UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROCEEDINGS OF CONFERENCE XXXI

A WORKSHOP ON "EVALUATION OF REGIONAL AND URBAN EARTHQUAKE HAZARDS AND RISK IN ALASKA"

September 5-7, 1985
Anchorage, Alaska

SPONSORED BY:
U.S. Geological Survey
Federal Emergency Management Agency
Alaska Division of Geological and Geophysical Surveys
and
Alaska Office of Emergency Services

EDITORS
Walter W. Hays and Paula L. Gori
U.S. Geological Survey
Reston, Virginia 22092

Open-File Report 86-79

Compiled by
Carla Kitzmiller and Wanda Fuller

Reston, Virginia
1986

(New odd page)

TABLE OF CONTENTS

ALASKA PROCEEDINGS

IB8 20130

New odd page)

EARTHQUAKES AND PUBLIC POLICY

by

Joe L. Hayes

Anchorage, Alaska

Because of Alaska's vast natural resources which lie beneath the ground, its climate, and unique tectonic activity, this State should place a priority on earthquake research and seismic monitoring.

Many Alaskans remember the great 1964 earthquake, but a majority of residents have come to this State since 1964. Some may be aware of the destruction that quake caused and many may be concerned about the potential of a similar incident.

It has always seemed a little ironic that the 1964 disaster fell on Good Friday because all of us who were here at that time certainly felt nothing good could come from that great quake. But there is good which is coming from that disaster. First, we remember the effect it had on this community. Second, we have conducted research about the effects of the quake and possible consequences of another such disaster. Third, we are evaluating how well Alaskans are prepared to handle such a disaster. And fourth, we have the potential to assume a role for the Nation as a leader in earthquake research and preparedness.

Because of the potential for another major quake and because of the building boom that continues to take place in the southcentral area, it is essential that we understand the geological makeup of areas in which we build, the potential for quake damage, and how to respond in the event of a quake. The simple fact is that Alaska, the most quake-active State in the Nation, does not yet have an adequate program in earthquake research nor does it have an adequate program to mitigate the effects of quakes. Why the public or government has not made this issue a priority until just recently is difficult to understand.

In health care, the least costly and most effective way of dealing with sickness is to prevent it through good health practices. The same philosophy should be useful for disaster prevention. It would certainly be wiser to understand how, when, and where a quake might occur and to develop an area with such information in mind--rather than to treat the human and physical damage that would occur afterward and that might be indirectly a result of improper engineering or planning caused by a lack of knowledge.

In 1983, I cosponsored legislation which at least began to address the problem as a part of State responsibility. Alaska law now reads, "collection, recording, evaluation, and distribution of data on seismic events and engineering geology and identification of potential seismic hazards throughout the State are in the public interest." The law added duties in the State Geologist's office to include the collection of seismic information, the identification of potential hazards, and the duty to inform public officials and industry about potential seismic hazards that might affect State development. Furthermore, I was able to insert language in the State budget to ensure adequate funding to meet these goals.

The directive is laudable as far as it goes, but it must be better defined and it must be supported by the necessary funds and personnel. While we as a State are dealing with limited revenues for dozens of priorities, we must remember that a lack of commitment to such research today only invites danger or preventable disaster tomorrow. With the massive construction taking place now and in the future, seismic information is critical.

We must continue, and enhance, our seismic monitoring efforts and consolidate the data into a central location for public access. We must establish a funding method to assure that the collection and distribution of seismic information is given the priority ranking it deserves. We must centralize our seismic data collection efforts and provide support for seismic data transmission. Among State, Federal, and university efforts we are conducting an increased amount of research, but at times there appears to be a lack of coordination in consolidating that information.

The Workshop on Alaskan Seismology, held in February 1982 in Wasilla, also encouraged the formation of a working group on quakes, volcanoes, and tsunamis, in part to address the consolidation problem just mentioned. Such a group would also be charged with educating the public about mitigation the hazards of potential disasters. This is a critical element to our overall public policy. Communities should be involved in preparedness activities and be given specific information on what to do in the event of a major quake.

Finally, Alaska should be recognized as a leader in quake research and preparedness. This recognition will come only from an aggressive commitment to quake research and efforts to make the research a priority. The best way to achieve these goals is through the gathering and distribution of seismic information such as that given in this series of Arctic Science Conferences. I hope that these symposia, particularly in the area of earthquake research, will continue as regularly scheduled events.

BACKGROUND AND SUMMARY OF THE WORKSHOP ON "EVALUATION OF REGIONAL AND URBAN EARTHQUAKE HAZARDS AND RISK IN ALASKA"

by

Walter W. Hays and Paula L. Gori
U.S. Geological Survey
Reston, Virginia 22092

INTRODUCTION

Seventy-five earth scientists, social scientists, engineers, planners, and emergency management specialists participated in a 3-day workshop on "Evaluation of Regional and Urban Earthquake Hazards and Risk in Alaska." The workshop, held in Anchorage, Alaska, on September 5-7, 1985, was sponsored by the U.S. Geological Survey (USGS), Federal Emergency Management Agency (FEMA), Alaska Division of Geological and Geophysical Surveys (ADGGS), and Alaska Office of Emergency Services (AOES).

The workshop was the thirty-first in a series of workshops and conferences that USGS has sponsored under the auspices of the National Earthquake Hazards Reduction Program (NEHRP) since 1977, usually in cooperation with FEMA, the lead agency in the NEHRP, and one or more other Federal and State agencies and institutions. Each workshop and conference has a general goal of bringing together producers and users of knowledge on the earthquake hazards of ground shaking, surface faulting, earthquake-induced ground failure, regional tectonic deformation, and, where applicable, tsunamis and seiches. In addition, each workshop has a specific goal of strengthening new and ongoing activities in the State or region to mitigate losses from earthquake hazards. In this workshop, the specific goal was to evaluate the advances made in the state-of-knowledge and the state-of-practice since the 1964 Prince William Sound earthquake and to identify the range of achievable actions that can be undertaken in the next 3-5 years to accelerate progress, both in terms of research and implementation goals.

The workshop was scheduled to precede a meeting of the National Earthquake Prediction Evaluation Council (NEPEC) which was continuing its technical evaluation of recent predictions of earthquakes in two areas: the Shumagin gap and the Yakataga gap. The record of seismicity in these two areas has gaps in the occurrence of major earthquakes.

SEISMICITY IN ALASKA

Alaska is a classic example of the problem of earthquake hazards mitigation in the Western United States. The earthquake threat, which in terms of relative seismicity of magnitude 4 earthquakes, is roughly 75 times worse than in the Pacific West. The threat is well known to the populace--mainly because of the occurrence of the 1964 Prince William Sound earthquake. Nevertheless, very little has been done to formulate and implement loss-reduction measures--mainly because of the low population density and the building wealth which make the risk per capita small. California, in contrast, has a much higher population density and greater building wealth.

The Gulf of Alaska is one of the most active tectonic regions in the World. Approximately 11 percent of the World's earthquakes occur there. The Pacific tectonic plate moves NNW at a rate of 6 to 7 cm/year relative to the North American Plate and is being subducted beneath the North American plate along what is called the Alaska-Aleutian subduction zone (Figure 1a and 1b). Many earthquakes are generated in the process. The 1964 Prince William Sound, Alaska, earthquake is an example of a "giant" earthquake generated in the Alaska-Aleutian subduction zone (Figure 2). This earthquake, now rated as the second largest earthquake to occur in the World in the period 1904-1984, was assigned a moment magnitude (M_w) of 9.2 (Kanamori, 1977). The largest earthquake, the 1960 Chile earthquake, was assigned a moment magnitude (M_w) of 9.5. (See Table 1). The 1964 Prince William Sound earthquake caused every types of earthquake hazards (Figure 3) and generated significant primary and secondary losses. Examples of the impacts included:

1. One hundred fifty deaths and economic losses of $500 million (1964 dollars) (Office of Emergency Services, 1972).
2. Widespread architectural damage, structural damage, and collapse in buildings as far away as 60 miles from the epicenter due to the severe ground shaking which had an estimated duration of shaking of more than 3 minutes. (Note: no strong motion records of the earthquake were recorded so the exact level of ground acceleration at various locations is unknown.)

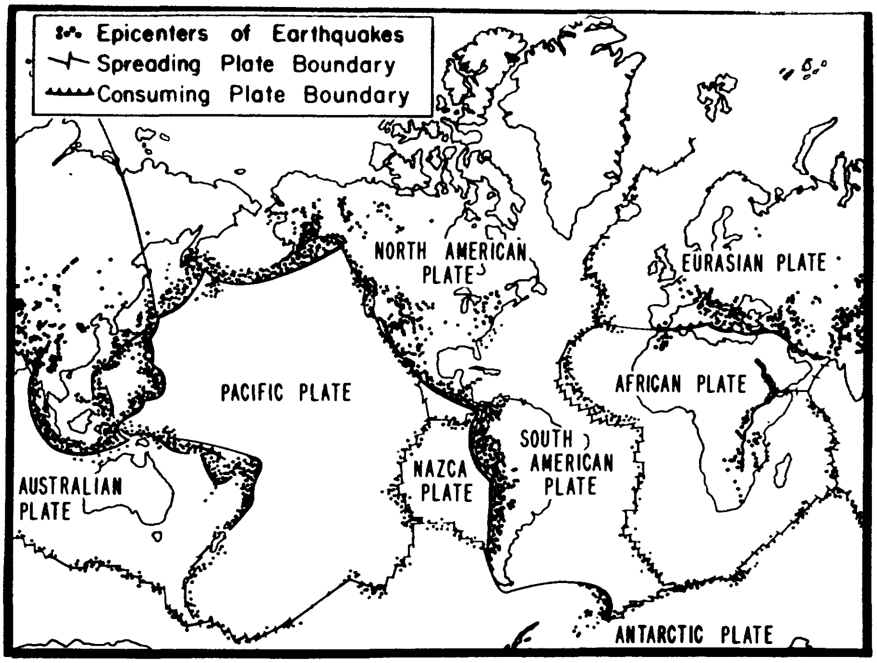


Figure 1a.--Map showing major tectonic plates of the World. The Pacific tectonic plate moves NNW at a rate of 6 to 7 cm/year relative to the North American Plate. The Alaska-Aleutian subduction zone is one of the most active tectonic areas in the World where the Pacific Plate is being thrust under Alaska.

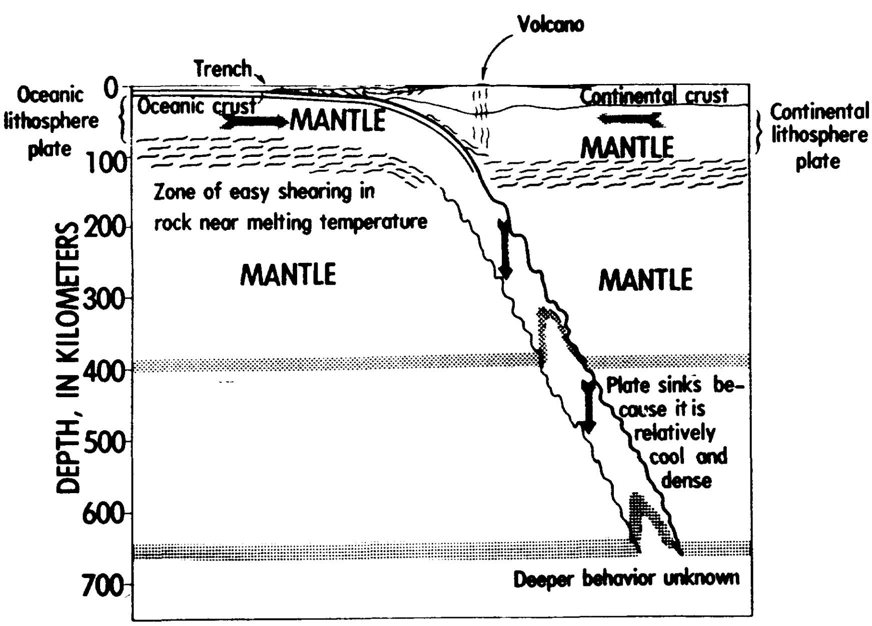


Figure 1b.--Schematic illustration of a subduction zone.

IS7 20130

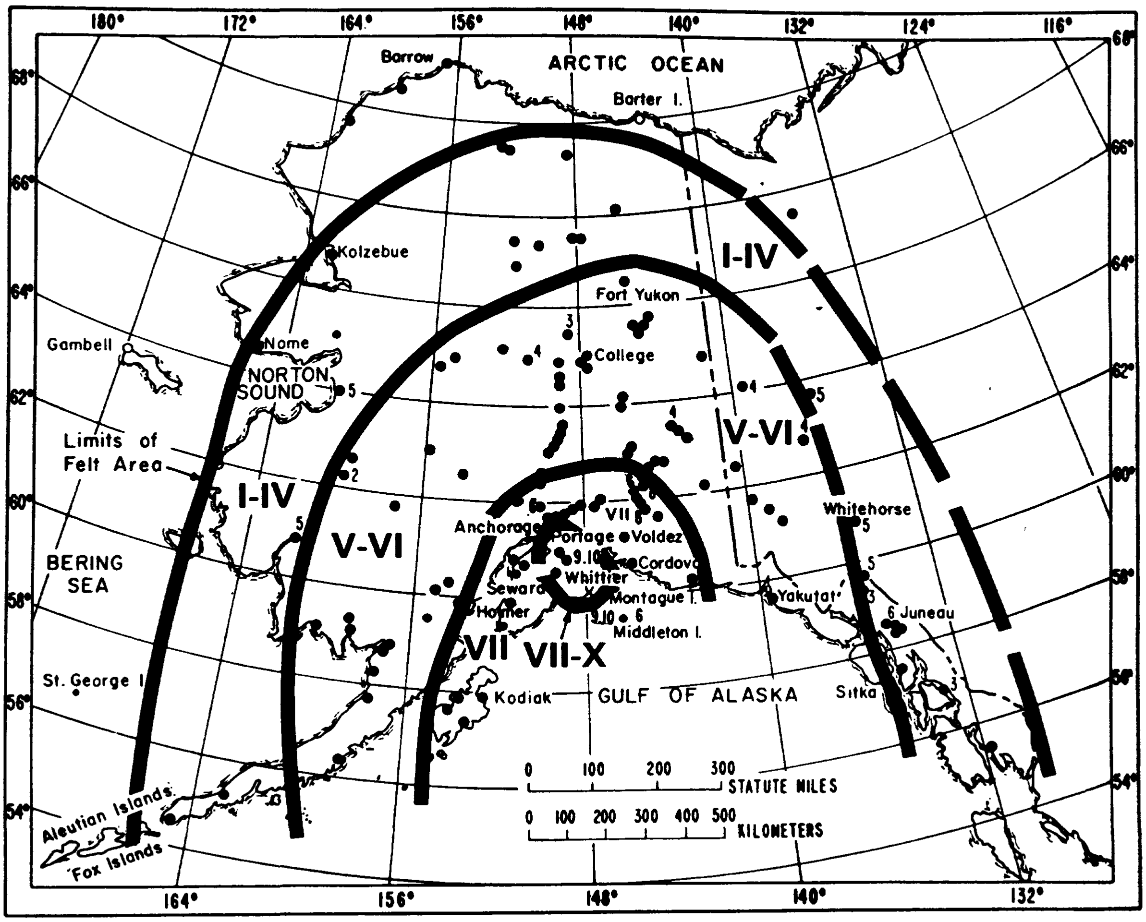


Figure 2.--Map showing isoseismal contours in terms of Modified Mercalli intensity for the 1964 Prince William Sound earthquake (from National Academy of Sciences Report on the Alaska earthquake). No strong ground motion records were obtained in this earthquake.

1S320130

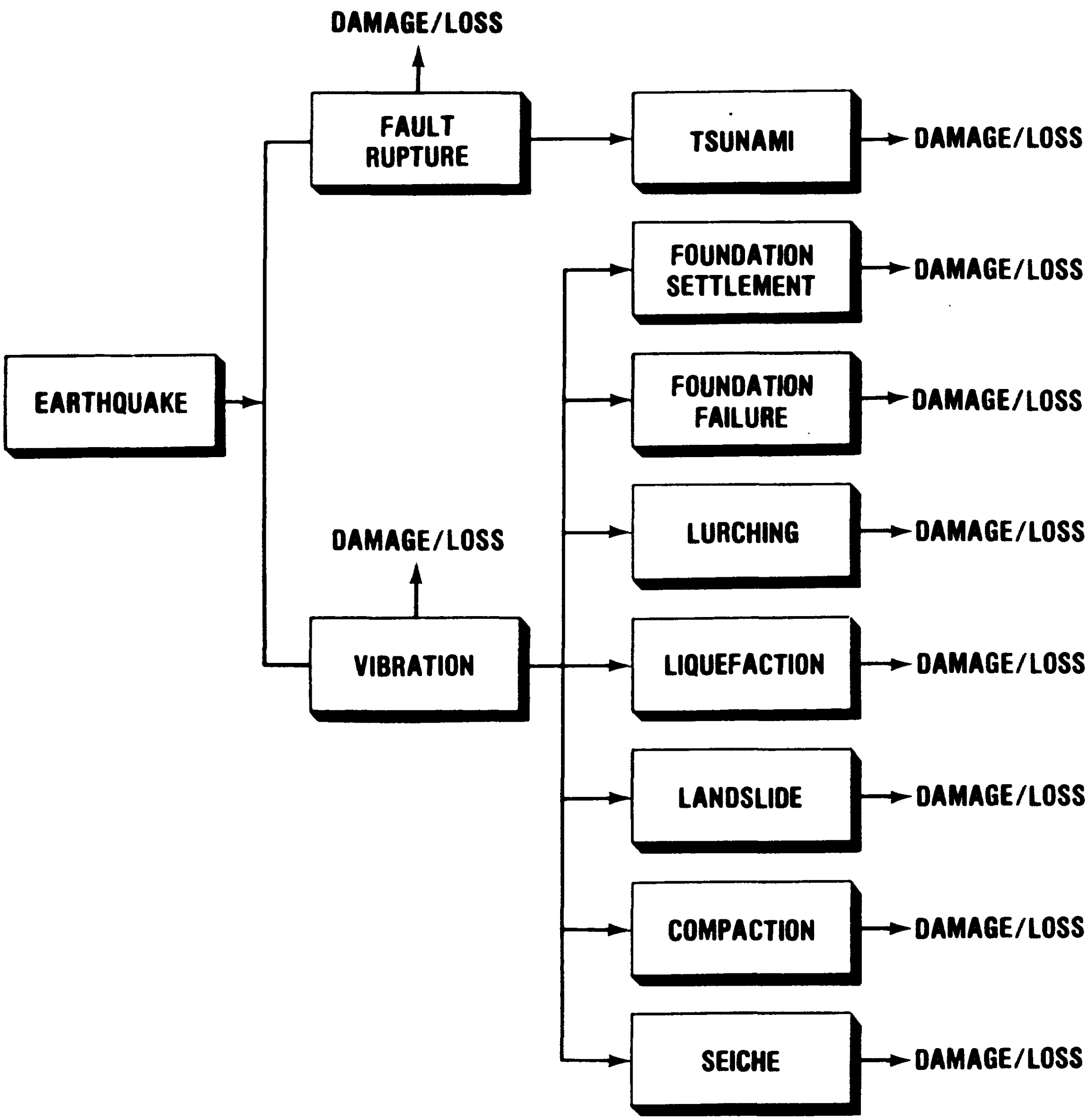


Figure 3.--Schematic illustration of the types of physical effects (hazards) that can occur in an earthquake. Each hazard can cause damage, loss of life, injuries, loss of function, and loss of confidence.

3. Extensive ground failures in downtown Anchorage that caused the ground surface to drop as much as 25 feet.
4. Regional tectonic deformation over an area of at least 77,000 square miles which resulted in shorelines rising or subsiding by as much as 30 feet, destroying ports and harbors in the process.
5. Surface fault rupture causing 30 foot changes in elevation.
6. Damaging tsunami waves having a local run up of 50 feet or more affecting both local and very distant locations.
7. Seiches causing spills of the contents of storage tasks.
8. Fires in Valdez and other areas.

The 1964 earthquake was the subject of a number of comprehensive reports sponsored by the USGS and the National Academy of Sciences.

Table 1. The World's ten largest earthquakes, 1904-1985 (from Davies, 1984).

Number	Location	Year	Mw
1	Chile	1960	9.5
2	Alaska	1964	9.2
3	Alaska	1957	9.1
4	Kamchatka	1962	9.1
5	Ecuador	1906	8.6
6	Alaska	1965	8.7
7	Assam	1950	8.6
8	Banda Sea	1938	8.5
9	Chile	1922	8.5
10	Kuriles	1963	8.5

Note: The moment magnitude scale (M_w) is used to define the magnitude of giant earthquakes (Kanamori, 1977). It is correct to call the M_w value a Richter magnitude because the moment magnitude scale is consistent with the original definition of magnitude proposed by Professor Charles F. Richter.

THE GROUND-SHAKING HAZARD IN ALASKA

Maps of the ground-shaking hazard have been prepared for Alaska (Thenhaus and others, 1985). These maps (Figures 4 and 5) require the best available data on: 1) seismicity, 2) seismogenic zones, and 3) seismic wave attenuation functions. Each step of the process requires fieldwork and careful research. The products (maps) are controversial if a large number of technical issues need resolution (Hays, 1984). A high level of controversy tends to impede their implementation in terms of zoning maps of the Uniform Building Code, earthquake-resistant design, and land use practices.

The ground-shaking hazard for the Anchorage area is compared in Figure 6 with the hazard in other urban areas of the United States. The values for the curve are obtained from maps such as those in Figures 4 and 5.

THE 1985 CHILE EARTHQUAKE

Information on the large earthquake (M_S = 7.8) that occurred near Valparaiso, Chile, on March 3, 1985, is included in this report because the experience and information provided by the 1985 Chile earthquake are very relevant to three regions of the United States: Southern Alaska, the Puget Sound area, Washington, and Puerto Rico. Similar effects as those in the Chile earthquake could happen in each of these three regions. All four regions have a similar tectonic setting, namely a subduction zone where one tectonic plate is sliding at the rate of several inches per year beneath another tectonic plate (see Figures 1a and 1b). The world's greatest earthquakes (e.g., 1960 Chile earthquake (Mw = 9.5) and 1964 Prince William Sound, Alaska, earthquake (Mw = 9.2)) have occurred in subduction zones. The 1960 and 1985 Chile earthquakes were caused by subduction of the Nazca tectonic plate beneath the South American plate. The 1985 earthquake caused 176 deaths, 2500 injuries, and economic losses from architectural and structural damage to buildings and lifelines adding to about $2 billion. Unreinforced masonry and adobe buildings sustained the greatest damage from ground shaking. Although, well-engineered buildings generally performed well, a hospital suffered extensive damage, indicating the need for stringent earthquake-resistant design criteria for critical facilities and tough inspection standards and enforcement procedures.

100-YEAR RETURN PERIOD ACCELERATION

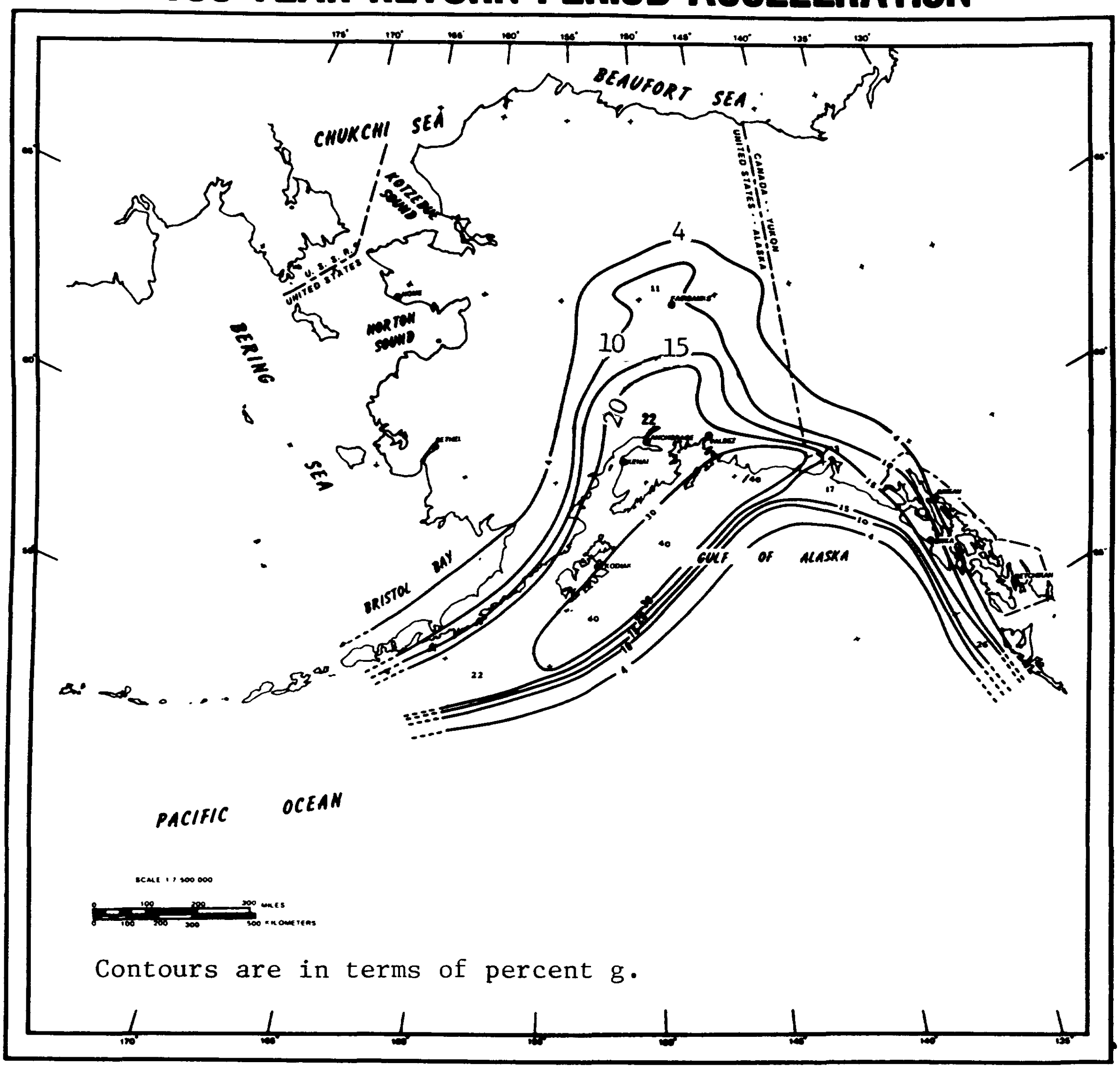


Figure 4.--Map showing the maximum level of peak horizontal bedrock acceleration expected in Alaska with an average return period of 100 years (Thenhaus and others, 1985). The corresponding exposure time is approximately 10 years. The values of acceleration have a 90 percent probability that they will not be exceeded during the exposure time. Soil effects must be considered separately.

2S1 20130

500-YEAR RETURN PERIOD ROCK ACCELERATIONS

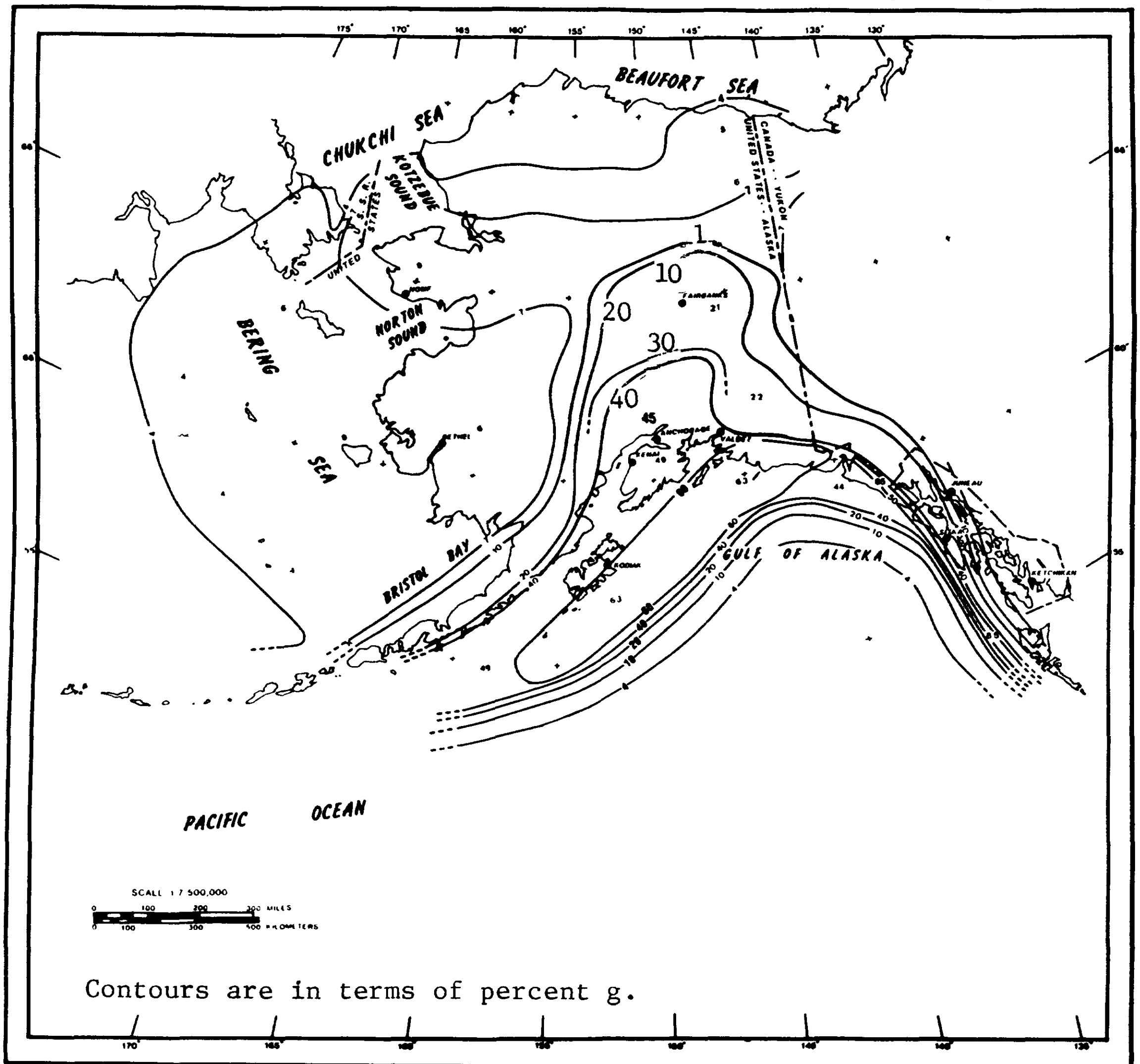


Figure 5.--Map showing the maximum level of peak horizontal bedrock acceleration expected in Alaska with an average return period of 500 years (Thenhaus and others, 1985). The corresponding exposure time is approximately 50 years. The values of acceleration have a 90 percent probability that they will not be exceeded during the exposure time. Soil effects must be considered separately.

2B5 20130

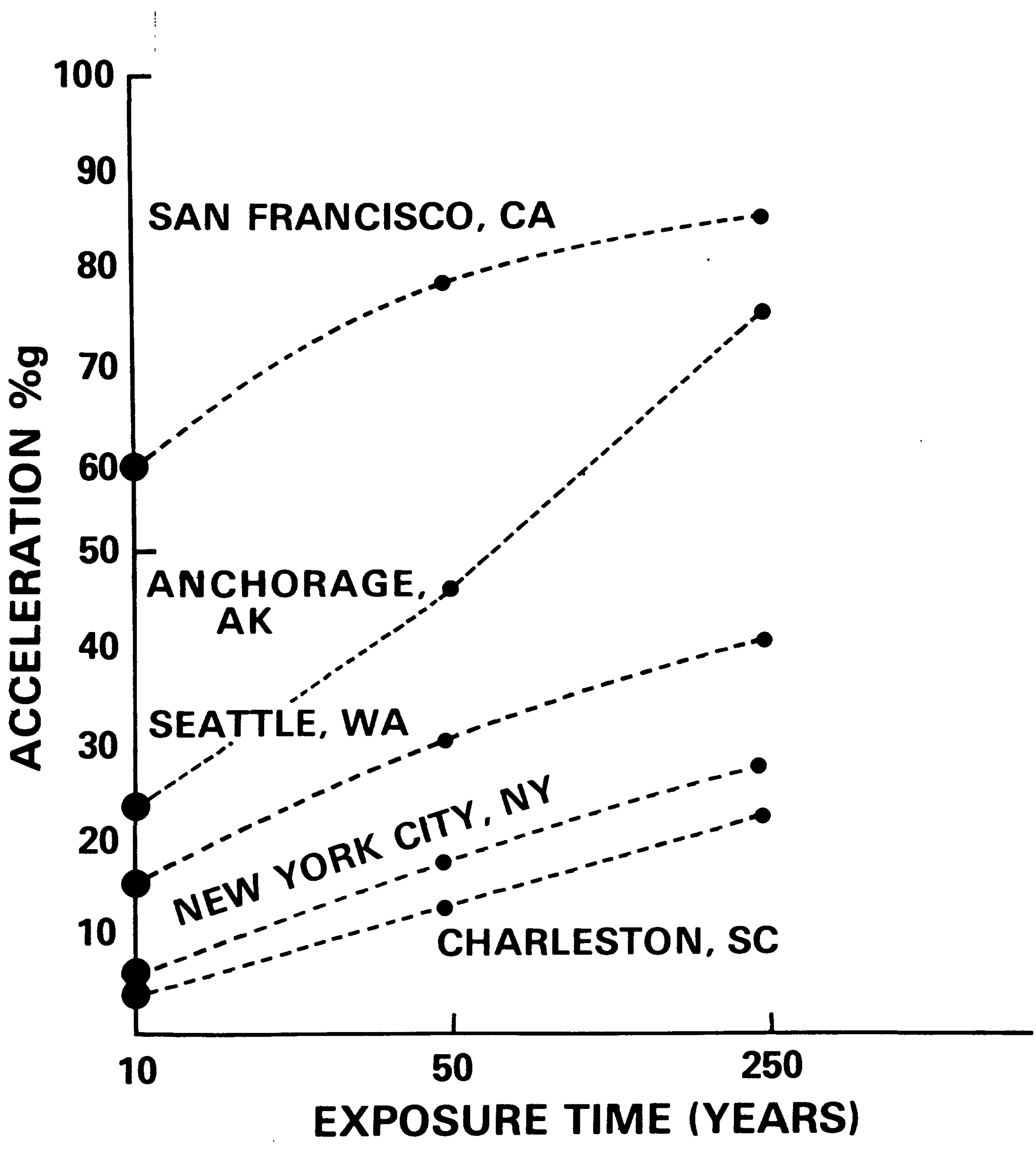


Figure 6.--Example of probabilistic bedrock ground-shaking hazard curves for various urban areas in the United States. These curves are based on data from Algermissen and others (1982) and Thenhaus and others (1985). Although controversy exists about the actual values of peak bedrock acceleration at a specific location, the relative values between locations are stable.

2B8 20130

An unprecedented set of 30 strong motion accelerograms (each having 3 components) documented the ground shaking in the 1985 Chile earthquake. The significant facts were: 1) ground shaking reached levels of 0.85 g. (horizontal) and 0.65 g (vertical), 2) both high and low ground-shaking frequencies were recorded, and 3) the duration of shaking was long (60-80 seconds). Other than in Japan, these ground motion data are the first comprehensive sample from a subduction zone earthquake; they are essential for probabilistic ground shaking hazard assessments and other applications that require a seismic wave attenuation function with specification of the dispersion in the median value.

The 1985 Chile earthquake also caused physical effects such as the following:

1. Numerous landslides occurred in the coastal mountains, locally blocking roads.
2. Liquefaction occurred in saturated beach sands.
3. Ground cracks were common in the epicentral area.
4. Part of the coastline subsided.
5. A small local tsunami having wave heights of 3.6 feet at Valparaiso, Chile, was generated. This tsunami caused wave runups of 1.7 feet in Hilo, Hawaii, and 0.2 feet in Seward, Alaska.
6. The extensive aftershock sequence that followed the mainshock included a M_s 6.6 earthquake on March 17, and a M_s 6.3 earthquake on March 19.

THE 1985 MEXICO EARTHQUAKE

Just before this report went to press, a great earthquake occurred in Mexico on September 19, 1985. This earthquake was the most devastating earthquake of the past decade in North America. It severely damaged Mexico City, the world's most populated metropolitan area. Because it was also a subduction zone earthquake having relevance for Alaska, Puget Sound, and Puerto Rico, its effects are summarized below for completeness.

The great 1985 Mexico earthquake, initially rated as M_s = 7.8 but later upgraded to M_s = 8.1, occurred at a depth of 18 km in the Mexico trench subduction zone where the Cocos tectonic plate is being subducted beneath the North American plate. The existence of a possible seismic gap in this portion of the Cocos plate and a general forecast of a large earthquake having an average recurrence interval of about 35 years had been made in 1981 by McNally. The specific time

254 20130

of the earthquake had not been specified, however. This earthquake was noteworthy because about 300 5-20 story buildings located in Mexico City, about 250 miles from the epicenter, collapsed partially or totally, causing an estimated 10,000 deaths, numerous injuries, and economic losses of possibly $5-10 billion. A quarter million people lost their homes. The extraordinarily high degree of damage at this large epicentral distance according to Rosenbleuth, (1986) was mainly due to a double resonance phenomenon (that is; earthquake-ground--ground-building). The long period (2 second) ground motion was amplified by the 50-meter thick, water-saturated, ancient lake bed underlying part of Mexico City and had a duration of more than 3 minutes (see Figure 7). The lake beds were recognized in 1964 by Zeevaert as having a characteristic site period of about 2 seconds, the natural period of vibration of a typical 20-story building. Past distant earthquakes (e.g., 1957 and 1962 Mexico earthquakes) had also caused damage in Mexico City that was attributed to site amplification. In the 1985 earthquake, six buildings collapsed at the Mexico General Hospital; about 400 doctors, nurses, and patients were trapped in the ruins of the Juarez hospital, just 8 blocks from the Presidential Palace. Government buildings, as a group, sustained considerable damage. Long distance telecommunications with the rest of the world were interrupted for several days after the earthquake due to the destruction of the main microwave transmitter and the lack of a redundant, backup system. Because of prior planning by US and Mexican scientists and engineers, a number of strong motion accelerographs were in place in the epicentral area at the time of the earthquake and recorded ground motions in the order of 0.18g, a low value for a great earthquake. Both the epicentral region and Mexico City were assigned an intensity of IX on the Modified Mercalli Intensity scale. A building code including a factor of soil conditions has been adopted and implemented in Mexico City since 1976, but it was not appropriate for the most severe affects of this earthquake.

These strong motion data, together with the data acquired in the March 3, 1985 Chile earthquake provided an unprecedented strong-ground motion data sample for subduction zone earthquakes. A building code as strict as any adopted in the United States had been adopted and implemented in Mexico City since 1976. It included a factor for soil conditions.

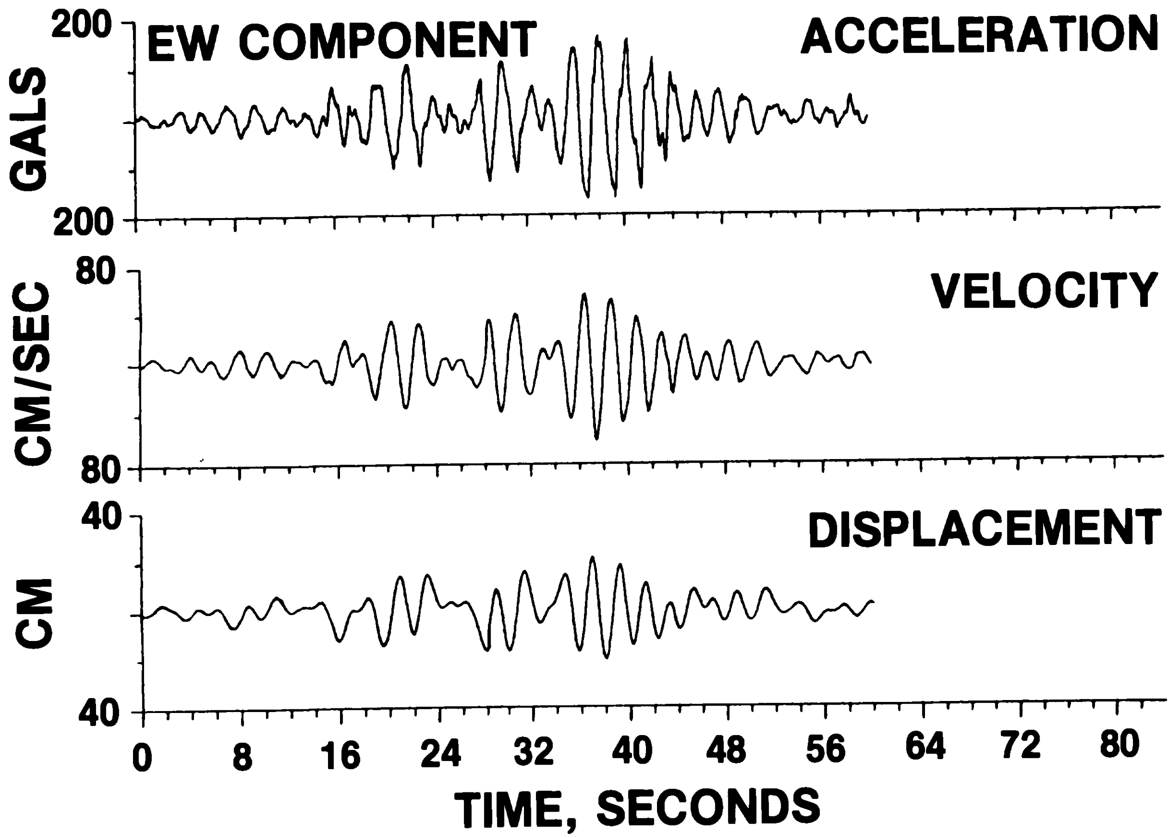


Figure 7.--Accelerogram (top) recorded at a free field location on the surface of the 50-meter thick lake beds forming the foundation in parts of Mexico City. The epicenter of the September 19, 1985 Mexico earthquake was located some 400 km to the west. The strong 2 second period energy in the accelerogram and the velocity (middle) and displacement (bottom) time histories derived from it are a consequence of the filtering effect of the lake beds which amplified the ground motion, (relative to adjacent sites underlain by firmer rock-like materials) about a factor of 5. The coincidence of the dominant period of ground shaking (2 seconds) with the fundamental period of vibration of tall buildings contributed to their collapse. These records were provided by the Universidad Nacional Autonoma de Mexico.

