rock strata.

Formation. A rock body or an assemblage of rocks which have some character in common; applied to a particular sequence of rocks formed during one epoch; a rock unit used in mapping.

Fracture. Breaks in rocks due to intense faulting or folding.

Free face. A sloping surface exposed to air or water such that there is little or no resistance to lateral movement of earth materials.

Frequency. The number of seismic wave peaks which pass through a point in the ground in a unit of time. Usually measured in cycles per second.

Friable. A term applied to rocks that are easily crumbled or pulverized.

Geodetic measurements. Controls on location (vertical & horizontal) of positions on the earth's surface of a high order of accuracy, usually extended over large areas for surveying and mapping operations.

Geology. The science which treats of the earth, the rocks of which it is composed, and the changes which it has undergone or is undergoing.

Geophysical surveys. The use of one or more physical techniques to explore earth properties and processes.

Gouge material. Finely ground material occurring between the walls of a fault, the result of grinding movements.

Graywacke. A hard, dark-colored, sandstone composed primarily of highly angular quartz and feldspar in a clay matrix. Usually contains significant quantities of rock fragments.

Ground cracking. Cracks usually occurring in stiff surface materials resulting from differential ground movement.

Ground failure. A situation in which the ground does not hold together such as in landsliding, mud flows, liquefaction and the like.

Ground lurching. Undulating waves in soft saturated ground that may or may not remain after the earthquake.

Ground strength. The limiting stress that ground can withstand without failing by rupture or continuous flow.

Ground response. The reaction of the ground to earthquake shaking.

Group. A local subdivision of a series of rocks, based on lithologic features. It usually contains two or more formations.

Hayward fault. A large and active branch of the San Andreas Fault System. It has been the center of many earthquakes, including the 1868 earthquake which was one of the largest ever to hit Northern California.

Hummocky. Lumpy land, or in small uneven knolls. This condition is a sign of previous extensive landsliding.

Hypocenter That point within the earth which is the center of an earthquake and the origin of its elastic waves.

Inactive faults. Identifiable faults which do not meet any of the criteria listed under "active faults".

Incompetent beds. Opposite of competent beds.

Inelastic deformation. Permanent deformation of materials either by flow, creep, or rupture.

Intensity. (See Table 1) A nonlinear measure of earthquake size at a particular place as determined by its effect on persons, structures, and earth materials. The principal scale used in the United States today is the Modified Mercalli, 1956 version. Intensity is a measure of effects as contrasted with magnitude which is a measure of energy. They are not the same.

Interstitial water. Water contained within the minute pores or spaces between the small grains or other units of rock.

Intrusion. An igneous rock that has been injected into older rocks; it has cooled and solidified from a molten condition under the cover of the surrounding rock mass.

Inundation. Flooding caused by water topping a dam or water released by dam, reservoir, levy or other break.

Isoseismic line. An imaginary line connecting all points on the surface of the earth where an earthquake shock is of the same intensity.

Lacustrine. Formed in a lake.

Landsliding. The perceptible downward sliding or falling of a relatively dry mass of earth, rock, or mixture of the two. Often loosely used to also include sliding of wet earth masses such as mudslides and earthflows.

Left-lateral fault movement. Generally horizontal movement in which the block across the fault from an observer has moved to the left.

Lenticular. Shaped approximately like a double convex lens. When a mass of rock thins out from the center to a thin edge all around, it is said to be lenticular in form.

Liquefaction. A process by which a water saturated sand lens loses coherence when shaken. Involved is the collapse of sand grains into intergranular voids which induces an increase in pore pressure and loss of strength. This loss of strength leads to a quicksand condition in which objects can either sink or float depending on their density.

Lithology. The description of rock composition and texture from observation of hand specimens or outcrops.

Mafic pyroclastic rocks. Pyroclastic rocks containing a high proportion of dark colored (mafic) rock and mineral constituents such as basalt.

Magnitude. The rating of a given earthquake is defined as the logarithm of the maximum amplitude on a seismogram written by an instrument of specified standard type at a distance of 62 miles from the epicenter. It is a measure of the energy released in an earthquake. The zero of the scale is fixed arbitrarily to fit the smallest recorded earthquakes. The scale is open ended but the largest known earthquake magnitudes are near 8-3/4. Because the scale is logarithmic, every upward step of one magnitude unit means a 32 fold increase in energey release. Thus, a magnitude 7 earthquake releases 32 times as much energy as a magnitude 6 earthquake. Magnitude is not the same as intensity.

Melange. A mixture or complex of rocks.

Micro-earthquake. A very small earthquake having a magnitude of 2 or less on the Richter scale.

Microseismic Event. An earthquake or man-induced vibrations observable only with instruments.

Miocene. An epoch of the upper Tertiary period. It ranges from 12 million to 26 million years before the present.

Modified Mercalli. See "intensity".

Monitoring fault movement. Use of survey methods over a period of time to measure displacement caused by creep over a period of time.

Morphology, slope. See "slope morphology."

Mudflow or mudslide. A flowage of heterogeneous debris lubricated with a large amount of water.

Normal fault. Vertical movement along a sloping fault surface in which the block above the fault has moved downward relative to the block below.

Period, natural. See "natural period".

Period, predominant. See "predominant period".

Physiography. A description of existing nature as displayed in the surface arrangement of the globe, its features, atmospheric and oceanic currents, climate, etc.

Plastic deformation. Under some conditions solids may bend instead of shearing or breaking as a result of seismic and geologic forces.

Pliocene. The latest epoch in the Tertiary period. It ranges from 7 to 10 million to 2 to 3 million years before the present.

Ponding. Accumulation of alluvial and colluvial deposits behind a fault-produced barrier.

Precipitate. The material resulting from the process of separating mineral constituents from a solution by evaporation (salt, etc.) or from magma to form igneous rocks.

Predominant period. A number representing the time between seismic wave peaks to which a building on the ground is most vulnerable. Usually measured in seconds.

Pumice. An excessively cellular, glassy lava of whitish or gray color. It is very light and will float on water.

Pyroclastic. A general term for fragmental deposits of volcanic materials, including volcanic conglomerate, agglomerate, tuff and ash.

Remote sensing. The acquisition of information or measurement of some property of an object by a recording device that is not in physical or intimate contact with the object under study. The technique employs such devices as the camera, lasers, infrared and ultraviolet detectors, microwave and radio frequency receivers, radar systems, etc.

Residual soil. A soil deposit formed by the decay of rock in place.

Reverse or thrust fault. Vertical or nearly horizontal movement along a sloping fault surface in which the block above has moved upward or over the block below the fault.

Right-lateral fault movement. Generally horizontal movement in which the block across the fault from an observer has moved to the right.

Sag ponds. Ponds occupying depressions along active faults. The depressions are due to uneven settling of the ground.

Sand boils. Turgid upward flow of water and some sand to the ground surface resulting from increased ground water pressures when saturated cohesionless materials are compacted by earthquake ground vibrations.

Scarp. An escarpment, cliff, or steep slope of some extent along the margin of a plateau, terrace, bench, and at the top of a slide.

Sediment. Solid material settled from suspension in a liquid.

Sedimentary rocks. Rocks, commonly stratified, formed by the accumulation of sedimentation in water or from air.

Seismograph. An instrument that writes a permanent continuous record of earth vibrations.

Seismic. Pertaining to an earthquake or earth vibration, including those that are artificially induced.

Seismology. The science of earthquakes and related phenomena.

Seismometer. A device which detects vibrations of the earth, and whose physical constants are known sufficiently for calibration to permit calculation of actual ground motion from the seismograph.

Shear. A mode of failure whereby two adjacent parts of a solid, slide past one another parallel to the plane of contact. To subject a body to shear, similar to the displacement of the cards in a pack relative to one another.

Slip, fault. See "fault slip".

Solid flow. Flow of a solid under long-time stress.

Strata. Layers of sedimentary rocks.

Strength, ground. See "ground strength".

Strike. See "attitude".

Strike-slip. Fault displacement parallel to the strike of the fault. See "attitude" and "slip".

Strong motion. Ground motion produced by a "strong" earthquake or one capable of producing damage to structures. The magnitude of such an earthquake may vary considerably according to the character of the earthquake.

Structural feature. Features produced in the rock by movements after deposition, and commonly after consolidation, of the rock.

Subsidence. A shrinking of a large area of land, usually observed as a shrinkage.

Surface wash. A loose surface deposit of sand, gravel, boulders, etc.

Syncline. A trough-shaped fold in rocks in which the strata dip inward from both sides toward the axis. The opposite of anticline.

Tectonic. Pertaining to or designating the rock structure and external forms resulting from the deformation of the earth's crust. Pressures causing such deformations often result in earthquakes.

Trace, fault. See "fault trace".

Thrust fault. See "reverse fault".

Topography. The physical features of the land, especially its relief and contour.

Torsional forces. Forces which act to twist the object in question.

Tsunami. A sea wave produced by large areal displacements of the ocean bottom, often the result of earthquakes or volcanic activity. Also known as seismic sea waves.

Unconformity. In sedimentary rocks sometimes strata of intermediate age between younger and older rocks are absent. This is usually caused by total erosion of the middle-aged sediment before the younger sediment was deposited.

Unconsolidated material. Opposite of "consolidated material".

Undulating waves. Waves that rise and fall.

Water Table. The upper surface of a zone of water saturation within the ground.

Wash, surface. See "surface wash".

Wave height. The difference in elevation between adjoining wave crests and troughs.

Our county's experience with floods that never reached such heights before or never flooded areas before illustrates man's inability to predict nature.

It seems, therefore, that two basic approaches are available to our county to cope with our natural environment.

First, determine what areas pose the greatest hazards to life and property within the county and avoid development in these areas.

Second, maintain the most effective disaster-response program practicable to cope with emergencies and reduce loss of life, injuries, and property damage.

In an attempt to meet the requirements of the state law, Siskiyou County in conjunction with other Northern California governmental agencies contracted with the California State University at Chico to analyze and evaluate the seismic history and potential for the 13 northeastern counties of California.

Following this report is a further summary and analysis by Dr. Rolland Berger, Office of Regional Programs, California State University, Chico.

Using these two documents and relating the data to Siskiyou County forms the basis for the findings and recommendations for action to be best prepared, avert, and to react to a seismic disaster.

Seismic Hazard in Northeastern California

Section IV

EARTHQUAKE HAZARD IN NORTHEAST CALIFORNIA

J.W. Guyton* and A.L. Scheel**

INTRODUCTION AND PURPOSE

The purpose of this study is to analyze existing seismological and geological data pertinent to earthquake hazard within a thirteen county area of Northeast California. The need for the study originates with the adoption by the California legislature in 1971 of an amendment to State Planning Law that includes a seismic safety element as a mandatory part of each city and county General Plan (Chap. 150, Section 65302 (F) of the Government Code).

The preparation of an effective seismic safety element necessitates not only detailed consideration of what has happened or might happen within a given jurisdiction, but also consideration of that jurisdiction within a larger area, a region. It is the regional aspect of seismic safety that this study addresses. We will present data and analysis that are useful to each governmental unit within the region even though the study is not oriented toward any single unit. This approach minimizes duplication of effort in some respects, even though each jurisdiction must still utilize supplementary data to construct its own seismic safety element.

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When this study was first conceived it was our plan to restrict it to a compilation of factual data. This would be useful, but would still necessitate analysis and interpretation of the data by each city and county planner, thus relegating a critical part of the procedure to a person least familiar with the data. Discussion with Rolland Berger of the Office of Regional Programs convinced us that we should not only compile but also analyze and interpret; this we have tried to do. In addition, Dr. Berger is preparing a separate paper in which he relates results of this study directly to planning policy for Northeast California. We hope that this approach will deliver maximum useful information to those who make decisions for Counties and Cities.

DEFINITION OF REGION

We have used the thirteen county region of northeast California (Fig.1) as defined by the Office of Regional Programs of California State University, Chico. The boundaries are arbitrary and do not correspond to any geologic or seismic region, but with the user in mind, we have elected to work with the political boundaries. It is essential that definite limits be set, because we will distinguish between earthquakes orginating within the region, which we will treat comprehensively, and those originating outside the region, which we will consider selectively.

SEISMIC HAZARD IN CALIFORNIA

California has been earthquake conscious since the disastrous San Francisco earthquake of 1906, but this consciousness was markedly reinforced by the Alaska earthquake of 1964 which served to remind responsible persons that disastrous earthquakes are not restricted to history books, but can and do demolish modern American cities. Then, to underline the point, Los Angeles was victimized by a moderate-sized but highly destructive earthquake in February, 1971. In consequence of this heightened awareness governmental bodies and agencies have endeavored to plan and act toward the reduction of seismic hazards both in California and the nation.

The following list of selected reports is offered to emphasize that planning and action is underway, and to provide the reader with a convenient listing of valuable references.

1. "Proposal for a Ten-Year National Earthquake Hazards Program" by the Ad Hoc Interagency Working Group for Earthquake Research, prepared for the Office of Science and Technology, Washington D. C., 1968.

2. "Earthquake Hazard Reduction", a report of the Task Force on Earthquake Hazard Reduction, prepared for the Executive Office of the President, Office of Science and Technology, August, 1970.

3. "First Report of the Governor's Earthquake Council", a report to the Governor of California (available from the California Division of Mines and Geology) November, 1972.

4. "A Study of Earthquake Losses in the San Francisco Bay Area", a report prepared for the Office of Emergency Preparedness by the National Oceanic and Atmospheric Administration, 1972.

5. "Urban Geology, Master Plan for California" by J. T. Alfors, J. L. Burnett, and T. E. Gay, Jr., California Division of Mines and Geology Bulletin 198, 1973.

6. "Meeting the Earthquake Challenge", by the Joint Committee on Seismic Safety of the California Legislature, Sacramento, California, 223 pages, 1974.

As one reads these documents two things emerge that are of general interest.

1. There is much yet to be done and to be learned. Some things that are very important, we simply don't know how to do. Other things that are very important, we know how to do, but have not committed the resources to cause them to be done everywhere or routinely.

2. Sincere efforts are being made to answer important questions, reorganize responsibilities among research and administrative agencies, revise research and operation priorities and increase funding.

In brief, the reports admit there has been some neglect in the past, but resolve that things will be better in the future.

THE PROBLEM OF IDENTIFYING SEISMIC HAZARD

The foregoing is interesting in light of the state requirement that each city and county prepare a seismic safety element. Guidelines published in September 1973 by the California Council on Intergovernmental Relations are quite specific with respect to what the local governments must consider. To elaborate with one example, the guidelines, (page IV-25, item 3-B), specifies, among other things, "Location of all active or potentially active faults, with evaluation regarding past displacement and probability of future movement." One may recall reading:

> Maps that delineate relative kinds and degrees of geologic hazards are as yet rare, and no fully satisfactory map of earthquake geologic hazards is available for any urban area. It is realized that such maps prepared in the near

> future will be little more than crude approximations, and the continuing decisions will have to be made regarding their detail and scale.
> (Earthquake Hazard Reduction, Office of Science and Technology, 1970, page 13.)

Other similar contrasts could be made between (1) the guidelines that demand information from the city and county planner and (2) the experts who say that data does not exist and that it is going to take many years and many dollars to get it. The fact is, county and city planners have been asked, firmly, to provide answers and maps to geologic problems that have eluded the U. S. Gological Survey, the California Division of Mines and Geology, and the U. S. Coast and Geodetic Survey (formerly responsible for many seismological studies now reorganized under the Geological Survey).

To reach the conclusion just stated is not to be critical of legislation requiring planners to prepare a seismic safety element; the need is real enough; but it is important to recognize that, for most areas, sufficiently detailed and pertinent data do not exist. To ask city and county governments to produce the information on short notice is an unrealistic solution, except possibly as a means of stressing the need and providing motivation for the future; but this demanding approach runs the risk of generating cynical responses to requirements perceived to be impossible to meet.

One final example will be given to illustrate the problem. The guidelines specify, among other things, that the seismic safety element will contain "Evaluation of slope stability...", and "Maps identifying location of...(unstable slopes)". It is pertinent to ask what a local planner has available with which to address the requirement. Alfors et al. (1973, pg. 27) presents a map of the state at a scale of 1:5,000,000 showing four degrees of landslide severity. Within an area of Butte County classified as "low severity" two landslides have closed or partially closed main state highways in the last few years, and without benefit of earthquake shaking. More vividly, within an area of Shasta County, also classified as "low severity", an extensive campground-administrative-commercial area within Lassen Volcanic National Park has been abandoned because of landslide hazard. Clearly a map at this scale does not serve the planner's needs. More detailed maps exist (e.g. Saul, 1973) at scales as large as 1:12,000 where many aspects of the soil and regolith are described and delineated in detail. Maps of this sort would solve the planner's problem, but of about 1000 15-minute quadrangles in California, fewer than a dozen have been completed. What then is the planner to do? Construct his own detailed maps? Hire the work done in detail? Use the existing 1:5,000,000 map and regard that as sufficient? Write an innocuous response that satisfies the letter of the law but really doesn't help advance the cause of seismic safety?

We have dwelled upon this topic at some length for two reasons. First, the planner has been given a very difficult task, perhaps an impossible task, and it needs to be said that it is not his fault if he cannot do it as well as his professional pride would desire. Second, the approach used to assess earthquake hazard in this study seems to us to be the best that can be done with available data. It is important for the reader to realize that the ideal, as represented by the General Plan Guidelines, is not attainable in most areas at the present time.

SEISMIC REGIONALIZATION

At various times efforts have been made to prepare maps that convey the degree of seismic hazard in an area. Four of these will be discussed now.

Urrick, 1948. This map prepared for the U. S. Coast and Geodetic Survey was an early attempt to express earthquake risk, and was subsequently adopted by the Pacific Coast Building Officials Conference for inclusion in the 1952 edition of their Uniform Building Code. Since then the U. S. Coast and Geodetic Survey has withdrawn the map from circulation because it was too general and subject to misinterpretation.

Richter, 1958. Figure 2 is a reproduction of a map showing the probable maximum intensities to be expected in California (Richter, 1959). This map is quite ambitious and has received a mixed reception, being both praised,criticized, but, more often, ignored.

Algermissen, 1969. This map (Fig. 3) has been widely reproduced and is probably the best available for the U. S., although it is "an interim map and does not represent the final form of a risk map of the United States" (U. S. Earthquakes, 1968, pg. 8).

Alfors et al., 1973. This map (Fig. 4) is the most complete and detailed yet offered for California. It expresses both probable maximum intensity (on the Modified Mercalli Scale, see Appendix I) as well as probable damage. The map is carefully labelled "preliminary map--subject to revision."