2B4 20130

THE REGIONAL EARTHQUAKE HAZARDS ASSESSMENTS PROGRAM ELEMENT OF THE NEHRP

Beginning October 1, 1983, U.S. Geological Survey initiated the new program element, "Regional Earthquake Hazards Assessments". This element, a part of NEHRP, was created to develop the basic information and the partnerships needed for evaluating earthquake hazards and assessing the risk in broad geographic regions containing important urban areas and to provide a basis for loss-reduction measures that can be implemented by local governments. The goal is to provide an integrated program having comprehensive research goals and producing generic information that can be used to reduce earthquake losses in urban areas. The scientific emphasis is on developing a fundamental physical understanding of the cause, frequency of occurrence, and the physical effects of earthquake ground shaking, surface faulting, ground failure, and tectonic deformation in various geographic regions. This element requires a high degree of team work, utilizing a multidisclipinary Task Force to accomplish the goals of each task. Users of the information produced by this program (for example: agencies of Federal, State, and local government involved in emergency response, building safety, and planning) cannot find such an integrated synthesis and evaluation of earthquake hazards in the scientific literature. Also, loss estimates have not been updated in most urban areas for many years and the risk may be seriously underestimated due to the sharp increase in building wealth and construction.

The interrelated tasks of the program element are described below:

Task 1: Information Systems - Because each research project produces basic data and information, the goal is to produce a comprehensive information system, available to both internal and external users, designed to give a data base that is as uniform in quality and as complete on a regional and urban scale as possible. Several categories of data can be identifed, including: seismicity, gravity and magnetics, well logs, seismotectonic data, fault trenching data, stress measurements, seismic reflection profiles, ground failure data, soils data, ground motion data, inventory of structures, damage assessments, bibliographic references, publications, and maps. Because of the potentially large scope of the task, care must be exercised to create a system that is both practical and economical.

Task 2: Hazards Evaluations and Synthesis - The goal is to use new and existing data to produce synthesis reports describing the state-of-knowledge about earthquake hazards (ground shaking, surface faulting, earthquake-induced ground failures, and tectonic deformation) in the region and recommending future research to increase the state-of-knowledge required for the development and implementation of loss-reduction measures. The research will provide a fundamental understanding of the nature and extent of the earthquake hazards. Development of models (hypotheses) and analysis of data are important aspects of this task.

Task 3: Ground Motion Modeling - The goal is to develop deterministic and probabilistic ground motion models and maps. Commentaries will be provided so that others can use the models for generating ground-shaking hazard maps and for evaluating the sensitivity of uncertainty in median values of important physical parameters.

Task 4: Loss Estimation Models - The goal is to develop economical methods of acquiring inventories of structures and developing a standard model for loss estimation. Commentaries on the use of such a model and its limitations will be provided so that others can use it. Loss estimates will be produced.

Task 5: Implementation - The goal is to foster implementation of loss-reduction measures in the urban area. In an urban area, the severity of an earthquake disaster depends upon three general factors. They are: a) the magnitude of the earthquake--the larger the magnitude the greater the potential for severe levels of ground shaking and other earthquake effects, b) the location of the earthquake source relative to an urban area--the closer the source of energy release to an urban area the greater the potential for damage, except in cases such as Mexico City where resonance effects must be considered, and c) the degree of earthquake preparedness within the urban area--the smaller the number of loss reduction measures adopted by the local community and the lower the level of preparedness, the greater the potential for consequences in an earthquake.

To increase the state-of-preparedness in an urban area, conferences and workshops are needed to bring together producers and users of earthquake hazards information. Participants representing business and industry, the private sector, and Federal, State, and local government will be involved in the conferences and workshops. Proceedings of the conferences and workshops will be disseminated to a wide audience, promulgating the research results and recommending actions, based on these results, that will increase the state-of-preparedness.

The scientific and engineering community are participating in this program element through the USGS's program of external grants and contracts. In 1984 and 1985, Alaska was assigned 4th priority in terms of allocation of USGS resources, following the Wasatch Front, Utah area (first), Southern California (second), and Northern California (third).

EVALUATION OF EARTHQUAKE HAZARDS AND ASSESSMENT OF POTENTIAL RISK IN ALASKA

The assessment of the potential risk (chance of loss) from earthquake hazards in an urban area is a complex task requiring: 1) an earthquake hazards model, 2) an exposure model (inventory), and 3) a vulnerability model.

A schematic illustration of the total range of consideration is shown in Figure 8. Each model is described briefly below with additional detail being provided by the papers contained in this report.

Earthquake Hazards Model--(See papers by Davies, Lahr, and others, Plafker, Nishenko, and Jacob, Preuss, Updike, Olsen, Schmoll, Jennings, Espinosa and others). Assessment of risk in Alaska is closely related to the capability to model the earthquake hazards of ground shaking, surface fault rupture, earthquake induced ground failure, tectonic deformation, and tsunamis. Most of the spectacular damage and losses in an earthquake are caused by partial or total collapse of buildings as a consequence of the severity of the horizontal ground shaking. However, ground failures triggered by earthquake ground shaking can also cause substantial damage and losses. For example, during the 1964 Prince William Sound, Alaska, earthquake, ground failures accounted for about 60% of the estimated $500 million total loss with landslides, lateral spread failures, flow failures, and liquefaction causing damage to highways, railway grades, bridges, docks, ports, warehouses, and single family dwellings. Surface faulting, which generally affects a long narrow area, has not occurred in the Eastern United

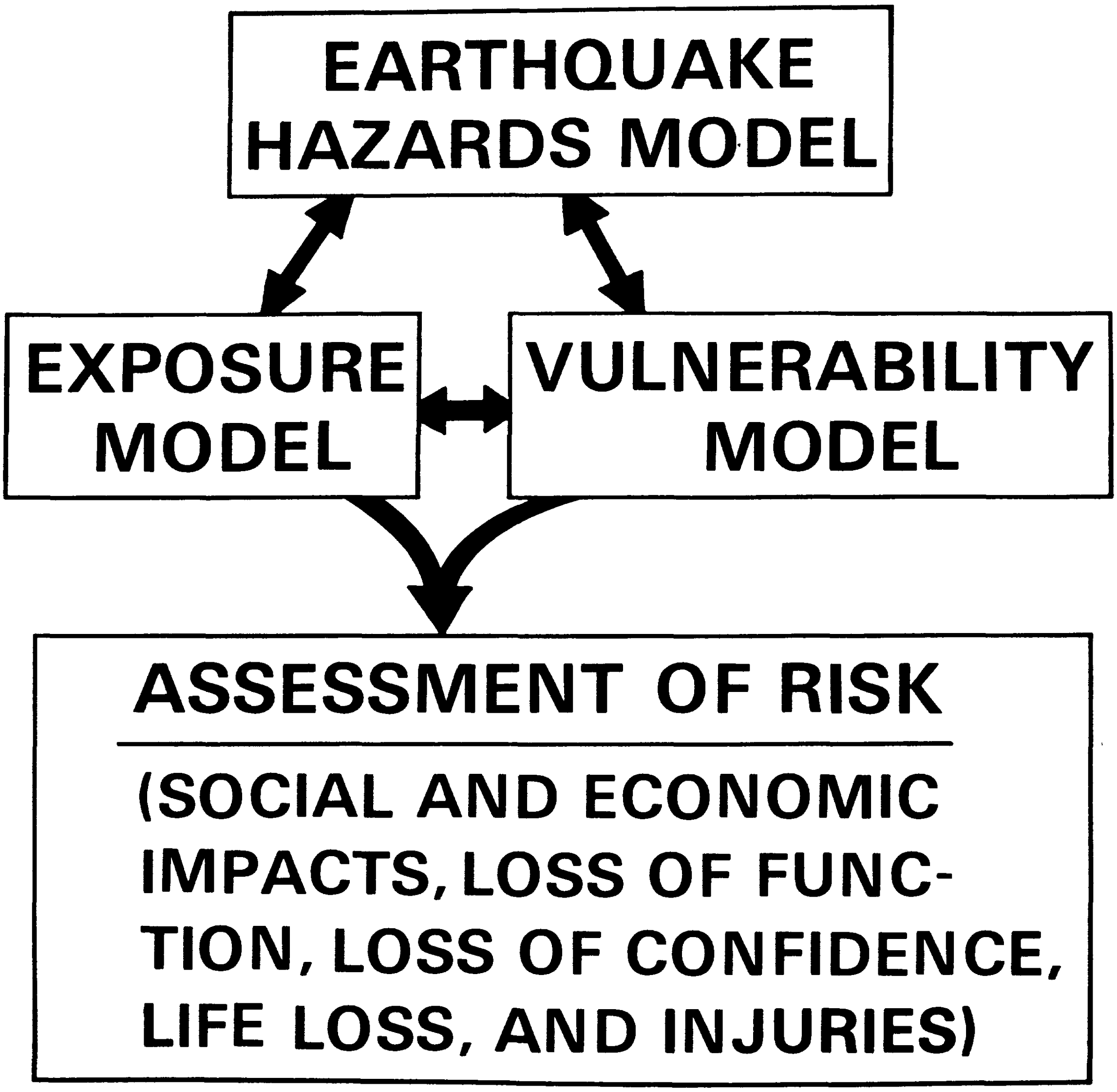


Figure 8.--Schematic illustration of the interaction between the three principal models needed for assessing the risk in an urban area.

2B2 20130

States except possibly in the 1811-1812 New Madrid earthquakes. Surface faulting, which generally occurs in earthquakes of magnitude 5.5 or greater in the Western United States, has damaged lifeline systems and single family dwellings, but has not directly caused deaths and injuries. Tsunamis, long period water waves caused by the sudden vertical movement of a large area of the seafloor during an earthquake, have occurred in Alaska and have produced loss of life. Destructive tsunamis have also affected Hawaii, Puerto Rico, the Virgin Islands, and the west coast of the United States. Historically, tsunamis have been absent on the east coast.

The earthquake hazards model must answer the following questions:

1. Where have past earthquakes occurred? Where are they occurring now?
2. Why are they occurring?
3. How often do earthquakes of a certain size (magnitude) occur?
4. How bad (severe) have the physical effects (hazards) been in the past? How bad can they be in the future?
5. How do the physical effects (hazards) vary spatially and temporally?

The answers to these questions are used to define the amplitude, frequency, composition, and duration of horizontal ground shaking--the three parameters that correlate best with damage.

Exposure Model--(See papers by Steinbrugge, Sheinberg, and Vyas). The spatial distribution of things and people exposed to earthquake hazards is called inventory. The inventory is one of the most difficult models to characterize. For risk assessment, the term structure is used to refer to any object of value that can be damaged by the earthquake hazards of ground shaking, surface faulting, ground failure, tectonic deformation, and tsunami wave run up. The various categories of structures include:

1. Buildings (residential, agricultural, commercial, institutional, industrial, and special use).
2. Utility and transportation structures (electrical power structures, communications, roads, railroads, bridges, tunnels, air navigational facilities, airfields, and waterfront structures).

3. Hydraulic structures (earth, rock, or concrete dams, reservoirs, lakes, ponds, surge tanks, elevated and surface storage tanks, distribution systems, offshore platforms, and petroleum systems).
4. Earth structures (earth and rock slopes, major existing landslides, snow, ice, or avalanche areas, subsidence areas, and natural or altered sites having scientific, historical, or cultural significance).
5. Special structures (conveyor systems, sky lifts, ventilation systems, stacks, mobile equipment, tower, poles, signs, frames, antennas, tailing piles, gravel plants, agricultural equipment, furnishings, and shelf items in the home).

A structure consists of many elements. To predict losses, the contribution of each individual element to the total response of a structure in response to the dynamic forces induced by ground motion (or another hazard) must be modeled.

Vulnerability Model--(See papers by Jennings and Steinbrugge). Vulnerability is a term describing the susceptibility of a structure or a class of structures to damage. The prediction of the actual damage that a structure will experience when subjected to a particular hazard (such as ground shaking) is very difficult as a consequence of:

1. Irregularities in the quality of the design and construction (e.g., some are designed and built according to a building code; some are not).
2. Variability in material properties.
3. Uncertainty in the level of ground shaking induced in the structure as a function of magnitude, epicentral distance, and local site geology.
4. Uncertainty in structural response to earthquake ground shaking, especially in the range where failure occurs.

A fragility curve can be used to represent failure of a specific type of structure (or a structural system) when it is exposed to the dynamic forces induced by ground shaking. For most structures, damage occurs as a function of the amplitude, frequency composition, and duration of ground shaking and manifests itself in various states ranging from "no damage" to "collapse." Specification of the damage states of a structure is very difficult because each state is a function of the lateral-force-resisting system of the structure and the severity of the hazard.

Options for Research and Mitigation--(See papers by Jennings, Preuss, Selkregg, Buck, Sheinberg, Carte', Turner and Sey, Wiggins, Combellick, Selkregg, and Kockelman). In conjunction with an assessment of the potential risk from earthquake hazards, answers are needed for the following questions:

1. What are the viable options for mitigating potential losses from earthquake hazards?
2. What research is needed to provide sound technical and societal bases for devising loss-reduction measures.

The answers to these questions encompass a wide range of possibilities and provide options such as the following:

1. Personal preparedness (See paper by Kockelman)--prepare on an individual basis for the consequences that are expected to occur, taking advantage of efficiencies provided by preparation for other natural hazards such as floods.
2. Avoidance (See papers by Preuss, Selkregg and Carte')--when the characteristics of the hazard are known, select the least hazardous areas for construction sites.
3. Land-use regulation (See papers by Selkregg, Preuss, and Carte')--reduce the density of certain types of buildings and facilities or prohibit their construction within parts of the area characterized by a relatively high frequency of occurrence or severity of effects.
4. Engineering design and building codes (see papers by Jennings and Johnson)--require buildings to have a lateral force-resisting system that is appropriate in terms of the frequency of occurrence and the severity of the hazard expected in a given exposure time (e.g., an exposure time of 50 years corresponds with the useful life of ordinary buildings).
5. Distribution of losses--use insurance and other financial methods to distribute the potential losses expected in a given exposure time.
6. Response and recovery (See papers by Johnson, Turner and Sey, and Buck)--plan response and recovery measures that will address all of the needs identified in realistic disaster scenarios.
7. A seismic safety organization--devise policy and plans to achieve seismic safety. (Note: such organizations now exist in California, Kentucky, South Carolina, and New York).

WORKSHOP PROCEDURES

The procedures used in the workshop were designed to enhance the interaction between all participants and to facilitate achievement of the general and specific objectives. The following procedures were used:

PROCEDURE 1: Scientists, social scientists, engineers, planners, and emergency management specialists, gave oral presentations in six plenary sessions.

PROCEDURE 2: Research reports and preliminary technical papers prepared in advance by the speakers were distributed at the workshop and used as basic references. The technical papers of the speakers were finalized after the workshop and are contained in this publication.

PROCEDURE 3: To stimulate interaction, to reinforce basic facts, and to provide a basis for defining priorities in the USGS's research and implementation programs, a questionnaire was utilized in conjunction with the first four plenary sessions. It is included below in the description of the plenary sessions.

PROCEDURE 4: The participants were encouraged to participate in three simultaneous discussion groups following the first five plenary sessions. The objective was to identify the scientific-legal political-social issues that must be resolved in current Alaskan urban and resource development and to devise creative strategies for dealing with these issues.

PROCEDURE 5: An ad hoc open house was held the first evening which provided an opportunity for participants to become acquainted and to interact informally.

PLENARY SESSIONS

Following introductory remarks by the Honorable Joe L. Hayes, former Speaker of the Alaska House of Representatives, the workshop process was developed in three plenary sessions involving all the participants. The themes, objectives, and speakers for each plenary session are described below.

SESSION I: EVALUATION OF EARTHQUAKE HAZARDS AND ASSESSMENTS OF RISK IN ALASKA: Knowledge and State-of-Practice

The objectives were to: 1) integrate scientific research and implementation activities, 2) define the problem indicated by the session theme, 3) clarify what is known about earthquake hazards in Alaska and, 4) identify knowledge that is still critically needed. These presentations served as a summary of the state-of-knowledge and state-of-practice and gave a multidisciplinary perspective.

OBJECTIVE: A series of overview type presentations identifying the advances in the state-of-knowledge and state-of-practice made since the 1964 Prince William Sound, Alaska earthquake. The emphasis was on answering the basic questions: WHERE?, WHY?, HOW BIG?, HOW OFTEN? WHAT ARE THE PHYSICAL EFFECTS (HAZARDS) AND POTENTIAL LOSSES (RISK)? and WHAT ARE THE OPTIONS FOR REDUCING POTENTIAL LOSSES?

SPEAKERS:
John Davies, University of Alaska
Lloyd Cluff, Pacific Gas and Electric Co.
Paul Jennings, California Institute of Technology
Karl Steinbrugge, Structural Engineer
Ted Algermissen, U.S. Geological Survey
Richard Buck, Federal Emergency Management Agency

SESSION II: REVIEW OF CURRENT RESEARCH AND IMPLEMENTATION ACTIVITIES IN ALASKA: Earthquake and Tsunami Potential

OBJECTIVE: Presentations and interactive discussion to provide a measure of the range of views and consensus on the status of current research and implementation products related to the earthquake and tsunami potential.

2B6 20130

SPEAKERS: Klause Jacob (Moderator), Lamont-Doherty Geological Observatory
Lidia Selkregg, University of Alaska
George Plafker, U.S. Geological Survey
Stuart Nishenko, U.S. Geological Survey

A questionnaire was used in sessions II-IV. It called for each research and implementation products to be ranked on a scale of 1 (lowest) to 5 (highest) and the assignment of priorities ranging from 1 (highest) to 3 (lowest) for the next 3-5 years work. The following instructions were given to each participant:

> On the basis of your experience, give your opinion or perception by circling the appropriate answer. For the status, circle a number ranging from 1 to 5, where the meaning is defined below.
>
> Number 1 means that we know very little and lack empirical and theoretical knowledge. Implementation is not yet feasible.
>
> Number 2 means that we have limited empirical and theoretical knowledge. Implementation is not yet credible.
>
> Number 3 means that we have adequate empirical and theoretical knowledge to solve the problem in a general way. Implementation is feasible and has an acceptable technical basis, but controversy exists.
>
> Number 4 means that we have sufficient empirical and theoretical knowledge to solve the first order problem reasonably accurately. Implementation is credible and can be fostered with minimal controversy.
>
> Number 5 means that we have the required empirical and theoretical knowledge to solve the first order problem completely. Implementation of loss reduction measures can be achieved and the appropriate partnerships exist to produce the required legislation and to enforce it.

QUESTIONNAIRE I: STATUS OF RESEARCH ON EARTHQUAKE AND TSUNAMI POTENTIAL IN ALASKA

Research topic	Status					Recommended Priority		
	Poor			Good		High		low
	1	2	3	4	5	1	2	3
A. RESEARCH								
1. Historic seismicity	0	5	14	10	4	2	14	12
2. Current seismicity	2	2	15	12	2	6	18	5
3. Activity of specific faults	3	12	9	7	1	22	9	0
4. Tectonic setting	0	2	17	12	2	3	10	13
5. Seismic gaps	0	7	14	10	2	3	21	6
6. Seismic sources	1	9	16	6	0	10	14	6
7. Earthquake recurrence	7	16	9	2	0	20	8	2
8. Tsunamigenic sources	0	16	10	5	1	5	13	11
B. PRODUCTS								
1. Seismicity maps	1	6	10	13	2	4	15	12
2. Map of seismic source zones	1	5	18	8	0	8	18	3
3. Map of tsunami source zones	3	10	14	4	1	5	12	13
4. Fault activity map	3	10	15	5	0	23	8	0
5. Seismotectonic maps	0	9	15	7	0	6	12	12

SESSION III: REVIEW OF CURRENT RESEARCH AND IMPLEMENTATION ACTIVITIES IN ALASKA: Ground Shaking Hazard.

OBJECTIVE: Presentation and Interactive discussion to provide a measure of the range of views and consensus on the status of current research and implementation products related to the earthquake ground shaking hazard.

SPEAKER: John Wiggins (Moderator), NTS/J.H. Wiggins Company
Alvaro Espinosa, U.S Geological Survey
Izzat Idriss, Woodward Clyde Consultants
John Lahr (Recorder), U.S. Geological Survey

* Note: Each number in the body of the questionnaire represents the number of respondents.

QUESTIONNAIRE II: STATUS OF RESEARCH ON THE GROUND SHAKING HAZARD IN ALASKA

Research topic	Status: Poor 1	2	3	4	Good 5	Recommended Priority: High 1	2	Low 3
A. RESEARCH								
1. Seismic source zones	0	7	20	4	0	9	10	10
2 Attenuation laws for acceleration	5	15	9	1	0	13	11	4
3. Attenuation laws for velocity	3	16	12	0	0	9	14	5
4. Attenuation laws for spectral velocity ordinants	3	18	9	0	0	8	12	7
5. Duration	4	12	11	5	0	14	15	1
6. Engineering properties of soil and rock	2	6	15	7	1	5	15	8
7. Local ground response	4	11	9	8	0	14	15	1
B. PRODUCTS								
1. Maps of seismic source zones	1	6	13	10	0	6	16	7
2. Probabilistic maps of ground shaking hazard	2	13	11	5	0	12	15	2
3. Maps of ground shaking hazard for specific scenarios	3	8	13	7	0	7	16	6
4. Maps of seismic risk zones	2	14	7	8	0	15	10	4
5. Engineering properties of surficial deposits	2	7	13	6	3	7	15	7

SESSION IV: REVIEW OF CURRENT RESEARCH AND IMPLEMENTATION ACTIVITIES IN ALASKA: Ground Failure Hazard

OBJECTIVE: Presentation and interactive discussion to provide a measure of the range of views and consensus on the status of current research and implementation products related to the ground failure.

SPEAKERS: Randy Updike (Moderator), Department of Natural Resources

David Cole, Dowl Engineers

Hal Olsen, U.S Geological Survey

William Kockelman (Recorder), U.S. Geological Survey

*Note: Each number in the body of the questioonaire represents the number of respondents.

385 20130

QUESTIONNAIRE III: STATUS OF RESEARCH ON THE GROUND-FAILURE HAZARD IN THE PUGET SOUND, WASHINGTON, AREA

Research topic	Status: Poor 1	2	3	4	Good 5	Recommended Priority: High 1	2	Low 3
A. RESEARCH								
1. Liquefaction potential	1	3	17	9	0	5	18	8
2. Landslide susceptibility	2	7	16	6	1	14	14	5
3. Reactivation of old landslides	1	13	8	8	0	9	20	3
4. Characterization of sensitive clay behavior	4	11	11	4	1	17	12	4
5. Characterization of the foundation	1	5	16	8	1	7	9	15
B. PRODUCTS								
1. Regional liquefaction maps	1	7	13	10	0	9	16	6
2. Regional landslide susceptibility maps	1	7	16	6	1	18	10	4
3. Maps of sensitive clay formations	4	8	16	5	0	14	12	5
4. Dam inundation maps	0	4	14	7	0	3	10	13

SESSION V: CURRENT ALASKAN URBAN AND RESOURCE DEVELOPMENT WHICH REQUIRE CONSIDERATION OF EARTHQUAKE HAZARDS

OBJECTIVE: Short presentations describing some of the problems and solutions for current Alaskan urban and resource development which requires consideration of the hazards of ground shaking, surface faulting, earthquake-induced ground failure, regional tectonic deformation, and tsunamis.

SPEAKERS:
Robert Page (Moderator), U.S. Geological Survey
Jogeshwar Singh, Harding-Lawson Associates
Henry Schmoll, U.S. Geological Survey
Barbara Sheinberg, Municipality of Anchorage
Ted Trueblood (Moderator 2), Alaska Railroad
Yogesh Vyas, Exxon Production Research Company
George Carte', Alaskan Tsunami Warning Center
David Cole, Dowl Engineers

*Note: Each number in the body of the questionnaire represents the number of respondents.

SESSION VI: IMPLEMENTATION OF SPECIFIC ACTIONS TO REDUCE POTENTIAL LOSSES FROM EARTHQUAKE HAZARDS IN ALASKA

OBJECTIVE: A series of presentation describing the current status of specific activities and suggesting actions that can be taken to increase knowledge and accelerate implementation of loss reduction measures in Alaska.

SPEAKERS: Gary Johnson, Federal Emergency Management Agency
Richard Buck, Federal Emergency Management Agency
Jim Sey, Alaska Division of Emergency Services
Jane Preuss, Urban Regional Research
George Carte', Alaskan Tsunami Warning Center
Lidia Selkregg, University of Alaska
John Wiggins, NTS/J. H. Wiggins Company
William Kockelman, U.S. Geological Survey
Joe Hayes, Consulting Engineer

DISCUSSION GROUPS

Three simultaneous discussion groups were formed on the second day to give the participants a chance to discuss some of the scientific-legal-political-social issues that may present obstacles to implementation of loss reduction measures in Alaska. The objective were: 1) to identify the obstacles and 2) to suggest creative strategies for dealing with them. The discussion leaders were: Group 1--Susan Tubbesing, Group 2--Jane Preuss, and Group 3--Paula Gori

The discussions were enriched by the wide variety of backgrounds of the participants (see Appendix A for a list of participants). Because some nonscientists and engineers were not familiar with the technical terms, a glossary of technical terms was provided (Appendix B) to facilitate communications. A directory of researchers is contained in Appendix C.

REPORTS OF THE DISCUSSION GROUPS

Discussion Group 1

Susan Tubbesing, (Moderator)	Natural Hazards Research and Applications Information Center
George Carte'	Alaskan Tsunami Warning Center
Rodney Combellick	Alaska Division of Geological and Geophysical Survey
C. B. Crouse	Earthquake Technology Corp.
Stephen Foo	Mobile Oil Company
William Kockelman	U.S. Geological Survey
Stuart Nishenko	U.S. Geological Survey
Henry R. Schmoll	U.S. Geological Survey
Jim Sey	Alaska Division of Emergency Services
Randy Updike	Alaska Department of Natural Resources

Discussion group 1 reviewed the history of hazard mitigation in Alaska, especially loss reduction before events. The group also looked at public attitudes towards adopting ordinances, plans, and legislation.

The group identified 10 concerns about seismic safety policy in Alaska:

1. Inadequate State policy and financial support for predisaster mitigation.
2. Needed technical information is not available or usable.
3. Many Federally funded programs on geological hazards have been terminated or reduced. State support is needed.
4. Alaska planning law offers no incentives or guidelines for consideration of geological hazards in local plans, etc. except under the Alaska Coastal Management Program (ACMP).
5. With the exception of some hazards-safety regulations for dams and health facilities, Alaska does not require consideration of geologic hazards in siting of critical facilities.
6. The State does not require explicit consideration of geological hazards in siting State facilities.
7. Existing disaster-preparedness programs and relief funds do not promote hazard mitigation.

8. Agency review for ACMP, Federal projects, etc. are hampered by inadequate technical information in hazards and lack compliance standards.
9. The State has not established minimum standards for professional registration of geologists who prepare geotechnical reports.
10. The State has no mechanism to issue formal notices of serious geological hazards.

The group discussed SB310, an Act establishing the "Alaska National Hazards Safety Commission," which was introduced in the State Legislature. The chance of its passage and strategies to get it passed were also discussed. Advocacy groups such as "League of Women Voters" might be enlisted to support the legislation since the act would improve safety for State citizens.

Alaska does not have legislation like the 1933 Field Act, which requires safe school design and construction in California. The Uniform Building Code (UBC) has not been adopted in its entirety by the State. Public education on hazards and SB310 is needed.

Recommendations--Group 1 endorsed "Geologic-Hazards Mitigation" in Alaska by Alaska Division of Geology. (See Combellick's paper) All of the recommendations contained in it were discussed and adopted. There were no objections to any areas except requiring "minimum qualifications" for those performing geotechnical review.

Recommendations for improvements in State policy:

1. Establish an Alaska Natural Hazards Safety Commission.
2. Develop State policies to support hazard mitigation at the State and local levels.
3. Establish a State-hazard monitoring program.
4. Amend the Alaska Municipal Code to promote local government action in hazard mitigation.
5. Regulate construction and major renovations of critical facilities.
6. Develop hazard-reduction requirements for State-funded construction projects.
7. Establish requirements for hazard mitigation at the local level as a condition for receiving disaster relief funds.

8. Provide better technical assistance to local governments and develop public education programs.
9. Develop a State hazards notification program.

Discussion Group 2

Jane Preuss (Moderator)	Urban Regional Research
Katherine West	U.S. Geological Survey
Jack Cervantes	Municipality of Anchorage
Klaus H. Jacob	Lamont-Doherty Geological Observatory
Richard A. Buck	Federal Emergency Management Agency
Paul C. Jennings	California Institute of Technology
J. P. Singh	Harding Lawson Associates
A. F. Espinosa	U.S. Geological Survey
Allan Divis	Terratech Ltd.
George Plafker	U.S. Geological Survey
Anne Pasch	Anchorage Community College
Bud Alto	Alyeska Pipeline Service Co.
Hal Olsen	U.S. Geological Survey
Robert J. Peters	URS Corporation

The consensus of group 2 was that there is a need for additional education pertaining to earthquake hazards. Education is considered vital to the solution of the problem. There is a need to sensitize people at all levels to the nature of earthquake hazards. The necessary education programs were organized into two categories: 1) earth sciences in the schools and general public and 2) education of decisionmakers.

People need to be convinced that it is in their self interest to be protected from earthquakes and other natural hazards. More earth science courses need to be taught in the schools. There is also a need to localize emergency preparedness instructions in small communities, as well as in metropolitan areas. People need to know what to do in emergency situations; they do not necessarily need to understand the scientific mechanisms.

The discussion group felt that Alaskans need to be site specific when they talk about hazards. For example, land spreading is a general problem in

Alaska. Landslides rather than faults need to be addressed in Anchorage. Communities should have earthquake response and mitigation policies, prior to obtaining Federal financial assistance.

Recommendations--Group 2 made the following recommendations:

1. The scientific community needs to become involved in planning and decisionmaking. The public needs an awareness and education program about geologic hazards.
2. Local funding is needed for education on earthquake hazards
3. The scientific community needs to inform the emergency preparedness community when an event is going to happen so they can prepare.
4. There is a need to simplify issues and to convert geotechnical information into a usable form for decisionmakers.
5. Long- and short-term cost-benefit evaluations of mitigation related construction costs are needed. Short-term economic interests are the real constraints to building safety and implementing good regulations.

Discussion Group 3:

Paula Gori (Moderator)	U.S. Geological Survey
Bob Page	U.S. Geological Survey
Barbara Steinberg	Municipality of Anchorage
Lloyd Cluff	Pacific Gas and Electric
John Taber	Lamont-Doherty Geological Observatory
John Lahr	U.S. Geological Survey
Yogesh Vyas	Exxon Production Research Company
David Cole	Dowl Engineers
Niren Biswas	Geophysical Institute
Lidia Selkregg	University of Alaska
Laura Beck	Municipality of Anchorage
John Wiggins	NTS/J. H. Wiggins Company

Opportunities and constraints for implementing land-use and other mitigation strategies to reduce earthquake losses--Group 3 identified the following opportunities to implementing hazard mitigation:

1. It is a State requirement that municipalities have a comprehensive

plan and a zoning ordinance. Municipalities are not required to have an "earthquake" element or regulation, but they may.

2. In order for municipalities to get funds from the State they must have a comprehensive plan.
3. Anchorage and other coastal cities are part of the Coastal Zone Management program. The guide or plan has a risk mitigation section which includes maps. These maps (one for faults areas one for areas prone to liquefaction, etc.) have been accepted in concept by the city of Anchorge. They, therefore, could be reflected in zoning and subdivision ordinances.

Group 3 identified the following constraints to implementing hazard mitigation measures:

4. Some individuals in Anchorage believe that laws and guidelines are necessary-that it is not enough only for the Coastal Zone Management maps to have been accepted in concept only.
5. Alaska does not require professional registration for geologists.
6. The architectural registration requires that architects pass an earthquake section.
7. Engineers do not have the above requirement for registration.
8. The planning and building permit staff of the city do not have enough staff to specialize, especially in geotechnical and earthquake issues.
9. The State and localities do not take advantage of their opportunities to site and build facilities and infrastructure to withstand earthquake ground shaking and ground failure.
10. Schools do not require special siting or building specifications.

Recommendations--Group 3 made the following recommendations to implementing hazard mitigation.

1. Enforce the Coastal Zone Management Act which includes a risk mitigation requirements.
2. Establish a Seismic Safety Commission.
3. Assist municipalities to complete earthquake safety studies.
4. Adopt a code of conduct for engineers and geotechnical professionals.
5. Hire city geologists to assist in planning and siting public facilities and reviewing site plans.

6. Increase the understanding of the State's, and professionals' legal liability.
7. Strengthen the earth sciences curriculum.
8. Work towards a major 25th anniversary conference in 1989 to recall the important lessons of the 1964 Prince William Sound earthquake.

REFERENCES

Algermissen, S. T., Perkins, D. M., Thenhaus, P. C., Hanson, S. L., and Bender, B. L., (1982), Probabilistic estimates of maximum acceleration and velocity in rock in the contiguous United States, U.S. Geological Survey Open-File Report 82-1033, 99 p. (with 6 maps at 1:7,500,000).

Davies, John N., (1984), Alaska's Earthquake, in The Northern Engineering, Geophysical Institute, University of Alaska, v. 16, no. 4, pp. 8-13.

Hays, W. W., (1984), Technical problems in the construction of a map to zone the earthquake ground-shaking hazard in the United States, Engineering Geology, v. 20, pp. 13-23.

Kanamori, Hiroo, (1977), The energy release in great earthquakes, Journal of Geophysical Research, v. 82, no. 20, pp. 2981-2988.

McNally, Karen, 1981, Plate Subduction and Prediction of Earthquakes along the Middle America trench in Simpson, D. W., and Richards, P. G., (Editors) Earthquake Prediction - An International Review, American Geophysical Union, Maurice Ewing Series, v. 4, pp. 63-72

National Academy of Sciences, (1964), The March 13, 1964, Prince William Sound Earthquake, Government Printing Office, Washington, D.C.

Office of Emergency Preparedness, Report to the Congress Disaster Preparedness, January 1972, v. 3, p. 80-81.

Rosenblueth, E., 1986, The Mexican Earthquake: a firsthand report, Civil Engineering, January 1986, pp. 38-40.

Thenhaus, P. C., Ziony, J. I, Diment, W. H., Hopper, M. G., Perkins, D. M., Hanson, S. L., and Algermissen, S. T. (1985), Probabilistic estimates of maximum seismic horizontal ground acceleration on rock in Alaska and the adjacent continental shelf, Earthquake Spectra, v. 1 no. 2, pp. 285-306.

Zeevaert, L., 1964, Strong Ground Motions Recorded During Earthquakes of May the 11th and 19th, 1962 in Mexico City, Bulletin of the Seismological Society of America, v 54, p. 209-229.

EVALUATION OF THE WORKSHOP ON "EVALUATION OF REGIONAL AND URBAN EARTHQUAKE HAZARDS AND RISK IN ALASKA"

by

Sallie A. Marston
University of Colorado
Boulder, Colorado 80309

On September 5-7, 1985 a workshop dealing with the earthquake hazards and risk in Alaska was conducted in Anchorage. At the conclusion of the two-and-one-half-day meeting participants were asked to evaluate the effectiveness of the workshop.

Responses were elicited on a five point scale: 1 and 2 representing the lowest level of agreement or a "no" response, 3 moderate agreement, and 4 and 5 highest agreement or a "yes" response (see Figure 1). Not all respondents answered all questions. Therefore percentages reflect the number of questions completed (compare Figures 1 and 2). Additionally, the percentages that are discussed in the text are a combined total of a positive rating of 3, 4 and 5.

The questionnaire asked workshop participants to vote according to various criteria: 1) the usefulness of the information and activities provided; 2) given the same opportunity would the participant attend the workshop and should future workshops should be planned; 3) the level of earthquake awareness and concern before and after the workshop. Finally, participants were asked to list one or two "positive" and "less than positive" aspects of the workshop and identify one or two possible future actions to carry out some of the specific recommendations of the workshop.

Evaluations were returned by twenty-four participants. Overall, the responses indicate that the workshop was successful in meeting its stated goals. Ninety-two percent of the participants found the workshop useful for increasing their knowledge of earthquake hazards in Alaska. Eighty-three percent felt that the workshop was useful for increasing their knowledge of the potential risks from earthquake hazards in Alaska. Ninety-six percent reported that the workshop was instrumental in increasing knowledge of some of the unresolved technical problems requiring further research. Eighty-three percent felt that the workshop increased their knowledge of the need for considering the earthquake hazard in Alaskan urban and/or resource development. In terms of improving the participants' awareness of some of the unresolved legal, political and social issues stemming from the Alaskan earthquake hazard, eighty-three percent found the workshop to be useful. Finally, ninety-one percent felt that the workshop added to their understanding of what actions could be taken to reduce potential losses form earthquake hazards in Alaska.

In a second aspect of the questionnaire, 91% of the respondents indicated that the workshop was helpful in providing new information and expertise and establishing a better understanding of the problems faced by researchers and decision makers.

In evaluating the various session formats, the formal presentations appear to have been considered the most useful (92% favored them) with the discussions following the presentations identified by only 74% of the respondents as useful. Note that 26% gave this format a low rating and 31% gave this session a moderate rating. Respondents favored small discussion groups (83%), the availability of papers and abstracts (83%) and informal discussions (86%). Again, it is important to note that the low and moderate ratings for small discussion groups, and the availability of papers and abstracts also are significant (see Figure 2).

Nearly all of the respondents answered affirmatively (96%) to a repeat of the workshop, with unanimous support for future workshops that would continue the work initiated at the September 5-7 meeting.

Pre and post workshop awareness of the earthquake threat in Alaska was equivalent, with 100% of the respondents indicating high awareness for both time periods. Concern about the state of earthquake preparedness in Alaska, while high (91%) prior to the workshop, increased following the workshop (100%).

A major goal of the workshop is to evaluate both concern and awareness as it may be reflected in future behaviors. In order to identify whether the workshop might inspire possible future mitigative action, the questionnaire elicited open ended responses regarding plans to carry out some of the specific recommendations made in the workshop. Actions suggested by respondents include increasing local awareness, improving building codes, developing seismic maps and seismic plans and, lobbying for a state commisson for earthquake hazard research.

The questionnaire also elicited open ended participant response on positive and less than positive aspects of the workshop. These comments were numerous and varied. Less than positive comments included the need for more state and local officials and politicians to attend the workshop; more time needed for discussion; indications that some talks were too technical, with advice that written handouts might alleviate the problem; and finally, the complaint that the workshop was essentially "preaching to the converted".

Many positive comments included an appreciation for the wide range of experts in attendance. Participants also complimented the graphics, speakers and the use of discussion groups.

FIGURE 1
EVALUATION
WORKSHOP ON "EVALUATION OF REGIONAL AND URBAN EARTHQUAKE HAZARDS AND RISK IN ALASKA"
Anchorage, Alaska, September 5-7, 1985

	Low 1 & 2	3	High 4 & 5
1. Did you find the workshop to be useful to you or your organization by increasing your knowledge of:			
a. earthquake hazards in Alaska?	2	8	14
b. the potential risk from earthquake hazards in Alaska?	4	14	6
c. some of the unresolved technical problems requiring additional or more focused research?	1	8	15
d. Alaskan urban and/or resource development which requires consideration of earthquake hazards?	4	10	10
e. some of the unresolved legal, political, and social issues that need to be resolved in Alaska?	4	6	14
f. achieveable actions that can be taken to reduce potential losses from earthquake hazards in Alaska?	2	11	10
2. Did the workshop benefit you or your organization by:			
a. providing new sources of information and expertise you might want to utilize in the future?	2	12	9
b. establishing better understanding of the problems faced by researchers and decisionmakers?	2	6	14
3. Did you find the following activities useful:			
a. formal presentations?	2	8	14
b. discussions following the formal presentations?	6	7	10
c. small discussion group sessions?	4	5	15
d. preprints of paper, expanded abstracts?	4	10	10
e. informal discussions during breaks and after hours?	3	1	18
4. If the clock were truned back and the decision to attend the workshop were given to you again, would you want to attend?	1	-0-	22
5. Should future workshops be planned to continue the work initiated at this meeting?	-0-	3	20
6. Prior to attending this workshop, I would rate my awareness of the earthquake threat in Alaska as	-0-	5	19
7. Prior to attending this workshop, I would rate my concern about the state-of-earthquake preparedness in Alaska as	2	7	15
8. I now rate my awareness as	-0-	-0-	24
9. I now rate my concern as	-0-	-0-	22

10. Please list two or three aspects of the meeting that you found to be positive and two or three aspects which you believe need improvement. In addition, list one or two specific actions you plan to undertake in the next 3-4 years to carry out specific recommendations made in the workshop.

3B6 20130

FIGURE 2
EVALUATION
WORKSHOP ON "EVALUATION OF REGIONAL AND URBAN EARTHQUAKE HAZARDS AND RISK IN ALASKA"
Anchorage, Alaska, September 5-7, 1985

	Low 1 & 2	3	High 4 & 5
1. Did you find the workshop to be useful to you or your organization by increasing your knowledge of:			
a. earthquake hazards in Alaska?	8	33	59
b. the potential risk from earthquake hazards in Alaska?	17	58	25
c. some of the unresolved technical problems requiring additional or more focused research?	4	33	63
d. Alaskan urban and/or resource development which requires consideration of earthquake hazards?	16	42	42
e. some of the unresolved legal, political, and social issues that need to be resolved in Alaska?	17	25	58
f. achieveable actions that can be taken to reduce potential losses from earthquake hazards in Alaska?	9	48	43
2. Did the workshop benefit you or your organization by:			
a. providing new sources of information and expertise you might want to utilize in the future?	9	52	39
b. establishing better understanding of the problems faced by researchers and decisionmakers?	9	27	64
3. Did you find the following activities useful:			
a. formal presentations?	8	33	59
b. discussions following the formal presentations?	26	31	43
c. small discussion group sessions?	16	21	63
d. preprints of paper, expanded abstracts?	16	42	42
e. informal discussions during breaks and after hours?	14	4	82
4. If the clock were truned back and the decision to attend the workshop were given to you again, would you want to attend?	4	-0-	96
5. Should future workshops be planned to continue the work initiated at this meeting?	-0-	13	87
6. Prior to attending this workshop, I would rate my awareness of the earthquake threat in Alaska as	-0-	21	79
7. Prior to attending this workshop, I would rate my concern about the state-of-earthquake preparedness in Alaska as	8	29	63
8. I now rate my awareness as	-0-	33	67
9. I now rate my concern as	-0-	8	92

10. Please list two or three aspects of the meeting that you found to be positive and two or three aspects which you believe need improvement. In addition, list one or two specific actions you plan to undertake in the next 3-4 years to carry out specific recommendations made in the workshop.