Each of these maps is a testimonial to the difficulty of determining the seismic hazard in a given area. More specifically:

> The making of truly adequate seismic risk or probability maps requires a long term research effort of great sophistication and involving many disciplines. In the broad view, it is almost impossible to separate the problems of seismicity and prediction, and anyone who asks for a completely satisfactory seismic probability map is in essence asking for a type of earthquake prediction. Even very generalized seismic risks maps, such as that of Figure 1, (Algermissen, 1969) are the subject of continuing vigorous debate among scientists and engineers.
>
> (Earthquake Hazard Reduction, 1970, pg. 11.)

The obvious next question is, how useful are the maps in assessing seismic hazard in Northeast California? A partial answer is given by Richter (1959) who, after lengthy analysis and attempts to construct such maps, concludes:

> Small-scale regionalization maps covering large areas are satisfactory only when they represent generalization of the results of microregionalization. They should serve as general index maps, from which the engineer or planning authority should pass to microregionalization maps for the localities where construction is intended.
>
> (Richter, 1959, page 158)

And further, "Regionalization can now be carried out for the whole of California, but involves some very rough estimates in desert and mountainous areas" (Richter, 1959, page 158). If Richter is correct, and we believe he is, then each of the foregoing maps is unsatisfactory because they are not generalized from more detailed maps. With scattered local exceptions, detailed maps do not exist.

But the maps described previously are the best available, and the challenge in 1974 is to do the best we can with what we have. What then can be learned from the maps if they are taken as valid? Careful inspection will show the status of individual cities and counties, but for the entire region we observe:

1. Most of the region should anticipate a maximum intensity of VI or VII (Modified Mercalli scale, see Appendix I).

2. The eastern part of the region should anticipate a maximum intensity of VIII, IX, or even X.

3. The southern part of the region is ambiguous, two maps suggesting a maximum intensity of VII, the third map suggesting as high as IX will be reached occasionally.

Before attempting to judge whether these estimates should be accepted and acted upon, we wish to examine the historical and geologic records.

EARTHQUAKE HISTORY: EARTHQUAKES IN THE REGION

The history of earthquake occurrence within a region offers the most objective insight possible (at present) into the future prospects for the region. Many persons will object to this statement, and with some merit. But we emphasize its objectivity, not the correctness of its extrapolation, and contend firmly that, for planning purposes, an objective approach that may be proven wrong is superior to a subjective approach that may, just as likely, be proven wrong. Superior to both, of course, would be a comprehensive, qualitative study using boreholes to locate faults precisely, years of strain gauge readings, detailed seismogeological mapping, and similar technical studies which may, someday, be available; but for now, earthquake history remains the best single, available benchmark.

What then is the earthquake history of Northeast California? We consulted three sources:

1. "Descriptive Catalog of Earthquakes of the Pacific Coast of the United States, 1769 to 1928" by S. D. Townley and Maxwell E. Allen, published in the Bulletin of the Seismological Society of America, V. 29, January, 1939.

2. "United States Earthquakes" published periodically (annually in recent years) by the U. S. Coast and Geodetic Survey, then by the National Oceanic and Atmospheric Administration, and, at present, by the U. A. Geological Survey. This series extends from 1928 through 1971.

3. "Earthquake History of the United States", publication 41-1 of the national Oceanic and Atmospheric Administration, Revised through 1970, published in 1973. A summary of the larger earthquakes of the U. S., extending back as far as 1638.

We searched these publications for every earthquake listed with epicenter in the defined region or, in the case of early earthquakes, where reports of shaking originated in the region.

NUMBER AND INTENSITY

Table I shows the total number of earthquakes known for the region arranged by intensity.

TABLE I

Earthquakes of Northeast California, 1851-1971 (all reports prior to 1931 have been converted from Rossi-Forel to Modified Mercalli)

Intensity (Modified Mercalli)		Number of earthquakes	Percent of total earthquakes
I to III		153	52
IV		68	24
V		41	14
VI		20 Plus 2?	7
VII		9 Plus 1?	3
VIII		0 Plus 1?	less than 1
	Total	291 Plus 4?	

The four questionable events were reported during the 1800's and are, for one reason or another, of dubious location or reality; one may have been a landslide; another may have originated in Nevada and simply been felt within the region. The other two are questionable because of poor reporting and record keeping a century ago.

The maximum intensity (see Appendix I for description of the Modified Mercalli scale of intensities) for which there is evidence, is VIII, and this single report is of questionable validity. There are nine established events where intensity VII was reached and significantly more events of intensity VI or less.

Noting that in the Modified Mercalli scale, it is intensity VII where mention is first made of "considerable damage" resulting, and this only for "poorly built or badly designed structures", we point out that, in the 120 years since the first earthquake was reported from this region, there have been nine (or ten) earthquakes capable of considerable damage to poorly built structures and only one (questionable occurrence) capable of considerable damage to "ordinary substantial buildings". We note at this same time that this record is equalled or surpassed by the St. Lawrence River region, Massachussetts, Missouri, Arizona, South Carolina, Utah, Montana, and Texas, and states not commonly thought of as seismic.

For most Northeast California occurrences the extent of the description is "windows rattled", so it would serve no purpose to reproduce data for every earthquake. Instead we present in Appendix II a chronological listing of only those earthquakes originating in the region that acheived an intensity of VI or greater.

DAMAGE, INJURIES, DEATHS. There is no record of any death or injury resulting from earthquakes within the region, and damage to buildings has been very minor; the following notes are the worst in this regard (Appendix II includes more detail and description of lesser phenomena):

1855 Large pinnacle of rock on the Downieville Buttes thrown down.

1866 Siskiyou County. Klamath River changed course, accompanied by landslide (may not have been earthquake).

1869 Report of $5,000 damage to buildings in Oroville.

(Whether local or from earthquake in Nevada is unknown. Report may be inaccurate).

1885 Glass broken and chimneys shaken down in Lassen County.

1888 Plaster cracked at Biggs.

1889 Lassen County, chimney thrown down at Willow Creek; Eagle Lake became muddy; crockery and glassware broken in Susanville.

1903 Willows, several brick walls cracked and plaster fell from many buildings.

1908 Chimneys thrown down in Lassen County.

1909 Chimneys damaged at Downieville. Minor damage to flumes, chimneys, plaster, and dishes in Sierra and Plumas Counties.

1915 Shasta County, Twin Valley; earth cracked, rocks thrown about, barn sagged, house tipped to one side. (Puzzling account; nothing recorded at Berkeley seismograph, nothing felt at Redding).

1919 Shasta County; chimneys damaged, ground fractured near Whitmore and Fern (puzzling account, similar to 1915 above).

1928 Chimneys thrown down at Weaverville.

1936 Rock slides reported on Lassen Peak and Chaos Crags.

1940 Chimneys cracked or twisted at several places in Butte County; plaster cracked at numerous places.

1945 Water pipes broken at Paradise, Butte Co.

1948 Plaster cracked.

1950 Herlong, Lassen Co; building shifted on foundation, buildings cracked; some underground pipes damaged; many chimneys broken; trusses and rafters split. Lesser damage in Doyle.

1950 Doyle; earth fracture in Long Valley.

1956 Plaster cracked at home near Manzanita Lake.

1958 Chimneys cracked at Hallelujah Junction, Lassen County.

1959 Loyalton; several chimneys fell, walls cracked, considerable glassware and merchandise fell.

1966 Plaster cracked at Forest Ranch (Butte Co.), rocks heard rolling downhill east of Oroville; some telephone service interrupted at Forest Ranch.

1966 Loyalton; lumber shed nearly collapsed, chimneys fell, walls cracked, fireplace collapsed; hairline cracks in cement block building.

1968 Chico; glass door broke in High School, several burglar alarms activated. Willows; plaster cracked.

This is a record that, while extensive, is not serious. Without denying the loss to some individuals, and possible fright to many, it can be stated confidently that this is not the sort of record that commands great concern.

LOCATION IN SPACE. Figure 5 shows the location in the region of all the known earthquakes; many locations are known only approximately and these are distinguished from those of better known location.

LOCATION IN TIME. The region experienced 291 known earthquakes in 120 years, yielding an average of 2.4 felt events per year. The region experienced 29 definite, significant events (intensity VI or greater) in 120 years of recorded history. This yields an average of one significant event every 4.1 years.

There is no obvious pattern to the recurrence of significant earthquakes. Some are separated by time intervals of less than a month, and there is one gap of 15 years with no significant events reported.

MAGNITUDE. Few Northeastern California earthquakes have magnitudes available because magnitudes are routinely calculated only for events well-recorded at several seismograph stations, and most of the events we are concerned with were too small or occurred prior to the installation of sensitive seismographs.

We found magnitudes available for 15 events, ranging from 3.3 to 6 1/4 - 6 1/2.

Table II presents these data.

TABLE II

Available Magnitudes of Northeast California Earthquakes

Magnitude	Number of Events
0-2.9	none reported
3.0-3.9	4
4.0-4.9	7
5.0-5.9	1
6.0-6.5	3

Of the three magnitude six earthquakes, one resulted in an intensity of VII and the other two were of intensity VI. Considering the more complete record of intensities, and making an admittedly tenuous correlation between intensity and magnitude, it seems safe to conclude that there is no reason to believe any earthquake of magnitude greater than 6.5 has originated within the region within the span of recorded history of the region.