SEISMICITY, SEISMIC GAPS AND EARTHQUAKE POTENTIAL IN ALASKA

By

John N. Davies

Alaska Division of Geological and Geophysical Surveys

Anchorage, Alaska

EARTHQUAKE OCCURRENCE IN ALASKA

Approximately 11 percent of the world's earthquakes occur in Alaska. Even considering that the land area of Alaska is only about three-tenths of one percent of the surface area of the world, this figure still understates the level of earthquake activity in Alaska during the past 80 years. It is only when the energy released by Alaskan earthquakes in this period is taken into account that a proper perspective is gained.

The ten largest earthquakes in the world since 1904 are listed in Table 1. Of these, three occurred in Alaska: the Good Friday earthquake of 1964 (M_w = 9.2, rank no. 2), the Andreanof-Fox Islands earthquake of 1957 (M_w = 9.1, rank no. 3), and the Rat Islands earthquake of 1965 (M_w = 8.7, rank no. 6). Three out of ten gives the right impression of the ratio of energy released in Alaska compared to the whole world for the period 1904-1984.

Table 1 is based on one compiled by Hiroo Kanamori which gives the energy released by each earthquake larger than M_w = 8.0 since 1904 for the world. In this list Alaskan earthquakes contribute 30 percent of the total energy. It appears during the past 80 years that Alaska has had a few really large earthquakes and that the rate of occurrence of medium-sized shocks is more normal. If one assumes that Alaska has 30 percent of the energy released by quakes larger than M_w = 8.0, but only 11 percent of that released by smaller quakes, then the energy released by earthquakes in Alaska since 1904 would be about 25 percent of the total for the world.

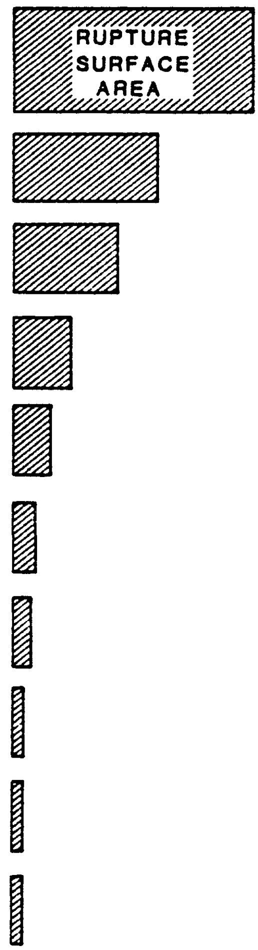
A Comparison with California

California is regarded by many as the archetype of "earthquake country" (Iacopi, 1971). California is indeed earthquake country, cut by the San

4S1 20130

Table 1. The World's Ten Largest Earthquakes 1904 - 1984

No.	Location	Year	M_W	Energy*
1.	CHILE	1960	9.5	2000
2.	ALASKA	1964	9.2	820
3.	ALASKA	1957	9.1	585
4.	KAMCHATKA	1952	9.0	350
5.	ECUADOR	1906	8.8	204
6.	ALASKA	1965	8.7	125
7.	ASSAM	1950	8.6	100
8.	BANDA SEA	1938	8.5	70
9.	CHILE	1922	8.5	69
10.	KURILES	1963	8.5	67



*Energy in dyne-cm x 10^{27}

Source: Based on data from Kanamori[1]

4B5 20130

Andreas fault system and many other faults; it has been the site of several historical great earthquakes. Most famous among these was the 1906 M_w = 7.8 earthquake which devastated San Francisco. All of the recent damaging earthquakes in California such as the San Fernando, Coalinga, and Morgan Hill events, were rated about 6.5 on the Richter scale.

One can compare this activity in California to that in Alaska by considering the histogram shown in Figure 1. This histogram shows the number of earthquakes larger than magnitude 5.5 in each of the years from 1976 through 1980 for both Alaska and California. It is easy to see from this comparison that Alaska also deserves to be called earthquake country. In Alaska, however, most of these large earthquakes occur in remote, sparsely populated regions so that many events with magnitudes in the 5 to 7 range cause little if any damage and go almost unnoticed.

MAJOR EARTHQUAKE ZONES IN ALASKA

The Alaska-Aleutian Subduction Zone

The vast majority of the large earthquakes in Alaska occur along the Aleutian Islands, the Alaska Peninsula, and the Kenai Peninsula. Almost three-quarters of the events shown on the map in Figure 2 fall in this region. Plotted on this map are the epicenters of all of the earthquakes larger than M_w = 7.2 for the period from 1897 through 1980, a total of 35 events (in fact, no events of $M_w \geq 7.2$ have occurred in Alaska since 1980). All three of the great Alaskan earthquakes listed in Table 1 occurred in this region.

The belt of earthquakes and volcanoes stretching from the western Aleutians to the Kenai Peninsula is known as the Alaska-Aleutian subduction zone. The great earthquakes here result from episodic slipping along the shallow contact zone between the Pacific and North American plates or the Pacific plate is thrust beneath the Alaskan portion of the North American plate. These earthquakes typically cause very strong shaking which lasts several minutes; significant, permanent uplift or subsidence over very large area; very large seismic sea waves or tsunamis which cause damage at great distances across the Pacific; extremely high wave run-up of a few to more than 30 m locally; and

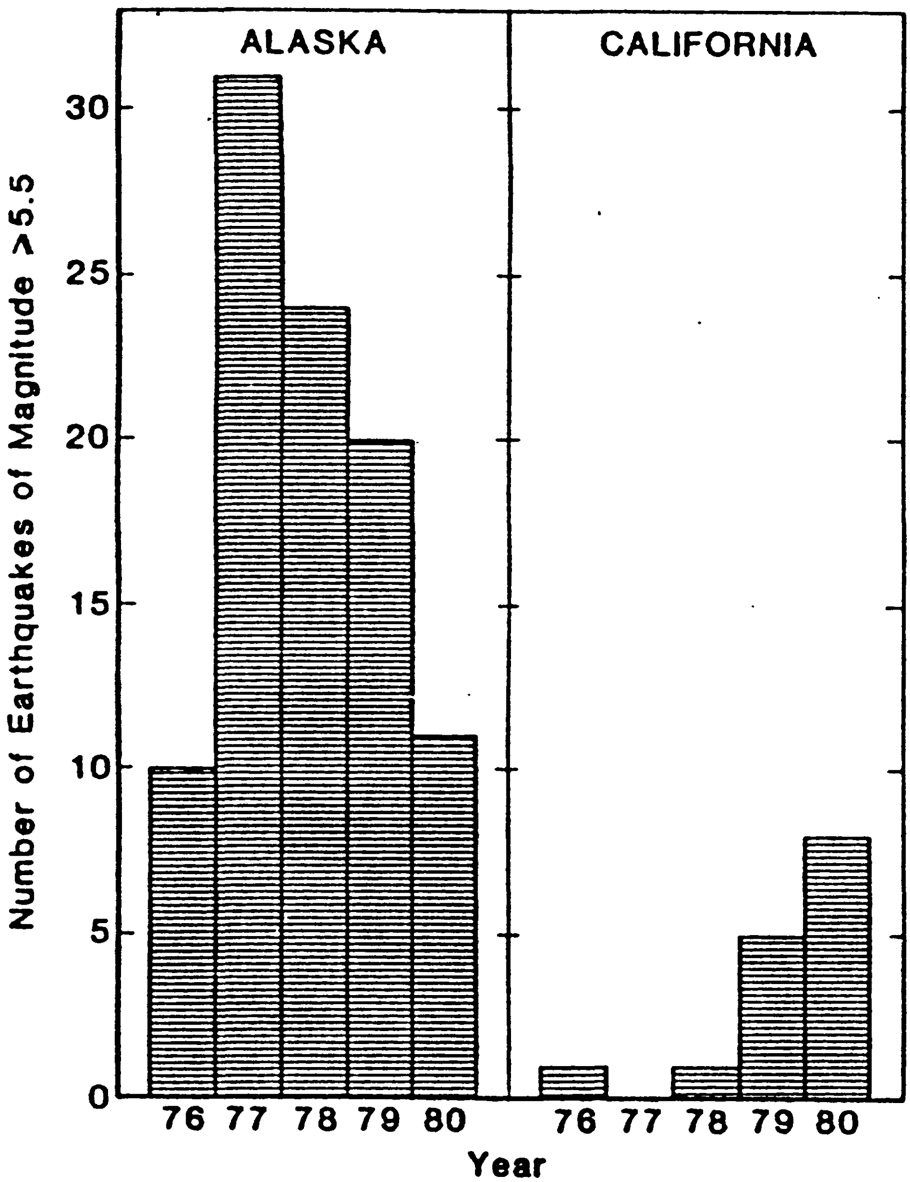


Figure 1.--International Seismological Center reports for earthquakes of magnitude $\geq$ 5.5 during the 5-year period from 1976 to 1980.

454 20130

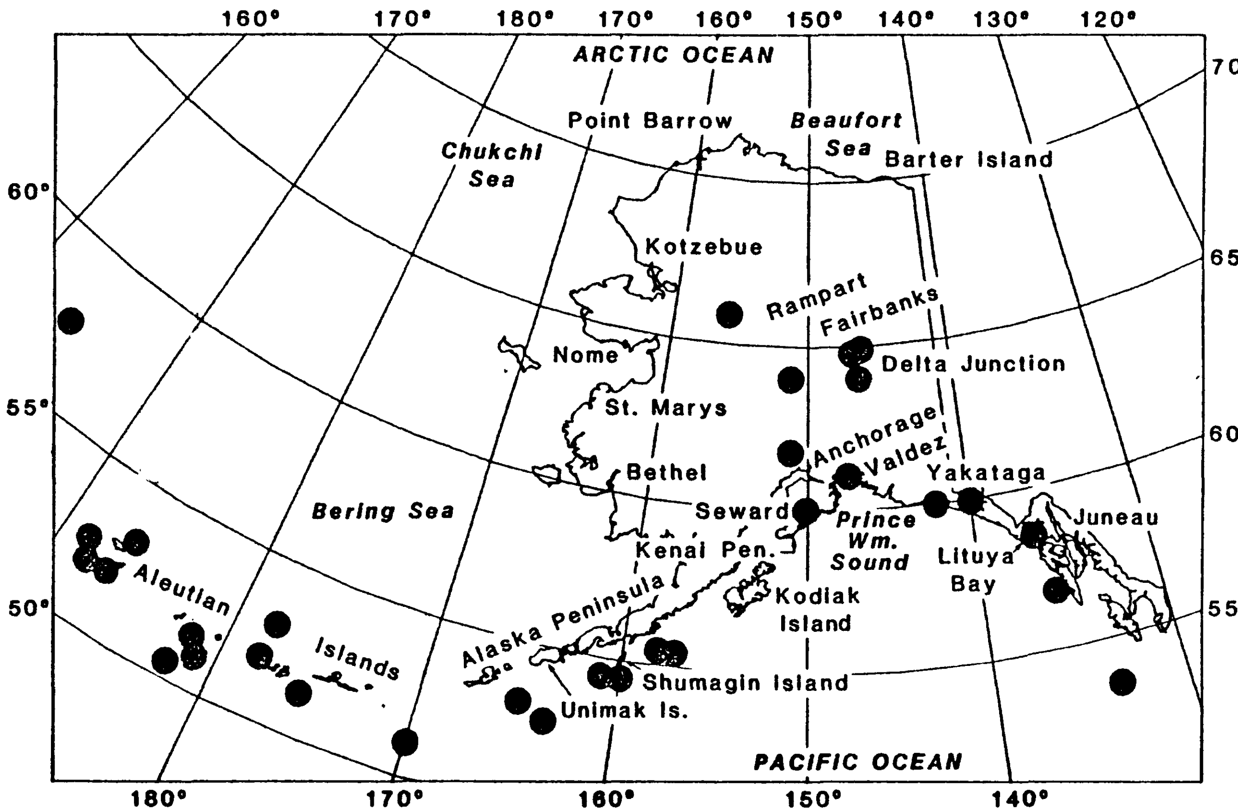


Figure 2.--The dots show the epicenter locations of all shallow (depth less than 70 km) earthquakes in Alaska of magnitude 7.2 or more from 1897 through 1980. The map shows 31 events, but two dots in the Yakutat - Yakataga area actually represent two events each, and two in the westernmost Aleutians are off the map. The 83-year record thus indicates that Alaska has 35 earthquakes of at least magnitude 7.2, or one every 2.3 years.

4S8 20130

many landslides, snow avalanches, and submarine slumps at distances out to 100 km from the epicenter.

The 1946 Scotch Cap earthquake generated an extremely large tsunami which completely destroyed the reinforced concrete lighthouse at Scotch Cap on Unimak Island in the Aleutians and caused significant damage in the Hawaiian Islands. The 1964 great Alaska earthquake caused permanent uplift or subsidence of tens of thousands of square kilometers from Prince William Sound to Kodiak Island. The tsunami did terrible damage at Kodiak, Seward, Chenega, and other coastal villages of Alaska and at places as distant as Newport, Oregon, and Crescent City, California. A secondary submarine slump near Shoup Bay in Valdez Arm created a seiche wave which broke off trees more than 35 m above Shoup Bay and which sloshed a wall of water about 7 m high through the town of Valdez. The long duration of the strong shaking in Anchorage, more than 60 km from the nearest point on the rupture surface, caused a dozen damaging landslides along the bluffs of Knik Arm and Ship Creek.

Queen Charlotte-Fairweather Transform Fault Zone

Five epicenters are shown in Figure 2 along the panhandle region in southeastern Alaska. These events occurred along the Fairweather fault which is part of a transform fault system along which the Pacific plate is sliding to the northwest (horizontally) by southeast Alaska. This region is known as the Queen Charlotte-Fairweather transform fault zone. Great earthquakes with Richter magnitudes up to the mid-8s can occur here, but the extremely large events in the high 8s and low 9s typical of the subduction zone to the west are not expected. Earthquakes in the transform zone occur on strike-slip faults which cut the surface of the earth in long straight lines. Offsets along these surface breaks can be on the order of meters, causing very intense shaking near the fault.

The 1958 Lituya Bay earthquake (M = 7.9) had a horizontal displacement across the Fairweather fault of about 15 m. The violent shaking from this quake dislodged a giant rockslide in Lituya Bay, causing a seiche wave which washed trees and soil from the bedrock of the opposite shore to an elevation more than 500 m(!) above sea level.

Interior, Northern, and Western Alaska

In the interior of Alaska there are five epicenters shown on the map of Figure 2. The largest of these quakes, the 1904 Rampart earthquake, is sometimes listed as having a magnitude of 8, though 7.3 is probably more correct. A sixth event south of the Alaska Range and about 50 km north of Anchorage occurred in 1943, had a Richter magnitude of 7.4 (M_s) and probably should be classed with these other mainland Alaskan events. All of these earthquakes occurred on faults which did not break the surface of the earth in a clear escarpment. Typically, these events have durations of strong shaking which last somewhat less than a minute. Rock fall and liquefaction of the soil can occur 30 to 50 km away from the epicenter. The 1937 Salcha earthquake left a number of fissures in the soil and caused a rockfall which closed the Richardson Highway. The 1958 Huslia earthquake caused widespread cracking and fissuring of the soil. A significant amount of liquefaction was indicated by the numerous sand flows and sinkholes seen after the quake.

There have been no events larger than M = 7.0 in western and northern Alaska including the offshore regions of the Bering, Chukchi, and Beaufort seas (excluding the Aleutian zone, of course). If one lowers the magnitude threshold a little and considers all events larger than M = 6.0, we begin to see a trend of epicenters defining a broad belt from the Fairbanks-Delta Junction area in interior Alaska through the Kotzebue-Nome area in western Alaska, and on across the Chukchi Sea into Siberia. If one lowers the threshold still further and considers all events larger than M = 4.5, then a second trend emerges. This is a broad belt of epicenters trending north-northeast, which again originates in the Fairbanks-Delta Junction area and goes through the Barter Island area of north-eastern Alaska. The two regions of lowest historical seismic activity in Alaska are the Kuskokwim and Yukon deltas region around St. Marys and Bethel and the western half of the north slope region centered around Point Barrow, with the latter being somewhat less active than the former.

4B1 20130

Alaskan Earthquake Statistics

We can get a reasonably quantitative sense of the relative hazards between these broad zones of Alaska by examining the historical record for earthquakes of magnitude greater than or equal to seven as compiled in Table 2. The events listed in that table have been assigned to three zones: (1) the subduction zone; (2) the transform zone; and (3) the mainland Alaska zone. Recall that no large earthquakes ($M \geq 7.0$) have occurred in Alaska outside of these three zones. That is not to say that it is impossible for a magnitude seven event to occur near Bethel or Barrow, e.g., just that the probability is considerably lower there relative to the three zones which have been active over the past 90 years.

For each of these active zones the number of independent events larger than or equal to magnitude seven and the time intervals between them are summarized statistically in Table 3. In the subduction zone, e.g., there have been 37 events of $M \geq 7.0$ during the past 90 years. Excluded from this tabulation are events that appear to be foreshocks or aftershocks of some other event. The mean repeat time, or average interval time for independent earthquakes of $M \geq 7.0$ in the subduction zone was 2.3 years, and it has been 5.0 years since the last such earthquake. The "time for 95% of cases" is the mean repeat time plus 1.645 times one standard deviation of the individual repeat times about their mean. This statistic assumes a Gaussian distribution of the repeat times which is clearly not true for the $M \geq 7.0$ case, but which may be true for the $M \geq 7.8$ case. It is simply meant to be a measure of how "overdue" a particular zone may be. If the time interval since the last event in a particular zone is longer than "95%" of all previously observed time intervals between events, then one might say that zone is overdue for an earthquake of the class in question. In the example of the subduction zone the time for 95% of previous intervals is 6.1 years, so the fact that it has been 5.0 years since the last event means that we are approaching being overdue for an earthquake of $M \geq 7.0$ there. However, for earthquakes of $M \geq 7.8$ it has been 20.9 years since the last event and the 95% time is 19.3 years, so in this case we are now overdue.

Table 2

MAJOR SHALLOW ALASKAN EARTHQUAKES: 1897 -1980

(After Abe and Noguchi, 1981 and 1983)*

#	YEAR	MO	DY	TIME	LAT.	LONG.	M_s	LOCATION	ZONE*
1	1898	6	29	1836	52.	+172.	7.6	Near Is.	S+
2	1898	10	11	1637	50.	180.	6.9	Rat/Andreanof Is.	S-
3	1899	4	16	1342	58.	-138.	6.9	S.E. Alaska	T-
4	1899	7	14	1332	(60.)*	(-150.)*	7.2	(Kenai Penin.)*	S+
5	1899	9	4	0022	60.	-142.	7.9	Gulf of Alaska	T+
6	1899	9	4	0440	60.	-142.	6.9	Gulf of Alaska	T-
7	1899	9	10	1704	60.	-140.	7.4	S.E. Alaska	T+
8	1899	9	10	2141	60.	-140.	8.0	S.E. Alaska	T+
9	1899	9	17	1250	59.	-136.	6.9	S.E. Alaska	T-
10	1899	9	23	1104	60.	-143.	6.9	Gulf of Alaska	T-
11	1899	9	23	1250	60.	-143.	7.0	Gulf of Alaska	T+
12	1900	10	9	1228	(60.)*	(-142.)*	7.7	(Kodiak)*	S+*
13	1901	1	18	0439	60.	-135.	7.1	S.E. Alaska	T+
14	1901	12	31	0902	52.	-177.	7.1	Andreanof Is.	S+
15	1902	1	1	0520	55.	-165.	7.0	Unimak Is.	S+
16	1903	1	17	1605	50.	-170.	7.0	(Fox Is.)	S+
17	1903	2	5	1826	52.	+175.	6.8	Near/Rat Is.	S-
18	1903	6	2	1317	57.	-156.	6.9	Alaska Penin.	S-
19	1904	8	27	2156	64.	-151.	7.3	Central Alaska	M+
20	1905	2	14	0846	53.	-178.	7.3	Andreanof Is.	S+
21	1905	3	22	0338	50.	180.	7.0	Rat/Andreanof Is.	S+
22	1905	9	15	0602	55.	+165.	7.4	Komandorsky	O+
23	1905	12	10	1236	50.	180.	6.9	Rat/Andreanof Is.	S-
24	1906	8	17	0010	51.	+179.	7.8	Rat Is.	S+
25	1906	12	23	1722	53.	-165.	7.3	(Unimak Is.)	S+
26	1907	9	2	1601	52.	+173.	7.4	Near Is.	S+
27	1908	5	15	0831	59.	-141.	7.0	S.E. Alaska	T+
28	1909	4	10	1936	52.	+175.	7.0	Near/Rat Is.	S+
29	1910	9	9	0113	51.5	-176.	7.0	Andreanof Is.	S+
30	1910	11	6	2029	53.	-135.	6.8	Queen Charlotte Is.	O-
31	1911	9	17	0326	51.	180.	7.1	Rat/Andreanof Is.	S+
32	1911	11	13	1613	52.	+173.	6.9	Near Is.	S-
33	1912	6	10	1606	59.	-153.	6.9	Kodiak Is.	S-
34	1912	7	7	0757	64.	-147.	7.2	Central Alaska	M+
35	1915	7	31	0131	54.	+162.	7.6	Kamchatka	O+
36	1917	1	30	0245	56.5	+163.	7.8	Kamchatka	O+
37	1917	5	31	0847	54.5	-160.	7.9	Alaska Penin.	S+
38	1923	5	4	1626	55.5	-156.5	7.1	Alaska Penin.	S+
39	1925	8	19	1207	55.25	+168.	7.0	Unimak Is.	S+
40	1926	10	13	1908	52.	-176.	7.0	Andreanof Is.	S+

4S620130

#.	YEAR	MO	DY	TIME	LAT.	LONG.	M_s	LOCATION	ZONE*
41	1927	10	24	1559	57.5	-137.	7.1	S.E. Alaska	T+
42	1928	6	21	1627	60.	-146.5	6.8	Gulf of Alaska	S-
43	1929	3	7	0134	51.	-170.	7.5	Fox Is.	S+
44	1929	7	5	1419	51.	-178.	7.0	Andreanof Is.	S+
45	1929	7	7	2123	52.	-178.	7.3	Andreanof Is.	S+
46	1929	12	17	1058	52.5	+171.5	7.8	Near Is.	S+
47	1933	4	27	0236	61.25	-150.75	6.9	S. Central Alaska	M-
48	1935	2	22	1705	52.25	+175.	7.1	Near/Rat Is.	S+
49	1936	11	13	1231	55.5	+163.	7.1	Kamchatka	O+
50	1937	7	22	1709	64.75	-146.75	7.3	Central Alaska	M+
51	1938	11	10	2018	55.5	-158.	8.3	Alaska Penin.	S+
52	1938	11	17	0354	55.5	-158.5	7.3	Alaska Penin.	S+
53	1940	4	16	0607	52.	+173.5	6.8	Near Is.	S-
54	1940	4	16	0643	52.	+173.5	7.1	Near Is.	S+
55	1940	8	22	0327	53.	-165.5	7.0	Unimak Is.	S+
56	1943	11	3	1432	61.75	-151.	7.4	S. Central Alaska	M+
57	1944	12	12	0417	51.5	+179.5	6.9	Rat Is.	S-
58	1945	4	15	0235	57.	+164.	7.2	Komandorsky	O+
59	1946	1	12	2025	59.25	-147.25	6.7	Gulf of Alaska	S-
60	1946	4	1	1228	52.75	-163.5	7.3	Unimak Is.	S+
61	1946	11	1	1114	51.5	-174.5	7.0	Andreanof Is.	S+
62	1947	10	16	0209	64.5	-147.5	7.2	Central Alaska	M+
63	1948	5	14	2231	54.5	-161.	7.5	Alaska Penin.	S+
64	1949	8	22	0401	53.75	-133.25	8.1	Queen Charlotte Is.	O+
65	1949	9	27	1530	59.75	-149.	6.7	Kenai Penin.	S-
66	1951	2	13	2212	56.	-156.	7.1	Alaska Penin.	S+
67	1953	1	5	0748	54.	+170.5	7.1	Near Is.	S+
68	1957	3	9	1422	51.3	-175.8	(8.1)	Andreanof Is.	S+
69	1957	3	9	2039	52.25	-169.5	7.1	Fox Is.	S+
70	1957	3	11	0958	52.25	-169.25	7.0	Fox Is.	S+
71	1957	3	11	1455	51.5	-178.5	6.9	Andreanof Is.	S-
72	1957	3	12	1144	51.5	-177.	7.0	Andreanof Is.	S+
73	1957	3	14	1447	51.	-177.	7.1	Andreanof Is.	S+
74	1957	3	16	0234	51.5	-178.75	7.0	Andreanof Is.	S+
75	1957	3	22	1421	53.75	-165.75	7.0	Unimak Is.	S+
76	1957	4	10	1129	56.	-154.	6.9	Kodiak Is.	S-
77	1957	4	19	2219	52.25	-166.	6.5	Unimak Is.	S-
78	1958	4	7	1530	65.5	-155.5	7.3	Central Alaska	M+
79	1958	7	10	0615	58.3	-136.5	7.9	S.E. Alaska	T+
80	1960	11	13	0920	51.4	-168.9	6.7	Fox Is.	S-
81	1964	2	6	1307	55.7	-155.9	7.0	Alaska Penin.	S+
82	1964	3	28	0336	61.1	-147.5	(8.4)*	Gulf of Alaska	S+
83	1965	2	4	0501	51.3	+178.6	(8.2)*	Rat Is.	S+
84	1965	2	4	0840	51.4	+179.6	7.0	Rat Is.	S+
85	1965	3	30	0227	50.3	+177.9	7.4	Rat Is.	S+
86	1965	7	2	2058	53.0	-167.6	6.5	Fox/Unimak Is.	S-
87	1965	7	29	0829	51.1	-171.3	6.7	Fox Is.	S-
88	1965	9	4	1432	58.3	-152.5	6.8	Kodiak Is.	S-

4B2 20130

#	YEAR	MO	DY	TIME	LAT.	LONG.	M_s	LOCATION	ZONE*
89	1966	7	4	1833	52.0	+179.9	6.8	Rat Is.	S-
90	1966	8	7	0213	50.6	-171.2	6.4	Fox Is.	S-
91	1969	11	22	2309	57.7	+163.6	7.1	Kamchatka	O+
92	1971	12	15	0829	56.0	+163.2	7.5	Kamchatka	O
93	1972	7	30	2145	56.8	-135.9	7.4	S.E. Alaska	T+
94	1975	2	2	0843	53.1	+173.6	7.4	Near Is.	S+
95	1979	2	28	2127	60.6	-141.6	7.0	S.E. Alaska	T+

*Explanation:

(1) Data for 1897-1912 from Abe, K. and S. Noguchi, 1983(a).

(2) Data for 1913-1917 from Abe, K. and S. Noguchi, 1983(b).

(3) Data for 1918-1980 from Abe, K., 1981.

(4) The following notes apply to the respective earthquake number:
- 4 - location very uncertain, felt reports suggest a more westerly epicenter, perhaps near the Shumagin Islands
- 12 - location very uncertain, felt reports suggest a more westerly epicenter, perhaps near Kodiak Island
- 68 - moment magnitude 8.7
- 82 - moment magnitude 9.2
- 83 - moment magnitude 8.7

(5) Earthquake zones were defined as follows:

S = Alaska-Aleutian subduction zone
T = S.E. Alaska transform zone
M = Mainland Alaska
O = Outside of Alaska (Kamchatka, Komandorsky, Queen Charlotte)
+ = M_s greater than or equal to 7.0
- = M_s less than 7.0

Table 3
Alaskan Earthquake Statistics
Independent Events, M ≥ 7.0, January 1897 - January 1986

Region	Major ($M_s > 7.0$)	Great ($M_s > 7.8$)
Alaska-Aleutian Subduction Zone		
Number in 90 years	37	7
Mean repeat time (years)	2.3	9.7
Time since last event (years)	5.0	20.9
Time for 95% of cases (years)	6.1	19.3
Date of the last event	1-30-81	2-4-65
S.E. Alaska Transform Zone		
Number in 90 years	8	3
Mean repeat time (years)	11.4	29.4
Time since last event (years)	6.9	27.5
Time for 95% of cases (years)	29.3	97.8
Date of the last event	2-28-79	7-10-58
Mainland Alaska Seismic Zone		
Number in 90 years	6	0
Mean repeat time (years)	10.7	?
Time since last event (years)	27.8	?
Time for 95% of cases (years)	24.5	?
Date of last event	4-7-58	?
All of Alaska		
Number in 90 years	51	10
Mean repeat time (years)	1.7	7.3
Time since last event (years)	5.0	21.0
Time for 95% of cases (years)	4.5	17.3
Date of last event	1-30-81	2-4-65

NOTES

1) The data base for these calculations is the catalog of large, shallow earthquakes in Alaska based on the papers of Abe and Noguchi given in Table 2 augmented by data for the period Jan. 1981 - Jan. 1986 from the National Earthquake Information Service (NEIS).
2) The mean repeat time for the $M_s > 7.0$ and $M_s > 7.8$ events is the average of the observed interevent times.
3) The "time for 95% of cases" is the mean interevent time plus 1.645 times one standard deviation of the individual interevent times about their mean.

In the transform zone neither class of earthquake is close to being overdue, so while an event of $M \geq 7.0$ could occur tomorrow, we would not be surprised if it did not occur for another 30 years.

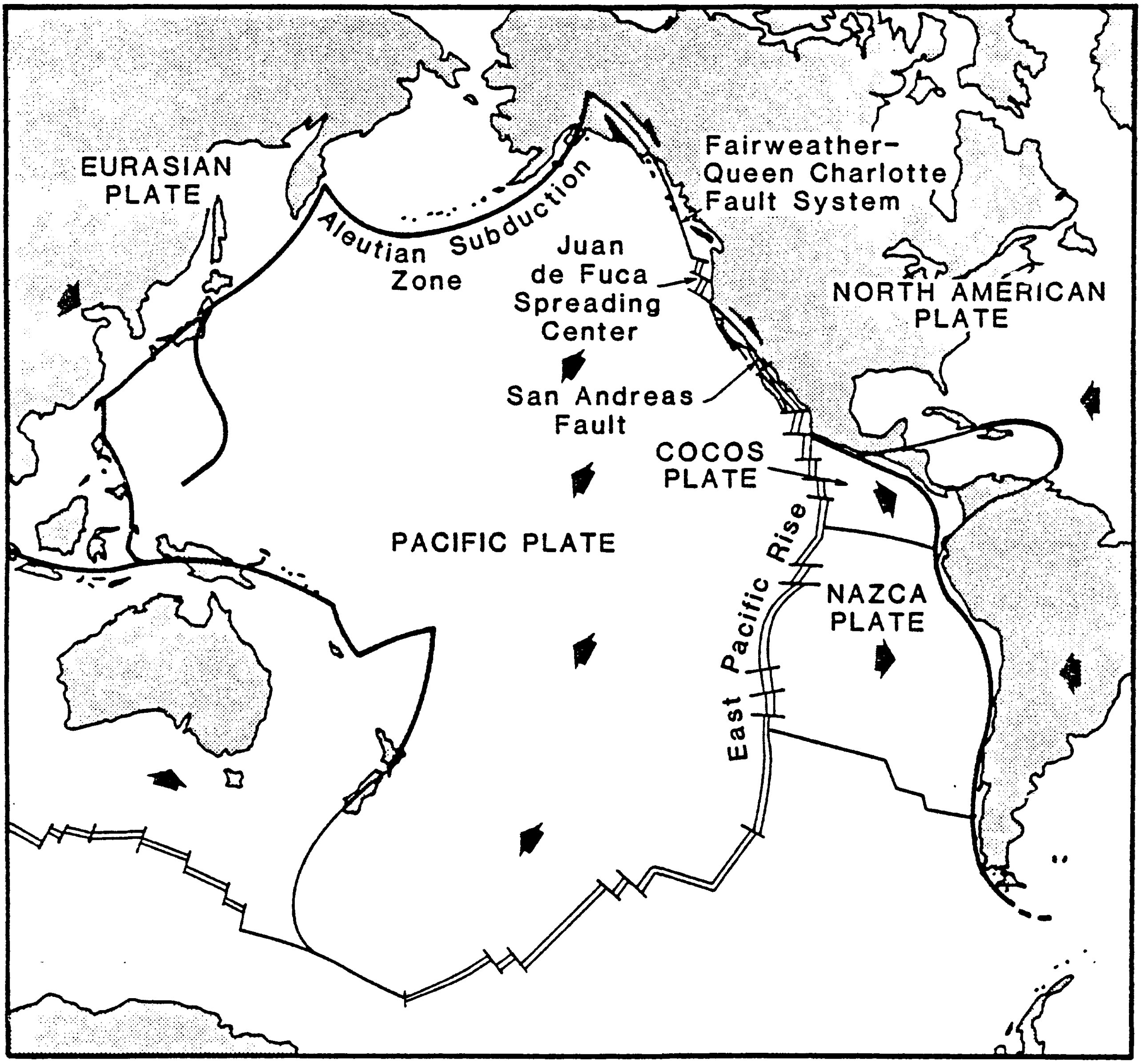
In the mainland Alaska seismic zone there have been no events of $M \geq 7.8$ during the past 90 years. This does not mean that such events are impossible, simply that they are less frequent than in the subduction zone. The mean repeat time for great earthquakes in this zone is probably on the order of a few hundred years, so it's not surprising that we have not recorded one given our short history here.

For major ($7.0 \geq M \geq 7.8$) earthquakes in the mainland zone the time since the last event is 27.8 years, and the time for 95% of the cases is 24.5 years, thus we are overdue here too.

It should be noted that these statistics apply to very large zones and that the mean recurrence times for a specific locality within one of these zones is much longer than the mean repeat time for the whole zone.

CAUSE OF EARTHQUAKES IN ALASKA AND LIKELIHOOD OF FUTURE SHOCKS

The direct cause of the very large earthquakes in southeastern Alaska and the Alaska Peninsula-Aleutian zone is the relative motion of the Pacific and North American (Alaska) plates (Fig. 3). The Pacific plate is continuously created by the upwelling of molten rock at the Juan de Fuca and East Pacific spreading centers. The Juan de Fuca spreading center lies offshore of British Columbia, Washington, and Oregon and forms the Juan de Fuca plate on one limb and the northernmost part of the Pacific plate on the other. The East Pacific spreading center begins in the Gulf of California and extends south and then southwesterly from Central America. This spreading center forms the Cocos and Nazca plates on one limb and the central part of the Pacific plate on the other. From the Juan de Fuca and East Pacific spreading centers the Pacific plate moves northwesterly relative to North America along the San Andreas and Queen Charlotte-Fairweather transform fault systems. Along these transform faults the plates slide past one another edge-to-edge. When the Pacific plate arrives at the Gulf of Alaska it can no longer move sideways by the North



DIRECTION OF PLATE MOTION

Figure 3.--Some of the plate tectonics features which give rise to the Pacific Ring of Fire. Most earthquakes and volcanoes occur around the margins of the pacific Basin, particularly in the subduction zones and along faults exhibiting strike-slip (lateral) displacement.

4B720130

American plate; here it begins subducting beneath Alaska. The Pacific plate is consumed beneath the North American and Eurasian plates along the Aleutian, Kurile, and Japanese islands.

The conveyor-belt-like motion of the Pacific plate from spreading center to subduction zone is thought to be driven by buoyancy forces. There may be a small amount of push as it "falls off" the topographic high at the spreading center and there is probably a much stronger pull as the cooler portion of the plate, far away from its origin at the spreading center, sinks under gravitational forces into the less-dense mantle. It is this relentless motion of the Pacific plate as it slides by southeastern Alaska and is thrust beneath the Gulf of Alaska and the Aleutian Islands that causes most of the earthquakes in Alaska.

Over the past 5 million years, about 290 km of Pacific plate has been thrust to the northwest underneath southern Alaska in the vicinity of Anchorage - an average rate of about 5.8 cm year. Since the slip during the 1964 Good Friday earthquake is calculated to have been about 10 m, it would take about 172 years to build up enough strain for a repeat of that devastating event. Note that this is an average number and that it is assumed that no ##?aseismic slip takes place; that is, that all of the 5.8 cm per year of relative motion between the Pacific and North American plates is taken up in strain that is entirely released in the form of great earthquakes. Extreme estimates of the repeat times for great earthquakes in southern Alaska range from 30 years to 1800 years.

Seismic Gaps

The deterministic notion of repeat times of large earthquakes described above leads to the idea of a seismic gap. If it takes a certain amount of time for strain to build up in a region following a large earthquake, then it follows that immediately after such an event the probability for another of similar magnitude is quite low. Conversely, if much time has elapsed since the last large event in an area where large earthquakes are known to occur, then the probability for a large shock in the near future is relatively high. Such an area is called a seismic gap (with a high seismic potential).

In southern Alaska there are two regions that have been identified as seismic gaps: one near Yakataga and the other near the Shumagin Islands and Cold Bay on the Alaska Peninsula. In each of these areas it has been at least 80 years since the last great earthquake ($M_w \geq 7.8$) occurred. In both areas, 80 years is approximately the estimated repeat time for an earthquake of about M_w = 8.0. Hence, both areas are "due" for a large earthquake (i.e., have a high seismic potential), so we wouldn't be surprised if one were to occur there tomorrow. On the other hand, we wouldn't be surprised if one did not occur there during the next 10 years. The quality of the data presently available to us restricts us to the following statement: There is a 30 to 90 percent chance of an earthquake of $M_w \geq 8.0$ occurring in the Yakataga and Shumagin gaps in the next two decades (Nishenko and Jacob, 1985). The range in probabilities arises out of different assumptions about how to do the statistics.

Faults Away from Plate Boundaries

We understand the probabilities for large shocks in the seismic gaps quite well by comparison to how well we understand that likelihood for large earthquakes on most faults that do not lie near plate boundaries. In most cases we have no direct information about the repeat time for large events on a given fault: all we know, for example, is that a certain fault may have been offset in the last 10,000 years - we may not even know if this offset was sudden, in one or more large events, or gradual, in some form of continuous creep.

One particularly important example of this situation is the Border Ranges fault which follows an arcuate path along the northern front of the Chugach and Kenai mountains from north of Cordova to the southwestern tip of Kodiak Island, a distance of over 1000 km. This great fault is thought to be the suture zone (or zone of collision) between parts of southern most Alaska which were rafted together about 40 million years ago. It is possible that portions of this suture zone are active today. There is some evidence, for example, that the portion near Eagle River has moved in the last 4,000 years. There is no large earthquake known to be associated with the Border Ranges fault. This leaves us with the uncomfortable and unsatisfactory conclusion that there is a possibility that there is a high probability for a large earthquake on this major fault system which runs right through Anchorage. Clearly more work is urgently needed to resolve this situation. In the meantime most, but not all, assessments of seismic hazard in the Anchorage area assume the fault to be active.

Again, this is only one example. There are many other major faults in southcentral, western, and northern Alaska which may or may not generate future large earthquakes: The Castle Mountain, Denali, Iditarod, Kaltag, and Tintina faults, to name just a few. Further, there are seismically active zones such as the Badger Road area near Fairbanks that has had thousands of earthquakes, including four events of magnitude 5.5 to 6.0 on one day - June 21, 1967. In this area we have earthquakes but no known fault. This makes it difficult to assess the likelihood of future, possibly larger events. We know these larger events can occur in the Interior: there were events of $M_s = 7.3$ in 1904 south of Rampart, near Salcha in 1937, and near Huslia in 1958. None of these earthquakes clearly occurred on a mapped fault. So, for the time being, we must lump all of these events into one large seismogenic zone and treat their occurrence statistically. This has the result that we "smear out" the probability of occurrence of future larger events over a very big area, with the consequence that some areas are underrated as to their seismic hazard and others are overrated. For the present, this is the best that can be done.

RISK REDUCTION

What can we do to improve this situation in the future, and what can we do to mitigate the effects of the inevitable future large earthquakes? The essential new information will come only from a long-term commitment to a program of seismic monitoring and geological mapping designed to identify and evaluate potential seismic sources in Alaska. As this new information becomes available, it must be incorporated into building codes and zoning requirements so that it is used to assure the cost-effective and safe development of the state.

That a long-term commitment to seismic risk reduction is cost effective was clearly demonstrated by a three-year study carried out by the California Division of Mines and Geology (CDMG). The results of this study are summarized in Figure 4. The histogram shown in this figure indicates three dollar values associated with each of a number of geologic hazards. The first value given is the expected cost to society if we proceed with the status quo. In case of seismic shaking, for example, this would be the expected loss in California due to collapse or major damage to structures if no new hazard mitigation programs were carried out between now and the year 2000. The second value given in each case is the expected reduction possible if state-of-the-art loss-reduction measures were in place from 1970 to 2000. The last value is the expected cost of implementing the best possible programs to reduce losses from the hazard. Again in the case of seismic shaking, this program would include measures such as identifying areas most likely to experience strong seismic shaking or ground failure as a result of large earthquakes in the next 20 years, so that efforts may be concentrated in these areas. Further measures would include the strengthening of some buildings and the removal of other (unreinforced masonry, for example), changes in occupancy, new building code requirements, and new zoning.

Summarizing the earthquake shaking case, we see that for the period from 1970 to 2000 the expected loss in California under current practices would be $21 billion, the possible reduction in these losses given state-of-the-art loss-reduction measures would be about $10.5 billion, and the cost to implement these measures would be about $2 billion. This gives a benefit/cost ratio which is better than 5:1, a pretty good return on investment by any standards! Some of the other major geologic problems yield even higher benefit/cost ratios. Loss of mineral resources to urbanization and landsliding, are both $10 billion-plus problems which have benefit/cost ratios in excess of 9:1. Clearly a little foresight would make good economic sense.