EARTHQUAKE HISTORY: EARTHQUAKES OUTSIDE THE REGION

Earthquakes need not originate nearby to be hazardous. In the great Alaska earthquake of 1964, the city of Anchorage suffered very extensive damage from ground shaking (i.e., not tsunami) at a distance of 90 miles from the epicenter. As we extend our consideration beyond the borders of the defined region for the first time we encounter "great" earthquakes, the major events for which California and, to a lesser degree, Western Nevada, are famous. These are the earthquakes that have had the potential or the accomplishment of inflicting dollar losses measured in the millions, casualties in the thousands, and of seriously disrupting the economic, physical, and social milieu of cities and counties.

We consulted "Earthquake History of the United States", N.O.A.A. Publication 41-1, 1973, for their listing of earthquakes for California (including "off the coast"), Nevada, and Oregon. We considered all of the "great" earthquakes on this list, as well as those of intensity VII or greater that occurred within 100 miles of the borders of the defined region. In Southern Oregon we accepted intensities as low as V to obtain a sufficient number of events to display the seismic areas of that relatively tranquil state. All of these events are located on Fig. 6. Information concerning effects in Northeast California were sought in Townley and Allen (1939) and "United States Earthquakes."

Of primary concern in this phase of the study is the question, "What is the range of intensity to which the defined region has been subjected owing to large earthquakes which have originated outside the region?" The answer to this question is provided by isoseismal maps (see Fig. 7 for an example) and descriptions of the earthquakes. Unfortunately isoseismal maps are not constructed for every earthquake.

The following earthquakes produced the effects in the defined region as noted (Tables III and IV).

TABLE III

Great earthquakes of California, Nevada, and Oregon

Date, Location, Magnitude	Remarks
1812, Dec. 21 Southern California Mag. Unknown	Disastrous in southern California no mention of northeast California
1838, June San Francisco Mag. Unknown	"Very severe" in San Francisco region to Monterey. No mention of northeast California.
1856, Jan. 9 Southern California Mag. about 8.3	Possibly the potentially most destructive earthquake in coastal Calif. ever. No mention of northeast Calif.
1872, March 26 Owens Valley Mag. Possibly 8.3+	Probably the greatest earthquake ever recorded in Calif. and Nev. Very destructive of property and lives. Int. VI in Chico, Marysville; IV-V Red Bluff; V in Downieville.
1906, April 18 San Francisco Mag. 8.3	The great Calif. earthquake of popular knowledge. Great destruction in San Francisco Bay Area. Maximum intensity of V in southeast part of northeast California.
1915, Oct. 2 Nevada Mag. 7 3/4	Felt over 500,000 sq. miles from Oregon to so. Calif. Intensities from II to V reported throughout northeast California.
1932, Dec. 20 Western Nevada Mag. 7.3	Extensive faulting, some damage in epicentral area. Felt over 500,000 mi. square. Maximum intensity V from northeast California.
1952, July 21 Kern County Mag. 7.7	Felt over 160,000 mi. sq., 12 killed, $50 million damage. Intensity I-IV as far north as Red Bluff, imperceptible north of there.
1954, Aug. 23 Western Nevada Mag. 6.8	Extensive damage in Nevada. Maximum intensity of V in eastern part of northeast Calif.

1954, Dec. 16 Dixie Valley, Nevada Mag. 7.1	Faulting 55 miles long. Damage in Nevada. Int. V in east from Modoc Co. to Sierra Co.; IV or less elsewhere.

TABLE IV

Selected Moderate Earthquakes of California, Nevada, and Oregon

Date, Location, Intensity		Damage - NE California
1836	San Francisco X	None
1860	Humboldt Bay VIII	None
1861	Contra Costa Co. VIII	None
1865	Sonoma Co. VII	None
1865	Eureka VIII-IX	None
1869	Virginia City, Nev. IX	Some Damage in Downieville. Oroville suffered $5,000 damage (but may have been another event).
1871	Mendocino Co. VII	None
1873	Del Norte Co. VII	Strong in Trinity Co. Felt in Red Bluff and Redding.
1876	Sonoma Co. VII	None
1881	Stanislaus Co. VII	Felt in Greenville.
1887	Carson City, Nev. VII	None
1888	Sonoma Co. VII	None
1888	Oakland VII	None
1889	San Francisco	None
1891	Napa Co. VII-VIII	None
1892	Vacaville, Solano Co., IX	None
1892	Winters, Yolo Co. IX	Minor damage in Butte and Yuba Co. Felt in Red Bluff.

Date, Location, Size		Damage - NE California
1893	Sonoma Co. VII	None
1898	Mendocino Co. VIII - IX	None
1908	Humboldt Co. VII	None
1909	Humboldt Co. VIII	Severe throughout Shasta Co., but damage was trivial. Felt widely in other places.
1914	Reno, Nev. VII	Int. IV at Susanville, no damage.
1920	Crater Lake, Oregon V	None
1923	So. Oregon V	Plaster fell at Alturas; Int. III at Susanville.
1927	Humboldt Bay VIII	Felt in Trinity Co., no damage.
1931	Talent, Oregon V	None
1932	Humboldt Co. VIII	Felt in Bieber, Shasta, and Shasta Springs; no damage. Int. IV at Anderson, Chico, Paradise, McCloud; no damage.
1933	Wabuska, Nevada VII	IV at Chico, Willows, Williams; no damage.
1948	Verdi, Nevada VII	VI at Loyalton, Sierraville; very minor damage; V at Butte City, Colusa, Downieville, Gridley, Marysville, Quincy, Susanville, Willows; no damage.
1951	Cape Mendocino VII	V at Red Bluff and Willows; no damage.
1954	Eureka VII	VI broke 10" wooden water main in McCloud; VI slight damage in Castella; chimney twisted in Red Bluff; two windows cracked in Redding; Int. I-III in Alturas and Chico; slight damage in Orland; two windows cracked at City Hall in Redding.
1962	Lake Co. VII	None

Date, Location, Size		Damage - NE California
1968	Santa Rosa VII	None
1968	Adel, Oregon V	None
1968	Calif.-Oregon Border V	V at Modoc County
1968	Calif.-Oregon Border VI	VI at Fort Bidwell, Modoc County; house sustained cracking of foundation, some shifting of frames and walls.
1969	Santa Rosa, VII-VIII	III in Sutter County
1971	San Fernando, Calif. XI	Not Felt.

DAMAGE, INJURIES, DEATHS. The "great" earthquakes of California history have not resulted in a single death or injury in Northeast California insofar as official records reveal. The damage they have done has been quite minor, less than that done by smaller earthquakes within the region or just outside the region. There is great ambiguity regarding $5,000 damage to Oroville in 1869, whether it was an effect of a Nevada earthquake or a coincidental local earthquake, or whether it was an earthquake at all. The two most significant reports are (1) 1954, when an earthquake near Eureka broke a wooden water main in McCloud, and (2) 1968, when an Oregon event cracked the foundation of a house in Modoc County. Other effects are similar to these produced by the stronger earthquakes that have occurred within the region, and can only be classified as minor.

The historic record indicates that great earthquakes occurring outside the region are not cause for concern to the cities and counties of Northeast California.

FAULTS

Although not all authorities are willing to attribute all earthquakes to consequences of movement on faults, the relation of earthquakes to active faults is well established in California. If we can identify active faults and learn their histories, we might be able to anticipate their future movements and, hence, future seismic hazard. This is why the planner is asked to consider the location and activity of faults.

The location of faults is available from several sources, including the Geologic Map of California (scale 1:250,000, California Division of Mines and Geology) and a special fault map prepared by the California Department of Water Resources (1964). Alfors et al. (1973, pg. 37) presents a summary map, reproduced here as Figure 8.

But the map of greatest current value is that of Jennings (1973) which distinguishes among faults in such a way as to permit interpretation as to whether the faults are active, possibly active, or probably inactive.

ACTIVE AND INACTIVE FAULTS. The guidelines for preparing a Seismic Safety Element include determination of "location of all active or potentially active faults, with evaluation regarding past displacement and probability of future movement." This is a fine goal, but one that will only be realized many years from now if the efforts of the U. S. Geological Survey and the California Division of Mines and Geology are greatly expanded.

At the present time there is no agreement among authorities as to working definition of "active" and "inactive". Some faults in California are "active" by everyone's definition, and some of these are receiving intensive study. There are many other faults that everyone would agree may be justifiably classified as "inactive" (even though authorities are still prone to point out that this doesn't mean the fault is "safe"). The real problem lies with a large number of faults that show geologically recent evidence of movement, but which have no historical record of displacement. Evaluating the past displacement of these faults is very difficult, and it may be impossible to date the time of last movement in years. Anticipating future behavior is more difficult yet.

Thus Jennings (1973) does not present a map entitled "Active Faults" or "Dangerous Faults" or "Potentially Active Faults"; he presents a "Preliminary Fault Map" which presents valuable information, but which still requires that the critical interpretation of "active" or "inactive" be made by the user. What Jennings does do is distinguish the following:

A. Faults having moved in historic time.

B. Faults that have displaced Quaternary rock-units, or show geomorphic evidence of having moved during Quaternary time. (Quaternary refers to the last 2 or 3 million years of geologic time).

C. Faults that show no evidence of having moved during the Quaternary.

The natural inclination is to regard A. as active, B. as potentially active, and C. as inactive. This procedure may be justifiable, but there is no assurance that it is correct.