These numbers, of course, apply only to California, where there is a very large population exposed to these hazards. A similar study is needed in Alaska to identify the problem areas where similar benefit/cost ratios might apply to our geologic problem. It is very likely that given properly scaled loss-reduction programs, similar benefit/cost ratios could be achieved for

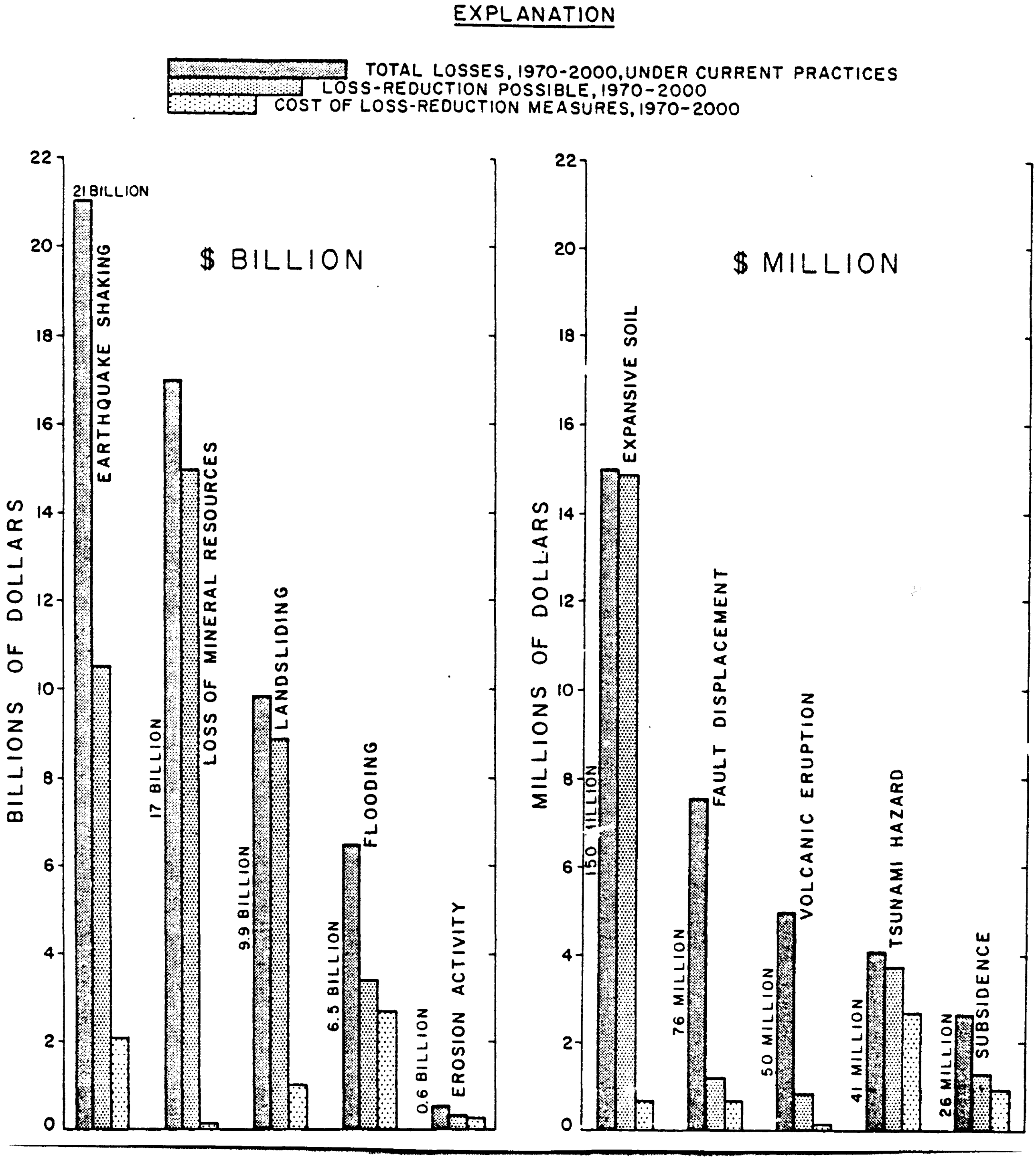


Figure 4.--Estimated losses from geologic problems in California, 1970-2000, and possible loss-reduction if state-of-the-art practices were used.

earthquake losses, loss of mineral resources, and frozen ground losses, to name just a few.

CONCLUSIONS

We have a rapidly developing urban and transportation infrastructure in Alaska which is vulnerable to an extremely high level of earthquake hazard. This hazard, while qualitatively well understood, cannot be adequately quantified for risk assessment purposes at the present level of knowledge. What is required is a two-fold commitment to improving our knowledge of the hazard and to carrying out appropriate loss-reduction measures. There is every reason to believe that substantial benefit/cost ratios can be achieved in Alaska with a well-planned program to reduce losses from earthquakes. Further, there are many other geologic problems in Alaska that likely will admit to similar loss-reduction efforts.

REFERENCES

Abe, K., 1981. Magnitudes of large shallow earthquakes from 1904 to 1980. Physics of the Earth and Planetary Interiors 27:72-92.

Abe, K., and Noguchi, S., 1983 (a). Determination of magnitude for large shallow earthquakes, 1898-1917. Physics of the Earth and Planetary Interiors 32:45-49.

Abe, K., and Noguchi, S., 1983(b). Revision of magnitudes of large shallow earthquakes, 1897-1912. Physics of the Earth and Planetary Interiors 33:1-11.

Alfors, John T., Burnett, John L., and Gay, Thomas E., Jr., 1973. The Nature, Magnitude, and Costs of Geologic Hazards in California and Recommendations for Their Mitigation. Urban Geology: Master Plan for California, Bulletin 198, California Division of Mines and Geology, Sacramento, California.

Iacopi, Robert, 1971. Earthquake Country. Lane Books, Menlo Park, California, 160 p.

Kanamori, Hiroo, 1977. The energy release in great earthquakes. Journal of Geophysical Research 82(20):2981-2988.

Nishenko, S. and Jacob, K., 1985. Hazards evaluation for large and great earthquakes along the Queen Charlotte-Alaska-Aleutian seismic zone: 1985:2005, unpublished ms, 12 p.

 5582013D

REGIONAL SEISMIC MONITORING IN SOUTHERN ALASKA:
APPLICATION TO EARTHQUAKE HAZARDS ASSESSMENT

by

John C. Lahr, Christopher D. Stephens, and Robert A. Page
U. S. Geological Survey
Menlo Park, California 94025

INTRODUCTION

The seismic activity of southern Alaska is a consequence of the NNW-SSE convergence of the Pacific and North American plates at a rate of about 6 cm/a. This convergent motion is accommodated by right-lateral strike-slip motion on the Queen Charlotte Islands fault and subduction of the Pacific plate along the Aleutian megathrust (Figure 1). The transition between these two fault zones is complex, and the Pacific-North American plate boundary is not identified with certainty along the eastern Gulf of Alaska. The plate motion in this region is not confined to a single, well-defined fault zone; rather it is distributed among faults bounding three tectonic blocks lying between the continental margin and the Denali fault (Lahr and Plafker, 1980). Most of the motion occurs between the Yakutat block and the Wrangell and St. Elias blocks. The Yakutat block, which is moving at nearly the velocity of the Pacific plate, is currently in the process of being accreted to Alaska.

The U.S. Geological Survey (USGS) began continuous high-gain seismic monitoring in southern Alaska in 1971 with a network of 10 stations in the Cook Inlet and Valdez regions. By 1974, the number of stations had increased to 54 and the monitored region had expanded eastward along the Gulf of Alaska as far as Yakutat Bay and northward to southern edge of the Wrangell Mountains. During subsequent years additional changes have been made in the network, including the temporary operation of additional stations for special studies, but the area covered by the network has remained relatively constant. Approximately 35,000 earthquakes have been located with data from

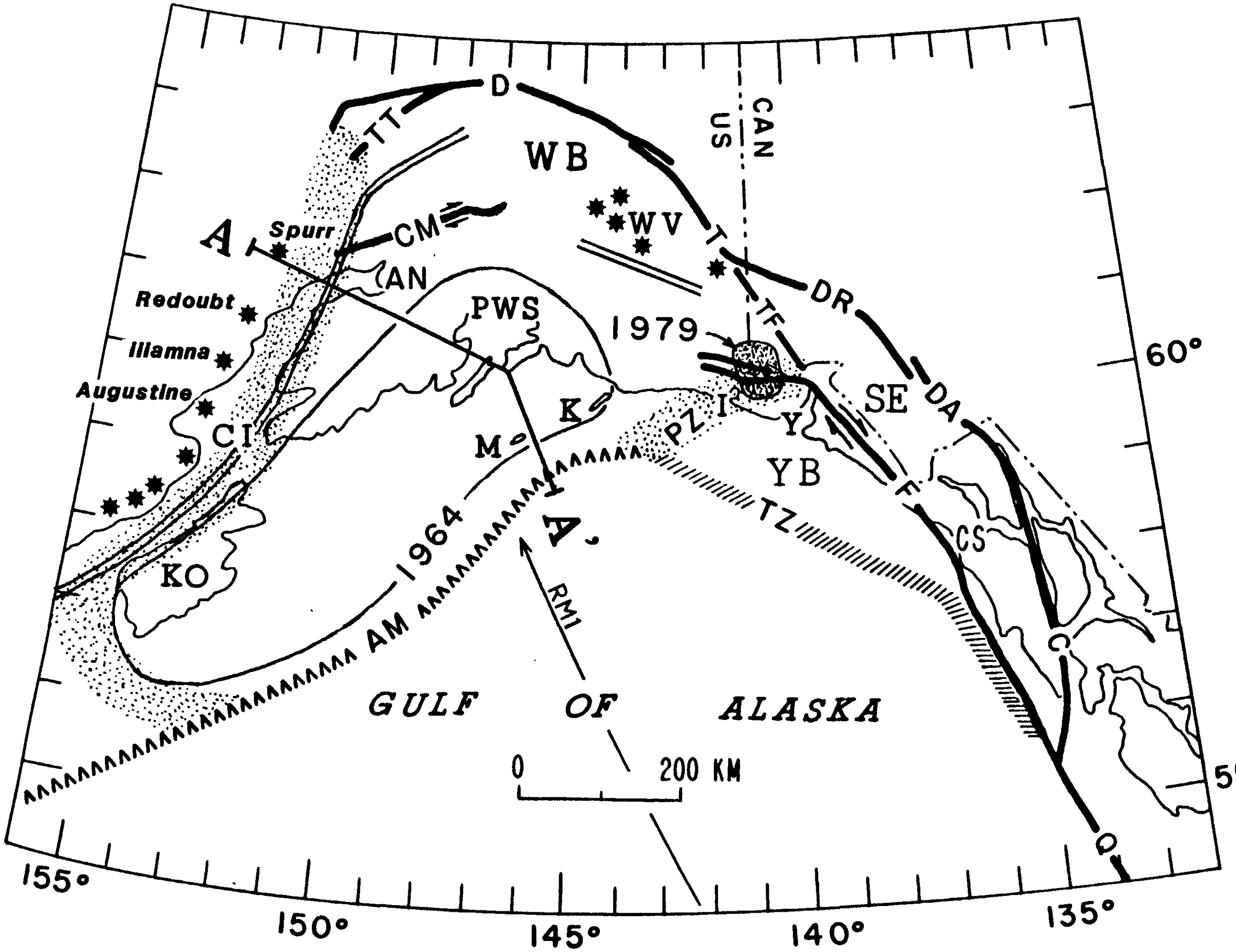


Figure 1. Map of southern Alaska and western Canada emphasizing principal regional tectonic features (Lahr and Plafker, 1980; Stephens and others, 1984). Location of cross section A-A' of Figure 2 is shown. KO, Kodiak Island; M, Middleton Island; K, Kayak Island; CI, Cook Inlet; AN, Anchorage; PWS, Prince William Sound (Valdez is near S of PWS); I, Icy Bay; Y, Yakutat Bay; CS, Cross Sound; WV, Wrangell volcanoes; 1964, rupture zone of 1964 Prince William Sound earthquake; 1979, rupture zone of 1979 St. Elias earthquake; AM, Aleutian megathrust; TZ, Transistion zone; Q, Queen Charlotte Islands fault; C, Chatham Strait fault; DA, Dalton fault; DR, Duke River fault; TF, Totschunda-Fairweather fault; T, Totschunda fault; D, Denali fault; TT, unnamed faults; CM, Castle Mountain fault; F, Fairweather fault; PZ, Pamplona zone; double line, 50 km isobath of Benioff zone; YB, Yakutat block; SE, St. Elias block; WB, Wrangell block; shaded zone from TT through CI to AM is speculative northwestern boundary of WB; RM1, Pacific-North American plate relative motion direction.

5B1 20130

the USGS southern Alaska network; an additional 3,000 to 4,000 events are currently being located each year. This data set constitutes an invaluable source of information for delineating seismic source zones and elucidating the regional seismotectonic framework, activities that are prerequisites for evaluating earthquake potential in hazard assessment studies. In addition, continued monitoring of the Yakataga seismic gap may provide valuable data for testing current and future hypotheses about earthquake precursors.

To show the relationship of earthquakes to major tectonic features, hypocenters within 50 km of the line A - A' (Figure 1), which extends from Mt. Spurr volcano to the Aleutian trench, are shown in cross section in Figure 2. The location of the Pacific plate has been inferred from the distribution of subcrustal (focal depths greater than about 40 km) earthquakes, the Benioff zone of seismicity. The Pacific plate is being subducted below the North American plate (Alaska) along the Aleutian megathrust, which crops out on the seafloor at the Aleutian trench. The seismicity can be divided into four tectonic source zones (Figure 2) as follows: 1) within the Aleutian megathrust zone; 2) within the subducting Pacific plate; 3) within the overriding North American plate away from the active volcanoes; and 4) within the North American plate along the axis of active volcanoes. Each of these source zones will be described briefly and some of the applications and limitations of the seismic network data will be discussed.

ALEUTIAN MEGATHRUST

The largest earthquakes in Alaska, such as the moment magnitude (M_w) 9.2 Prince William Sound earthquake of 1964, result from slip on the Aleutian megathrust, the northward dipping interface between the Pacific and North American plates. The most recent large thrust earthquake in the region was the 1979 St. Elias earthquake of magnitude (M_s) 7.1, which occurred north and east of Icy Bay (Figure 1). Data from the USGS network were critical in delineating the lateral extent of the rupture zone and in monitoring the magnitude and temporal distributions of the aftershocks (Stephens and others, 1980). To better resolve the depths of aftershocks and thereby the geometry of the inferred buried rupture, Page and others (1984) supplemented the

 555 20130

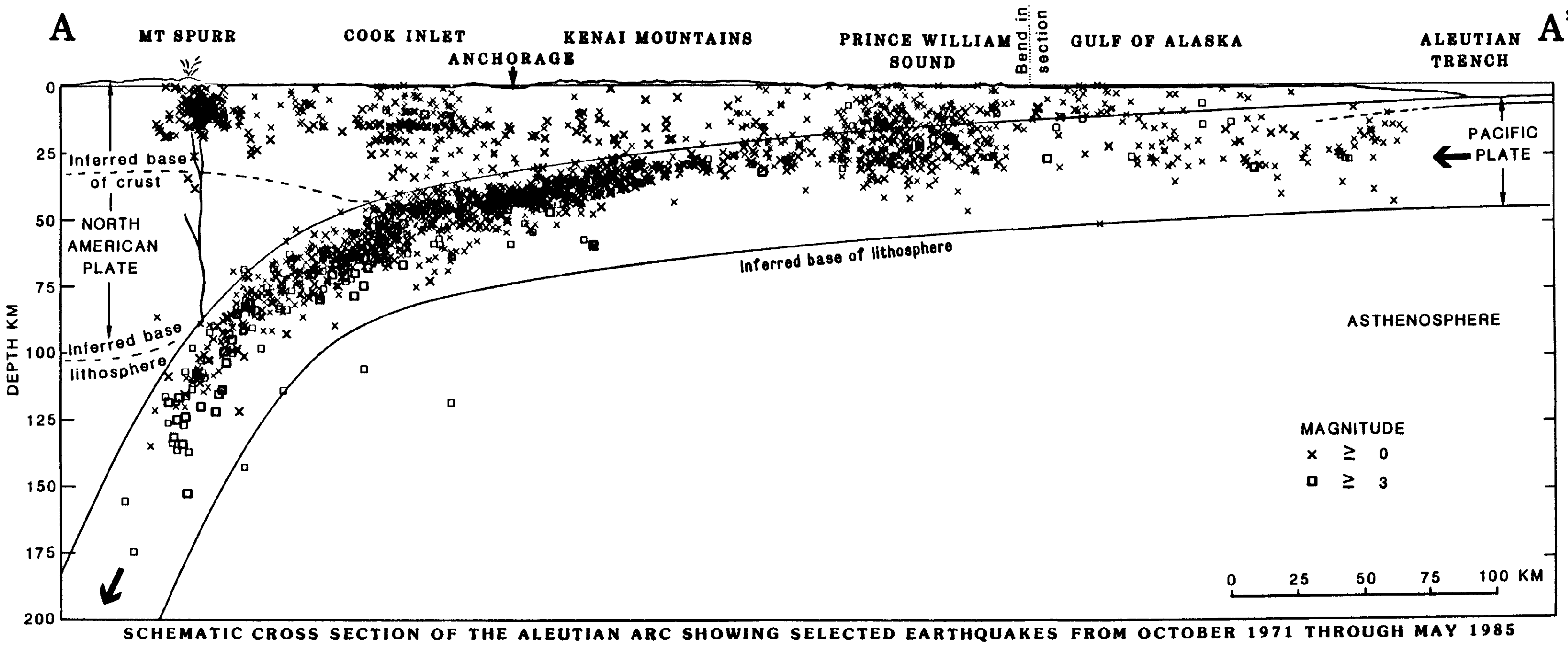


Figure 2. Cross section showing hypocenters of earthquakes with 4 or more P-phase readings, 1 or more S-phase readings and root-mean-square residual less than or equal to 0.6 s. View is northeast. 2604 events within 50 km of line A-A', shown in Figure 1, are included. Structures modified from Plafker and others, 1982. The offsets within the Benioff zone below Cook Inlet and the tendency for crustal events to concentrate near certain depths are thought to be artifacts of the location proceedure.

regional network with a temporary array of 4 seismographs near the center of the rupture zone. They found that the distribution of accurately located hypocenters locally defined a thin (3 km thick), sub-horizontal planar fault zone at a depth of 11 to 14 km. Thus the combination of regional monitoring and a short-term special study was able to resolve the principal features of the sequence.

Within the rupture zone of the great 1964 earthquake (Figure 1), relatively few events believed to be on the Aleutian megathrust have occurred since the regional network was installed. Nonetheless, the position of the subducted Pacific plate and hence the location of the megathrust beneath the Anchorage region (Figure 2) has been inferred from the distribution of Benioff zone events.

An important unresolved question for the Anchorage region is the depth beneath which slip on the megathrust occurs aseismically, that is without earthquakes. Based on the distribution of aftershocks and elastic models of the coseismic crustal deformation, the megathrust slipped to a depth of about 20 km in 1964. If the transition to asesimic slip occurs at 40 km depth, as has been suggested for the Aleutian arc in general (Davies and House, 1979), then seismic rupture could occur on a section of the megathrust downdip from the 1964 rupture, directly below Anchorage at 30 to 35 km depth (Lahr and others, 1984). It is possible that careful study of the focal mechanisms of earthquakes recorded by the regional network within or near the megathrust could assist in determining the location of this transition.

Knowledge of the average rate of occurrence and temporal distribution of shocks on the megathrust, from the smallest that pose a potential hazard to the largest that could occur, such as the 1964 earthquake, is important for the assessment of seismic hazard in southern Alaska. Only the accumulation of a record of earthquakes that is at least comparable in duration to the return times of the events, which for the largest shocks is probably well over 100 years, will make it possible to determine those rates with confidence. Regional monitoring over a few decades can provide important information for the smaller shocks, but not for the largest earthquakes. More timely approaches for the largest shocks are to extend the record back in time through geologic studies, such as the study of Plafker and Rubin (1978) of uplifted marine terraces on Middleton Island, or to draw analogies with other arcs that have a longer seismic history.

Another important function of the USGS network is to monitor an area in which a major earthquake is expected in the future, possibly within a decade or two. The plate boundary between Icy Bay and Kayak Island has not broken in a major earthquake since the Yakutat Bay earthquakes of 1899 and is one of only three zones along the entire Alaska-Aleutian arc that has not ruptured within the past 50 years. McCann and others (1980) concluded that this region - the Yakataga seismic gap - is the likely site for a great (M>7.7) earthquake prior to 2000. Seismicity patterns in and around this region are reviewed continuously for changes that might alter our assessment of the imminence of a major earthquake. Thus far, the data obtained from the regional seismic network show a pattern of seismicity that has remained remarkably stable both in time and space. Even if the gap filling event is not predicted in advance, valuable data will have been gathered that can be used to test current and future hypotheses about earthquake precursors.

ACTIVITY WITHIN THE PACIFIC PLATE

Seismicity within a subducted plate is attributed to some combination of bending stresses, stresses due to phase transformations and temperature gradients, and stresses resulting from the pull of the deeper portions of the slab, which is sinking due to gravitational forces. The largest Benioff zone events recorded worldwide have been near magnitude 8 (Abe and Kanamori, 1979). In the southern Alaska region, the Benioff zone has been the most active source of earthquakes since regional monitoring began in 1971. Even though the criteria for selecting shocks to be located emphasize shallow events, most of the events processed occurred within the subducted Pacific plate (Figure 2).

Focal mechanisms of Benioff zone events recorded by the regional network are quite varied, but many are compatible with the least compressive stress axis oriented downdip within the plane of the subducted plate (Lahr, 1975; Lahr and Stephens, 1982). For example, two magnitude 6 earthquakes occurred in July and September 1983 near Columbia Bay on the northern edge of Prince William Sound. These are the largest events in the Prince William Sound region since the M_w 9.2 earthquake of 1964. Using portable stations to augment the regional network, Page and others (1985) showed that well-located aftershocks define a northwest-dipping fault zone that was activated between 22 and 35 km depth. The focal mechanisms indicated predominantly normal faulting consistent with downdip-oriented tension. Based on the distribution of Benioff zone events in adjacent areas, these two events are inferred to have occurred within the upper part of the subducted plate.

The July 1983 shock produced an acceleration of 0.32 g at Valdez, 50 km away, the largest acceleration yet recorded for an Alaskan earthquake. Strong-motion seismographs were not deployed in Alaska until after the 1964 earthquake. Clearly the hazard associated with events originating within the subducted Pacific plate must be factored into the overall seismic hazard assessment.

ACTIVITY WITHIN THE NORTH AMERICAN PLATE

Although shallow-focus crustal earthquakes are much less frequent than those within the Benioff zone, their potential close proximity to structures and the possibility for surface faulting requires that they be given careful consideration in hazard assessments. Generally the distribution of shallow earthquakes in southern coastal Alaska is diffuse, and the events cannot be clearly associated with mapped fault traces. One feature that is recognized near Anchorage is a zone of persistent shallow activity that parallels the strike of the Benioff zone, with epicenters located between the 35- and 50-km depth contours drawn on the top of the Benioff zone (below Cook Inlet in Figure 2). This zone does not appear to be associated with surface faulting and the potential for large events has yet to be established.

In a few cases earthquakes have been associated with mapped faults. Activity along the Castle Mountain fault system was so sparse prior to 1984 that no events had been unequivocally associated with it. However, the Talkeetna segment of the fault near Sutton was the source of a 5.7 m_b (5.2 M_s) earthquake on August 14, 1984 (Lahr and others, 1985). This event involved

5S7 20130

right-lateral slip on a steeply north-dipping, buried segment of the fault. Slip did not extend to the surface. In fact, geologic evidence for Holocene displacements is lacking for this segment of the fault (Detterman and others, 1976). On the contiguous Susitna segment, however, Holocene displacements are clearly evident (Detterman and others 1974). This illustrates the need for both geologic and seismic studies in assessing the activity of faults. The seismic potential of the Castle Mountain fault is clearly important because of its proximity to Alaska's principal population center (40 km from Anchorage, 15 km from Palmer, 10 km from Wasilla). Although a rough estimate of the maximum size of an event on the Castle Mountain fault can be made based upon the length of the fault, it is more difficult to assess the frequency with which such events might occur because the average slip rate is not known.

In evaluating the seismic potential of other mapped faults, the experience with the Castle Mountain fault must be borne in mind: regional seismic monitoring for 13 years could not clearly associate earthquakes with the Castle Mountain fault, and when the fault did rupture, a segment without identifiable Holocene displacements broke. Clearly other faults may likewise constitute a hazard despite the current lack of definitive seismic or geologic evidence.

VOLCANIC EARTHQUAKES

Shallow earthquakes are commonly associated with active volcanoes and often increase in number and size prior to an eruption. The southern Alaska seismic network was used to investigate the 1976 eruptions of Augustine volcano. The eruptions were preceeded by an increase in minor seismic activity that began as late as October 1975 (Kienle and Forbes, 1976). This activity was detected by University of Alaska stations on Augustine Island. Activity increased until at least January 2, by which time all of the stations on the island had failed, possibly due to mudslides. Monitoring continued at a distance, however, using stations from the regional network. On January 22, 1976 a very energetic swarm of events began at the same time as the first of a series of eruptions. In addition to documenting the sequence of earthquakes that accompanied the 1976 eruptions, the regional stations recorded gradually increasing and then gradually decreasing signals with a dominant frequency of

2 to 7 Hz that are believed to be a direct result of tremor generated by the eruptions. Seven of the eruptions also generated atmospheric pressure disturbances that traveled at about 0.3 km/s and were recorded at regional seismographs up to 318 km away.

The current USGS network includes two stations on or near Mt. Spurr volcano and one station each near Mt. Redoubt and Mt. Iliamna volcanoes. The University of Alaska operates one station near Mt. Redoubt and a number of stations on Mt. Augustine. A zone of shallow, predominantly low-magnitude (< 2) seismicity has been observed along the volcanic axis, and near Mt. Spurr pronounced spatial and temporal clustering of events has occurred (Page and others, 1982). In addition to shallow earthquakes, the Crater Peak seismograph, which is on the volcanic pile, records a large number of low-frequency (2-4 Hz) signals with durations of up to several tens of seconds. Most of the events appear to originate from the volcanic pile, but precise locations are not possible because phases cannot be identified and correlated between stations. A shallow volcanic origin for the events is suspected, but their exact cause is not yet resolved. Daily counts of volcanic events are made by the USGS Branch of Alaskan Geology in Anchorage in order to detect increases in activity that could presage an eruption of one of these volcanoes.

CONCLUSION

Earthquake studies have played a key role in developing the current working model of plate interactions in southern Alaska and will continue to provide a vital source of information for refining this model as we monitor the dynamic processes acting in Alaska. This information is essential for improving our evaluation of earthquake potential. Continuous seismic monitoring is also a prime strategy for documenting possible precursors to major earthquakes within the identified seismic gaps along the Pacific margin in Alaska and precursors to eruptions of the active volcanoes along Cook Inlet.

REFERENCES

Abe, Katsuyuki and Kanamori, Hiroo, 1979, Temporal variation of the activity of intermediate and deep focus earthquakes, Journal of Geophysical Research, v. 84, p. 3589-3595.

Davies, J. N. and House, Leigh, 1979, Aleutian subduction zone seismicity, volcano-trench separation, and their relation to great thrust-type earthquakes, Journal of Geophysical Research, v. 84, p. 4583-4591.

Detterman, R. L., Plafker, George, Hudson, Travis, Tysdal, R. G. and Pavoni, N., 1974, Surface geology and Holocene breaks along the Susitna segment of the Castle Mountain fault, Alaska, U.S. Geological Survey MF Map 618, 1 sheet.

Detterman, R. L., Plafker, George, Russell, G. T. and Hudson, Travis, 1976, Features along part of the Talkeetna segment of the Castle Mountain-Caribou fault system, Alaska, U.S. Geolological Survey MF Map 738, 1 sheet.

Keinle, Juergen and Forbes, R. B., 1976, Augustine - evolution of a volcano, in Annual Report of the Geophysical Institute, 1975/76, University of Alaska, Fairbanks, Alaska, p. 26-48.

Lahr, J. C., 1975, Detailed seismic investigation of Pacific-North American plate interaction in southern Alaska, Ph.D. dissertation, Columbia University, 141 p.

Lahr, J. C. and Plafker, George, 1980, Holocene Pacific-North American plate interaction in southern Alaska: Implications for the Yakataga seismic gap, Geology, v. 8, p. 483-486.

Lahr, J. C. and Stephens, C. D., 1982, Seismic activity in the vicinity of Anchorage, Alaska, 1972-1982, Proceedings of the 33rd Alaska Science Conference, 16-18 September, 1982, Fairbanks, Alaska, Arctic Division, American Association for the Advancement of Science, p. 113. Also in EOS, v. 64, p. 89-90.

Lahr, J. C., Stephens, C. D. and Page, R. A., 1984, Resolution of seismic source zones in the Anchorage area, Alaska [abs.], Earthquake Notes, Eastern Section, Seismological Society of America, v. 55, p. 16.

McCann, W. R., Perez, O. J. and Sykes, L. R., 1980, Yakataga gap, Alaska: Seismic history and earthquake potential, Science, v. 207, p. 1309-1314.

Page, R. A., Hassler, M. H., Stephens, C. D. and Criley, E. E., 1984, Fault zone geometry of the 1979 St. Elias, Alaska, earthquake, in The United States Geological Survey in Alaska: Accomplishments during 1982, U.S. Geological Survey Circular 939, p. 65-67.

Page, R. A. Waller, J. A. and Stephens, C. D., 1982, Recent seismicity around Spurr, Redoubt, and Iliamna volcanoes, southern Alaska, Proceedings of the 33rd Alaska Science Conference, 16-18 September, 1982, Fairbanks, Alaska, Arctic Division, American Association for the Advancement of Science, p. 142.

Plafker, George, Bruns, T. R., Winkler, G. R. and Tysdal, R. G., 1982, Cross section of the eastern Aleutian arc, from Mount Spurr to the Aleutian trench near Middleton Island, Alaska, The Geological Society of America, Map and Chart Series MC-28P.

Plafker, George and Rubin, Meyer, 1978, Uplift history and earthquake recurrence as deduced from marine terraces on Middleton Island, Alaska, in Proceedings of conference VI, Methodology for identifying seismic gaps and soon-to-break gaps: U. S. Geological Survey Open-File Report 78-943, p. 687-721.

Reeder, J. W., Lahr, J. C., Thomas, J. A., Conens, Sue and Blackford, M. E., 1977, Seismological aspects of the recent eruption of Augustine volcano, EOS, v. 58, p. 1188.

Stephens, C. D., Fogleman, K. A., Lahr, J. C. and Page, R. A., 1984, Wrangell Benioff zone, southern Alaska, Geology, v. 12, p. 373-376.

Stephens, C. D., Lahr, J. C., Fogleman, K. A. and Horner, R. B., 1980, The St. Elias, Alaska, earthquake of February 28, 1979: Regional recording of aftershocks and short-term pre-earthquake seismicity, Bulletin of the Seismological Society of America, v. 70, p. 1607-1633.

SEISMIC SOURCES IN ALASKA

by

George Plafker
U.S. Geological Survey
Menlo Park, California 94025
and
Klaus H. Jacob
Lamont-Doherty Geological Observatory
Palisades, New York 10964

Shallow seismic sources in Alaska are primarily associated with the major faults on the boundary between the Pacific plate (PAC) and North American plate (NAM) in southeastern Alaska and the Aleutian Arc, faults along the margins of three tectonic blocks in south-central Alaska, and a small number of intraplate faults throughout Alaska and the Bering and Beaufort Sea shelves (Fig. 1). Subcrustal earthquakes coincide with slabs of subducted Pacific lithosphere beneath the Aleutian arc to maximum depths of 300 km, and beneath the Wrangell volcanic arc to 100 km. The relative motion of PAC to NAM is northwestward, increasing progressively from 5.8 cm/yr in the eastern Gulf of Alaska to >8 cm/yr in the western Aleutians. PAC-NAN motion in the complex region between the northern Gulf of Alaska, the Denali fault system, and the western Alaska Range is concentrated mainly along the boundaries of the Yakutat block (YB), Saint Elias block (SEB)1, and Wrangell block (WB). YB is strongly coupled to PAC, and SEB and WB are strongly coupled to NAM, although relative motions occur between all of these tectonic units.

PAC-NAM plate boundary faults capable of generating large or great earthquakes are the submarine Queen Charlotte dextral transform in the eastern Gulf of Alaska (1949 Queen Charlotte Mw=8.1 and Sitka Ms=7.6); the Aleutian megathrust system of thrust to dextral-oblique thrust faults extending from the western Gulf of Alaska at about 155° W longitude to about Amchitka at 180° longitude (1938 Mw=8.2, 1946 Ms=7.4, 1957 Adak Mw=9.1); and the western Aleutian oblique-dextral transform boundary from west of Amchitka to almost Kamchatka

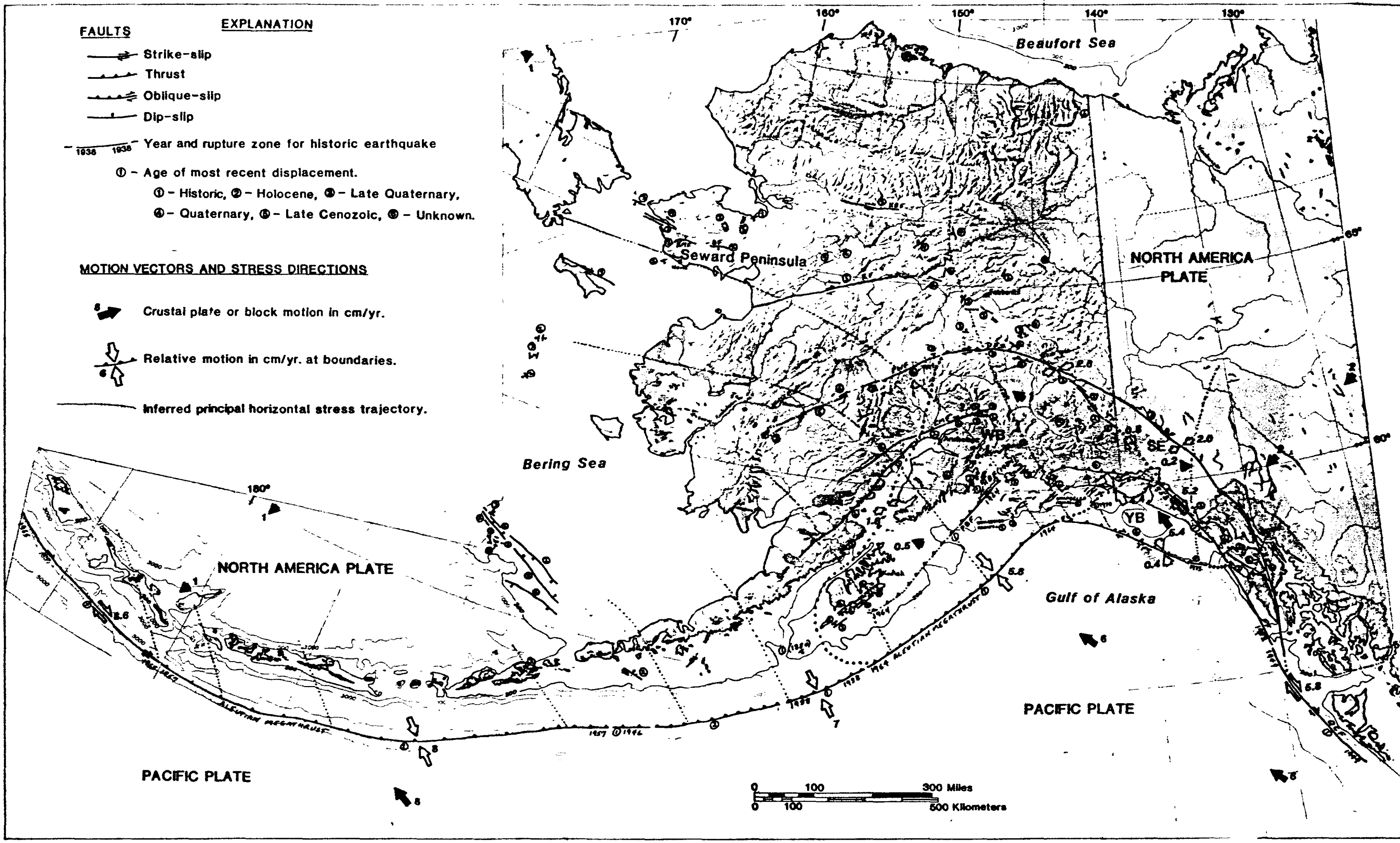


Figure 1.--Generalized map showing known or suspected Late Cenozoic faults in Alaska, rupture zones of historic earthquakes, absolute and relative crustal plate and tectonic block displacements in cm/yr, and inferred stress trajectories. Plate and block motions after Minster and Jordan (1978) and Lahr and Plafker (1980). Stress trajectories modified from Nakamura and others (1980).

6B8 20130

near 164° E longitude. In this western segment decoupling takes place between oblique thrusting in the force-arc (1965 Rat Islands Mw=8.7) and lesser, dextral strike slip in the back-arc (1975 Near Islands Ms=7.6). Seismic gaps capable of generating major earthquakes (Ms=8.5) are located in the Shumagin and Unalaska Islands segments, and in the westernmost Aleutian arc in the Komandorski Islands segment, which is in USSR territory. Probabilities for major events (Mw≥7.8) to occur in these three gaps are estimated to be about 35-95 percent, 35-70 percent, and 35-78 percent, respectively (for time period 1985-2005).

The YB-SEB boundary is the Fairweather dextral fault (an onshore extension of the Queen Charlotte transform) along which the 1958 Lituya earthquake (Mw=8.2) occurred. The YB-PAC boundary is the submarine lower slope Transition fault system along which the 1973 Cross Sound thrust earthquake (Ms=6.7) occurred. The YB-WB boundary is the Pamplona submarine thrust zone and its eastern onshore extension north and east of Icy Bay. This continuous thrust belt has had a number of large historic events with magnitudes Ms≤8.5. Parts of this thrust system and the associated Chugach-St. Elias thrust faults may have slipped during the 1899 earthquake sequence (Ms=8.5, 7.8, 8.4, and several associated Ms=7-7.5 shocks); the 1979 St. Elias earthquake (Ms=7.1) occurred on a down-dip extension of this system beneath the northern margin of the Yakutat block.

The YB is essentially moving with the PAC plate, but with a slightly lower velocity (5.4 cm/yr relative to NAM, and 0.4 cm/yr relative to PAC). As a consequence, a large relative motion occurs along the dextral Fairweather transform fault (at the eastern boundary), and at the Pamplona thrust zone (at the northern boundary of YB), against SEB and WB, respectively. In contrast the 0.4 cm/yr of YB vs. NAM represents a relatively slow oblique thrust motion along the Transition fault system and its inferred down-dip detachment that may separate YB by a subhorizontal plane from the underlying PAC plate. Recurrence periods and maximum magnitudes on this Transition fault and inferred detachment system could be quite long (1,000 yrs, Mw>8), but neither of these two quantities are as yet constrained by seismic, historic or geologic data. The Pamplona zone on the YB-WB boundary contains the Yakataga Seismic Gap along which a major earthquake (up to Mw=8.3) has been forecast to occur with a probability of 35 to 55 percent during the next two decades on the bases of seismologic data. Terrace studies near Icy Bay near the eastern end of this gap, and at Middleton Island near the western end, suggest recurrence intervals on the order of 500 to 1,500 years. The last event comparable to the 1899 earthquake sequence in Yakutat Bay at the eastern end of this zone occurred 380 years ago based on paleoseismic data. The geologic data clearly suggest much longer recurrence intervals for great earthquakes involving significant tectonic deformation than do probability estimates made from the historic and instrumental record.

The PAC-WB margin is the eastern segment of the Aleutian megathrust, located between 144° and 155° W longitude. Along it the great 1964 Alaska earthquake (Mw=9.2), probably the 1900 (Ms=8.1) event, and several earlier large earthquakes occurred. The YB-WB margin is the megathrust's northeastern continuation, along the Pamplona zone.

In the northeast and north of WB the WB-NAM margin is associated with the system of dextral transform to oblique thrusting of the Denali and Totschunda faults; the WB-SEB boundary is a poorly defind, inferred fault zone connecting the Fairweather with the Totschunda fault. The northwestern boundary of the WB with NAM is also poorly defined and may correspond to a zone of diffuse shallow seismicity that diverges southward from the Denali fault west of McKinley Park, straddles Cook Inlet and Shelikof Strait, and joins the Aleutian megathrust southwest of Kodiak Island. Motion of the WB relative to NAM is taken to be a counterclockwise rotation about an axis near Kodiak Island so that its northeastern edge moves dextrally, relative to NAM and the SEB, at a maximum rate close to 1 cm/yr; its northern edge moves obliquely convergent relative to NAM in the Alaska Range; and the block's western margin causes shortening vs. NAM ranging from about 1 cm/yr at the northern western margin to a negligibly small rate at the southern margin. In contrast, the PAC-WB convergence rate along the block's southeastern thrust margin is much higher at about 5.8 cm/yr. Paleoseismic data suggest that the dextral and oblique slip segments of the boundaries of the WB block--particularly the Totschunda fault--are potential sources for major earthquakes. The McKinley region has had a few moderate-sized crustal earthquakes of which at least one is confirmed to be a thrust mechanism with NW-SE directed shortening.

The YB-SEB boundary is the Fairweather fault, the WB-SEB boundary is the fault zone inferred to connect from the Fairweather fault to the Totschunda fault, and the SEB-NAM boundary is the Duke River, Dalton, and Chatham Strait system of faults. YB is moving northwestward relative to the SEB at a velocity of 5.2 cm/yr, and SEB relative to NAM at no more than 0.2 cm/yr. The low relative SEB-NAM block motion and lack of evidence for late Holocene displacements suggests that the northeastern block boundary of SEB has a low seismic potential.

Large onshore Holocene faults that cannot be related to the plate and block boundaries described above are scarce in Alaska, and there are no known large Alaskan intraplate earthquake that can be related to surface faults in the interior of the blocks or plates. The Castle Mountain fault is an east-northeast trending fault entirely within the WB. Field data suggest that it is a north-dipping reverse fault with a dextral component, and earthquake data suggest predominantly dextral slip at depth. Paleoseismic data suggest that the last surface displacement of this fault was between 225 and 1,700 years ago. The fault is of special importance because it is capable of generating a large earthquake in close proximity to the Anchorage urban area. The November 3, 1943 (Ms=7.3) event may have been associated with this fault. A mostly offshore fault zone, the Patton Bay fault zone, extends southwestward from Montague Island past Kodiak to Chirikof Island on the fore-arc shelf. Although this fault zone lies within WB, it is a splay off the Aleutian megathrust, and may be considered as the approximate landward margin of the zone of deformation along the PAC-WB boundary. This thrust zone slipped during the great 1964 earthquake in which it displayed up to 7.9 m slip on a northwest-dipping reverse fault.