FAULTS OF NORTHEAST CALIFORNIA. Jennings (1973) shows three small faults of northeast California as having moved in historic time:

FAULTS OF NORTHEAST CALIFORNIA. Jennings (1973) shows three small faults of Northeast California as having moved in historic time:

Sierra County - A zone about 12 miles long in Eastern Sierra County where ground displacement accompanied the September 12, 1966 Truckee earthquake. This breakage was extensive, but minor, appearing almost entirely in unconsolidated natural fill. This breakage may not even be associated with a fault, but may be attributable solely to the passage of gravitational waves (Kachadoorian et al, 1967, pag. 4).

Plumas County - Three lines of breakage each about two miles long in Mohawk Valley, labelled as occurring in 1875, hence probably the January 24 earthquake described by Townley and Allen (1939) as "heavy shock", intensity VI (Rossi-Forel). No other details are given.

Lassen County - Two lines of breakage, each two miles long, southeast of Honey Lake, accompanied the December 14, 1950 earthquake of intensity VI. The breakage is very close to the epicenter and may mark disruption of the surface above an active fault.

Another occurrence, not indicated on Jennings' map, was the occurrence near Fort Bidwell in Modoc County of ground breakage accompanying the June 3, 1968 Oregon earthquake. "U. S. Earthquakes" describes a fissure at least 550 feet long with vertical offset as much as 18 inches. This may reflect movement above a buried fault, but was probably caused by the earthquake rather than being the cause of the earthquake.

Jennings' map shows a much more extensive network of quaternary faults within the region, especially within the mountainous, volcanic northeast part (see also Fig. 8). These faults are usually conspicuous in topography, and although little detailed study has been made of them, are familiar parts of the landscape in this area. These are faults with a few tens or a few hundred feet of displacement that probably resulted from readjustment of surface rocks made necessary by the withdrawal of lava from underneath during times of volcanic eruptions. These are not, with two exceptions, the major zones of deformation that accompany mountain building episodes. The two exceptions are the Honey Lake fault separating the Diamond Mountains from the Honey Lake basin in Lassen County, and the Surprise Valley fault, separating the Warner Mountains from Surprise Valley of Modoc County. These two faults are of large displacement (thousands of feet), and movement on these faults has resulted in the creation of large block mountains, or mountain ranges.

These quaternary faults are significant in that most of them (perhaps all, if the truth were known) have prominent vertical displacement. They are, as a generalization, normal faults, in contrast to the famous faults of Coastal and Southern California, which are mostly of horizontal (strike-slip) displacement. The significance of this is that the faults create prominent steep-faced scarps that are not conducive to building. While it is true that there are roads across these faults, and buildings are located near them, the relief across the fault discourages construction directly on the fault itself. Thus there is less danger than would be the case if strike-slip faults were abundant, for it is these faults that one must make special efforts to avoid.

Jennings' map shows many pre-quaternary faults in the mountainous parts of the region, but these we can ignore. If there _is_ such a thing as an inactive fault, it would be these, and although Jennings especially warned that these are not necessarily "dead", they will be so regarded here.

What then can we infer about earthquake hazard from the foregoing? First, that "active" faults are very rare in the region. The few that do exist are quite small, and it is equally possible that they are consequences of earthquakes rather than causes. We think it would be prudent to initiate an investigation of those localized areas in Sierra, Plumas, Lassen, and Modoc Counties with known ground rupture, but we do not regard them as especially hazardous. Certainly there should not be anything constructed directly across the break, but there would seem to be little hazard nearby. Second, though there are many potentially active faults within the region, they are small in length and displacement, and carry their own "stay off" sign in the form of a topographic scarp. Third, the two biggest faults, Honey Lake (Lassen County) and Surprise Valley (Modoc County) would be presumed to hold the greatest threat of large, destructive earthquakes. The distribution of earthquakes during the last 120 years does not point to these faults as being especially hazardous, but one should not overlook the possibility that earthquakes do occur on these faults with recurrence intervals of more than 120 years. Although there is no evidence that these faults are especially dangerous, it would seem prudent to conduct field observations along these two faults to see if the absence of evidence is because there is none, or because it simply has not been discovered.

Finally, mention should be made of faults that may exist under the surface of the Sacramento Valley. Jennings (1973)

Having mentioned this possibility, we can dismiss the possible faults from consideration as being not in evidence, and inaccessible to study. But we should not forget that they may be there despite the clean, unblemished appearance of the Sacramento Valley on the fault map.

FUTURE SEISMIC ACTIVITY

MAXIMUM INTENSITY. Although earthquake prediction is currently the subject of much research, it is not yet possible to predict future seismic activity with reliability. We can only extrapolate from past experience and hope that nature does not have too many surprises for us.

Earthquakes are caused by natural processes within the earth that proceed at very slow rates compared to human perception; timespans of many thousands or several millions of years are typical. Recognizing this we are justified in inferring that the next thousand years will be like the last thousand years. The problem is that we rarely know what the last thousand years has been like in sufficient detail. The earthquake record in Northeast California extends only slightly more than one century into the past, and only the most recent 50 years of this span are completely satisfactory.

In brief, we would probably be correct in anticipating the next thousand years if reliable records extended for a thousand years into the past. To anticipate the next 100 years from the last 100 years is less justifiable owing to the brevity of experience in comparison with the tempo of the natural process.

At this junction there are three alternative ways to proceed:

1. Assume the best: The best possibility is that our brief earthquake history is an adequate sample, and that for the foreseeable future, the events of the known past will not be exceeded. We note that an extensive study of possible earthquake effects in the San Francisco Bay region (Nat'l Oceanic and Atm. Adm., 1972) assumed as their largest, most disastrous model earthquake, one equal to the 1906 earthquake. There is justification for this reasoning, but it is risky. There is absolutely no reason to believe that the future will be <u>less</u> active than the past. For it to be exactly equal to the past would seem too fortuitous to be readily accepted. Thus it is prudent to anticipate that the future will hold something greater than recorded history reveals.

2. Assume the worst: A touchstone of seismologic thought is that if you wait long enough any given location will be subject to shaking of great intensity. The New Madrid, Missouri earthquakes of 1811 and 1912, and 1912, and the Charleston, South Carolina earthquake of 1886 remind us that you do not have to be in a notorious seismic area to be subject to extremely severe earthquake shaking. Indeed, one of the great problems of regional seismic risk maps has to do with these two earthquakes forcing inclusion of these two areas in a high-risk category. This being so, should not all geologically similar regions of the U. S. be so classified? The person who would make a seismic-risk map for the U. S. thus faces a cruel dilemma...he must either ignore major events, or include virtually all of the U. S. as high risk, an action that minimizes the utility of his map. This approach is safe, for if with the passage of time, that which is anticipated does not occur, it is simply because not enough time has passed. Thus the day of judgment is postponed into the future to a time when being proven wrong would no longer be an embarrassment.

   City and county planners need not take the distant future into account, and perhaps should not try. Castles of Europe and England remind us that while it is possible to build to last for hundreds of years, it is not necessarily wise to do so.

Thus we reject this approach as begging the question, which should be "What is to be expected in the near future?" rather than, "What is possible in the indefinite future?"

3. Compromise: One might be at ease assuming that the near future will bring what the known past has delivered plus a little more. From the known distribution of intensities (Table I) we note that while VI has been relatively common, VII has been sparse, and VIII has been very rare, if it has been reached at all. Thus we might be justified as predicting VIII as the highest intensity that should be planned for. The other obvious choice would be to plan for IX, but, as we review damage reports we feel (albeit intuitively) that reported intensities have been overestimated often and not underestimated at all; hence the VI and VII reports suggest, to us, that an "honest" VIII is more likely than an "honest" IX is.

LOCATION. What part of the region is most likely to be subjected to the maximum intensity? Reviewing data from previous sections, we note that the highest intensities from the past have originated from earthquakes within the region, and that the larger of these are distributed throughout the region without any obvious pattern. (There are distinct clusters of low-intensity events, but these we will ignore.) Thus we believe that the maximum intensity can be reached anywhere in the region. Over a very long period of time it is likely that this maximum might be repeated more often in some parts of the area than in others (and here the clusters of low-intensity events should be considered), but we do not believe that frequency of repetition is particularly pertinent to the immediate study, nor would it be determinable if it were pertinent.

EARTHQUAKE HAZARD IN PERSPECTIVE

This study has taken a thorough look at earthquake history in Northeast California. Based on past occurrences we have been able to make some intelligent projections for future planning; but it is necessary to back up and take a broader view of earthquake hazard for the region. Earthquake hazard must be seen in the proper perspective. Two hundred ninety one earthquakes are known within the study area since 1769, but does that mean that Northeast California is earthquake prone, or earthquake safe overall? Brief comparison with other regions benefits us here.

In the San Francisco Bay Area alone, for example, a few major earthquakes of high intensities have caused alarmingly serious losses in dollars and lives. The following table enumerates those quakes:

TABLE V

Some San Francisco Earthquakes

Year	Location	$ loss at time of quake	Lives lost
1865	San Francisco	500,000	0
1868	Hayward	350,000	30
1898	Mare Island	1,400,000	0
1906	San Francisco	500,000,000	700
1955	Oakland Walnut	1,000,000	1
1957	San Francisco	1,000,000	0
	Total	504,250,000	731

Source: Alfors, 1973.

A total of only six earthquakes accounted for over

$500,000,000 in damage, and a total of only three quakes accounted for the deaths of 731 persons. This in an area much smaller than the present study area. In Northeast California, the greatest known earthquake intensity is VII, with the possibility of an intensity VIII quake in Oroville in 1869. Damage has been negligible. No lives have been lost. Since 1769, there has been no record of any death nor even any injury received as a consequence of earthquakes in this region. Some of the most serious disturbances reported were cracked walls, fallen chimneys, broken pipes, and split rafters; but in the main, Northeast California earthquakes have caused only "rattling dishes, cracked plaster, and creaking walls."

On the other hand, there are regions within the U. S. with less active seismic histories. In the entire state of Kansas, only nineteen earthquakes have been reported since 1867. Three of those quakes were Intensity VI or VII; the others were between I and V. Three of the quakes had their epicenters outside Kansas, but were felt within the state. In all of Kansas' earthquake history damage has been slight, and no lives have been lost.

Although Kansas has been considerably less active than Northeast California, the difference is not significant to planners because the consequences of each region's earthquakes have been virtually the same, little or no damage, and no loss of life. The difference between Northeast California and the Bay Area is, of course, significant to the planner.

Earthquake hazard must, also, be viewed with respect to other natural hazards within the region. In Northern California, particularly in the Sacramento Valley, flooding is feared more than any other natural hazard. While flood prediction in the area is imperfect, there is no doubt that even with extensive flood control measures, the waters of the various rivers and streams will periodically overflow their banks and flood the surrounding land. Agriculturalists who have lost orchards and crops know this. Riverside dwellers who have seen their homes torn away by a torrent know this.

In one flood alone, that of December 1955 which flooded Yuba City, 55 people died and losses were in the millions of dollars (Hartman, 1964, pg. 26). In Siskiyou County, damage to county roads alone was estimated at $4,000,000. In Butte County damage to public property was estimated at $750,000 (Jackson, 1955, pg. 91).

All this is not to say that concern for seismic safety is unnecessary, but the planner would do well to keep the hazard of earthquakes in the proper perspective so that he may judiciously direct his energies.

SUMMARY OF CONCLUSIONS

1. Existing seismic risk maps of California and the United States are unreliable because they are not based upon more detailed study of smaller areas. Also, existing maps are contradictory in some county-sized areas, and there is no objective way to choose which is correct.

2. Earthquake history is the most objective guide to the future that is presently available to us.

3. There is written record of 295 earthquakes having occurred in Northeast California since 1851; 22 of these achieved an intensity of VI (M.M.), 10 an intensity of VII, and one questionable occurrence of intensity VIII.

4. Of known earthquakes in the region, 90% were of intensity V or less, capable only of very minor damage or no damage at all.

5. There have not been any injuries or deaths caused by earthquakes in the region.

6. Property damage caused by earthquakes in the region has been very small.

7. There is no evidence of an earthquake greater than magnitude 6.5 having occurred in the region.

8. Earthquakes occurring outside the region in California, Nevada, and Oregon have not had any greater effects in the region than much smaller earthquakes originating within the boundaries of the region.

9. There are four small areas within the region that should be treated as active faults. Each of these should be investigated more, but do not appear to be of major concern. Building should not be permitted in these areas.

10. There are many faults that must be regarded as potentially active, but they do not pose a serious threat.

11. There are two large faults, the Honey Lake fault and the Surprise Valley fault, that should become the subjects of additional study. While there is no evidence that they are dangerous, evidence is not yet complete.

12. There are many faults in the region that can be classified as inactive.

13. Planning within the region should be based upon a maximum intensity earthquake of VIII (M.M.). Such earthquakes will not occur frequently.

14. The hypothetical intensity VIII earthquake might occur anywhere in the region.

15. Earthquake hazard in Northeast California is not great compared to the rest of California.

16. Earthquake hazard in Northeast California is not great when compared with other natural hazards in the same region.

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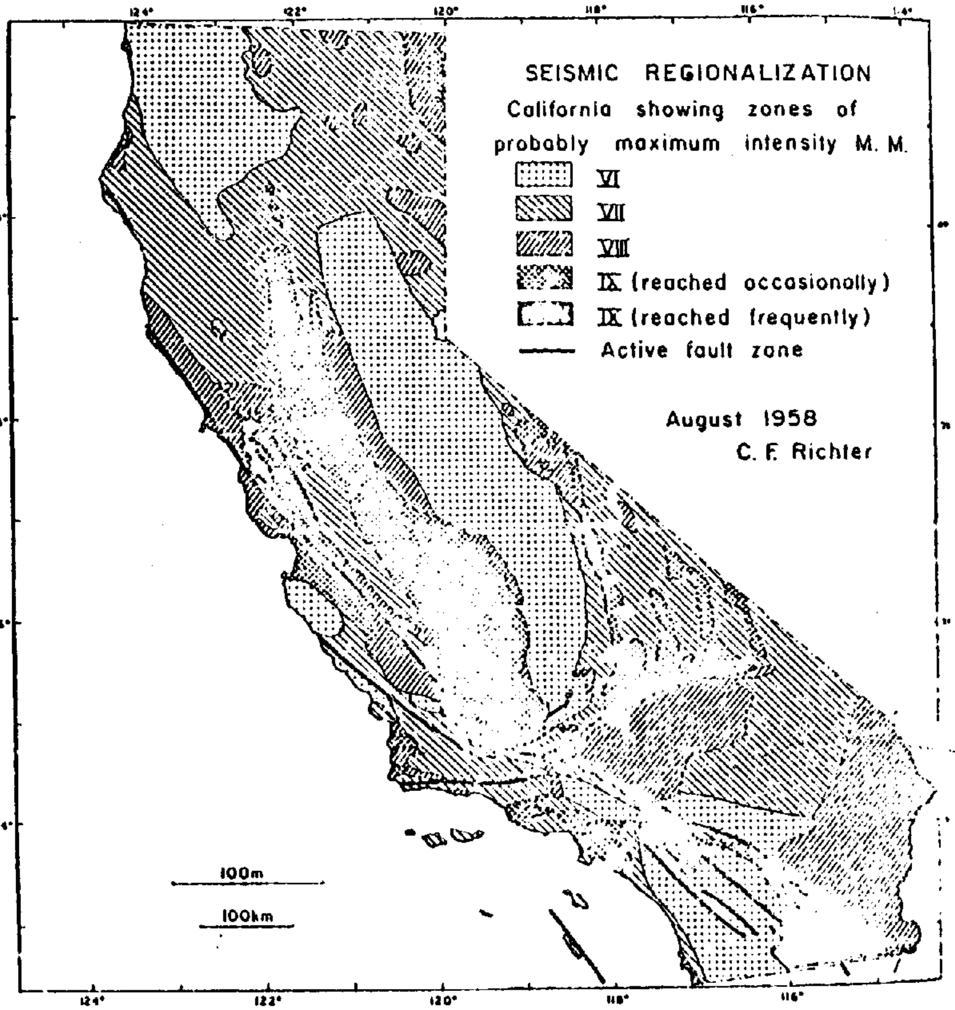