Within the NAM plate there is clear evidence of Holocene displacements on the east-west trending Kigluaik and Bendeleben normal faults on the Seward Peninsula and their offshore extensions onto the Bering Sea shelf. Holocene faults with minor seismicity are mapped offshore near Prudhoe and Camden Bay on the Beaufort Sea shelf. Several faults of undated but suspected Quaternary age are located on the Bering Sea shelf and appear to be related to normal faulting along the edges of Neogene basins on the shelf. Most of these offshore faults do not appear to have Holocene displacements. A few severe earthquakes are known from historic felt reports from the Pribilof Islands, but the causative faults are not known.

Large faults with known or suspected Quaternary displacements occur within continental Alaska; none of these faults have had unequivocal Holocene displacements. On the other hand, earthquakes sometimes with magnitudes as large as Ms=7-7.8 have occurred during historic times in interior Alaska. Because all occurred prior to establishment of adequate seismic networks, their epicenters are so poorly constrained that often it is not clear whether they are associated with any of the known nearby surface faults. A large earthquake (Ms=7.7-8.3?) occurred in 1904, reportedly near 64°N and 151°W, in the lowlands northwest of McKinley National park with reported damage at Rampart; on July 7, 1912, a Ms=7.5 event occurred in central Alaska; the Fairbanks earthquake of October 16, 1947 measured Ms=7.0-7.2. Moderate-sized earthquakes have occurred near the Yukon River in central Alaska, near the Kobuk River trench south of the western Brooks Range, and low-level seismicity is known in the northeastern Brooks Range where it approaches Camden Bay and the Beaufort Sea.

It is not known whether the swarm-like seismicity in zones such as those near Fairbanks or the Yukon River crossing of the Trans-Alaska Pipeline is related to crustal faulting driven by large-scale tectonic stress systems, or is related to some other process such as emplacement of magma at shallow depths. No potentially active surface faults have been found in these areas. Sporadic alkali-basalt magma occurrences of Quaternary age are widespread in central Alaska and particularly in west-central Alaska, the Seward Peninsula and the Bering Sea shelf. This suggests a mildly extensional stress regime in contrast to the dominantly compressional stress regime in much of the remainder of Alaska.

Earthquakes and tsunamis related to volcanic activity are a potential hazard to military installations and to several important ports and fishing communities in the Aleutian arc (including its shores facing the Bering Sea), on the Alaska Peninsula, and in lower Cook Inlet. Volcanic earthquake hazards may also exist in the Wrangell Mountains and at Edgecumbe Volcano or Kruzof Island near Sitka. However, the most tsunamigenic earthquakes can be expected along the convergent segments of the Aleutian megathrust and its eastward extension into the Pamplona thrust zone. Major destruction in Alaska resulted from the tsunami waves (and landslide-generated local waves) triggered by the 1964 Alaska earthquake, the 1958 Lituya earthquake and, to a lesser extent, the 1948 Adak earthquake.

Subcrustual Aleutian earthquakes with depths between 50 and at most 300 km are thought to be rarely larger than Mw=7.5, but there is a possibility that an earthquake on June 2, 1903, near 57°N and 156°W (southwest of Katmai), with magnitude 8.3(?) may have been 100 km deep.

Normal-faulting events associated with flexure of the Pacific plate in and seaward of the Aleutian trench are rare; their maximum credible magnitudes could be as large as Mw=8, and they may also induce tsunamis. The March 3, 1929, earthquake near 50.9°N and 169.7°W in the central Aleutians with a magnitude Mw=8.0±0.5 may have been such a normal-faulting event that caused a perceptible tsunami in Hawaii.

HAZARDS EVALUATION FOR LARGE AND GREAT EARTHQUAKES ALONG THE QUEEN CHARLOTTE - ALASKA - ALEUTIAN SEISMIC ZONE: 1985-2005

by

Stuart P. Nishenko

National Earthquake Information Center

U.S. Geological Survey, Denver, CO 80225

Klaus Jacob

Lamont-Doherty Geological Observatory

of Columbia University

Palisades, NY 10964

INTRODUCTION

Conditional probabilities for the ocurrence of large, great (and giant) earthquakes along specific segments of the Queen Charlotte-Alaska-Aleutian (QC-A-A) seismic zone are presented for the time interval 1985-2005. Time-dependent recurrence models are combined with simple Gauss and Weibull distribution functions to forecast the likelihood of future events in this region. At present, areas of high seismic hazard include the Yakataga gap as well as a large portion of the Alaska Peninsula (including the 1938, Shumagin gap and 1946 segments as well as possibly the Unalaska gap). Areas of low seismic hazard include the entire Queen Charlotte seismic zone (1949 [excluding the possible Cape St. James gap], 1972 and 1958 rupture zones), the 1964 Gulf of Alaska, portions of the 1957 Central Aleutian and the 1965 Rat Islands zones.

The QC-A-A seismic zone is divided into 17 segments based on (1) the rupture zones of the most recent large or great earthquakes, as defined by aftershock distributions, and (2) variations in the amount of coseismic displacement within individual rupture zones.

For each individual segment or gap along the QC-A-A seismic zone, input for the time-dependent Gaussian model consists of the date of the last large earthquake, the estimated repeat time and the standard deviation of time intervals between events (the coefficent of variation). For the majority of the QC-A-A seismic zone, the date and size of the last event is known. Estimates of repeat time are calculated by dividing the coseismic displacement in the previous event by the rate of fault motion. Note that these estimates do not account for the effects of aseismic slip on recurrence intervals, and hence, represent minimum repeat time and maximum probability estimates. Where available, repeat time estimates are supplimented by historic and geologic data as well. The coefficent of variation along any segment of the margin is poorly known, and we uniformly assign a standard deviation equal to 33% of the estimated repeat time in our estimates. A standard deviation of 33% is similar to that found in studies along other simple transform and convergent plate boundaries (Sykes and Nishenko, 1984; Nishenko, 1985).

For comparison to the above evaluation, we have also modeled the catalog of historic repeats (and possible repeats) from Jacob (1984) along sections of the A-A seismic zone using a Weibull distribution function.

Both of these time-dependent descriptions of earthquake hazard (or conditional probability) are compared and contrasted to estimates of seismic hazard baed on a Poisson model of recurrence. The Poisson based estimates of conditional probability are termed time-independent or static, as they do not include the amount of time elapsed since the previous shock. In general, conditional probabilities based on the Poisson model cluster around 10-40% for a 20-year time window throughout the entire QC-A-A seismic zone. Estimates of seismic hazard based on all 3 models are presented in Table 1 and Figures 1 and 2.

Overall, as seen in Table 1 and Figures 1 and 2, recurrence time estimates based on both the last shock and historic/geologic data vary by a factor of two, while the range of probability estimates for each model, are within 10-20% of each other. This reflects the fact that 2/3 of the margin has ruptured within the last 20-30 years, and is now within the first 1/3 or less of a new seismic cycle. The segments with the largest uncertainties (and possibly the highest probabilities) are along the Alaskan Peninsula (the 1938 and Shumagin gaps). The poor resolution reflects a fundimental lack of data concerning the sizes and locations of previous earthquakes in this area.

Time-dependent estimates of conditional probability that are lower than the Poisson estimates for any particular segment are suggested to indicate a low level of seismic hazard. Areas of low hazard (i.e. less than 10-20% for the next 20 years) presently include the entire Queen Charlotte seismic zone (1949 [excluding the possible Cape St. James gap], 1972 and 1958 rupture zones), the 1964 Gulf of Alaska, portions of the 1957 Central Aleutians and the 1965 Rat Islands zones. Note that while the hazard for Mw>9 earthquakes along the 1964 Gulf of Alaska zone is presently low, we cannot rule out the possibility for

TABLE 1: CONDITIONAL PROBABILITY ESTIMATES FOR THE QUEEN CHARLOTTE - ALASKA - ALEUTIAN SEISMIC ZONE : 1985 - 2005

LOCATION	LAST SHOCK	DT (yrs)	Mo ($x10^{27}$ d-c)	LENGTH (km)	WIDTH (km)	SLIP (cm)	SLIP RATE (cm/yr)	ESTIMATED REPEAT TIME	OTHER DATA	CONDITIONAL PROBABILITY POISSON	GAUSS	WEIBULL
1. Cape St. James	??											
2. Queen Charlotte Is.	1949 Mw 8.1	36	12	490	(15)	550	5.5	100		18.1%	6.6%	
3. Sitka	1972 Ms 7.4	13	4	175	(15)	500	5.2	90		19.9%	2.3%	
									1927, 45 y 1880, 47 y	35.3%	18.4%	
4. Lituya Bay	1958 Mw 7.7	27	7	350	(15)	450	5.2	86		20.7%	6.7%	
									Max. Disp. 6.5 m, 118 y	15.6%	2.4%	
									1848, 110 y	16.6%	3.0%	
5. Yakutat Bay	1899 Mw 8.2	86	20	100-125	75	600	4.8	125		14.8%	18.1%	50.6-59.1%
									Geodetic 380 y	5.1%	0.5%	
6. Yakataga	1899 Mw 8.1	86	20	125-200	75	250	4.2	52		31.9%	96.5%	50.6-59.1%
7. Prince William Sound	1964 Mw 9.2	21	820	750	180	1215	6.5	187		10.0%	0.5%	18.1-19.6%
						3000			Geodetic 461 y	4.2%	0.1%	
									Geologic 897 y	2.2%	0.03%	
8. Gulf of Alaska	1964 Mw 9.2	21						187		10.0%	0.5%	18.1-19.6%
9. Kodiak Is.	1964 Mw 9.2	21						187		10.0%	0.5%	18.1-19.6%
9A. Kodiak Is.									Historic Ms 7.4-8 40-60 y	28.3-39.3%	14.8-49.2%	

TABLE 1: CONDITIONAL PROBABILITY ESTIMATES FOR THE QUEEN CHARLOTTE - ALASKA - ALEUTIAN SEISMIC ZONE : 1985 - 2005

LOCATION	LAST SHOCK	DT (yrs)	Mo ($x10^{27}$ d-c)	LENGTH (km)	WIDTH (km)	SLIP (cm)	SLIP RATE (cm/yr)	ESTIMATED REPEAT TIME	OTHER DATA	CONDITIONAL PROBABILITY POISSON	GAUSS	WEIBULL
10. Alaska Pen.	1938 Mw 8.2	47	50	300	120	200-300	7.1	28-42		37.9-51.0%	90.0-99.9%	33.6-36.1%
									Historic 50-91 y	19.7-32.9%	15.1-73.5%	
11. Shumagins	1903 M8.3, Ms6.9	82		(250)	(100)				Historic 60-100 y(?)	18.1-28.3%	33.0-87.3%	49.1-57.0%
	1847	138									68.4-99.1%	66.9-79.6%
12. Unimak Is.	1946 Ms 7.4	39	13	100	100	200-300	7.7	24-42		37.9-56.5%	81.2-99.9%	29.6-30.6%
13. Unalaska	1957 Mw 8.8	28		(1200)	70		8.3					23-23.6%
14. Central Aleutians	1957 Mw 8.8	28		(1200)	70	400-600	8.3	48-72		24.2-34.8%	12.8-44.2%	23-23.6%
15. Andreanof Is.	1957 Mw 8.8	28	200	600	70	950-1580	8.3	115-191		9.9-15.9%	0.6-2.8%	23-23.6%
16. Rat Is.	1965 Mw 8.7	20	125	500	70	700	8.6	81		21.8%	5.2%	17.4-19%
						280	5	56		30%	17.2%	
									Historic 59 y	28.7%	14.5%	
17. Commander Is.	1849/58?	136										66.4-78.9%

653 20130

References for Table 1

Entire QC-A-A seismic zone:

Sykes, L.R., J. Geophys. Res., 76, 8021-8041, 1971.

Sykes, L.R., J.B. Kisslinger, L.House, J.N. Davies and K.H. Jacob, Science, 210, 1343-1345, 1980.

Specific segments along the QC-A-A seismic zone:

1 and 2] Bostwick, T.D., Ph.D. thesis, Univ. British Columbia, 1984.

Rodgers, G.C., Earthquake Pred. Res., in press, 1985.

3] Page, R., Earthquake Info. Bull., 5, 4-9, 1973.

4] Plafker, G., T. Hudson and T. Bruns, Can. J. Earth Sci., 15, 805-816, 1978.

5 and 6] McCann, W.R., O.J. Perez and L.R. Sykes, Science, 207, 1309-1314, 1980.

Plafker, G., T. Hudson and M. Rubin, EOS, Trans. AGU, 61, 1110, 1980.

Thatcher, W. and G. Plafker, Geol. Soc. America abs. with Programs, 9, 515, 1977.

7, 8, 9] Plafker, G., U.S. Geol Survey Prof. Paper 543-I, 1967.

Plafker, G. and M. Rubin, U.S. Geol. Survey Open File Rpt. 78-943, 687-722, 1978.

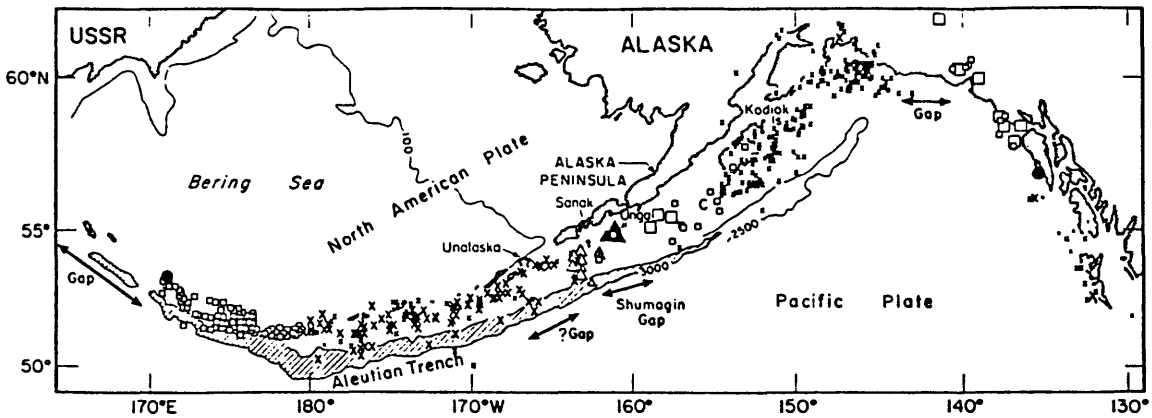
Ruff, L. and H. Kanamori, Phys. Earth Planet. Int., 31, 202-230, 1983.

10,11,12] Davies, J., L. Sykes, L. House and K. Jacob, J. Geophys. Res., 86, 3821-3855, 1981.

13,14,15] Wahr, J. and M. Wyss, J. Geophys. Res., 85, 6471-6477, 1980.

Ruff, L., H. Kanamori and L. Sykes, EOS, Trans. AGU, 66, 298, 1985.

16] Ruff, L. and H. Kanamori, Phys. Earth Planet. Int., 31, 202-230, 1983.



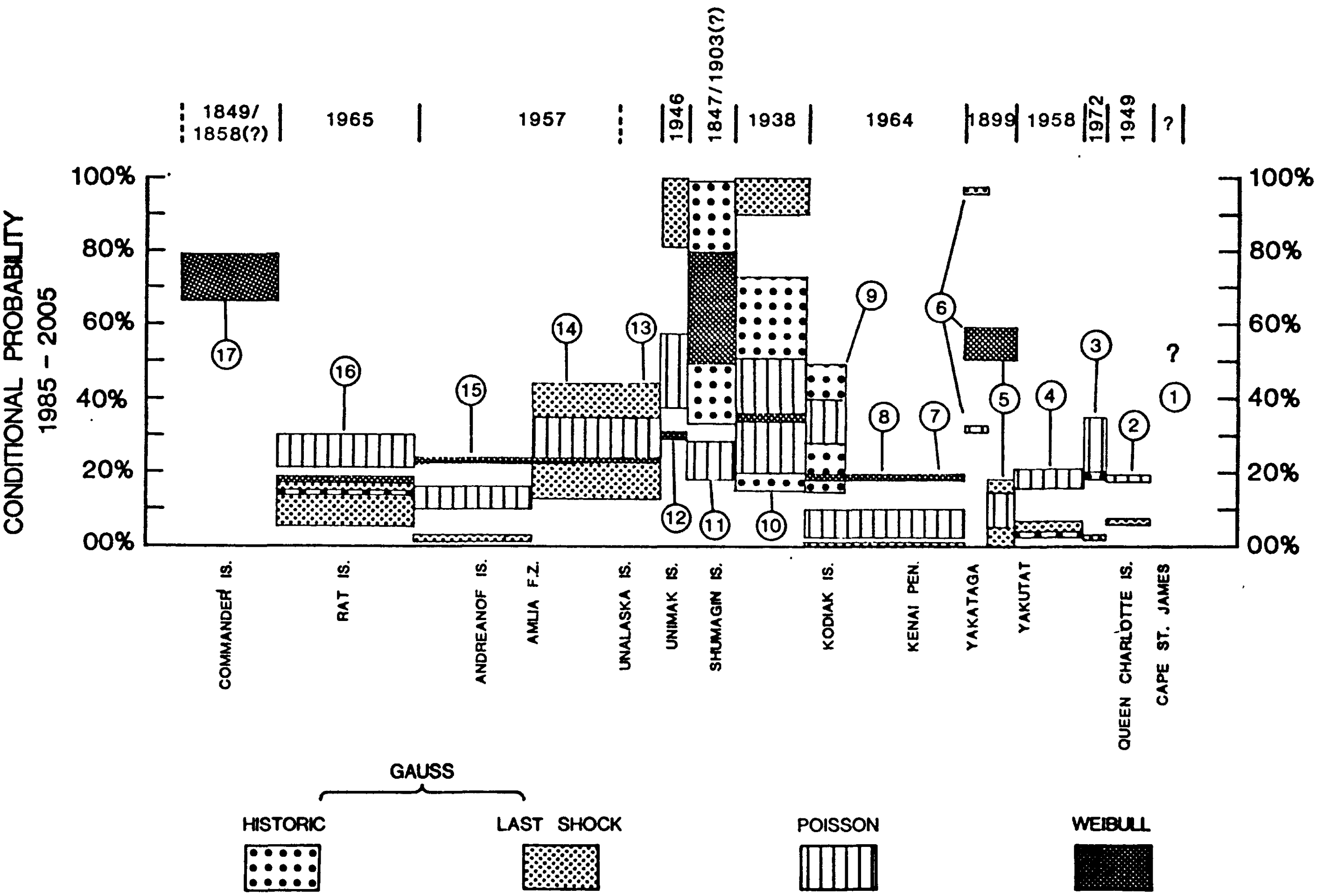


Figure 1.--Conditional probability estimates for large and great interplate earthquakes along the Queen Charlotte-Alaska-Aleutian seismic zone: 1985-2005. Encircled numbers refer to fault zones or segments listed in Table 1. For each segment, the percentages and the height of box represent the range of calculated probabilities based on Gaussian, Poisson, and Weibull models (see bottom of figure for appropriate symbol). Dates and vertical bars at the top of the histogram refer to the time and lateral extent of the last large or great earthquake in each segment. For zone 9 (Kodiak Island), probabilities are presented for rerupture as a part of the 1964 zone and as an independent unit. Note that the zones with the highest overall probabilities also have the largest uncertainties.

6Bb 2013D

CONDITIONAL PROBABILITY
QUEEN CHARLOTTE-ALASKA-ALEUTIAN SEISMIC ZONE
1985-2005

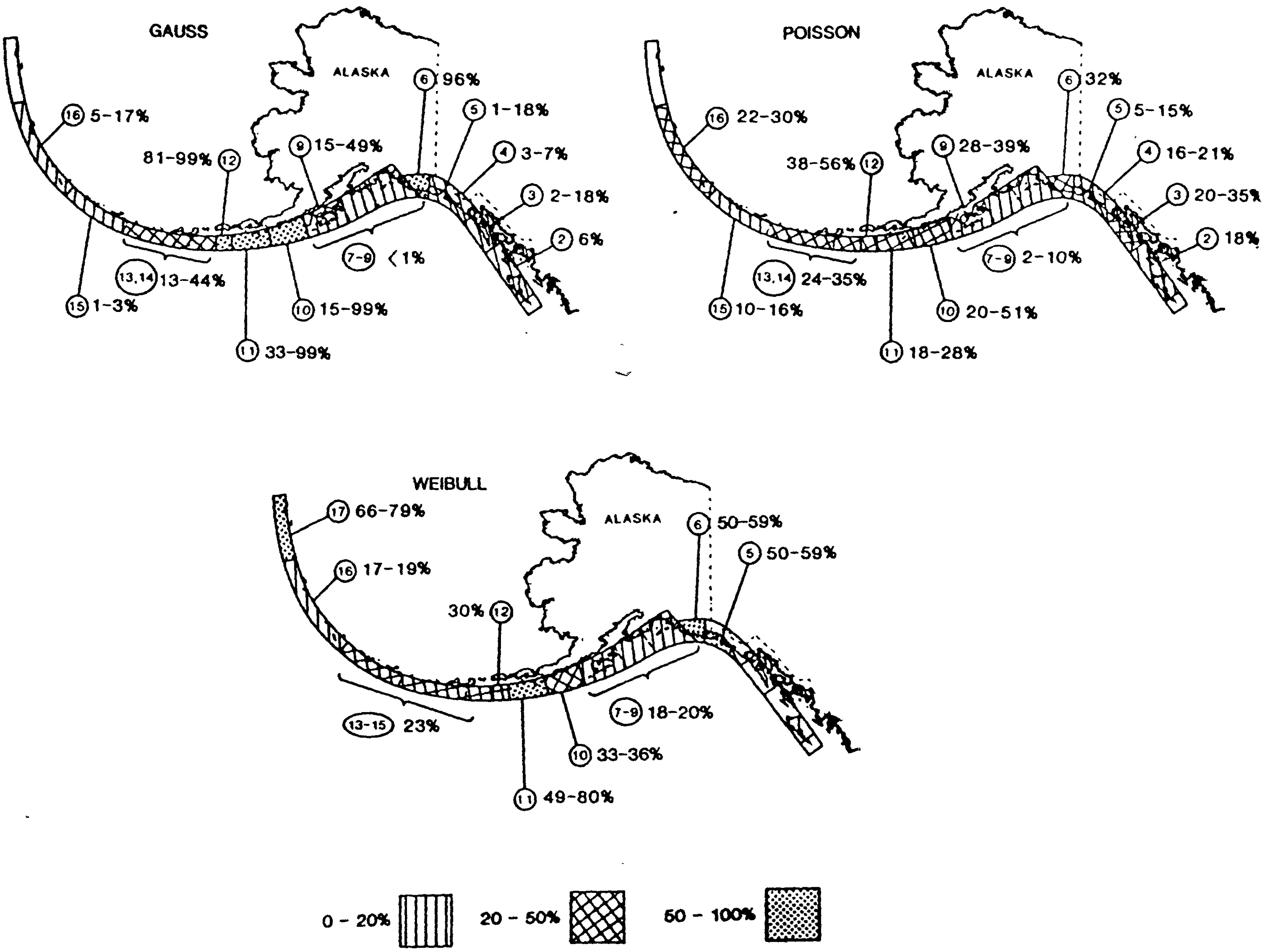


Figure 2.--Comparison of conditional probability estimates for large and great interplate earthquakes along the Queen Charlotte-Alaska-Aleutian seismic zone: 1985-2005. Encircled numbers refer to the fault zones or segments listed in Table 1. The percentages besides each zone represent the range of calculated probabilities from Gaussian (top), Poisson (middle), and Weibull (bottom) models. The shading of each fault segment corresponds to the mean probability estimate (see bottom of figure for key). Blank areas denote segments with lack of sufficient data for a particular recurrence model.

652 20130

the ocurrence of smaller (Mw7.5-8) events in this area, as is seen historically for the Kodiak Island region. Time-dependent estimates that are greater than the Poisson estimates are judged to indicate a high level of seismic hazard. Areas of high seismic hazard (i.e. greater than 50% for the next 20 years) presently include the Yakataga gap as well as a large portion of the Alaska Peninsula (including the 1938, Shumagin gap and 1946 segments as well as possibly the Unalaska gap). While the degree of resolutuion is poor for some of these gaps, the spatial proximity of a number of high hazard areas along the Alaskan Peninsula raises the scenario whereby rupture in one segment may trigger activity in adjacent segments and produce a larger event than any one single segment. Historically, this section of the margin, Kodiak Island to the Shumagins, was ruptured by a great (M>8) earthquake in 1788 with an estimated rupture length of at least 600 km. The Commander Islands gap, in the westernmost Aleutians, presently has a high probability for recurrence based on the extrapolation of the Weibull data. Few other data, however, exist to independently constrain the hazard level in the Commander Islands area.

REFERENCES

Jacob, K., Estimates of long-term probabilities for future great earthquakes in the Aleutians, Geophys. Res. Lett., 11, 295-298, 1984.

Nishenko, S. P., Seismic potential for large and great interplate earthquakes along the Chilean and southern Peruvian margins of South America, Jour. Geophys. Res., 90, 3589-3615, 1985.

Sykes, L. R. and S. P. Nishenko, Probabilities of occurrence of large plate rupturing earthquakes for the San Andreas, San Jacinto and Imperial faults, California: 1983-2003, Jour. Geophys. Res., 89, 5905-5928, 1984.

IMPLEMENTATION FRAMEWORK TO REDUCE POTENTIAL LOSSES FROM TSUNAMI HAZARDS IN ALASKA

by
Jane Preuss, Urban Regional Research
Seattle, Washington 98104

INTENT

A high percentage of the damage and 119 of the 132 killed in the 1964 Alaska earthquake was attributable to tsunamis. The purpose of the project described in this paper is to develop a planning approach which responds to the tsunami hazard.

The project technique was first to gain a more precise understanding of the causes of damage by using a hydrodynamical model to simulate the characteristics of the 1964 event at decreasing scales of geographic size and increasing levels of specificity. A series of measures designed to mitigate potential losses from tsunamis and to maximize safety requirements during the emergency response period are then proposed for the case study community of Kodiak.

BACKGROUND ASSUMPTIONS: REGIONAL SCALE

The regional analysis verified wave heights, travel patterns and arrival times of the incident wave. The methodology was to apply a far field/deep water numerical model to 3 subregions (Region A - 1,600x900km; Region B - 800x400km; and Region C - 100x100km).

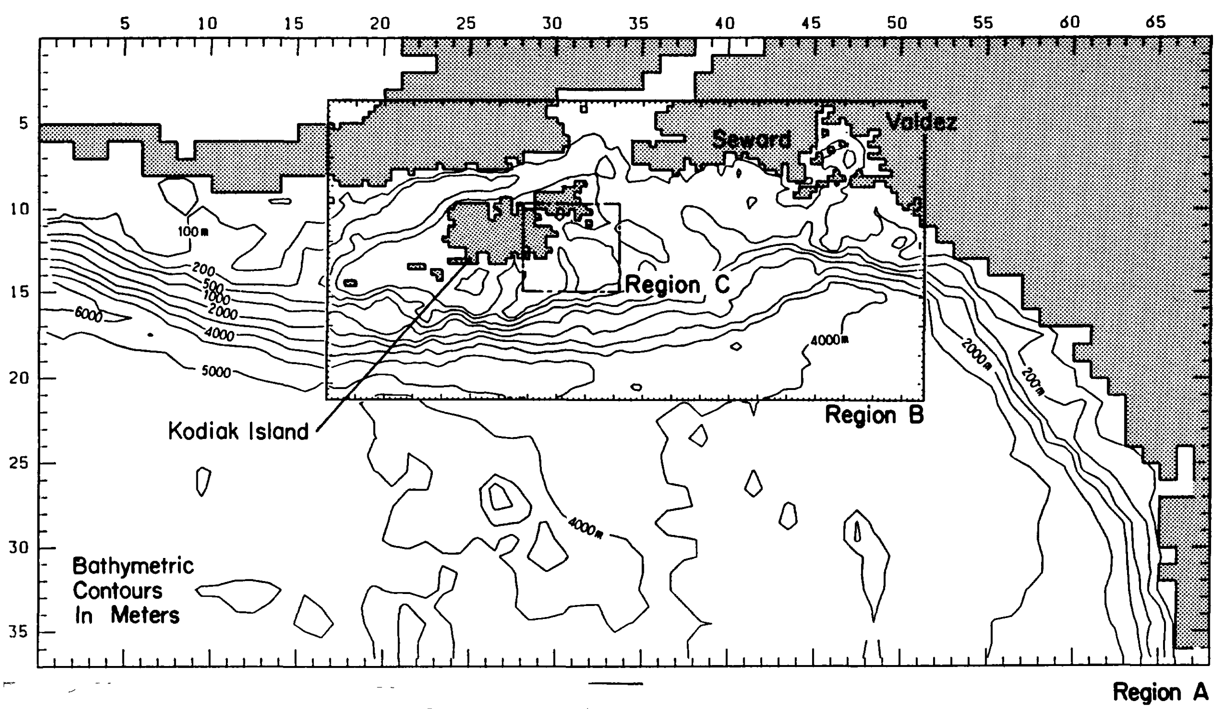


Figure 1: Computational Scheme

The largest region was primarily concerned with defining source characteristics. This information was used to project generation and propagation of the tsunami to the off-shore regions in the vicinity of Kodiak.

Region C

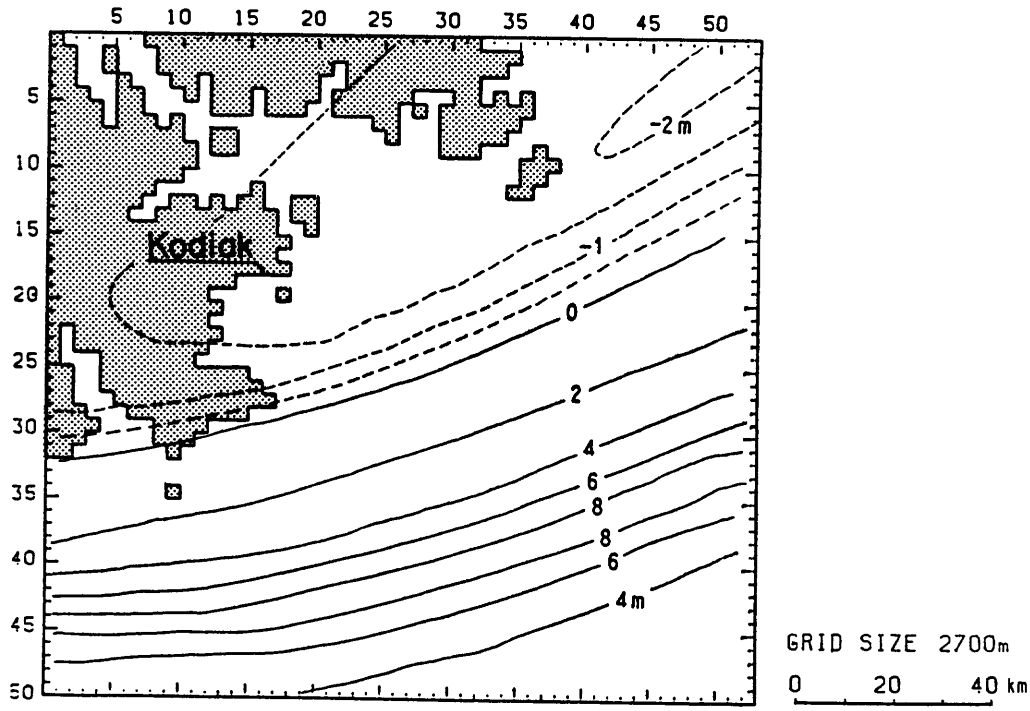


Figure 2: Assumed Vertical Displacement (after Pflaker, 1969)

BACKGROUND ASSUMPTIONS: PROJECT SCALE

The underlying purpose of the project scale analysis is to develop an approach to managing land development which both encourages continued economic viability of waterfront activities and maximizes protection.

It was first necessary to gain a more precise understanding of the dynamics of the tsunami near and at the shoreline. The focus of the project scale was therefore to project the run-up height of the design tsunami (1964 magnitude) and to assess the effects of this run-up on structures and other objects located near the shoreline. Information from the regional analysis was used as the basis for defining the characteristics of the incident wave as it entered Chiniak Bay at Kodiak. Near field calculations using non-linear shallow water wave theory project maximum wave amplitude, velocity, and maximum inundation area for four sub regions.

Area D	Area:	50 x 30km	Grid Size	900 meters
Area E	Area:	15 x 10km	Grid Size	300 meters
Area F	Area:	6 x 4km	Grid Size	100 meters
Area G	Area:	1.5 x 1km	Grid Size	33 meters

 7S420130

In order to maximize the urban planning utility of the research findings care was taken to correlate the boundaries of Area G with land use patterns. Area G therefore includes all of the downtown business district and the majority of the canneries.

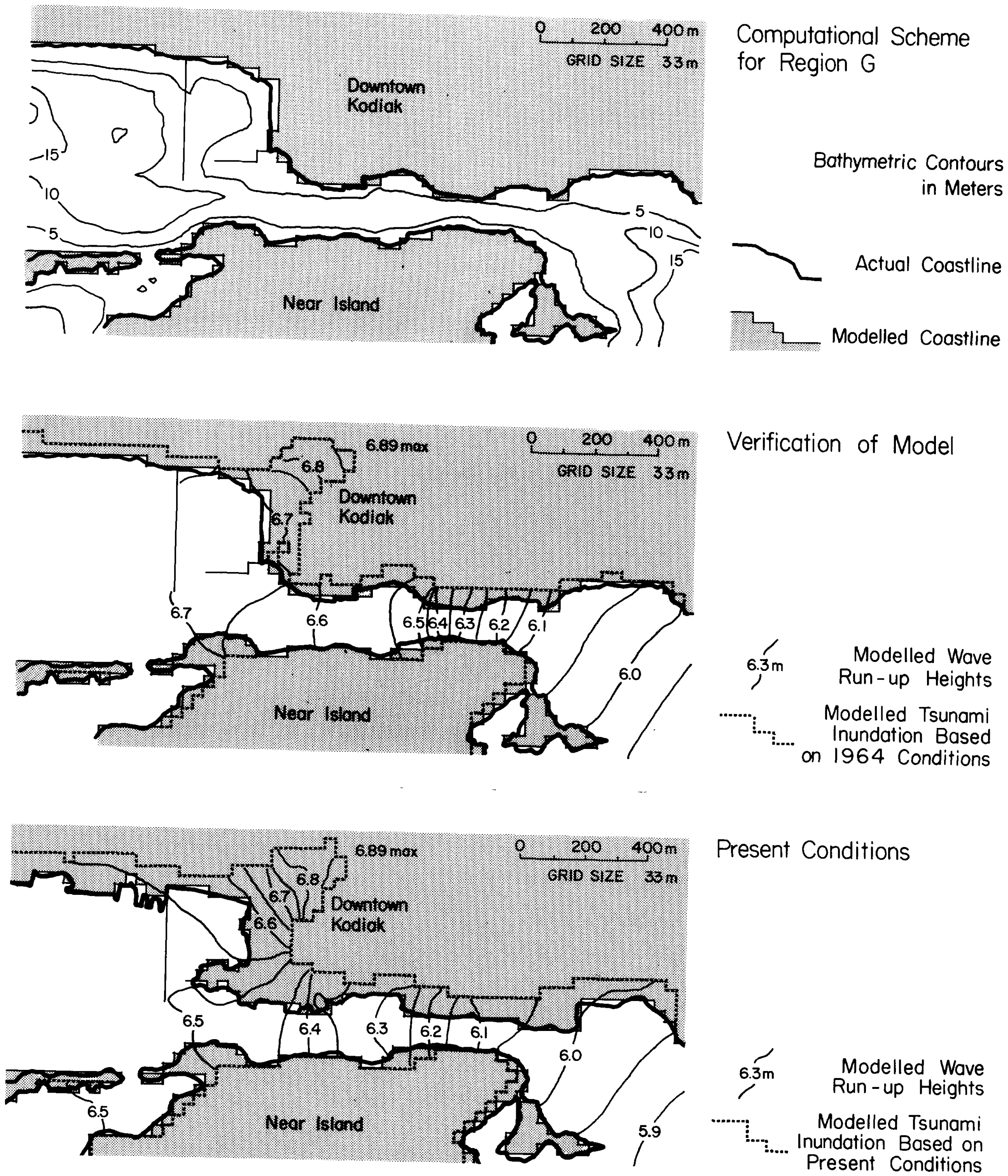


Figure 3: Definition of Region G

758 20130

Data for Region G was mapped in a series of transparent overlays. This format provides a vehicle for planning practioners to visually correlate conditions today with conditions in 1964. It is also used as the basis for calculating and evaluating the effects of a future repeat event. Information collected for Region G includes such variables as are listed below. The next step in the process was to define the dimensions of the planning area subject to tsunami inundation. Figure 4 correlates the computer projected run-up height with the inundation level observed in 1964.

- o Land Use 1964: building use, type of construction, road locations
- o Pre-tsunami Ground Elevations
- o Ground Elevations immediately after the Tsunami
- o Ground Elevations after Reconstruction
- o Vegetation: 1964
- o Land Use: 1985
- o Building Location and Construction Type: 1985
- o Vegetation: 1985
- o Breakwater Dimensions: 1964
- o Breakwater Dimensions: 1985
- o Location of Critical Facilities (Power Plants, etc.): 1985

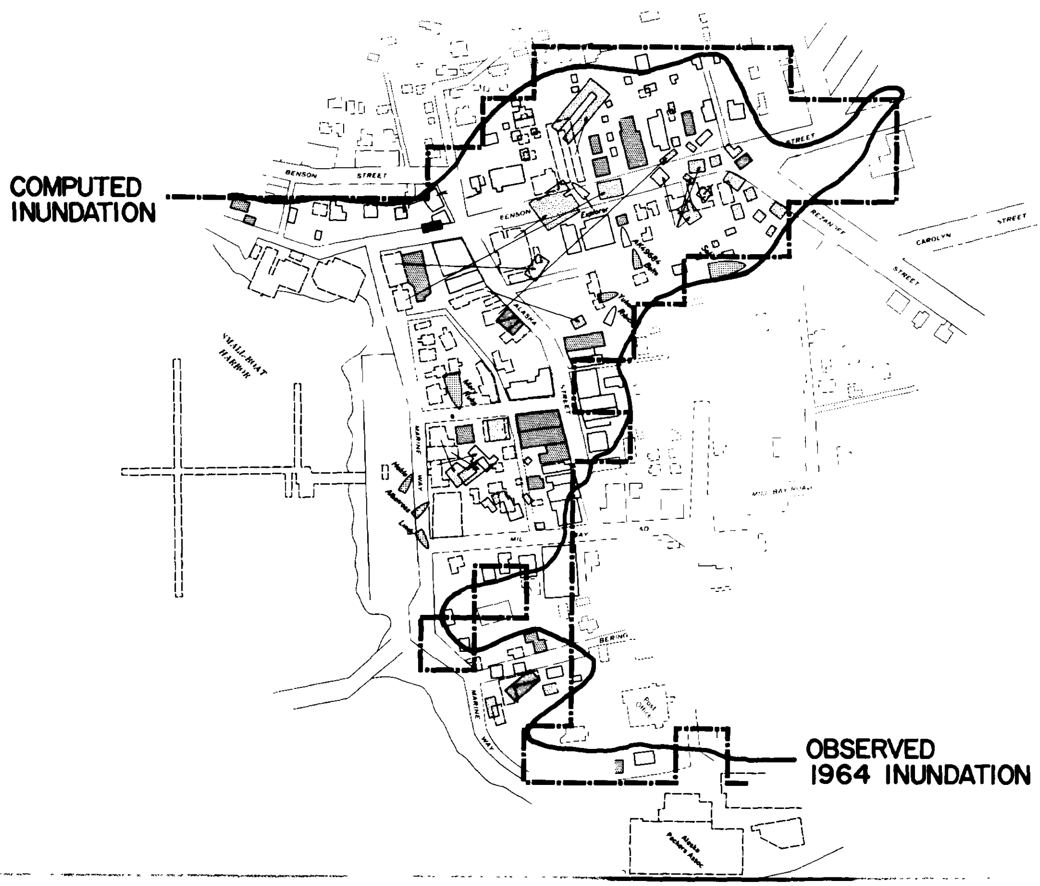


Figure 4: Comparison of Computed Run-up with Observed Inundation. Note close correlation between computed and observed boundaries.

PLANNING FRAMEWORK

The underlying planning problem for tsunami susceptible areas is that the tsunami phenomenon is not only extremely complex but also that the event is virtually unpredictable. Responsive plans must therefore address both a high level of uncertainity with regard to time and characteristics of the tsunami event and a relatively high level of precision with regard to causes of damage. This prototype planning strategy first refines the description of damage into categories addressed by the traditional planning/mitigation and preparedness processes. Subsequently, a range of approaches are suggested to address these relatively well defined characteristics of vulnerability.

The effects of a tsunami event can result from direct forces and from indirect or secondary effects caused by interaction of the tsunami forces with land uses, flammable material, moored boats, etc. As shown in Table 1 tsunami effects have therefore been classified into three categories based on their end results. Direct causes of damage are attributable to submergence (whole or partial) with the resulting water pressure, and to the velocity of the moving water.

Secondary impacts are essentially caused by the direct impacts in conjunction with other forces. For example bouyant forces may have lifted a structure from its foundations or a boat from its moorage, or surge forces may have created momentum which when added to other forces will move a structure in the direction of the current. Damage is subsequently caused by the floating debris (boats, cars, logs, etc.) impacting buildings.

Table 1
Components of Tsunami Losses

Type of Effect	Cause
Direct Tsunami Impacts	Water forces (surge, buoyant, drag, hydrostatic) Loss of ground support (erosion)
Secondary Impacts	Impact forces/Floating debris (boats, cars, logs) Fire and contamination spread by water
Loss of Life	Inadequate time for warning Inadequate evacuation routes Inadequate education and preparation in how to respond to a warning

The first two effects described above result in property damage. The third type of effect is loss of life. Minimizing lives lost is to a large extent dependent on proper warning and on the subsequent appropriate behavior of people in the hazard area and tends to be addressed administratively through education programs.

Implementation of mitigation and preparedness activities currently occurs through a multi-faceted framework involving many agencies and jurisdictions. To date, however, analysis of planning practices in Kodiak reveals that the tsunami hazard is rarely an explicit consideration. In order to correlate the activities needed to minimize tsunami effects listed in Table 1 the elements of comprehensive planning have been correlated with mitigation and preparedness activities in Table 2.

Table 2
Comprehensive Planning Framework

Comprehensive Plan Elements	Functions: Mitigation	Functions: Emergency Preparedness
Land Use and Economic Development	Minimize Flooding Building Collapse	
Recreation and Open Space	Buffer	Gathering Places
Transportation Vehicular Pedestrian		 Evacuation Search and Rescue

A two part framework can then be proposed to integrate mitigation and preparedness considerations into the comprehensive planning process. Part I is The Damage Control District, Part II is The Life Safety District.

PART I: DAMAGE CONTROL DISTRICT

Objectives of the Damage Control District are to protect property from both the direct and secondary causes of damage. This district encompasses the harbor and all of the land area potentially inundated.

Within the District four special zones create a range of administrative options addressing various aspects of the tsunami hazard. Although, all of the sub-zones are within the Damage Control District, their dimensions are defined in relation to characteristics of the hazard. The inland boundary of the Damage Control District is the computed tsunami reoccurance elevation which has been projected at the 30 foot elevation. The seaward boundary encompasses the breakwater and all of the water borne uses in the near shore area which potentially could be swept inland including boats, and piers. The geographic boundaries of the Damage Control District for Kodiak are based on the numerical calculations summarized in Figure 5a-5c.

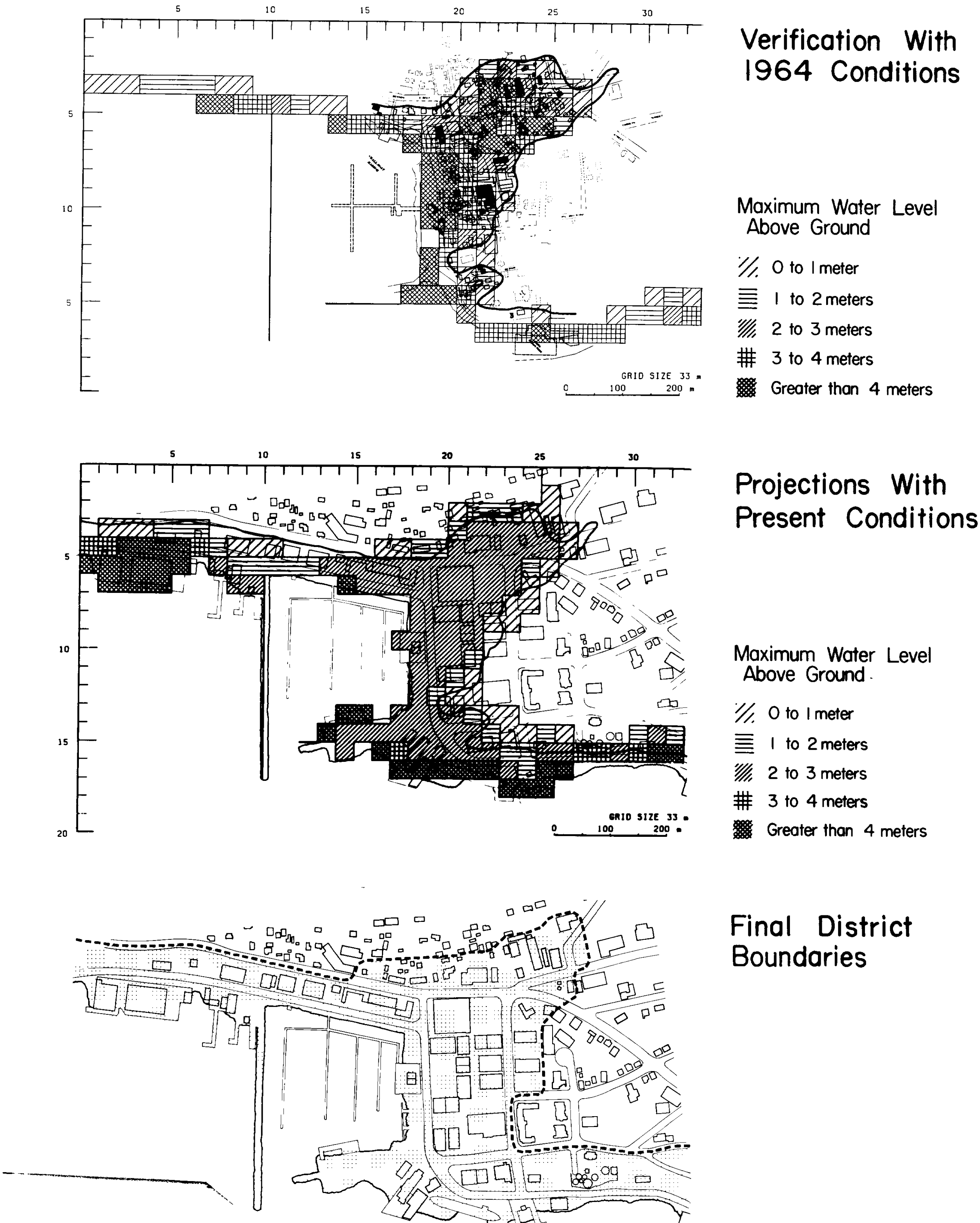


Figure 5: Definition of Planning District Boundaries

Building Safety Zone

Flood level, water velocity and impact from debris result in building collapse, structural and non-structural damage, and/or foundation failure. Standards must therefore address:

- o Resistance of Structures to Water Pressures
- o Protection of Structures from Debris

Damage caused by direct effects have been organized into categories based on projected water level above ground. It is expected that structures subject to more than 3m of water will also be most vulnerable to water borne debris.

Table 3

Projected Damage Categories

Maximum Water Level above Ground	Damage
0 1m	Slight Damage
1 2m	Slight or Moderate Damage
2 3m	Moderate Damage
3 4m	Possibly Salvagable
4m*	Unsalvagable*

*Also susceptible to debris impacts.

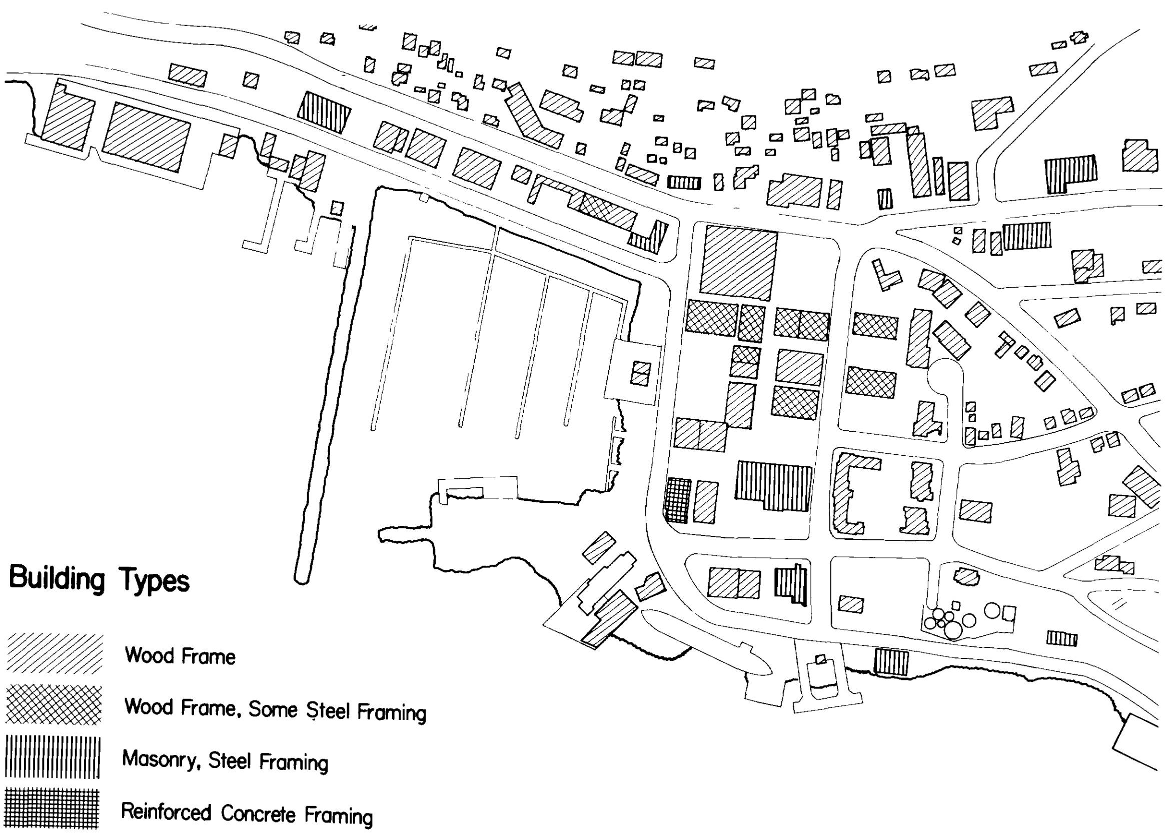


Figure 6: Existing Building Construction Types

 7B220130

Based on the projected inundation/flooding levels a series of sub-areas have been defined to guide administrative decisions relating to building standards and siting criteria for new construction. Within the damage susceptibility sub-area new construction standards would then be correlated with water volume, wave velocity, and vulnerability to floating debris. These standards would address foundation design, type of framing; building orientation (siting); water proofing; and/or ground level use/first story elevation.

Use Review for Critical Facilities and High Occupancy Uses

In order to minimize the number of lives at risk, a Building Use Review District would establish stringent standards for specified critical and high occupancy uses. Within this review district new critical facilities (hospitals, schools, fire and police stations) could not be built. Specified high occupancy structures such as auditoriums and theaters could also not be built. Other high occupancy structures such as hotels, and apartment buildings would be subject to standards pertaining to construction type.

Fire Protection District

Inventory of cannery and related uses in Kodiak reveals a heavy concentration of potentially flammable materials stored on site. For example, fuel tanks are loosely anchored and electrical vaults are located adjacent to highly combustable materials. These uses are subject to two types of hazards: 1) being impacted by boats borne inland and 2) breaking lose and hitting nearby buildings. Both types of hazards can result in fire.

Boundaries of the fire safety would be co-terminous with the entire Damage Control District. All uses such as oil storage tanks, gas stations and storage of hazardous materials would be reviewed in terms of siting and construction of protective measures. Special attention would be given to fuel storage and other combustable materials.

Measures to minimize fire damage could include:

- o Limitation on uses which result in high damage potential such as gas stations
- o Enclosed protection of dangerous uses such as fuel tanks
- o Creation of open space buffer zones around hazardous uses
- o Automatic shut-off values for fuel storage tanks

Water Safety District

A major cause of damage in 1964 was from boats which struck buildings as they were carried inland. The primary objective of the Water Safety District would therefore be to prevent uses in this district from becoming a hazard to uses on the shore. The components of the district includes:

- o The Breakwater
- o Boat Moorages, Docks, and Piers
- o Boats

Special attention should be given to securing the moorages of boats which will remain bearthed in the harbor. Tsunami resistant bearths could be constructed for selected high intensive loading docks.

Protective Buffer District

It is inevitable that certain uses such as cars in the mall parking lot will become an additional hazard to structures further inland. Another aspect of building safety is therefore to protect potentially hazardous uses and designated structures such as existing high occupancy buildings from impact.

A special parking district would be created to facilitate removal of parking from the most hazardous areas susceptible to greater than 3 or 4 M of inundation.

Trees have been found to retard the velocity in areas where water depth is less than 2 meters. A planting program would be implemented for inland areas subject to less than 2-3 meters of inundation.

Barriers retarding the wave run-up must be designed to stop the movement of the water body and/or of debris. In order to overcome the motion of the tsunami several forces must be overcome including water pressure, inertia, and friction between the earth and water. Buffers could be any of the following types.

- o Fill selected areas and protect the fill with reinforced retaining structure above the height of the projected "worst case" wave
- o Protective Dikes or Walls
- o Protective pilings surrounding uses to be protected from impact
- o Protective plantings in appropriate areas

PART II: LIFE SAFETY DISTRICT

The objectives of the Life Safety District are to protect lives by facilitating evacuation out of the hazard area, and to maximize search and rescue efforts after an event. Geographically the Life Safety District consists of two components. One is the evacuation zone. The second is the receiving zone. Administratively the Life Safety District consists of the geographic zones and the operational preparedness plan.

The inland boundary of the Evacuation Zone is based on numerical projections illustrated in Figure 6 as modified for safety to the 40 foot contour (modified from 30 foot for the Damage Control District). The Receiving Area begins above the 100' elevation.

Evacuation Zone

Evacuation considerations consist of three principal elements: a Warning System; a Vehicular Evacuation Plan and a Pedestrian Evacuation Plan.

Warning System

The physical component of the warning system at the local level (within Kodiak) pertains to delineation of an area within which a warning signal can be clearly received. The geographic limits of the evacuation area must therefore be clearly defined.

- An integral component of the warning system is public preparedness. The population at risk, including seasonal populations, must be educated to understand what to do in the event of a warning. They must know where to go and the routes to take.
- Educational programs and rescue procedures must be established for "special" target populations such as elderly and transient workers who may not be aware of the tsunami hazard. Many of this latter population do not speak english..

Vehicular Evacuation/Transportation Plan

Implementation of the vehicular element of the evacuation plan will include identification of vechicular routes and traffic routing priorities for vehicles which are parked in the area. It must also accommodate vehciles assisting special designated populations, such as those

 753 20130

residing in the retirement home, and large groups, such as in the theater. These routes will later be used for search and rescue and for cleanup operations. This routing plan would define alternative routes linking the Life Safety District with the Receiving Zone.

A supplementary operational plan would develop standards for maintenance and for winter clearing of designated streets and sidewalks which link the evacuation zone and the receiving areas.

Pedestrian Evacuation

Cannery workers, employees and patrons of the many businesses, especially along Shelikoff Street are within accessible pedestrian evacuation routes. Pedestrian evacuation can be facilitated in terms of:

- o Construction of Stairs and/or sidwalks
- o Sidewalks designated for clearing during the winter

LIFE SAFETY
DISTRICT

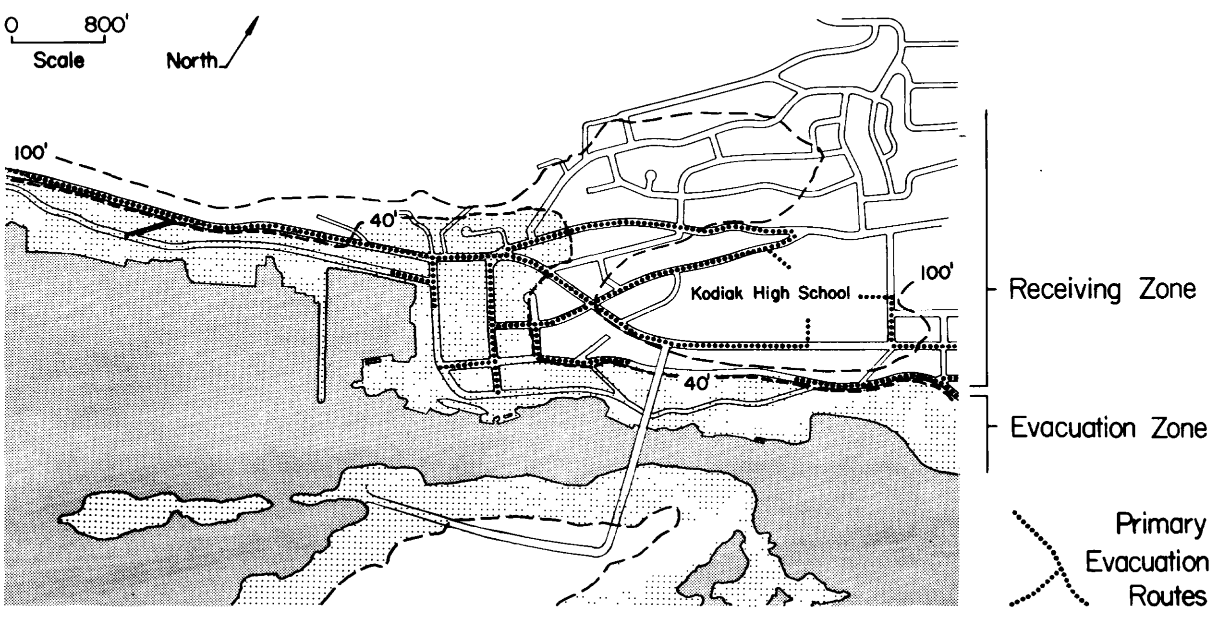


Figure 7: Life Safety District

 7B720130

Receiving Zone

People within the evacuation zone would be directed to designated areas such as the school complex in the receiving area. The receiving zone consists of two primary elements:

- o Refuge Sites

  Safe refuge sites to which people can go until their homes are again safe. Places of refuge (schools, hospitals, etc.) must be clearly identified outside the hazard zone.

- o Congregation Places for the Response Team.

  Places are identified which will be available for the rescue and response workers to gather in order to receive instructions after the event. Large spaces such as the Borough parking lot will be required.

INTEGRATED IMPLEMENTATION FRAMEWORK

The traditional comprehensive planning process consists of three primary elements (land use, transportation, and open space). Typically, however, communities implement special purpose plans such as those listed in Table 4, Column 1 through a range of ordinances and programs. Implementation of the Damage Control District and the Life Safety District would therefore occur through the special districts which are described above in conjunction with the on-going planning process. Once the functional distribution of responsibilities has been defined the specific implementation responsibility, including financial implications of damage prevention, and emergency preparedness measures can be identified. Through this integrated approach to planning and implementation it is also possible to maximize multi-purpose utility of major facilities, e.g. parks, and circulation routes.

Table 3

Integration of Comprehensive Planning, and Emergency Preparedness

1 Typical Subject Matter	2 Comprehensive Plan Considerations	3 Emergency Preparedness	4 Mitigation
Transportation	Arterial, and Secondary Roads - alignment and maintenance Pedestrian Facilities	Evacuation Route On-going Maintenance Search and Rescue	
Open Space	Major Recreation Neighborhood Parks	Staging Area	Fire Buffer
Land Use and Economic Development	Land Use Designation Allowable Density Development Intensity Siting Criteria	Vertical Evacuation Protection of Critical Facilities	Use Review Building Standards Protective Barriers

Comparison of existing conditions in Kodiak with a range of measures to minimize losses demonstrates implementation of this integrated approach. Figure 8-a is a section which indicates structure locations and areas filled since 1964. All existing structures are wood frame, Type C construction. Foundations are slab on grade. Figure 8-b would redevelop the area according to standards pertaining to foundations (piling) and required steel frame construction. Parking is relocated behind structures in order not to contribute to the hazard of floating debris. Other recommendations include elevated protective dike/sea wall, and reinforcing the boat moorages and docks. New construction requirements address foundations and framing standards.

ACKNOWLEDGEMENTS:

The project is funded by the National Science Foundation Science Foundation Grant Number CEE-8408237. Nobuo Shuto of Tohoku University, Sendai, Japan, Hiroshi Sakuramoto and Shigeru Yamaki of INA Civil Engineering Company, Tokoyo, Japan are responsible for the project's numerical modeling.

Richard Hodge of Urban Regional Research is responsible for graphics.

Section A-A

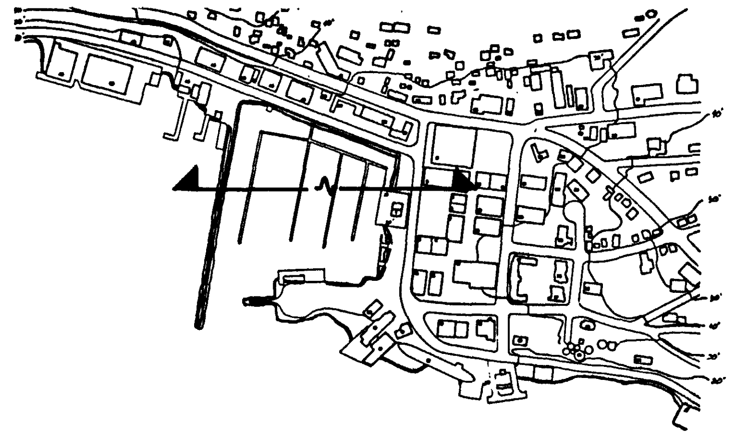


Figure 8-a:

Existing Conditions

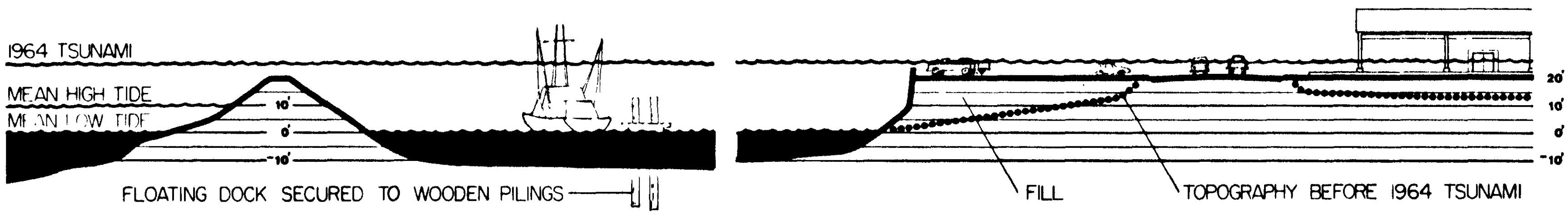
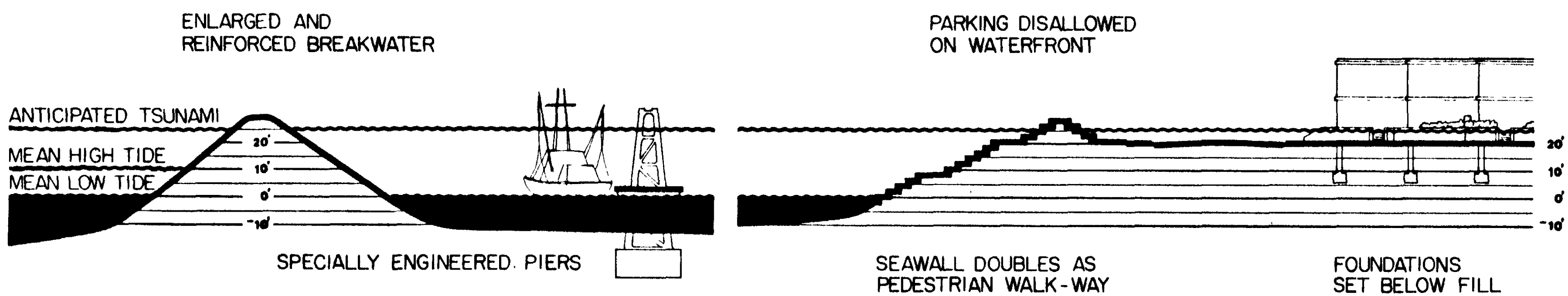


Figure 8-b

Proposed Mitigation



STATUS OF EARTHQUAKE HAZARD RESEARCH IN THE ANCHORAGE AREA
AND UPPER COOK INLET, ALASKA

by

Randall G. Updike
Engineering Geology Section
State of Alaska, Department of Natural Resources
Division of Geological and Geophysical Surveys

INTRODUCTION

The vigorous social and economic growth of Anchorage and vicinity in the past two decades is a notable commentary on the capabilities of science and technology to meet the demands of a cosmopolitan center in a rigorous geologic environment. Among the many major engineering and construction tasks that confront development of the municipality, the consideration of earthquake hazards continues to be a pervasive issue. The catastrophic results from the 1964 Prince William Sound earthquake clearly indicated the devastation that can result from major earthquakes.

Anchorage in 1984 is a substantially different and more complex city than that of twenty years ago. New buildings, life-line networks, transportation systems, and demography have significantly enhanced the potential risk to life and property during future earthquakes.

Within the past five years, primarily through the efforts of the U.S. Geological Survey (USGS) and the Alaska Division of Geological and Geophysical Surveys (ADGGS), significant advances have been made toward a better understanding of the geological parameters associated with earthquake hazards for Anchorage. Two primary areas of concern are being addressed by this research: (1) seismic sources that would directly impact Anchorage, and (2) the response of Anchorage geological materials to these seismic events. Though the two are intimately related, the research approaches and objectives are fundamentally quite different.

EARTHQUAKE SOURCES

Southcentral Alaska is situated astride a zone wherein the Pacific Ocean plate is being subducted beneath the North American plate along a zone from southeastern Alaska to the Aleutian Islands, called the Aleutian megathrust. This thrust zone is about 30 km (20 mi) beneath Anchorage. The result of this very slow (6 cm/yr), continuous interaction is the sudden and variable release of energy as deep-foci earthquakes from within or above the megathrust zone. This has been the source of most of the major Alaskan earthquakes in the 20th century. Other abstracts in this volume address this phenomenon in more detail.

Associated with the plate boundary stress buildup in the crust, rock near the earth's surface will occasionally rupture along faults that may be several kilometers in length. These fault movements release large quantities of energy as shallow-focus earthquakes. For several years, two major faults have been recognized near to Anchorage.

The Castle Mountain Fault extends southwest from the Matanuska Valley, through the town of Houston, and continues for many miles as a linear trace across the lowlands on the west side of Cook Inlet (Detterman and others, 1974). Reconnaissance efforts through trench excavations and geologic mapping have determined late Holocene (less than 3,000 years) movement but no recurrence determinations yet exist (Bruhn, 1979). Lahr and others (1985) recently concluded that at least a 95-km length of this fault near Palmer should be considered active based upon recent seismicity.

The Border Ranges Fault system occurs lies at the base of the Chugach Mountains directly east of the city. It has been mapped at various scales from southeastern Alaska, through the Kenai Peninsula and southwest through Kodiak Island. Segments of this great fault system from the Matanuska Valley to Turnagain Arm are currently being mapped in careful detail (1:25,000) by Updike and others under a cooperative USGS-ADGGS project to determine precise location, sense of movement, magnitude of displacement, and degree of activity. Investigations to date (e.g., Updike and Ulery, 1983) have identified local scarps offestting Holocene geologic deposits which directly correlate with adjacent fault exposures in bedrock. Continuing studies are addressing the critical question of whether such scarps are of tectonic origin which would reflect the occurrence of large earthquakes within the past ten thousand years.

Assuredly, other faults in the Chugach Mountains and beneath Cook Inlet may be capable of generating infrequent earthquakes of moderate to large magnitudes, but their identity is unknown. On-going geologic mapping in conjunction with various geophysical methods may shed light on these questions. The important point to recognize is that the megathrust mechanism is currently operating beneath Anchorage, promising a future of seismicity along the subduction zone as well as near-surface fault zones. Dependent upon which of these sources is responsible for future seismic events, the ground response and possible damage patterns for Anchorage may be quite different than previous earthquakes. Multiple-scenario emergency response plans require an accurate definition of both surface faults and subduction zone seismicity.

RESPONSE OF GEOLOGIC MATERIALS

The effect of subjecting Anchorage soils to the severe vibrations of a seismic event will vary throughout the city. The near-surface soils tend to amplify the incoming energy waves, and this amplification varies according to physical properties, thicknesses, and location of the soil. Currently, the Municipality of Anchorage, U.S. Geological Survey, and Alaska DGGS are cooperatively monitoring various localities in the city to better assess the variability of these ground acceleration properties, and are correlating these records to the subsurface geology of the region. This work is summarized in other abstracts in this volume.

A major cause of loss of life and property in Anchorage in 1964 was due to ground failure (landslides). Two mechanisms that have been identified as causes are liquefaction and sensitive silt and clay collapse. Liquefaction involves the buildup of positive pore pressures in non-cohesive soils (silt and sand) with attendant decrease in effective stresses, resulting in mobility of the soil while the earthquake is occurring. Lateral spreading of the soils results, disrupting structures constructed on or in these soils. Liquefaction caused 1964 damage, for example, along the Seward and Glenn Highways, at the Anchorage Port, and in Knik and Turnagain Arms (Hansen, 1965; Kachadoorian, 1968; McCulloch and Bonilla, 1970).

Sensitive silty clays are fine-textured cohesive soils which were deposited to form a flocculated fabric resembling a "house-of-cards". The voids of this fragile framework may be saturated. Due to the intense shearing stresses induced by large earthquakes, the "card houses" collapse, the water is liberated, hydrostatic pressures build up, and lateral movement results. This phenomenon is discussed by Olsen in another abstract of this volume. The large 1964 translatory landslides at "L" Street, 4th Avenue, Turnagain Heights, and elsewhere are currently believed by Olsen, myself, and other current investigators to be the result of sensitive clay failure within the Bootlegger Cove Formation which underlies much of the western half of the city (Updike, 1983a, 1984a; Updike and others, 1985; Updike and Carpenter, 1985).

CURRENT RESEARCH

Until recently, the understanding of the distribution and dynamic behavior of the soils in Anchorage had not advanced beyond the few detailed studies done immediately after the earthquake (Shannon and Wilson, 1964; Seed and Wilson, 1967; Seed, 1968; Kerr and Drew, 1965, 1968). Cooperative efforts of ADGGS and the USGS, and with the assistance of consultant engineers, have provided several new insights.

Laboratory testing

In conjunction with several geotechnical drilling programs in the past five years, numerous undisturbed core samples of Anchorage soils have been acquired. The stratigraphy of each borehole has been carefully logged and the cores subjected to a suite of static engineering tests to calibrate the geologic strata with their in situ physical properties (e.g., Updike and others. 1985). Certain samples were retained for state-of-the-art testing programs including cyclic triaxial and resonant column tests to correlate dynamic behavior with stratigraphy (Updike and others, 1982; Lade and others, 1985).

In conjunction with the engineering laboratory tests, geologic studies have specifically focused on the depositional history, sedimentary structures, and post-depositional alteration of the soils. A first phase of a systematic micropaleontologic study of the Bootlegger Cove Formation has recently been completed by Ruth Schmidt under contract with ADGGS. An examination of pore water chemistry by Yousef Kharaka (USGS-Menlo Park) has shown a significant relationship between cations, anions, and clay sensitivity ratios (Updike and others, 1985). An analysis of in situ soil particle fabrics using a scanning electron microscope has documented the "card-house" fabric within the sensitive soils, as well as a honey-comb fabric that has rarely been observed anywhere in the world (Updike and Oscarson, 1984). These geologic studies are re-affirming that the potential for future failures is just as great as in 1964.

In situ testing

Geotechnical engineers have long recognized that sampling and laboratory testing have inherent shortcomings related to sample disturbance and laboratory representation of ambient field conditions. This is particularly true for non-cohesive soils. The standard penetration test, which involves driving a specified split-spoon sampler into the soil utilizing a specific amount of hammer energy, has for many years been the widely adopted test for in situ soil conditions in Anchorage. Liquefaction susceptibility studies still use SPT values as a baseline even though it clearly has shortcomings of standardization and calibration.

The electric cone penetration test (CPT) was first used in the Anchorage area by ADGGS about three years ago (Updike, 1984a, 1984b). This test involves forcing a strain-gauge-instrumented probe into the ground at a constant penetration rate using a hydraulic ram with a 20-ton reaction force. Continuously recorded soundings of end-bearing and friction resistance are digitally stored, later to be computer analyzed for soil property characterization. Calibration between SPT and CPT techniques now exists for major Anchorage soils and liquefaction susceptibility of area soils has been assessed. The CPT is gaining wider usage on major engineering projects in the region by consultants and by Alaska Department of Transportation and Public Facilities.

Geophysical methods of in situ testing are primarily limited to the geophysical logging techniques used by hydrologists to define density, saturation, and porosity, and to shear wave velocity measurements. The latter method has recently been used on both research and applied projects in Anchorage (see Updike and others, 1985) where the shear modulus and damping ratio of soils are desired for seismic modeling of soil response spectra. At least two local engineering firms currently offer this capability. Other methods of in situ properties measurement are being tested including the pressuremeter and field shear vane but research data are still insufficient.

Immediately following the 1964 earthquake the Corps of Engineers installed and monitored several slope indicator casings in and adjacent to the major landslides (Shannon and Wilson, 1964). In recent years, some additional slope indicator casings have been installed by the Municipality and USGS. These casings have served as passive in situ monitoring systems which have been recently surveyed and summarized by Updike (1983b). With two exceptions in the 4th Avenue slide are, all other casings showed no record of movement through 1980.

Field mapping

Two distinct mapping programs are being conducted by ADGGS in cooperation with the USGS. The first is focused on the Border Ranges fault zone and includes detailed mapping of both bedrock and surficial deposits of the 1:25,000 scale metric quadrangles along the west front of the Chugach Mountains (e.g., Updike and Ulery, 1983). The objective of this program is to produce a complete series of geologic quadrangle maps from the Knik River valley on the north, through Eklutna, Peters Creek, Eagle River, and east Anchorage, to Turnagain Arm on the south. In addition to identifying the location of all faults and their activity along the mountain front, other geologic hazards and constraints such as landslides, avalanches, and flooding, will be identified and assessed. I, as the principal investigator, have been greatly benefited by the long-term experience in the region by Hank Schmoll (USGS-Denver) and Richard Reger (ADGGS-Fairbanks).

Detailed mapping of both bedrock and surficial deposits is providing added insight into the tectonic history of the Chugach Mountains, as well as the glacial history of the mountains and adjacent populated lowlands. Additional information on the location of economic minerals and construction materials (sand, gravel, quarry stone) results from the mapping.

The second mapping program is committed to describing and graphically portraying the engineering geology underlying Anchorage in three dimensions. This Anchorage mapping is proceeding with two different objectives. One mapping program, led by Hank Schmoll and others, under the direction of Al Espinosa (USGS-Denver), is focused on mapping the entire unconsolidated sedimentary stratigraphic column of up to several hundred meters and the underlying bedrock configuration, with the goal of modelling expected seismic accelerations across the city. Other abstracts in this volume detail this effort. The second mapping project, under the direction of myself, is focused on detailed engineering geologic characterization of the upper 50 m of unconsolidated sediments beneath Anchorage, with the objective of more accurately defining the ground failure potential beneath the city. This objective requires the accumulation of hundreds of geotechnical borehole and water well logs which are inventoried on a data retrieval system. Once stratigraphic units are identified and mapped in the subsurface from logs or at the surface from exposures, the known suite of engineering test data for that unit can be applied so that the mapping not only elucidates the geology of the region but also the variability of geotechnical properties.

These mapping data are becoming fundamental documents for planning and zonation, seismic risk assessment, emergency response planning, and hazard mitigation, supplementing the widely used earlier mapping of Miller and Dobrovolny (1959), and Schmoll and Dobrovolny (1972). A first east-west cross-section to bedrock in central Anchorage has been published by Schmoll and Barnwell (1984). Detailed engineering geology maps and cross-sections of the area north of Ship Creek, which includes the Anchorage Port and Government Hill is completed (Updike, 1985; Updike and Carpenter, 1985). Two reports have been produced to cover the detailed geology of south Anchorage (including International Airport, Turnagain Heights and Campbell Lake) (Ulery and Updike, 1983; Updike and Ulery, 1985). The detailed engineering geology of the downtown to midtown segment, which will connect the segments already completed is currently underway by ADGGS and will mesh with on-going USGS-funded ground-failure potential mapping by Moriwaki (Woodward-Clyde Consultants). Colored maps and cross-sections are the basic products of the ADGGS work. The aerial distribution, thickness, and current physical properties of the sensitive and liquefiable soils are primary objectives of this mapping effort.

The mapping has found that both types of soils are widespread and are responsible for numerous landslides throughout history.

FUTURE RESEARCH NEEDS

Our current understanding of seismic sources, particularly the Castle Mountain and Border Ranges faults, is at best simplistic. The detailed mapping of both faults with an emphasis toward determining Holocene movements is a first and basic step. These efforts will need to be augmented with subsurface exploration which will eventually include excavations across the fault traces, seismic refraction and reflection profiles, and other geophysical methods including gravity and magnetic surveys. These investigations must keep open the distinct possibility of finding additional active faults within the Chugach Mountains and beneath the Cook Inlet lowlands.

Our full appreciation for the diverse behavior of Anchorage area soils has not been realized. Advanced methods of in situ geotechnical testing currently in use in the contiguous U.S. must be brought to Alaska. The current pressures to make greater use of tidal flats and stream flood plains raises the issue of liquefaction susceptibility of soils that a few years ago were considered unsuitable for construction. In situ testing of these soils as well as the Bootlegger Cove Formation must be emphasized in future geotechnical research. The first steps toward a municipality-wide rapid-access geotechnical data bank have been made by ADGGS. In cooperation with private industry, the USGS, and the Municipality of Anchorage, this data bank should be computerized and made easily accessible for industry and government agencies, as well as for future research.

Beyond the issues of seismically-induced ground failure, ground acceleration as a function of the varied geology of the Municipality is not well understood. This far-reaching concern can only be addressed through the direct interface of three-dimensional geologic mapping and a carefully deployed network of strong motion accelerometer stations in Anchorage. Long-term data-collection and analyses will be necessary to establish viable criteria for strong motion behavior of various areas in the region, and this can only be realized through the cooperative commitment and efforts of the Municipality, the USGS, and ADGGS.

REFERENCES

Bruhn, R.L., 1979, Holocene displacements measured by trenching the Castle Mountain fault near Houston, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 61, p. 1-4.

Detterman, R.L., Plafker, G., Hudson, T., Tysdal, R.G., and Pavoni, N., 1974, Subsurface geology and Holocene breaks along the Susitna segment of the Castle Mountain fault, Alaska: U.S. Geological Survey Miscellaneious Field Studies Map MF-618.

Hansen, W.R., 1965, Effects of the earthquake of March 27, 1964, at Anchorage, Alaska: U.S. Geological Survey Professional Paper 542-A, p. A1-A68.

Kachadoorian, Reuben, 1968, Effects of the earthquake of March 27, 1964, on the Alaska highway system: U.S. Geological Survey Professional Paper 545-C, p. C1-C66.

Kerr, P.R., and Drew, I.M., 1965, Quick clay movements, Anchorage, Alaska: Springfield, Virginia Technical Information Service, Document AD630-111. 133 p.

Lade, P.V., Updike, R.G., and Cole, D.A., 1985, Cyclic triaxial tests of the Bootlegger Cove Formation, Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigation 85- , in press.

Lahr, J.C., Page, R.A., and Fogleman, K.A., 1985, The 1984 Sutton earthquake--new evidence for activity of the Castle Mountain fault (Abst.): Seismological Society of America Annual Meetings Program with Abstracts.

McCulloch, D.S., and Bonilla, M.G., 1970, Effects of the earthquake of March 27, 1964, on the Alaska Railroad: U.S. Geological Survey Professional Paper 545-D, p. D1-D161.

Miller, R.D., and Dobrovolny, Ernest, 1959, Surficial geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Bulletin 1093, 128 p.

Schmoll, H.R., and Dobrovolny, Ernest, 1959, Generalized geologic map of Anchorage and vicinity, Alaska: U.S. Geological Survey Map I-787-A, scale 1:24,000.

Schmoll, H.R., and Barnwell W.W., 1984, East-west geologic cross-section along the Debarr line, Anchorage, Alaska: U.S. Geological Survey Open-File Report 84-791, 10 p.

Seed, H.B., 1968, Landslides during earthquakes due to soil liquefaction: Journal of the Soil Mechanics and Foundations Division, v. 94, no. SM5, p. 1053-1122.

Seed, H.B., and Wilson, S.D., 1967, The Turnagain Heights landslide, Anchorage, Alaska: Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, v. 93, p. 325-353.

Shannon and Wilson, Inc., 1964, Report on Anchorage area soil studies, Alaska, to the U.S. Army Engineer District, Anchorage, Alaska: Seattle, Shannon and Wilson, Inc., 109 p.

Ulery, C.A., and Updike, R.G., 1983, Subsurface structure of the cohesive facies of the Bootlegger Cove Formation in southwest Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 84, 5 p., scale 1:15,840, 3 sheets.

Updike, R.G., 1983a, Seismic liquefaction potential in the Anchorage area, south-central Alaska (abst.): Symposium on liquefiable deposits in the western United States, Geological Society of America, Rocky Mountain/ Cordilleran Sections Annual Meetings, Salt Lake City, Abstracts with Programs, p. 374.

__________, 1983b, Inclinometer strain analyses of Anchorage landslides, 1965-80: Alaska Division of Geological and Geophysical Surveys Professional Report 80, 141 p.

__________, 1984a, The Turnagain Heights landslide--an assessment using the electric cone penetration test: Alaska Division of Geological and Geophysical Surveys Report of Investigation-F, 84-13, 55 p.

__________, 1984b, Liquefaction susceptibility analysis for foundation soils, Knik River Bridge, Glenn Highway, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigation 84-26, 33 p.

__________, 1985, Engineering geologic maps, Government Hill area, Anchorage, Alaska: U.S. Geological Survey I-series map, I-1610.

Updike, R.G., and Carpenter, B.A., 1985, Engineering geology of the Government Hill area, Anchorage, Alaska: U.S. Geological Survey Bulletin 1588, in press.

Updike, R.G., Cole, D.A., and Ulery, C.A., 1982, Shear moduli and damping ratios for the Bootlegger Cove Formation as determined by resonant-column testing, in Short Notes on Alaskan Geology - 1981: Alaska Division of Geological and Geophysical Surveys Professional Report 73, p. 7-12.

Updike, R.G., Olsen, H.W., Schmoll, H.R., Stokoe, K.H., II, and Kharaka, Y.F., 1985, Geologic and geotechnical conditions adjacent to the Turnagain Heights landslide, Anchorage, Alaska: U.S. Geological Survey Bulletin, in press.

Updike, R.G., and Oscarson, R.C., 1984, The dynamic behavior of sensitive clays as indicated by microfabric studies (abst.): Geological Society of America Cordilleran Section Meetings, Anchorage, Abstracts with Programs, v. 16, no. 5, p. 338.

Updike, R.G., and Ulery, C.A., 1983, Preliminary geologic map of the Anchorage B-6NW (Eklutna Lake) Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-8, scale 1:10,000, 2 sheets.

Updike, R.G., and Ulery, C.A., 1985, Engineering geologic map and cross sections, southwest Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 89.

SENSITIVE CLAYS IN THE BOOTLEGGER COVE FORMATION

by

Harold W. Olsen

U.S. Geological Survey

Denver, Colorado 80225

INTRODUCTION

The Prince William Sound Earthquake of March 27, 1964 triggered five major landslides in the Bootlegger Cove Formation beneath downtown and residential areas of Anchorage. Geologic evidence indicates that similar landslides occurred at various times in the past, probably in response to historic earthquakes. The conclusion appears to be inescapable that the Anchorage area is threatened by major landslides during future earthquakes.

Possible approaches for mitigating the potential hazards from such landslides, short of relocating parts or all of the City of Anchorage, have yet to be developed. In large measure, this appears to be due to the lack of an adequate understanding of the distribution and properties of the materials in the Bootlegger Cove Formation whose failure can be triggered by earthquakes.