Fig. 2. Seismic Risk Map, Richter, 1959

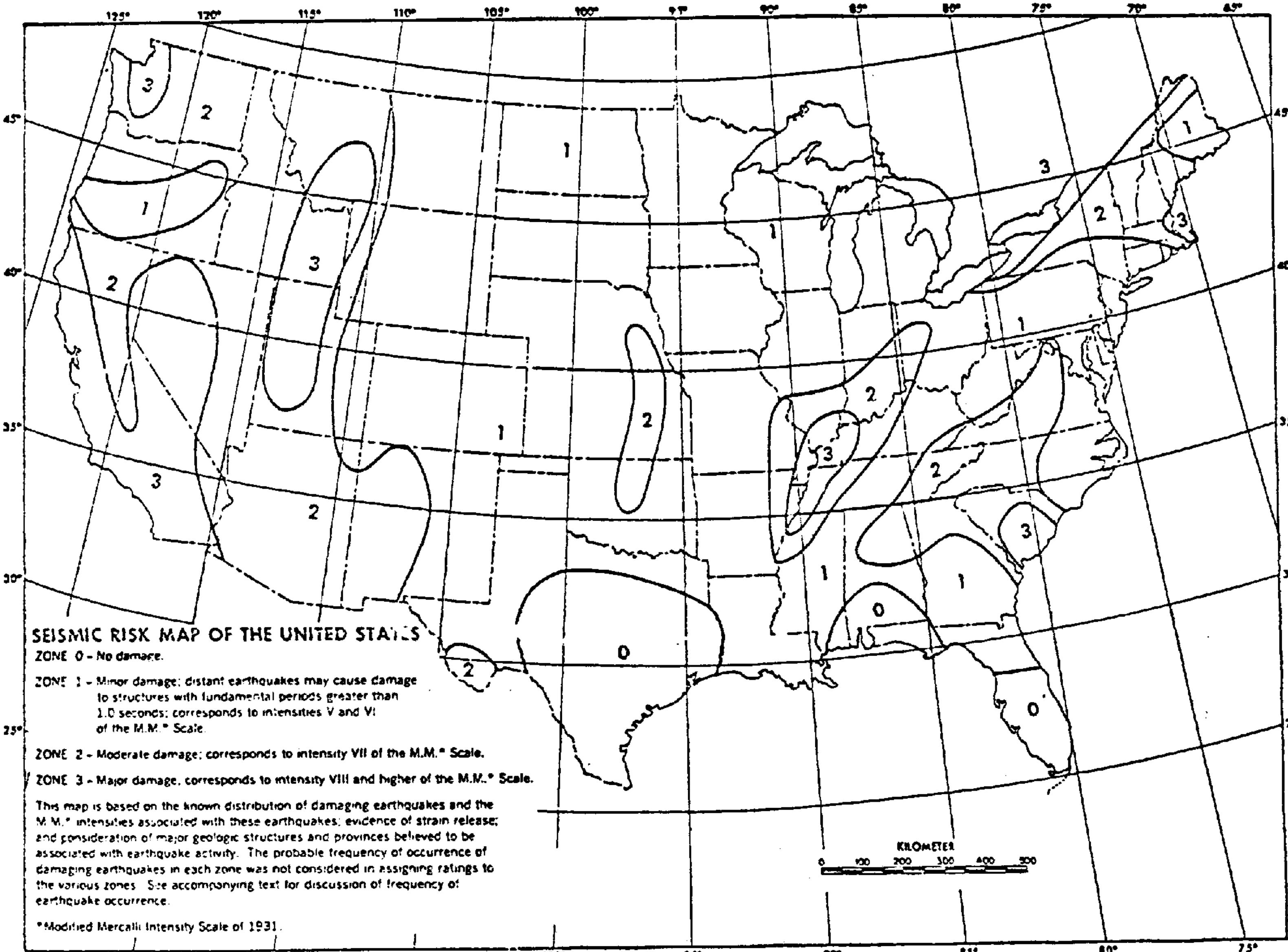

Fig. 3. Seismic Risk Map, Algermissen, 1969

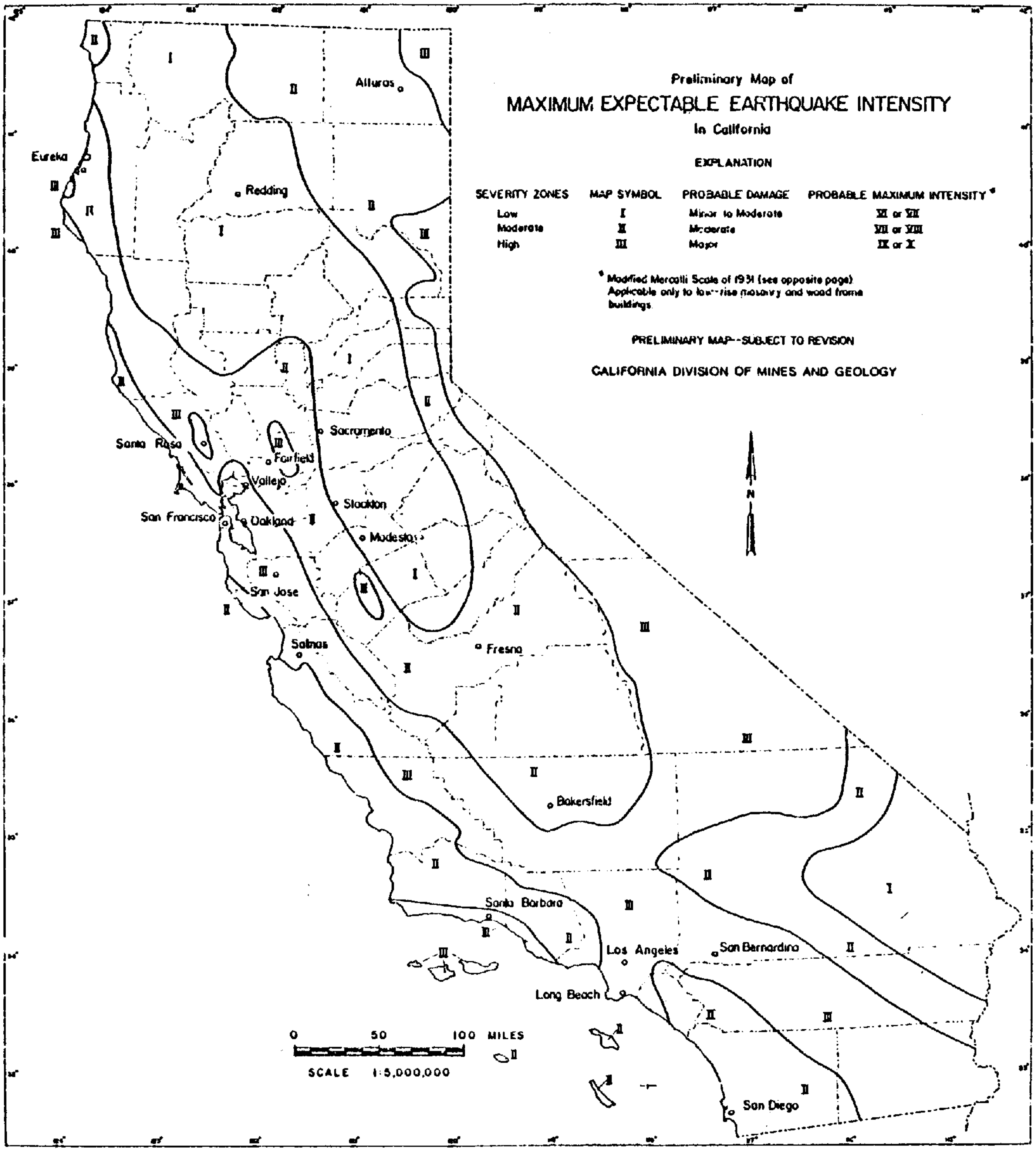

Fig. 4. Seismic Risk Map, Alfors et. al., 1973

APPENDIX I

INTENSITY SCALES

Intensity scales measure the strength of an earthquake by observing the effects it had on people, buildings, and objects. When one speaks of the intensity of an earthquake, he refers to the greatest intensity usually observed near the epicenter. But one may also speak of intensity at a particular location; thus an intensity VIII earthquake in Butte County might have an intensity of V at Redding. Roman numerals are used for intensity to keep them distinct from magnitude, another measure of strength, but one that is decidedly different in meaning.

Rossi-Forel Scale. This scale was widely used between 1883 and 1931, but changes in building construction gradually rendered it obsolete.

Modified Mercalli Scale of 1931. This scale replaced the Rossi-Forel scale in 1931 in publications of "United States Earthquakes." Originally established in 1902, it was significantly modified in 1931, hence the name. In 1956, Richter reworded the scale without changing the intent. Today one finds two versions in circulation, the 1931 version and the 1956 rewording; either is acceptable, and they are interchangeable.

The 1931 version is given below because it is used in "United States Earthquakes" from which much of the data for this study were taken. Alfors et al. (1973, p. 21) gives the rewording proposed in 1956 by Richter (note: this version is not "the Richter scale", which is a magnitude scale). Rossi-Forel equivalents are given at the end of the descriptions which follow.

I. Not felt except by a very few under specially favorable circumstances. (I)

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II)

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III)

IV. During the day, felt indoors by many, outdoors by a few. At night, some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably. (IV to V)

V. Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI)

VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII)

VII. Everybody runs 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 motorcars. (VIII-)

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 in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX)

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken (IX+)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X)

XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines 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 air.

APPENDIX II

CHRONOLOGICAL LIST OF EARTHQUAKES OF INTENSITY VI OR GREATER ORIGINATING IN NORTHEAST CALIFORNIA

Due to the length and detail of this chronology dating from 1855, it has been omitted from the report, but is on file in the office of the Planning Commission and is available for public inspection.

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SIGNIFICANCE OF SEISMIC HAZARDS IN NORTHEASTERN CALIFORNIA FOR PUBLIC POLICY

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Guyton and Scheel prepared a history of all reported earthquakes in REGIONAL PROGRAMS MONOGRAPH #1 entitled "Earthquake Hazard in Northeast California." They summarize by saying that the maximum intensity reliably reported in historic times was VII on the Modified Mercalli Intensity Scale of 1931. Intensity VII is described, "Everybody runs 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 motorcars." They further report that there are no known deaths or injuries due to earthquakes. Property damage has been minimal to both private and public improvements. Earth displacement has been minimal. The largest earthquakes originating outside of the region have not produced shock intensities in Northeast California as great as the quakes originating within the region.

During the first 120 years of recorded history in Northeast California earthquakes have not been an important enough hazard to justify any significant recognition in public policy. However, we realize that earthquakes occur very infrequently. The fact that Northeast California has not suffered a serious earthquake during the past 120 years does not mean that we will not have one in the next 120 years. Guyton and Scheel suggest that prudent planning for the future take into consideration the possibility of earthquake intensity of VIII(MM). This intensity would produce, "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 in small amounts. Changes in well water. Persons driving motorcars disturbed." We suggest that some attention be given to the following matters which may be earthquake related.

Landslides. Steep slopes, loss of vegetation, soil type, saturation, and earthquakes are all contributing factors to landslides. All of these factors may exist simultaneously in selected locations. Particular attention should be given to slope stability in Environmental Impact Reports. It is well to bear in mind that landslides can take place on level ground if the subsurface slide face is at an angle. Careful studies should be done to examine the possibility of land-slides into reservoirs which may place overload stresses on dams.

Infiltration of Groundwater in Sewage Mains and Interceptors. The infiltration of groundwater in a sewage collection system can overload the treatment plant and render it ineffective. Most of the cracks which open in mains and interceptors are probably due to differential settling within a short period after construction. Small cracks grow to large cracks. We have no direct evidence to establish that ground-shaking due to earthquakes has caused small cracks in our sewage collection systems. However, it would seem that extra care in design, construction, and repair of the collection system should be exercised to minimize the possibility of fractures due to ground shaking.