IMPORTANCE OF SENSITIVE CLAYS

In their final report on the 1964 Anchorage area soil studies, Shannon and Wilson (1964) concluded that the earthquake-induced landslides could have been triggered in the middle zone of the Bootlegger Cove Formation, either by liquefaction of sand or by strength loss in sensitive clay. Subsequent analyses of the Turnagain Heights landslide suggested that the sands should have liquefied before significant strength loss could have developed in the sensitive clays (Seed and Wilson, 1967). Thereafter, Seed (1968) included the 1964 earthquake-induced landslides in the Anchorage area in his compilation of case histories for Landslides During Earthquakes Due To Soil Liquefaction on the grounds that "there is good evidence to show that the major cause of the Anchorage slides was probably liquefaction of sand layers, and sand and silt seams and lenses within the clay deposit."

Thus the 1964 earthquake-induced landslides in Anchorage came to be identified as an important example of the need for research concerning liquefaction of sands as a cause of earthquake-induced ground failures. In comparison, the significance of the 1964 Anchorage slides concerning strength loss of sensitive clays as a cause of earthquake-induced ground failures received little attention.

Since 1964, substantial advances have been made in the development of methodology for evaluating the liquefaction susceptibility of sands. Of particular interest is the approach based on in situ cone penetrometer data that was not available in 1964, and which has been employed in several recent subsurface investigations in Anchorage (Idriss and Moriwaki, 1982; Updike, 1984; Updike and Carpenter, in press). Where these investigations have encountered sand strata in the soft and sensitive middle zone of the formation, the results show that the sands are generally too dense to liquefy during large-magnitude earthquakes. In addition, recent geologic studies indicate that the thin seams and lenses of silt and sand in the formation are abundant in the relatively stiff upper zone, but rare in the underlying soft and sensitive middle zone where the failure planes of the 1964 Anchorage slides developed (Updike and others, in press). In consequence, it now appears probable that the 1964 Anchorage slides were triggered by strength loss in sensitive clays, and that these materials govern the potential for earthquake-induced ground failures in the Bootlegger Formation during future earthquakes.

SENSITIVE CLAY BEHAVIOR

The strength of most clays deteriorates with disturbance. When the potential strength loss is large, the clays are classed as sensitive. Clays that are extremely sensitive are often called "quick" clays because their strength can be reduced by disturbance to such a low value that they behave like a viscous fluid.

The characteristics of sensitive clay behavior are twofold, namely, the potential strength loss, and the rate at which strength deteriorates with disturbance. These characteristics are not, in general, related. For example, some quick clays loose strength rapidly in response to minor disturbance, whereas other quick clays lose strength only after extensive disturbance (Soderblom, 1974).

Sensitive clay behavior arises from the transformation of the clay fabric from a flocculated to a dispersed state. This transformation is often referred to as a collapse of the clay structure. The flocculated fabric develops during sedimentation, and post-depositional changes in the pore fluid chemistry tend to disperse the clay fabric. However, bonds between the clay particles resist dispersion until broken by disturbance. The strength of these bonds governs the effort required to break down the initial flocculated fabric. Thereafter, the pore fluid chemistry governs the degree to which the clay fabric becomes dispersed (Mitchell, 1975; Quigley, 1980; Torrance, 1983).

SENSITIVITY OF THE BOOTLEGGER COVE CLAYS

Figure 1 summarizes the scope of existing information concerning the sensitivity of the Bootlegger Cove clays. The dashed curves differentiate materials of low, medium, high, and extremely high sensitivity, where the degrees of sensitivity are distinguished in terms of the sensitivity scale used by Shannon and Wilson (1964). This scale is shown below, together with the relative abundance of the material groups, based on data from about 2100 samples tested in 1964 (Hansen, 1965).

<table>
<tr><th>Degree of Sensitivity</th><th>Sensitivity Ratio</th><th>Relative Abundance</th></tr>
<tr><td>Low</td><td>< 4</td><td rowspan="2">86%</td></tr>
<tr><td>Medium</td><td>4 - 10</td></tr>
<tr><td>High</td><td>10 - 40</td><td>13%</td></tr>
<tr><td>Extremely High</td><td>> 40</td><td><1%</td></tr>
</table>

The sensitivity ratio is the ratio of the undisturbed strength to the remolded strength of the same material. Note that this scale relates to the potential strength loss of a material, but not to the rate at which its strength deteriorates with disturbance.

In figure 1, the most sensitive materials are shown with the lowest undisturbed strengths, consistent with the findings of the 1964 Anchorage area soil studies (Shannon and Wilson, 1964). The end points of each curve are defined by strength measurements on core samples in undisturbed and remolded states. The dashed curves between the end points indicate the strength deteriorates with disturbance at a rate that has not yet been defined, except for the hachured zone on the lowest curve. The hachured zone represents the information obtained from laboratory cyclic loading tests in 1964, which

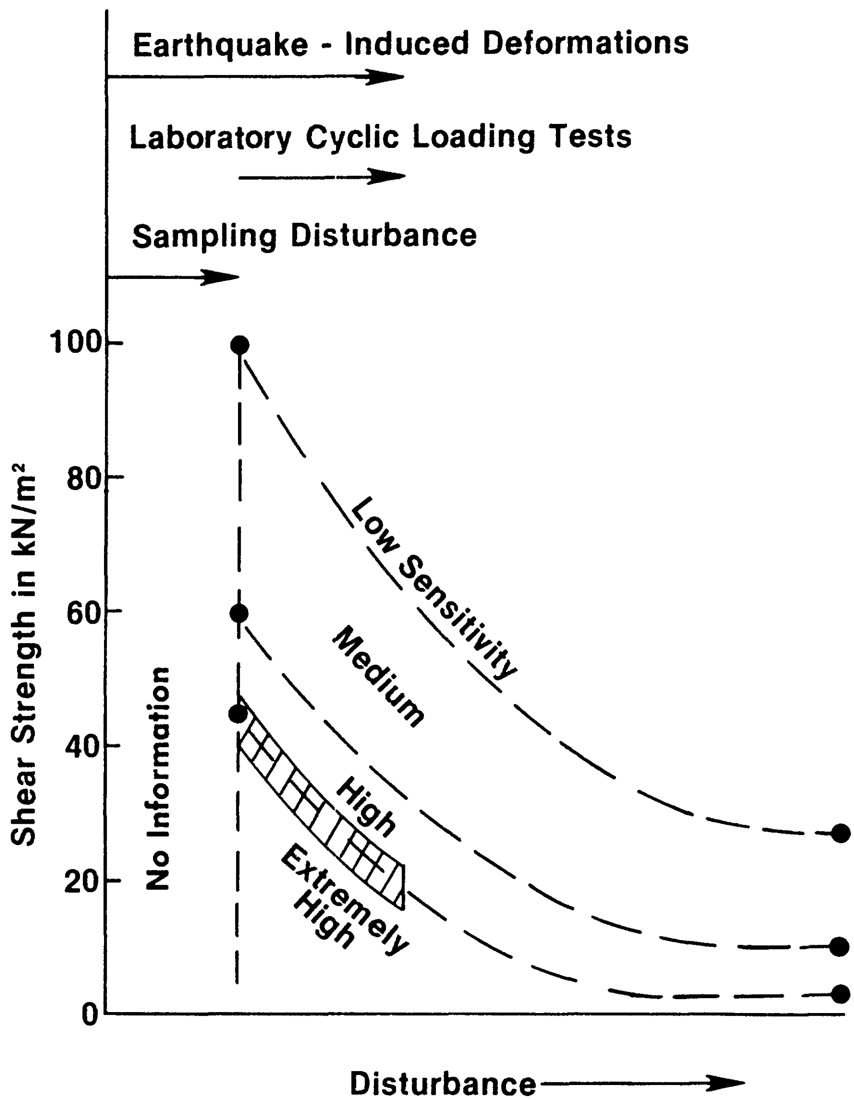


Figure 1. Scope of existing information on the sensitivity of the Bootlegger Cove clays.

95/20/30

describe the rate of strength degredation from disturbance caused by simulated earthquake-induced deformations (Shannon and Wilson, 1964).

The distribution and properties of the sensitive clays in the Bootlegger Cove Formation are best known near the eastern end of the Turnagain Heights Landslide. At this location the existing data base includes the information obtained by Shannon and Wilson in 1964, and additional data obtained in recent years by the Alaska Department of Natural Resources and the U.S. Geological Survey (Updike and others, in press). The recent data are emphasized herein because they include information from a variety of tests at one site, including, in situ cone penetration tests, downhole and crosshole seismic velocity measurements, and laboratory geotechnical and geochemical measurements on nearly-continuous undisturbed samples from the formation.

Figure 2 shows one of the cone penetration records together with a log of the facies identified in the undisturbed cores from the adjacent boreholes. The soft, middle zone of the formation lies between an elevation of about 8 m above, to about 4 m below, mean sea level. This zone is overlain and subdivided by massive sand layers. Note that the material between the sand layers is weaker than that below. The same strata in the middle zone of the formation are also evident in the shear wave velocity data in figure 3. Intervals of relatively high shear wave velocity reflect the sand layers, and the lowest shear wave velocity occurs in the upper part of the middle zone between the sand layers.

The variation of sensitivity (strength loss potential only) in the profile is indicated by the remolded laboratory vane strength data in figures 4 and 5 that were obtained from the nearby undisturbed cores. Low remolded strength values indicate high sensitivity values, as shown by the correlation in figure 6. This correlation is based on the data from the samples used in

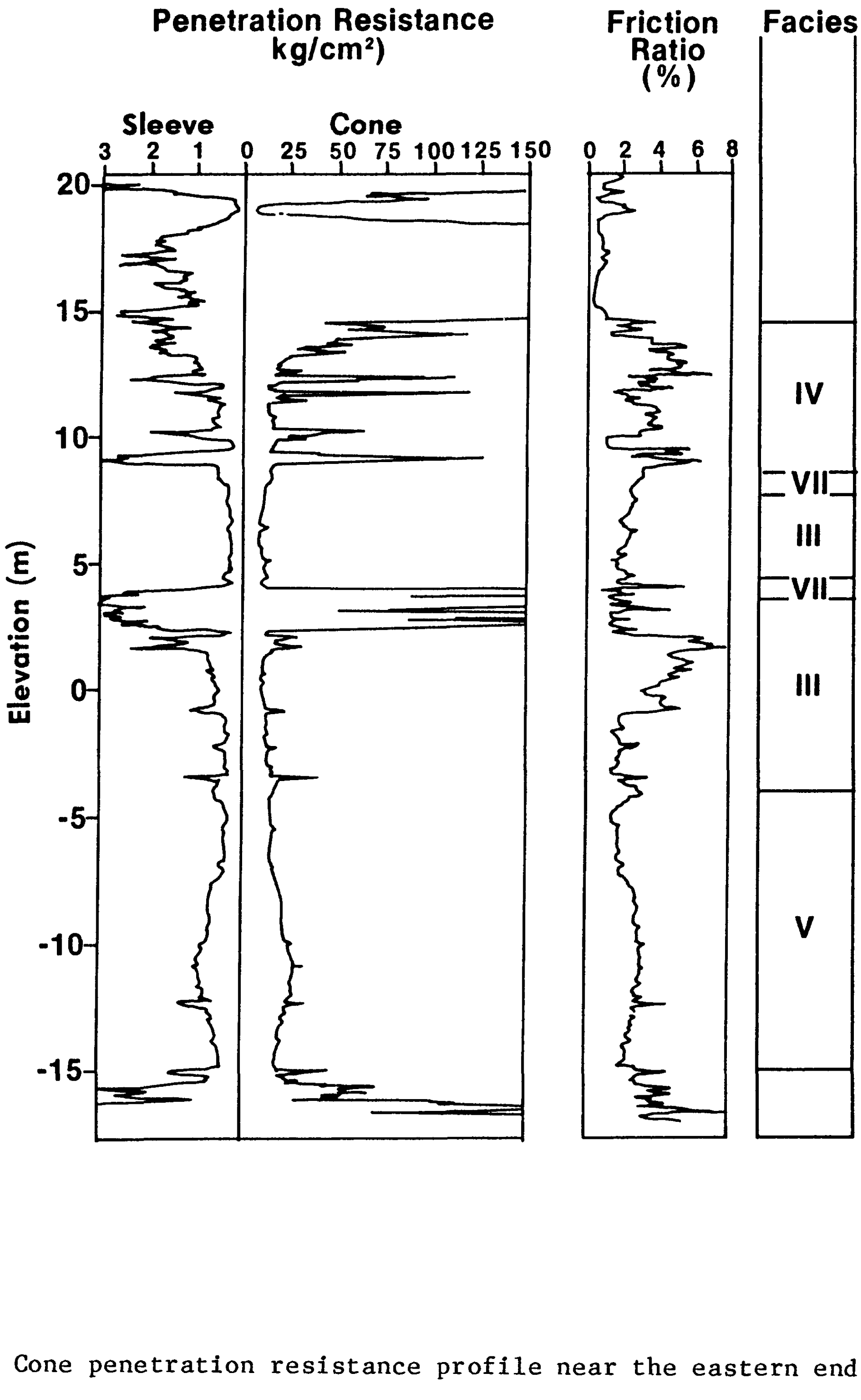


Figure 2. Cone penetration resistance profile near the eastern end of the Turnagain Heights landslide.

9B8 20130

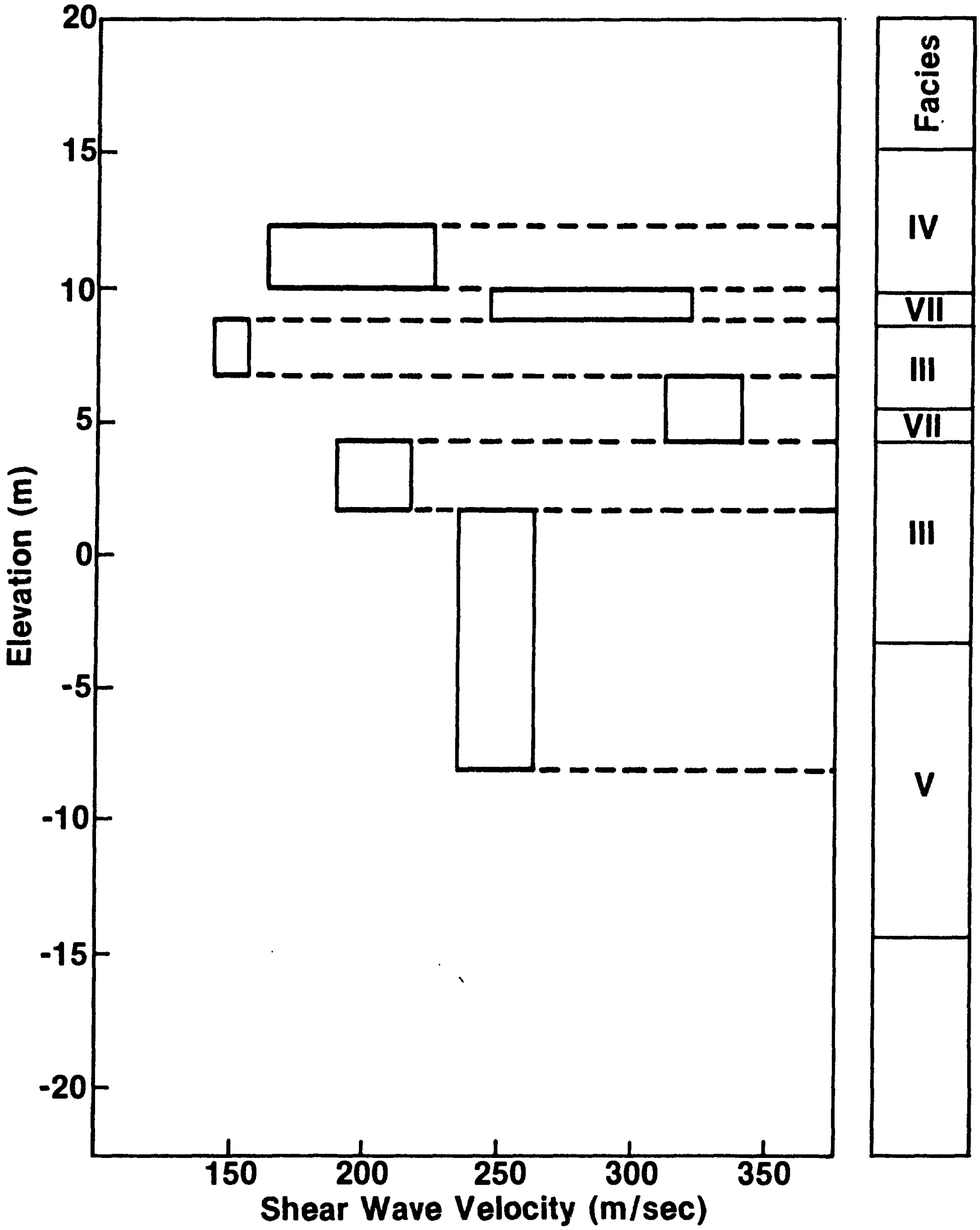


Figure 3. Shear wave velocity profile near the eastern end of the Turnagain Heights landslide.

954 20130

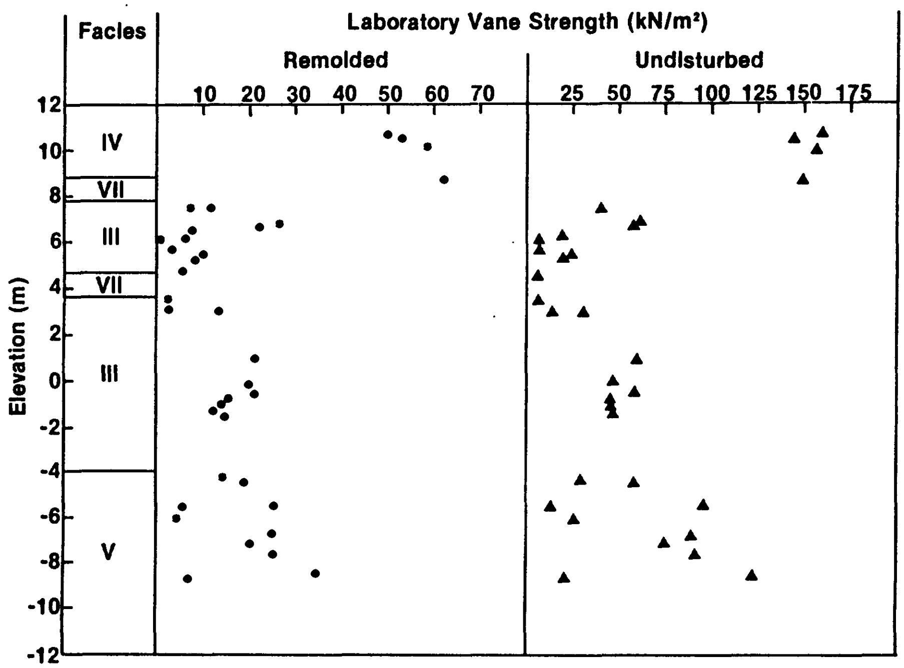


Figure 4. Remolded and undisturbed laboratory vane strength profiles on the nearly-continuous cores from near the eastern end of the Turnagain Heights landslide.

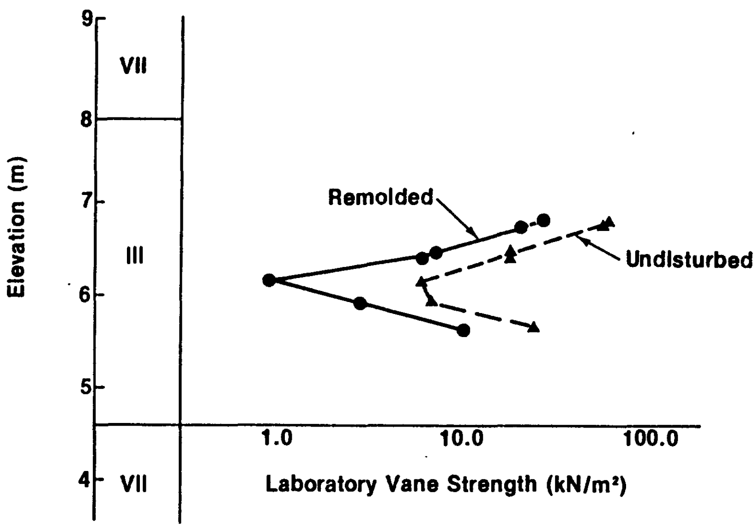


Figure 5. Remolded and undisturbed laboratory vane strength data on the core between elevations 5.3 and 6.8 m.

958 20130

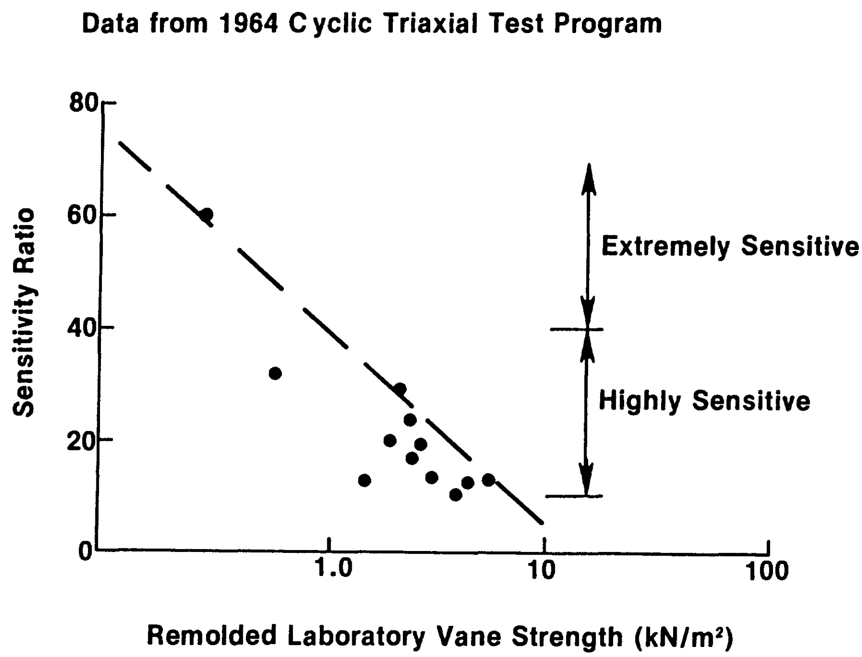


Figure 6. Correlation of sensitivity ratio with remolded laboratory vane strength, based on data from the 1964 cyclic triaxial test program.

9B4 20130

the 1964 cyclic test program (Shannon and Wilson, 1964). The correlation is defined by the upper bound of the data points in recognition of the fact that even though extreme care was used to minimize sampling disturbance when these samples were taken, sampling disturbance cannot be completely avoided and hence the sensitivity ratio values obtained on undisturbed samples are less than in situ values.

Figure 4 shows that highly sensitive materials occur in strata of varying thickness at several depths in the profile. Highly sensitive strata are present not only in the soft middle zone of the formation, but also in the lower zone. Between these highly sensitive strata, the materials are of low to medium sensitivity.

The thickest and most sensitive stratum in figure 4 is in the upper part of the middle zone between the sand layers, consistent with the location of the minimum values of cone penetration resistance and shear wave velocity in figures 2 and 3. This sensitive stratum is also evident in the 1964 data from both the eastern and western ends of the Turnagain Heights Landslide, and its elevation is consistent with the elevation of the failure plane of the Turnagain Heights Landslide (Shannon and Wilson, 1964). Also, comparison of figures 4 and 6 indicates the sensitivity of this stratum is generally consistent with the sensitivity of the samples that were used in the laboratory cyclic triaxial test program in 1964.

Within this highly sensitive stratum, at an elevation of about 6 meters, an interval of very-low-strength material, having the visual appearance of a fluid, was found between appreciably stronger materials above and below in a single 4 and 1/2 in-diameter by 5 ft-long shelby tube sample. The strength data obtained on this core are shown in figure 5. The remolded strength data indicate the very-low-strength interval consists of extremely sensitive material.

In the same interval, the very low undisturbed strength is also of interest because the presence of such low strength material in situ is neither plausible nor evident in the in situ cone penetration and shear wave velocity data (figures 2 and 3). It therefore appears that the undisturbed strength values obtained on this core are low, compared with in situ values, due to sampling disturbance. Moreover, the closely associated variations of undisturbed and remolded strength values with depth indicate that sampling disturbance decreases the undisturbed strength by an amount that increases with the sensitivity of the material. This relation is further indicated, in figure 4, by the closely associated variations of undisturbed and remolded strengths with depth for the entire profile.

Figure 7 shows the pore fluid chemistry data plotted to facilitate comparisons with the remolded strength data in figures 4 and 5. The data show chemical conditions in the middle and lower zones of the formation consistent with those associated with sensitive clays in both Canada and Scandinavia, namely, a low total concentration of dissolved solids (TDS), and a predominance of monovalent cations compared with divalent cations (Mitchell, 1976; Quigley, 1980; Torrance, 1975, 1983). It is well known that these conditions are required for the dispersion of clay particles.

The data in figure 7 further show marked anomalies (reversal of trends with depth) in the concentrations of organic carbon and anions in the most sensitive stratum in the profile. Previous studies have shown that organic matter is often associated with extremely sensitive clays, particularly in Scandanavia (Soderblom, 1974). Regarding anions, very little is known about their importance as controls on the sensitivity of clays in other locations. In the Bootlegger Cove clays, the geochemical reactions involved and the regional controls on their occurrance remain to be determined.

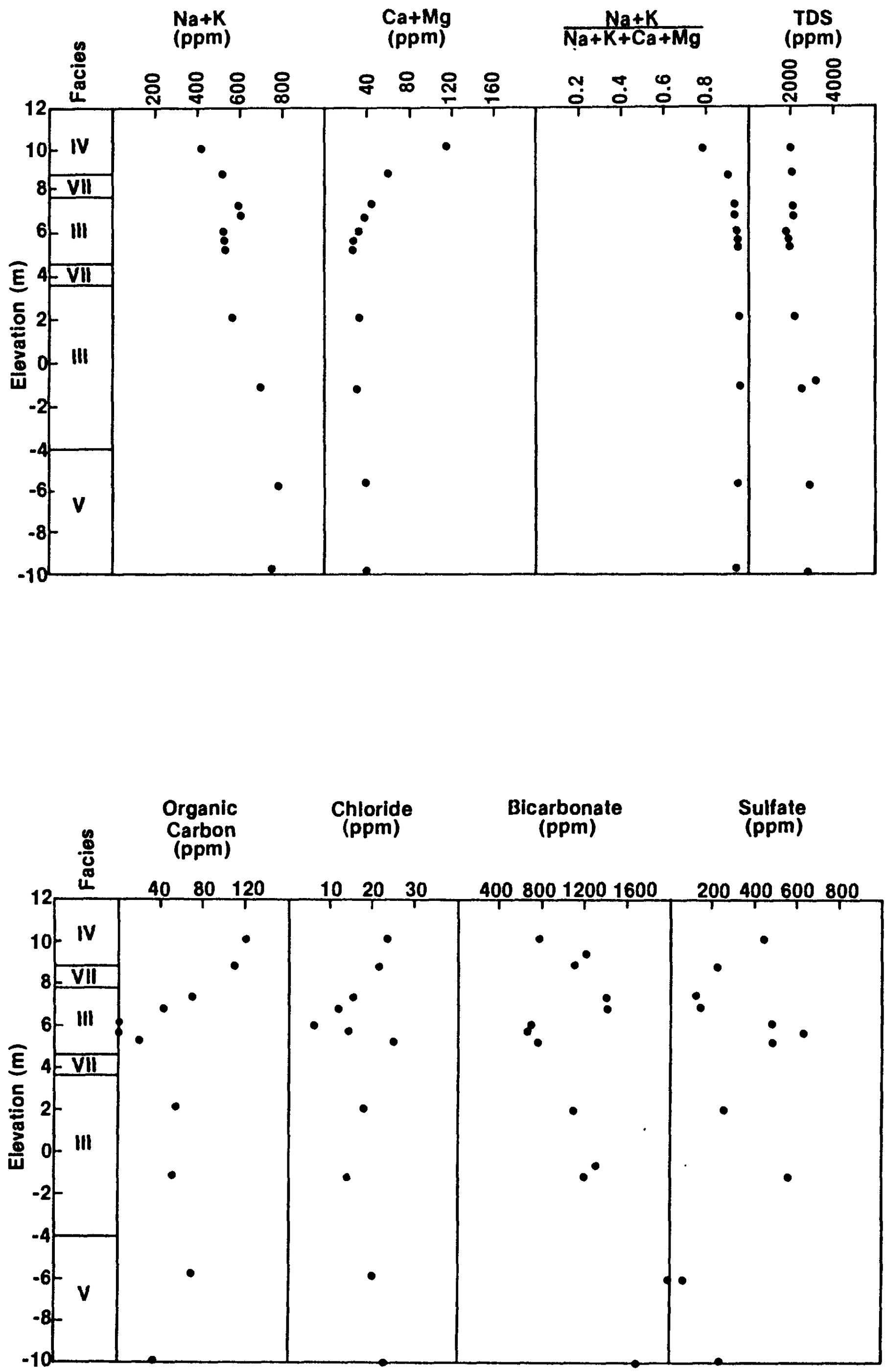


Figure 7. Pore fluid constituent concentration profiles in the nearly-continuous cores from near the eastern end of the Turnagain Heights landslide.

9S6 20130

RESEARCH NEEDS

The issues that need to be clarified, concerning the distribution and severity of earthquake-induced ground failure hazards from sensitive clays in the Bootlegger Cove Formation, include the geologic origin, regional distribution, and in situ properties of the highly and extremely sensitive strata in the formation.

It needs to be recognized that these issues cannot be addressed effectively either with existing data or with conventional soil property testing methods. The existing data are based primarily on samples obtained with conventional sampling methods that are incapable of retrieving good quality samples of highly sensitive materials. Existing dynamic laboratory testing methods have rarely been used because they are expensive, and also because the significance of the results that can be obtained is clouded by disturbance effects of unknown magnitude. Finally, appropriate in situ methods for identifying highly sensitive strata and for measuring their dynamic properties have yet to be developed.

Significant research concerning these issues will require innovative experimental approaches: (1) that enable sensitive clays to be differentiated and classified not only in terms of their strength loss potential but also with regard to the rate at which their strength deteriorates with disturbance, (2) that allow disturbance effects either to be avoided, or measured and taken into account, in both in situ and laboratory measurements; and (3) that are designed to obtain not only geotechnical data but also the geochemical and geologic data needed for understanding the regional controls on the distribution and in situ properties of the most sensitive clay strata in the Bootlegger Cove Formation.

REFERENCES CITED

Hansen, W.R., 1965, Effects of the earthquake of March 27, 1964, at Anchorage, Alaska: U.S. Geological Survey Professional Paper 542A, p. A1-A68.

Idriss, I.M., and Moriwaki, Yoshihaiu, 1982, Anchorage Office Complex geotechnical investigation, Anchorage, Alaska, V. 1, Seismic hazards evaluation: San Francisco, Woodward-Clyde Consultants, p. 6-1 to 6-3.

Mitchell, J.K., 1976, Fundamentals of Soil Behavior: John Wiley and Sons, New York, 422p.

Quigley, R.M., 1980, Geology, minerology, and geochemistry of Canadian soft soils: a geotechnical perspective: Canadian Geotechnical Journal, V. 17, p. 261-285.

Seed, H.B., 1968, Landslides during earthquakes due to soil liquefaction: Journal of the Soil Mechanics and Foundations Division, ASCE, V. 94, no. SM 5, p. 1055-1122.

Seed, H.B., and Wilson, S.D., 1967, The Turnagain Heights landslide, Anchorage, Alaska: Journal of the Soil Mechanics and Foundations Division, ASCE, V. 93, p. 325-353.

Shannon and Wilson, Inc., 1964, Report on Anchorage area soil studies, Alaska: Shannon and Wilson, Inc., Seattle, Washington, Inc., 109 p.

Soderblom, Rolf, 1974, New lines in quick clay research: Reprints and Preliminary Reports No. 55, Swedish Geotechnical Institute, Stockholm, 468p.

Soderblom, Rolf, 1974, Organic matter in Swedish clays and its importance for quick clay formation: Swedish Geotechnical Institute Proceedings No. 26, 89p.

Torrance, J.K., 1975, On the role of chemistry in the development and behavior of sensitive marine clays of Canada and Scandanavia: Canadian Geotechnical Journal, v. 12, p. 326-335.

Torrance, J.K., 1983, Towards a general model of quick clay development: Sedimentology, V. 30, p. 547-555.

Updike, R.G., 1984, The Turnagain Heights landslide--an assessment using the electric cone penetration test: Alaska Division of Geological and Geophysical Surveys, Report of Investigations 84-13, 48p.

Updike, R.G., and Carpenter, B.A., in press, Engineering geology of the Government Hill area, Anchorage, Alaska: U.S. Geological Survey Bulletin.

Updike, R.G., Olsen, H.W., Schmoll, H.R., Kharaka, Y.F., Stokoe, K.G., in press, Geologic and geotechnical conditions adjacent to the Turnagain Heights landslide, Anchorage, Alaska; U.S. Geological Survey Bulletin.

USGS ENGINEERING GEOLOGY PROJECTS IN THE ANCHORAGE AREA, ALASKA: A REVIEW

by

Henry R. Schmoll
U. S. Geological Survey
Denver, CO 80225

INTRODUCTION

Anchorage began in 1915 as a tent city near the mouth of Ship Creek. It was built to support construction of the Alaska Railroad, itself one of the major engineering works of the state. Little thought was likely to have been given to siting conditions for new construction in the city, at least for anything as light and temporary as a group of tents. Soon, however, permanent structures were built, and the center of town moved up from Ship Creek valley to its present site, the smooth-surfaced gravel plain on which our workshop is taking place (Capps, 1940, p. 12). It seemed like a good place for a town: there were good, well-drained natural foundation conditions, plenty of gravel and sand for construction purposes, and, as time went on, a good place for an airfield. Eventually an artesian water supply was discovered that bubbled up from beneath a thick bed of clay. The inhabitants thought they had it quite good.

The catastrophic events of March 27, 1964, proved somewhat otherwise, and ever since then there has been some awareness that earthquakes and earthquake-induced landslides would have to be contended with. Eventually there were even maps that indicated in a general way where such landsliding might take place, as well as the many other places where it almost certainly would not.

Any new construction in the metropolitan area, should, one would think, take earthquake shaking and slope instability into account; some siting and design of construction seem to, more and more these days, whereas others most clearly seem not to have done this. Questions that legitimately arise include: (1) How seriously should carefully devised guidelines intended to warn of such hazards be taken? (2) How thoroughly are the guidelines based on scientific knowledge? (3) How sound is that scientific knowledge? (4) How did it reach its present level? and (5) Is that level adequate for the purpose intended, and if not, what further level must be attained? This paper will attempt to review some aspects of these questions, and in so doing will touch upon the developing relationship between various parts of the geologic and engineerng communities and the community at large that occupies the burgeoning metropolitan Anchorage area.

Geological research related to local earthquake-hazards investigations in the metropolitan Anchorge area can be considered to have begun about 36 years ago. Its early stages were dominated by workers of the Engineering Geology Branch of the U. S. Geological Survey (USGS). Work by these individuals and successive investigators has continued intermittently to the present, and this review is devoted principally to summarizing that work. From the beginning, concurrent studies by the Water Resources Division of the USGS (WRD) have contributed on a steady basis, and work by other organizations, in particular the Alaska Division of Geological and Geophysical Surveys (ADGGS), has become increasingly important in recent years. In this paper, however, these other efforts are discussed only as they relate to the USGS engineering and environmental geology investigations.

The main purpose of this review is to establish a context within which ongoing and newly proposed geological and seismological research may be placed. It may refresh the memories of those who have been on the scene through a substantial part of this time, and serve as a guide and perhaps note of caution for more recent workers who may have only a more casual view of the history of previous investigations. The goals of past projects will be presented briefly, including consideration of the varying extent to which they were concerned with earthquake-hazard evaluation. Some assessment will be made as to how well the goals appear, at least from one vantage point, to have been met. This review then might also serve as a point of departure for a discussion by others at this workshop who have used information from these investigations, regarding how they perceive the success or failure of the investigations in reaching their goals, and how they regard the strengths and weaknesses of the projects. Future investigations might then avoid past pitfalls and proceed instead in directions that may be more fruitful.

Much of the content of this review has been gleaned from material in the files of the projects under consideration, and from discussions over a period of many years with the personnel involved, especially pioneers Ernest Dobrovolny and Robert D. Miller, who until recently shared an office in their mutual period of retirement, and to whom acknowledgment is warmly given.

PREVIOUS PROJECTS

The project of Dobrovolny and Miller, 1949-1959

In 1948, within a few years of the formal establishment of an organizational base within the USGS for undertaking regional and urban area engineering geological studies, Ernest Dobrovolny made a brief trip to Alaska to determine the desirability, if any, of undertaking such work in what was then still a remote outpost of urban America--Alaska was still 11 years away from statehood. From Denver, Colorado, where the Engineering Geology Branch was newly ensconced after a departure from traditional USGS headquarters at Washington, D. C., three or four urban centers in Alaska appeared to be perhaps equally qualified candidates for such studies. Dobrovolny recommended selection of Anchorage, correctly predicting that it was the area most likely to expand and thus where the greatest benefit would accrue from the proposed investigations.

Consequently the first Anchorage project was begun in 1949 by Dobrovolny and R. D. Miller, with field work in that and the next few years. The principal effort of that project was to produce the first, and still the most basic, geologic map of the metropolitan area, published originally in a preliminary version (Dobrovolny and Miller, 1950), and later in final form (Miller and Dobrovolny, 1959), at about the same time that Alaska achieved statehood. Another principal thrust of the project was to decipher the geologic history of the area, mainly concerned with Pleistocene glaciation, on the basis of the detailed local work. The conclusions were at variance somewhat with concurrent but more regionally based interpretations of Karlstrom (1964), and to a lesser degree with those of WRD workers (Cederstrom and others, 1964). Efforts were made during the 1950s to reconcile opposing views, but without much success [Miller allegedly had thoughts of pushing Karlstrom off the cliff during one discussion], and the ground was laid for variant interpretations and unresolved problems of reconstructing geological events that persist to the present. These controversies are regarded mostly as an indication of (1) the complexities of the local geology, (2) the incompleteness of the preserved geologic record, and, especially, (3) the remaining need for the enhanced dating of deposits that may lead to a more satifactory resolution of geological uncertainties than has been attained heretofore.

A major achievement of the project was the identification and naming of the single most significant geologic unit within the metropolitan area, the Bootlegger Cove Formation (nee Bootlegger Cove Clay). The project also sampled and analyzed physical properties of this and other principal geologic units that underlie the metropolitan area. These early determinations were to become important as the first guide to behavior of geologic materials in response to construction processes that accompany urbanization, as well as to naturally occurring seismically induced disturbance. The Dobrovolny-Miller project was not directed at delineation of earthquake hazards per se, which at that time were considered as but one aspect of a broader regional engineering geologic investigation. Nevertheless, there was an awareness of the potential for strong ground motion resulting from large magnitude earthquakes. The role that the very soft Bootlegger Cove Formation could play in developing large-scale ground failure during such seismic events was duly noted in a prophetic paragraph (Miller and Dobrovolny, 1959, p. 103-104). The implications of those statements were to be realized more quickly and with greater impact than the authors probably could foresee.

<u>Work immediately following the 1964 earthquake</u>

A vast investigative effort was undertaken by a veritable army of workers from all possible geological and related organizations following the devastating earthquake of March 27, 1964. This effort took place throughout southern Alaska, was reported voluminously, and is summarized, for example, by Eckel (1970). Although investigations relevant to the Anchorage area are reported in a number of publications, the principal summary of geologic effects in the Anchorage area is that of Hansen (1965). In particular, he included concise descriptions of the major areas of ground failure that were the principal causes of property damage and financial loss. The investigations summarized therein, based on large amounts of new data, greatly enhanced establishment of the nature of the geologic problems that remain fundamental to wise and safe land use. Nevertheless, basic questions, particularly as to precise mechanisms of ground failure within the Bootlegger Cove Formation, were not resolved by these intense but relatively short-lived studies. Consequently the determination of suitable measures to solve the geological problems in a way satisfactory for optimum land use development and minimization of risk was not attained at that time, nor has it been since.

The project of Dobrovolny and Schmoll, 1965-1974

In the years following statehood, and prior to the 1964 Alaska earthquake, another event pertinent to this summary of geological studies occurred: the establishment of the Greater Anchorage Area Borough (GAAB). This new governmental entity lay outside of the preexisting City of Anchorage (restricted mainly to what is now the downtown area) but occupied a large part of the metropolitan area, as well as including a much larger area within the Chugach Mountains to the east. The events of 1964 did make clear, at least to some, the desirability of a basic land use oriented geologic investigation as a prerequisite for logical guidance to the development of this relatively vast and geologically not well known area ["how many other surprises do the rocks have in store for us?"]. Consequently, when special longer-term funding for post-earthquake geologic investigations was under consideration by the U.S. Congress, the GAAB requested that the USGS undertake studies comparable to those begun in 1949 but that would extend such work into the new GAAB area. The time and mood was right for such a request, and it was indeed granted; it is unlikely, however, that the request would have been made at all without the firm guidance of Lidia Selkregg, then member of the GAAB Planning Commission, and, ever since, the outspoken conscience of geology at various administrative, political, and educational levels within the Anchorage area.

In 1965 the proposed project was begun by Dobrovolny and the present writer, and indeed in its early years was devoted mainly to work within the "back country" of the GAAB, although at least some of the new area, especially that northeast of the city along Knik Arm, was and still is the site of continued urbanization. In addition to relatively conventional geologic studies, another thrust of the project was an effort to make geology and its application to land use planning a larger part of the awareness of those responsible for the orderly development of the area (Dobrovolny and Schmoll, 1968). In this connection, and in company with personnel of the WRD, whose cooperative studies with both the City and the GAAB were well established, numerous meetings and field trips were held with GAAB administrative and political leaders, and it is hoped that at least some groundwork was laid for the continued interest in and further acceptance of geological input to the land-development process. Paradoxically, it was apparent from the start that in the area of the City, where most of the principal landslide destruction occurred, and where many of the geotechnical puzzles still lay, the politicoeconomic environment was not amenable to such geoproselytization. Efforts of the project, both geoscientific and geopolitical, were not aimed in that direction to the extent that it now may seem that they might have been.