Structural Failures in Buildings. The principle structural damages sustained during the last 120 years have been due to weakened chimneys. Building inspections and building codes should pay attention to the sturdiness of chimneys and other roof structures exposed to the weather such as parapets. Construction of new schools, hospitals, apartments, commercial and industrial buildings should be to high standards to withstanding MM intensity VIII shocks. Care should be exercised in drawing building code changes to specify standards to be met, rather than to specify materials and crafts. A building code can become a means for greatly increasing the cost of construction without adding to quality. Many materials suppliers and building trades are not above perpetuation of their self interests through adoption and enforcement of unnecessary restrictions in a building code.

Disaster Response. Every unit of government should be prepared to marshall and manage forces within their jurisdiction to meet disasters due to fire, flood, earthquake, civil disorder, accidents, and war. While we believe that the possibility of disaster from an earthquake has a very low probability, the possibility cannot be ruled out. With regard to earthquake hazard the greatest likelihood in disaster response is that resources from Northeastern California will be called upon to provide assistance to emergency forces dealing with an earthquake disaster in the San Francisco Bay area. Thought should be given to the minimum complement of forces necessary to continuation of services in this part of the state; this will provide a clear picture of the emergency vehicles and trained personnel which can be dispatched to the aid of other communities.

Reservoir Failure. Communities lying in the inundation path below a major reservoir have a special interest in knowing the consequences of structural failure. These reservoirs were designed with large safety margins which are believed to be adequate. However, we must recognize that the intensity, magnitude and epicenters of earthquakes cannot be predicted accurately. Under these circumstances it behooves us to examine even the most unlikely possibilities and consider the appropriate contingency plan for even unlikely possibilities. These contingency studies are the responsibility of those units of government directly affected.

Scaling the Response to the Size of the Problem. Earthquakes in other parts of the country and other parts of the world have been known to cause severe damage. Northeast California has a history of quakes. It would be easy to conclude that it is only a matter of time before we experience a major quake. Further, that public policy should provide for this contingency. The evidence does not seem to support this line of reasoning. However, it would appear that earthquake hazard in Northeast California does justify some attention to the issues set forth in this report.

Consideration of Existing Structural Hazards

1. Dams, Public Utilities, and Services

The problem of failure of dams is indeed a massive concern. Water is considered to be the most powerful, naturally occurring force affecting man. The destruction and power resulting from the failure or overtopping of a dam (seiche) is beyond the comprehension of most people. Inundation maps are currently being prepared by the Office of Emergency Services and are currently not yet available.

In reviewing this potential for damage, one must consider at least two major factors: Volume of water released and proximity to large population concentrations.

It would be unwise to speculate about damage to civilian populations without accurate data, however, it appears that most population centers are not in direct danger from flooding of any greater potential than exist from other natural causes.

2. All emergency service facilities should develop the capability to function when public utility services are interupted. Hospitals should have independent and adequate emergency generators and water supply systems. Radio communication systems should be developed to enable the rapid dispersion of medical aid where and when needed.

Police and sheriff offices should also have back-up systems to assure the maintenance of county wide, as well as statewide, communication.

Fire stations should have available independent syphon pumps to provide water from streams, lakes, or wells should water mains be out of service. Fires are probably the second most damaging affect of earthquakes, and often due to the inability to adequately contain them. may cause more actual damage than the earthquake.

All gas lines as well as water lines should be equipped with emergency valves to close the major lines when a rupture occurs. This is to prevent the escape of gas with resulting fires, and to preserve water supplies for later emergency use.

3. Substandard Public Buildings

Public buildings pose one of the more troublesome risk problems due to the nature of the services provided, the public is more or less captive and since they have no choice of whether to use the public facility or not, it is vital that all public buildings be as earthquake proof as reasonable. This is vital for numerous reasons:

a. To protect the lives and safety of the public and employees required to use the facilities.

b. To insure that the functions of government and provisions of public services continue to function efficiently.

c. To provide operations bases to aid in the restoration of all functions of civilian life to normal as rapidly as possible.

A comprehensive earthquake analysis of all public buildings should be initiated. Special evaluation will be necessary in older buildings; especially unreinforced-brick structures which, while of historic value, may pose great hazards to life.

Unreinforced-brick or concrete structures appear to be the major structural hazard within this area.

The problems of building over active or potentially active faults presents the greatest danger. This is due to the predominance of most fault activity being of a normal or thrust configuration rather than lateral, which in most cases means that even minor movement can destroy buildings even where shaking or intensity is low.

Other geologic features such as relative depth to bedrock, the nature of subsurface geology, and potential for liquidfaction should be considered when designing buildings. This, of course, does not relate to single-family or duplex-type buildings, but should be a consideration in public or multi-story buildings.

SAFETY AND SEISMIC-SAFETY ELEMENTS

A. Safety (Fire and Geologic Hazards)

Section 1. Summary and Objectives

Government Code Section 65302.1 requires a Safety Element of all County General Plans, as follows:

> "A Safety Element for the protection of the community from fires and geologic hazards including features necessary for such protection as evacuation route, peak-load water supply requirements, minimum road widths, clearances around structures, and geologic hazard mapping in areas of known geologic hazards."

The objective of this element is to introduce safety considerations into the planning process in order to reduce loss of life, injuries, damage to property, and economic and social dislocation resulting from fire and dangerous geologic occurrences.

FIRE PROTECTION REQUIREMENTS OF THE CITIZENS OF SISKIYOU COUNTY

The Board of Supervisors has established fire protection districts. Since Siskiyou County is not basicly an urban county with unincorporated urban populations, these districts are formed at the request of residents of a particular area. To date, Siskiyou County has established 12 fire protection districts. These include: Happy Camp District, Copco Lake District, Hornbrook District, South Yreka District, Scott Valley District, Callahan District, Montague District, Gazelle District, Butte Valley District, Tulelake District, Mount Shasta District, and the Dunsmuir District. These districts have varying capacities, which vary directly with equipment, manpower, and relative response time. In addition, during the fire season the fire fighting capability of the California Division of Forestry, Shasta-Trinity, Klamath, Modoc, and Six Rivers National Forests, and on occasion the state of Oregon's forest fire fighting units, are available to assist in the fire control. The state and federal agencies will not respond to a structure fire unless there is an endangering of state or federal lands through spreading of the fire.

The Public Resources Code defines hazardous fire areas, restrictions on use, and minimum protection requirements, administration of which is carried out by the State Division of Forestry.

The Public Resources Codes setforth provisions for the reduction of fire hazards around buildings located on land which is covered with flamable material. A firebreak of at least thirty (30) feet is required to be maintained around buildings by removing all flamable vegetation or other combustible growth. Additional widths of firebreak may be required under extrahazardous conditions. Firebreak clearance is, also, required around electrical transmission poles and towers.

Burning is regulated by permits issued by the State Forester. Provisions must be made to control erosion in areas where vegetation has been removed for firebreaks.

Siskiyou County is in the process of amending its Subdivision Ordinance. In conjuction with the evaluation of this ordinance, the county's Improvement Standards are also being revised. This revision will evaluate and establish the mimimum road widths required for development, the minimum water supply requirements in those developments which have public water systems, and controls to some extent the design of subdivisions and road extensions to avoid hazardous design which can result in the inability to move emergency equipment down roads or the severing of single-entrance roads by fires or other occurrences, which would result in the trapping of citizens in a dangerous area.

VOLCANIC HAZARDS

With a quick look around the county, it is apparent that Siskiyou County has been subject to volcanic activity in the past. Although there is no record of active volcanism within time, the possibility of eruption or related volcanism must not be overlooked. However, it would be premature to establish numerous procedures and special plans to meet the needs of the volcanic disaster. The plans that are evolved to meet any disaster in the county can obviously be implemented to meet a volcanic disaster. Further, it is normal that prior to any direct volcanic eruption the activities are preceded by numerous seismic occurrences of varying magnitude. It is, therefore, critical that any seismic activity which can be placed as occurring either within the county's boundaries or in the very near vicnity should be carefully observed and thoroughly examined.

One of the most important problems of safety is knowning not only that a safety hazard exists, but where the hazard is located. The Siskiyou County Planning Department in its county-wide zoning investigations has contracted with the Soil Conservation Service for generalized soils maps of Siskiyou County. Included in these soils maps are delinations of areas subject to landsliding. These delinations are general and specific recommendations must be based upon on-site inspection in relation to any proposed development of the property. The principal advantage of the mapping is that it allows the establishment of areas of concern so that hazards are not overlooked. The Soil Conservation Service has in the past established flood-plain zoning in the Scott Valley's watershed area, and the county is in the process of having the balance of the flood-zones within the county established by the federal government. Specific seismic hazard areas are discussed in the seismic-safety portion of this element.

Recommendations:

The following policies should be established to protect the public health and safety.

1. Dissemination of Seismic Safety Information.
   Geologic and structural hazard information relating to private development should be readily available.

2. Dissemination of Seismic Emergency Information.
   Emergency information available at the Office of Emergency Services should be more widely distributed.

3. Radio Communication Facilities
   The radio communication capabilities should be evaluated both for the ability to withstand seismic damage and as to effectiveness as an area-wide communications network.

4. Public Buildings
   All public buildings should be reviewed for structural adequacy and the ability to survive a major earthquake. This is imperative for structures housing safety and rescue equipment and communications center buildings. Occupation of high risk buildings should be minimized whenever possible.

5. Geologic Hazard Management Areas.
   The County should initiate a "GH", Geologic Hazard Zone in which all uses would require a use permit to assure acceptable development in a known hazard area. Hazard areas will be established by agencies capable of making geologic evaluations.