Nevertheless, as time passed, it became apparent that by far the greater interest and need was for increased work within the metropolitan area, including the area of the City and of the previous project, in part because of the increase in data becoming available as development proceeded, compared to what was available in 1949. Furthermore, the creation of Chugach State Park in the mountains directly east of the metropolitan area precluded imminent exurbanization of that area and thus reduced the immediate need for much of the work undertaken there. The resulting change in project direction culminated in the publication of a so-called folio series of geological derivitive maps (Schmoll and Dobrovolny, 1972a, 1972b, 1973, 1974; Dobrovolny and Schmoll, 1974; Freethey, 1976). These maps utilized a more modern and larger-scale base map than the earlier work, albeit one made just before the 1964 earthquake and consequently somewhat outmoded. Each folio map was restricted in subject matter and designed to be more readily understandable to nongeological users than a conventional geologic map. This procedure was fashionable at the time and widely employed elsewhere in the nation. Whether the procedure, and the philosophy underlying it, was appropriate, a point about which the writer has subsequently entertained some doubt, is perhaps a suitable topic for discussion at this workshop. Concurrently, under the auspices of the University of Alaska, further efforts at making both geological and other envioronment-related studies more readily available were undertaken (Selkregg and others, 1972). Meanwhile the nearly completed work in the larger part of the GAAB was somewhat neglected, and remains largely unpublished to this day.

One of the shortcomings of the folio series, philosophical considerations aside, was the lack of any presentation of subsurface data. The importance of this element was recognized, not only to meet the varied needs of the engineering profession, and of geologists reconstructing past events, but to provide data for seismologists as well, for at that stage it was also intended to begin work on earthquake-hazard evaluation. Plans were made in the latter stages of the project to continue the investigations in that direction, in cooperation with A. F. Espinosa and others, as well as with the WRD personnel in whose domain the subsurface lay. The time was not right, however; national priorities lay in more populous parts in the country, and the project under discussion came to a rather lame end.

Other work, 1974-1983

During this interval some efforts were made to continue the Anchorage project described above on informal basis, but publications were limited largely to a few temporary addenda to the folio series. These were developed to meet the needs of WRD reports or because of other local interest (for example, Zenone and others, 1974; Schmoll and others, 1980, 1981; Schmoll and Emanuel, 1981, 1983). In addition, however, some further stratigraphic work also continued (Schmoll and Gardner, 1982).

Related work by the present writer and others on the west side of Cook Inlet did, however, provided a needed broader regional understanding of the Cenozoic geology of upper Cook Inlet basin. Such efforts have begun to yield a basin-wide synthesis (Schmoll and Yehle, 1983; Schmoll and others, 1984) that will aid further work in the Anchorage area as well.

During this period the first serious work on the sediments in Turnagain Arm, most of which are exposed at low tide and are under water at high tide, was undertaken by A. T. Ovenshine, Reuben Kachadoorian, and Susan Bartsch-Winkler (Ovenshine and others, 1976; Bartsch-Winkler and Ovenshine, 1984). Later some work of this type was extended to Knik Arm as well (Bartsch-Winkler, 1982; Bartsch-Winkler and Schmoll, 1984a, 1984b). While much of that effort was sedimentological in character, it has provided a framework and basic understanding of these extensive deposits not previously available. The importance of these studies will no doubt increase in future years as proposed arm crossings and other offshore structures inevitably become realized.

A single USGS/Engineering Geology initiative consisted of a new investigation in the vicinity of the Turnagain Heights landside of 1964, undertaken by H. W. Olsen, a project that involved drilling, coring, and testing of material from the Bootlegger Cove Formation (Olsen, this volume). This work, done cooperatively with R. G. Updike of the ADGGS, among others, has attempted to delve into the question of mechanisms of earthquake-induced landslides, and while not providing all the answers, it at least points the way to finding such answers. The first principal report of this work is now finalized (Updike and others, in press).

The dominant engineering geologic effort during this period, however, was the ADGGS program of further investigations into the nature of the Bootlegger Cove Formation led by R. G. Updike, and funded cooperatively with the USGS (Updike, this volume). Large amounts of accruing data on distribution of the formation and on its physical properties and engineering geologic characteristics were synthesized, and, in addition, imaginative new approaches were used in gathering further data. This work, combined with that of Olsen, neatly complements the earlier work described above, and furthermore bears more directly than any of the earlier investigations on the problem of earthquake-induced ground failure.

On the politcal scene the major event of this period was the union of the former City of Anchorage and GAAB to form a new, all-encompassing entity, the Municipality of Anchorage. Among other effects, this has given the engineering geological and seismological community a single political point of contact, a particularly logical development inasmuch as the former boundary between the two political units was not well recognized in the geology. Geopolitical strides that followed the union include, among others, (1) establishment of the Anchorage Geotechnical Commission, an advisory group that is made up largely of representatives of a greatly expanded private sector in the engineering and geological fields, and that has substantially aided communication between the scientific-engineering and political communities, and (2) the inclusion of a geologist-planner, Barbara Sheinberg, on the staff of the Community Planning Department, developments that long were goals of the Dobrovolny-led projects.

CURRENT PROJECT

Beginning in about 1983, and coincidentally concurrent with the organizational consolidation within the USGS of the engineering geology and seismology elements that earlier had been proposed to meld into a continuation of the Anchorage project, a phoenicular new Anchorage project did arise. This project, led by A. F. Espinosa, is designed in effect to take on the remaining tasks that were originally intended to carry the previous project to its logical conclusion (Espinosa and others, this volume).

Among the early efforts of this new project has been resumption of subsurface studies, of which the first preliminary report has appeared recently (Schmoll and Barnwell, 1984). These subsurface studies are intended to lead to completion, in effect, of the old folio series, with production of one or more subsurface maps (as implied in Schmoll and others, 1985).

In addition, the uncompleted geologic maps of the entire municipality are in active preparation for publication once again, both at the scales of the existing mapping for much of the mountainous part of the area, and at the larger 1:25,000 scale of the post-1964 topographic base maps. This work will be accomplished in cooperation with R. G. Updike and others of the ADGGS, who have meanwhile begun more detailed mapping in parts of the area (for example, Updike and Ulery, 1983).

CONCLUDING REMARKS

At various times it began to appear from this vantage point that, after some years of effort to establish ties necessary for significant utilization of the geological work, not very much had actually been accomplished along these lines, and there was uncertainty as to whether the earlier geologic efforts would have very much of the intended impact. Today, however, in light of the developments cited above, there seem to be grounds for guarded optimism, and the wideranging nature of the participants at this workshop, and even the very existence of the workshop itself, are added evidence to support this view.

As the current and newly proposed projects progress, the results of the mainly geologic investigations discussed here will be combined with seismological data compiled from existing and newly acquired records to yield the long-sought areal evaluation of response to strong ground motion caused by major earthquakes. Such information, together with the advanced analyses of the behavior of the Bootlegger Cove Formation as proposed by Olsen (this volume), will complete the package of seismogeotechnical data, the first elements of which were initiated about 36 years ago. The community will then have, for the first time, an adequate database on the basis of which scientifically supportable recommendations on appropriate land use can reasonably be made.

It may seem naive, in retropsect, to have thought that such a necessarily broad foundation could be achieved by a single two or three year project staffed by two young and enthusiastic geologists, or even by subsequent more extended projects staffed by a small number of more experienced but thus older personnel. Yet a beginning had to be made, and it was. And, as inevitably needed, further work continued slowly, while the community itself continued to grow and mature. We now have in sight the completion of the first round in the acculumation and interpetation of the necessary data. And it appears that we also have a community that has taken at least the initial steps toward the wise utilizaton of these data and interpretations.

REFERENCES

Bartsch-Winkler, Susan, 1982, Physiography, texture, and bedforms in Knik Arm, upper Cook Inlet, Alaska, during June and July, 1980: U.S. Geological Survey Open-File Report 82-464, 6 p, 1 sheet, scale 1:63,360.

Bartsch-Winkler, Susan, and Ovenshine, A. T., 1984, Macrotidal subarctic environment of Turnagain and Knik Arms, upper Cook Inlet, Alaska: Sedimentology of the intertidal zone: Journal of Sedimentary Petrology, v. 54, no. 4, p. 1221-1238.

Bartsch-Winkler, Susan, and Schmoll, H. R., 1984a, Convoluted beds in late Holocene intertidal sediment at the mouth of Knik Arm, upper Cook Inlet, Alaska: U.S. Geological Survey Circular 868, p. 105-108.

______1984b, Bedding types in upper Holocene distributary tidal channel sequences, Knik Arm, upper Cook Inlet, Alaska: Journal of Sedimentary Petrology, v. 54, no. 4, p. 1237-1248.

Capps, S. R., 1940, Geology of the Alaska Railroad region: U.S. Geological Survey Bulletin 907, 201 p.

Cederstrom, D. J., Trainer, F. W., and Waller, R. M., 1964, Geology and ground-water resources of the Anchorage area, Alaska: U.S. Geological Survey Water Supply Paper 1173, 108 p.

Dobrovolny, Ernest, and Miller, R. D., 1950, Descriptive geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Open-File Report, 11 p., 2 maps.

Dobrovolny, Ernest, and Schmoll, H. R., 1968, Geology as applied to urban planning: an example from the Greater Anchorage Area Borough, Alaska: International Geological Congress, 23d, Prague, 1968, Proceedings, Section 12, Engineering geology in country planning, p. 39-56. Reprinted, 1975, in Betz, Frederick, Jr., ed., Environmental geology: Benchmark Papers in Geology, v. 25, p. 49-66. Reprinted, 1976, in Tank,

R. W., ed., Focus on environmental geology: New York, Oxford University Press, p. 11-26.

______1974, Slope stability map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-E, scale 1:24,000.

Eckel, E. B., 1970, The Alaska earthquake, March 27, 1964: Lessons and conclusions: U.S. Geological Survey Professional Paper 546, 57 p.

Freethey, G. W., 1976, Relative permeability of surficial geologic materials, Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Investigations Map I-787-F, scale 1:24,000.

Hansen, W. R., 1965, Effects of the earthquake of March 27, 1964, at Anchorage, Alaska: U.S. Geological Survey Professional Paper 542-A, 68 p.

Karlstrom, T. N. V., 1964, Quaternary geology of the Kenai lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 443, 69 p.

Miller, R. D., and Dobrovolny, Ernest, 1959, Surficial geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Bulletin 1093, 128 p.

Ovenshine, A. T., Bartsch-Winkler, Susan, O'Brien, N. R., and Lawson, D. E., 1976, Sedimentation in the high tidal range environment of Turnagain Arm, Alaska, in Miller, T. P., ed., Recent and ancient sedimentary environments in Alaska: Anchorage, Alaska Geological Society Symposium Proceedings, p. M1-M26.

Schmoll, H. R., and Barnwell, W. W., 1984, East-west geologic cross section along the DeBarr line, Anchorage, Alaska: U.S. Geological Survey Open-File Report 84-791, 11 p., 1 pl.

Schmoll, H. R., and Dobrovolny, Ernest, 1972a, Generalized geologic map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-A, scale 1:24,000.

______1972b, Slope map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-B, scale 1:24,000.

______1973, Construction materials map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-C, scale 1:24,000.

______1974, Foundation and excavation conditions map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-D, scale 1:24,000.

Schmoll, H. R., Dobrovolny, Ernest, and Gardner, C. A., 1980, Preliminary geologic map of the middle part of the Eagle River valley, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 80-890, 11 p., 1 pl., scale 1:25,000.

______1981, Preliminary geologic map of Fire Island, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 81-552, 4 p.

Schmoll, H. R., and Emanuel, R. P., 1981, Generalized geologic map and hydrologic properties of the Potter Creek area, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 81-1168, 1 pl., scale 1:25,000.

______1983, Geologic materials and hydrogeologic characteristics in the Fire Lakes-Eklutna area, Anchorage, Alaska: U.S. Geological Survey Open-File Report 83-479, 1 pl., scale 1:25,000.

Schmoll, H. R., and Gardner, C. A., 1982, Diamicton of subglacial or subaqueous origin, Fire Island, Anchorage, Alaska: International Union for Quaternary Research (INQUA), XI Congress, Moscow, U.S.S.R., Abstracts, v. 1, p. 282.

Schmoll, H. R., Odum, J. K., and Espinosa, A. F., 1985, Seismotechnistratigraphic cells: an approach to the analysis of subsurface geology at Anchorage, Alaska, for seismic zonation stuidies: Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 710.

Schmoll, H. R., and Yehle, L. A., 1983, Glaciation in the upper Cook Inlet basin: a preliminary reexamination based on geologic mapping in progress, in Thorson, R. M., and Hamilton, T. D., eds., Glaciation in Alaska--Extended abstracts from a workshop: Alaska Quaternary Center, University of Alaska Museum Occasional Paper no. 2, p. 75-81.

Schmoll, H. R., Yehle, L. A., Gardner, C. A., and Odum, J. K., 1984, Guide to surficial geology and stratigraphy within the upper Cook Inlet basin [prepared for the 80th annual meeting of the Cordilleran Section, Geological Society of America]: Anchorage, Alaska Geological Society, 89 p.

Selkregg, L. L., and others, 1972, Environmental atlas of the Greater Anchorage Area Borough, Alaska: Anchorage, University of Alaska, Arctic Environmental Information and Data Center, 105 p.

Updike, R. G., Olsen, H. W., Schmoll, H. R., Kharaka, Y. K., and Stokoe, K. H., in press, Recent subsurface geologic and geotechnical srtudies adjacent to the Turnagain Heights landslide in Lynn Ary Park, Anchorage, Alaska: U.S. Geological Survey Bulletin.

Updike, R. G., and Ulery, C. A., 1983, Preliminary geologic map of the Anchorage B-6 NW (Eklutna Lake) quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-8, 2 pl., scale 1:10,000.

Zenone, Chester, Schmoll, H. R., and Dobrovolny, Ernest, 1974, Geology and ground water for land-use planning in the Eagle River-Chugiak area, Alaska: U.S. Geological Survey Open-File Report 74-57, 25 p., 1 pl.

FORMULATING EARTHQUAKE RESISTANT DESIGN CRITERIA*

by

Paul C. Jennings

California Institute of Technology

Pasadena, California 91125

INTRODUCTION

The primary function of design criteria in general, and earthquake-resistant design criteria in particular, is to restate a complex problem that has unknowns and uncertainties into an unambiguous, simplified form having no uncertainties. The design criteria should provide clearly stated guidelines for the designers. For example, when actually designing a structure, an engineer needs to know the forces and deformations that the structure should be able to resist. Some of these forces, such as dead loads imposed by gravity, are well known, but other that result from transient actions of nature or man, such as earthquake, wind or live loads, are not known. This lack of knowledge must somehow be circumvented and a precise, unambiguous statement of the design conditions must be given to the design engineer. This is accomplished by means of the design criteria. The designer also needs to know the properties of the materials and structural elements that will be used, but as these are not precisely known, mainly because of imperfections in materials and workmanship, the design criteria must also take this into account. In the preparation of the design criteria, allowance must be made for the uncertainties, and it is necessary to be cognizant of all the unknowns for which allowances must be made.

The traditional engineering design criteria, for example those in the Uniform Building Code, specify live loads that are greater than the actual loads typically encountered, and specify allowable design stresses that are appreciably less than the expected ultimate strength of the material. The purpose of this procedure is to ensure extra strength that is sufficient for unforeseen variations in loads, in material properties, and in workmanship.

---

* This paper is abstracted, with modifications, from the EERI Monograph "Earthquake Design Criteria" by G. W. Housner and P. C. Jennings.

These criteria, in effect, tell the design engineer: "if you design according to these requirements, the structure will be considered adequate." A similar approach could be taken for earthquake-resistant design if the conditions were more or less the same for all projects. However, because the seismic hazard varies markedly from place to place and because structures and facilities vary in importance, cost, length of life, ease of repair, materials of construction and consequences of failure, the formulation of seismic design criteria for other than ordinary buildings cannot, in general, be codified simply; special knowledge and judgment are required for formulating the criteria.

THE USE OF SEISMOLOGICAL AND GEOLOGICAL DATA

When designing structures for a seismic region, what the engineer would really like to know is the strongest ground shaking that the site under consideration will experience during the life-time of the planned facility. This pre-knowledge, however, is not available, so recourse must be had to estimating what might happen in the future by studying what has happened in the past. Seismological and geological data form the basis for estimating future ground motions, including shaking and possible fault rupture, and studies for important facilities sited where the possibility of major earthquakes must be considered nearly always involve geologists and seismologists.

The seismic history of a region in the U.S. shows what has happened in the recent past, for example the last two hundred years, and thereby gives an indication of what might be expected in the next two hundred years. In a similar way, geological studies can give information on the occurrence of faulting and earthquakes over a longer time span, typically thousands or hundreds of thousands of years, and can thereby provide longer term estimates of the activity of faults than is available from the historical record alone. In this sense the past is used by the geologists and seismologists to predict the future. The correct use of the recommendations of geoscientists by earthquake engineers requires an understanding of the terminology and concepts used by scientists.

EARTHQUAKE MAGNITUDE

Any measurement that characterizes the size of the area of strong shaking, or the extent of the "felt area," or the total energy released in shaking, could serve as an indication of the size of the earthquake. As originally developed by C. F. Richter at the California Institute of Technology, the earthquake magnitude scale uses as the pertinent measurement the peak amplitude recorded by a standard Wood-Anderson seismograph, which has a natural period of 0.8 seconds, approximately 80% of critical damping and a magnification of 2800. The peak amplitude, A, of Wood-Anderson seismograms varies over the surface of ground in a manner similar to the variation of intensity of ground shaking, being very small at large distances from the fault and thousands of times larger close to the fault; so for a measure, the $\log_{10}A$ is used. The plot of $\log_{10}A$ forms a hill-shaped surface and the volume of the hill would be a good measure of the size of an earthquake, but it would not be practical to evaluate. A less precise, but more practical, measure is that defined by Richter:

$$M_L = \log_{10}A - \mathrm{lotg}_{10}A_0(\Delta)$$

In this expression, M_L is the local magnitude, Δ is the epicentral distance in kilometers, and $A_0(\Delta)$ is the Wood-Anderson amplitude corresponding to an earthquake with magnitude zero. The variation of $A_0(\Delta)$ with distance was determined from data and the level was fixed by setting its value at 10^{-3} millimeters for a distance of 100 km. Two different seismographic stations will not, in general, compute the same value of M_L, and the "official" value is usually the weighted average from several records. Also, the magnification of the standard Wood-Anderson instrument and of almost all other seismographs is such that the instruments are driven off-scale by motion strong enough to be felt, so the use of seismographs to determine the magnitudes of larger earthquakes necessarily requires the readings to be made at large distances where the character of the ground motion is much different from that near the fault. At such distances, the motion does not contain direct information about the nature of the close-in, potentially destructive shaking.

Seismic waves change their character as they travel away from the causative fault. In particular, at larger distances the compression waves, shear waves and surface waves separate out and the nature of the waves also change. This has led to certain refinements in determining earthquake magnitudes, and other magnitude scales have come into use. The most common of these are the surface-wave magnitude M_s, the body-wave magnitude M_b, and the moment magnitude M_w. In general, the different magnitude scales do not give the same numerical values, although they agree at some levels and there are empirical techniques for converting from one to another. At distances of a thousand kilometers and more, surface waves of 20-second period predominate in observed seismograms and the amplitude of this motion is used to determine M_s, which is the value most commonly reported in the press for major earthquakes. Earthquakes smaller than about $M_L = 6$ typically do not generate enough surface waves for a determination, so the M_s scale is designed to agree with M_L for magnitudes in the range of 6 to 6-1/2. For larger earthquakes the value of M_s consistently exceeds that of M_L. For example, the 1906 San Francisco earthquake had the approximate magnitudes $M_s \approx 8.3$ and $M_L \approx 6.9$. The largest observed local magnitudes are in the 7 to 7-1/4 range, whereas surface wave magnitudes as high as 8.6 have been assigned.

For the very largest earthquakes in history, such as the Chilean earthquake of 1960 and the Alaskan earthquake of 1964, the surface-wave magnitude "saturates" in the sense that it cannot well distinguish two very large events of different fault lengths on the basis of the maximum amplitude of the 20-sec surface waves. For this reason H. Kanamori developed the moment magnitude, M_W. This magnitude scale is based on the total elastic strain energy released by the fault rupture, and this is related to the seismic moment M_0 defined by

$$M_0 = \mu AD$$

in which μ is the modulus of rigidity of the rock, A is the area of the rupture surface of the fault and D is the average fault displacement. M_0 can be estimated from geological evidence which defines the area and extent of rupture, or from records of long period seismographs at large distances, for which even the largest earthquake appears to be a relatively short event. Because M_W and M_0 do not saturate and do measure all the energy released, even that at periods of tens and hundreds of seconds, they are of more fundamental scientific interest to seismologists than the local magnitude, M_L. The largest earthquake on the moment magnitude scale is the Chilean event of 1960 which had a fault length of approximately 600 miles and an assigned value of $M_W = 9.9$, compared to $M_S = 8.6$.

Having these different magnitudes introduces an element of confusion into earthquake engineering. The most commonly used magnitudes, as given in Gutenberg's and Richter's Seismicity of the Earth (Ref. 4) or in the U.S.G.S. publication United States Earthquakes (Ref. 15), are M_L for moderately large earthquakes (M = 6.4 for 1971 San Fernando) and M_S for large earthquakes (M = 8.4 for 1964 Alaska).

The consistent use of M in this way means that its value will convey an idea of the size of the event. Because practices vary, it is advisable to ascertain what magnitude scales are used in any presentation concerning magnitudes.

SEISMOLOGICAL DATA

Depending on the region, seismological data are available in various amounts and degrees of quality. There are countries with some form of seismic record going back as much as two or three thousand years, while the historical record in the western United States is seldom as long as two hundred years. Instrumental seismology has, of course, a much shorter history with a maximum of about one hundred years. Similarly, there are some regions having networks of seismic instruments sufficiently good to record all perceptible shocks and to determine their locations to within a few kilometers; however, most seismic regions have much less extensive coverage. Seismological data of high quality imply instrumentally determined magnitudes and epicenters of all significant events, with locations accurate enough to correlate earthquakes with geologic features of the region. Earthquake data must include a sufficiently large number of events so that enough earthquakes of larger magnitudes are present to characterize events that must be considered in the design.

For engineering purposes the magnitudes are approximate indices of the size of the earthquake; the local magnitude gives a measure of the strength of shaking and M_s indicates the area that might be affected by strong ground motion. In earthquake engineering practice, it is customarily assumed that two earthquakes having the same magnitude will have similar characteristics, including ground shaking, other things being equal; but it should be kept in mind that other things (tectonic setting, depth of rupture, rock type, fault mechanism, rate of activity, etc.) are seldom entirely equal.

The adequacy of seismological data for purposes of design depends upon having sufficient earthquakes in the historical record, with magnitudes and locations determined, so that large magnitude events are also included. For example, if the data include only earthquakes having $M_L < 5$ the probability distribution for large earthquakes would not be defined and it would be of questionable reliability to extrapolate to the probability of earthquakes $M_s > 8$. Lacking sufficient data to define a probability distribution, it is customary in U.S. practice to assume a distribution for magnitudes that is consistent with the seismic history of California, even though this introduces a degree of uncertainty.

In the less seismic regions of the U.S., the seismological data are relatively few and are typically of poor quality. For example, in the eastern part of the country the available historical information on damaging earthquakes seldom includes the instrumentally determined local magnitude of the event but instead gives Modified Mercalli Intensity (MMI) numerals. The MMI index provides information of a lower quality than the magnitude, not only because it is based on personal observations of earthquake effects instead of instrumental records, but also because the actual interpretation is often unreliable.

GEOLOGICAL DATA

The seismic history of the United States, about one to three hundred years depending on location, is a relatively short time for assessing the frequency of earthquake occurrence. For reliable statistical studies to be made, the duration of the seismic history should be long compared to the average time between large earthquakes, a time which appears to range from as short as about one hundred years to several thousand years, depending on the degree of activity of the region. For example, major earthquakes away from continental margins, such as have occurred in central China and the central United States, appear to have the longest recurrence intervals.

The relatively short-time information provided by seismological history can be supplemented by geological information about long-time tectonic processes that are measured in thousands or hundreds of thousands of years. For example, faults that can be identified as having experienced slip during the past hundreds, thousands, or tens of thousands of years provide information about the seismic hazard of a region, but it is a difficult scientific problem to quantify this information.

In the best cases, the geological evidence will be sufficient to establish the length over which a fault has ruptured, the amount of cumulative fault displacement, and information about the period of time over which the movements have taken place. In addition, it is sometimes possible to make inferences concerning whether the fault has moved once, a few times, or many times during its active history. For faults that are active up to the present, geological data such as this can be used to help estimate the magnitudes and frequency of occurrence of earthquakes that may reasonably be expected in the future. It is equally useful if the geological data can be used to rule out the expectation of a specific fault generating an earthquake, which is an extremely important point for faults that may traverse or pass near the site of a critical facility and could pose a hazard both from shaking and fault displacement. If it can be demonstrated that the near surface geological materials are undisturbed, this is conclusive evidence that the fault has not ruptured (and thereby generated an earthquake) since the formation of the oldest undisturbed material. Depending on the age of material and the critical nature of the facility under design, the lack of movement over an established number of years may eliminate the fault from further consideration in formulating the design criteria. For most ordinary construction, a fault that has not moved in Holocene times (the last 11,000 years) can be considered inactive, whereas for the design of nuclear plants, it has been ruled that a fault that has moved once in the last 35,000 years or more than once in the last 500,000 years must be considered as a possible source of future earthquakes.

Depending on the geological data and the judgment of the geologist, various procedures have been employed to interpret the seismic hazard posed by a given fault. The crudest approach is that which simply assigns a maximum size to the earthquake that the fault can generate. This earthquake is variously known as the Maximum Capable Earthquake, Maximum Credible Earthquake, Safe Shutdown Earthquake, Contingency Level Earthquake, etc. For example, a fault whose discernible length is approximately 40 miles might be assigned a Maximum Capable Earthquake (MCE) of $M_s = 7$, or one with a discernible length of 15 miles might be assigned a MCE of $M_s = 6.5$. The MCE represents a "worst case" situation and by itself is not a very informative number, for it does not distinguish between a fault that will have events of the approximate size of the MCE once per 200 years and one for which the return period is once in 500,000 years, even though this information would be very important to engineers preparing seismic design criteria.

SEISMOLOGICAL AND GEOLOGICAL INFORMATION REQUIRED FOR DESIGN

Geological and seismological consultant should address the question of probability of occurrence. A report that merely states "the recommended design earthquake is a Magnitude $M_s = 7.5$ at a distance of 20 km," is incomplete because it gives no indication of the frequency of occurrence of the earthquake. In addition, the geoscientist has made a decision about engineering design which is outside his area of competence. The expertise of geological and seismological consultants is related to geologic and seismic hazards, and their reports should describe the possible earthquakes together with estimates of probability of occurrence, or the possible intensity of ground shaking together with its estimated probability of occurrence. The incorportion of the information into the design criteria should be the responsibility of persons who understand engineering design and the performance of structures, and who can balance the hazard posed by earthquakes with that posed by other problems such as flooding and extreme winds.

A seismological report on a site will usually contain an estimate of the frequency of occurrence of earthquakes within a specified region. For a large, relatively seismic, region, such as the state of California, a rather good estimate can be made because of the large number of historical earthquakes.

For smaller regions within California, or less seismic regions, the historical record of earthquakes may contain so few events that estimates will be unreliable. Usually it is assumed that the distribution of earthquakes of various magnitudes within a region is similar to the distribution for California, and the California distribution is scaled to fit the historical record of the region. This might be described in the report by saying that N earthquakes of magnitude M, or greater, are expected in a 100 year period, and this would be sufficient for constructing the frequency distribution. For some region of low seismicity it can be assumed that the probability of occurrence of very large earthquakes is negligibly small, but for other regions it may not be easy to decide whether or not the probability is negligible.

Strong motion accelerograms recorded in the past illustrate the kind of ground motions to be expected in the future, and the ground motion to be considered in the design can be described by three components of ground acceleration which are consistent with recorded accelerograms. The recommendations of an earthquake consultant should, preferably, present ground accelerations in the form of appropriate recorded accelerograms from particular earthquakes, or synthesized accelerograms that have appropriate intensity, duration, and frequency characteristics.

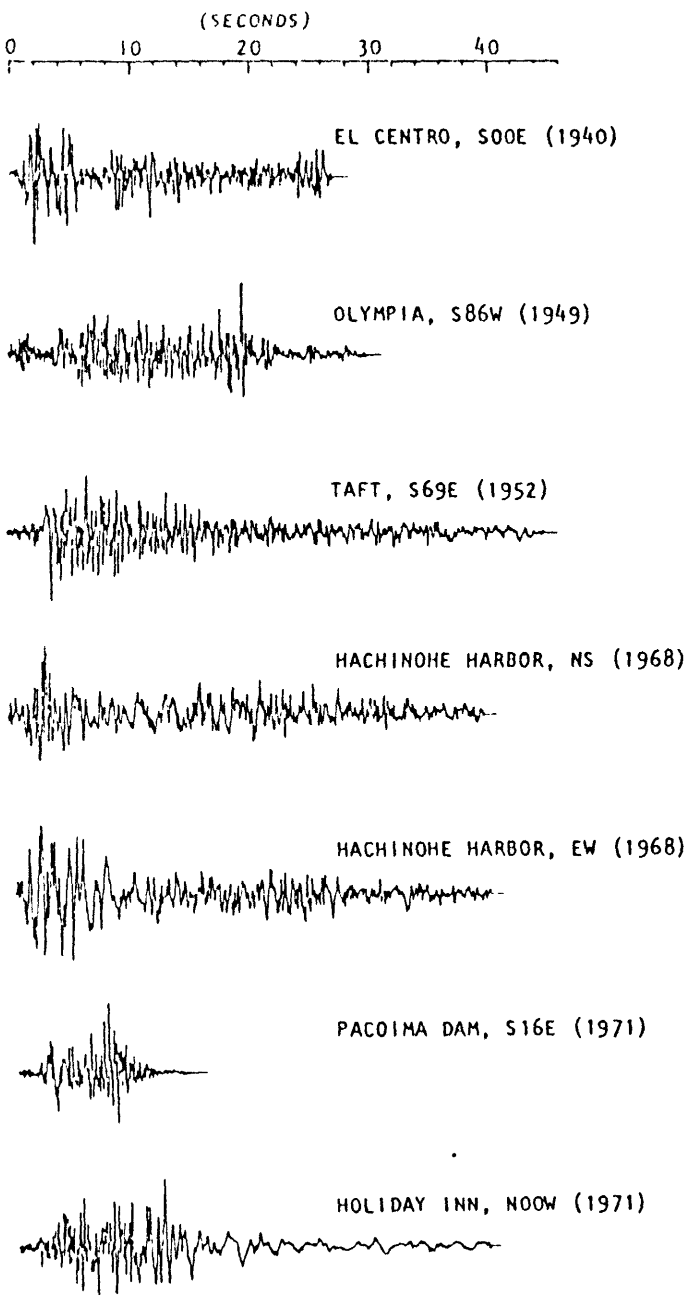
The frequency of occurrence of strong shaking can be specified using the return period which is the average time between earthquake motions of a specified strength or greater. The probability of an occurrence in any one year for an event with a return period R is 1/R, and this can be used to calculate the probability of the occurrence in a longer period of time. For example, the probability of experiencing the shaking with a return period of 100 years in a given 100 year period is found by considering the probability of having at least one such shaking, and the probability of going through the entire 100 years without experiencing the event. These two probabilities cover all possibilities and must therefore add to unity, and since the probability of escaping the 100 year earthquake in one year is 0.99, and for two years is (0.99) (0.99), etc., we have the equation

$$P_{100} = 1-(0.99)^{100} = 0.63$$

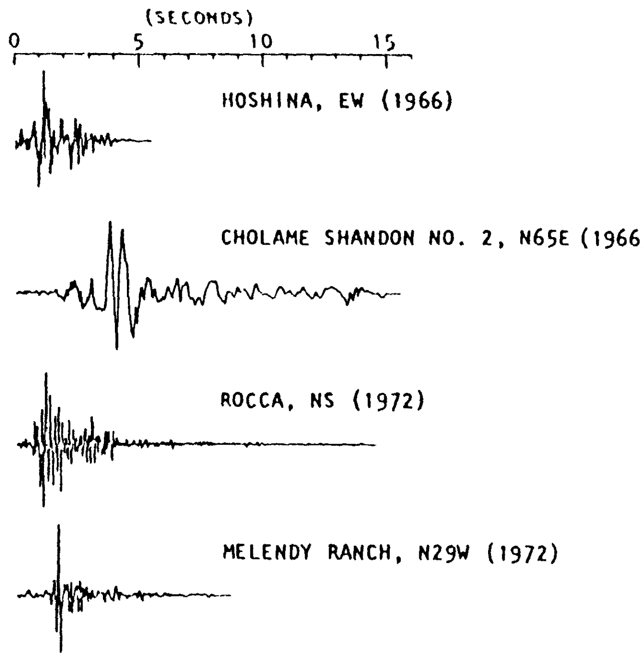
where P_{100} is the probability of occurrence of one or more ground motions with an average return period of 100 years, in a given 100-year period. With a 37% probability (that is, $0.99^{100} = .37$) of not having an earthquake, $P_{100} = 0.63$, i.e., there is a 63% chance of experiencing the 100-year event in a given 100-year period (some 100 year periods may experience 2 or 3 such events).

Often the intensity of ground shaking is described by giving a value of peak acceleration, but by itself this is an ambiguous and oversimplified description, for two ground motions having the same peak acceleration can have appreciably different intensities so far as structural response is concerned. (See the accompanying figures). A related problem occurs when the seismologist or geotechnical consultant describes the ground motion by recommending a smooth "design spectrum," often tied to an estimate of the peak ground acceleration or an "effective acceleration." To take these concepts literally is a mistake. A "design spectrum" is not the same as a response spectrum of actual ground motion or a smoothed "average spectrum," and it is preceisely this difference that involves engineering judgment. In addition, there is not yet a clear, accepted definition of "effective acceleration." The concept arises because of the poor correlation between peak acceleration and the actual response of structures.

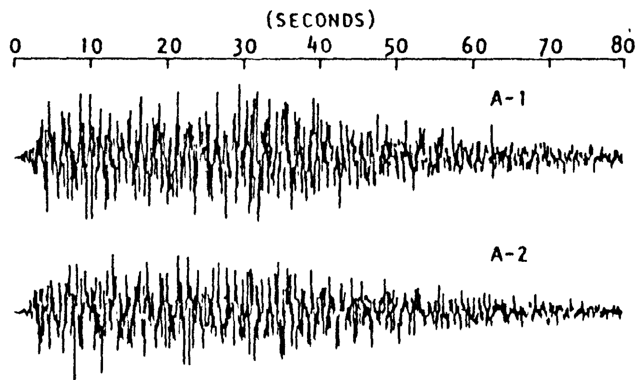
The key step in setting the earthquake design criteria is fixing the level of a smooth design spectrum. The relation of the design spectrum to the response spectra of the expected motions of the design earthquake, or earthquakes, depends on the probability of occurrence of the events under consideration and the degree of conservatism needed for the project. If the structure to be designed is highly ductile and ductile response is acceptable, the design criteria can be set at a significantly lower level than the response spectra of the expected motions. On the other hand, where essentially linear response



(a)



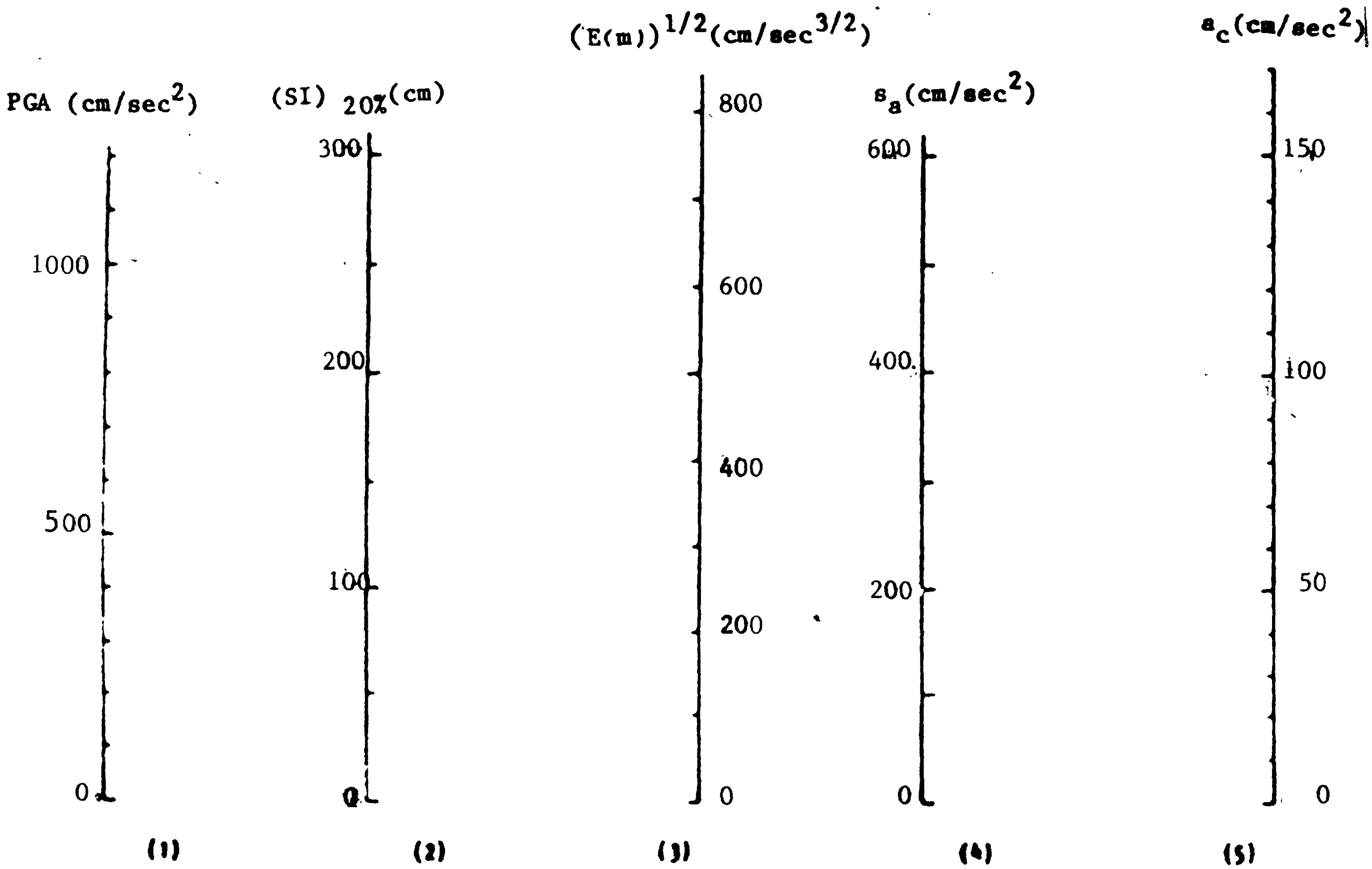
(b)



(c)

Accelerograms from different earthquakes. Group (a) shows accelerograms from $M_s = 6\frac{1}{2}$ to $7\frac{1}{2}$ earthquakes. Group (b) includes records obtained close to the fault in smaller earthquakes, plotted to a different time scale. The much longer records in group (c) are artificially generated accelerograms modeling the expected ground motion close to the fault in a great ($M_s = 8+$) earthquake.

1154 20130



Ratings of accelerogram strength by different measurements of the intensity of shaking. The measurements of intensity used are explained in the text. No single-parameter measure of strength of shaking has proved completely satisfactory; measuring strength by peak acceleration, though commonly used, is not entirely satisfactory.

1158 20130

and a high degree of conservatism are required, the design spectrum may be set well above the response spectra of the expected motions. In most major projects, the appropriate level of conservation is determined in a pluralistic manner with inputs from the owner, concerned regulatory agencies, earthquake engineers and geoscientists.

Seismic Hazard Studies, Anchorage, Alaska

by

A. F. Espinosa, H. R. Schmoll, S. R. Brockman, L. A. Yehle,
J. K. Odum, J. A. Michael, and K. S. Rukstales
U. S. Geological Survey
Office of Earthquakes, Volcanoes, and Engineering
Denver, Colorado 80225

SUMMARY

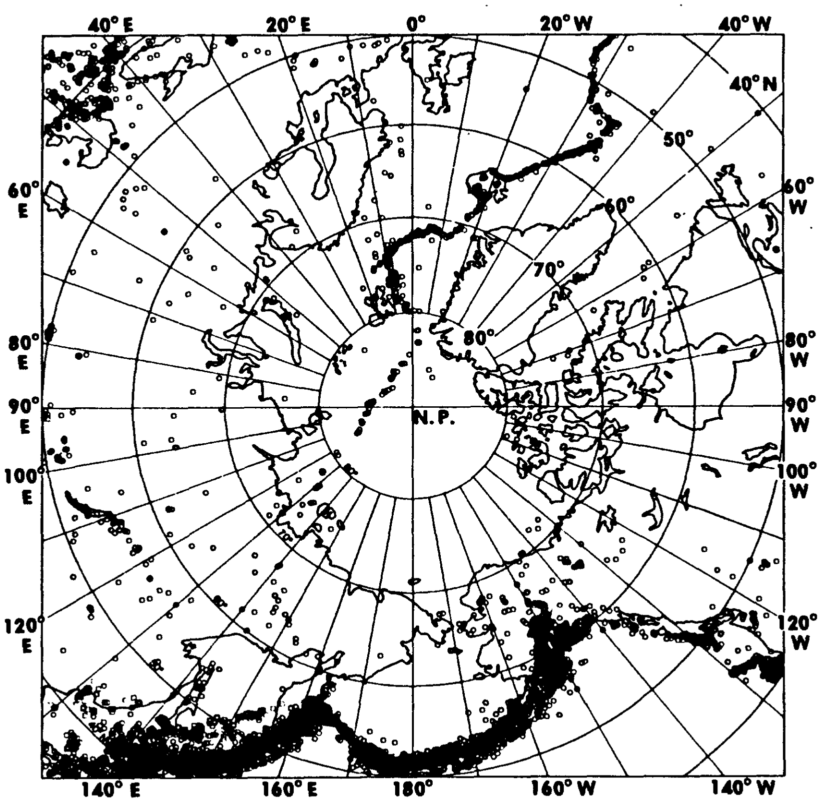
The project "Seismic Hazard Studies, Anchorage, Alaska," encompasses the entire Municipality of Anchorage as well as some surrounding areas. In order to quantify the seismic hazards of this area a series of ground-shaking maps and surficial geologic maps of Anchorage and vicinity are being drawn. One of the specific objectives in this project is to determine the nature and variability of ground shaking in the region and to learn how the changes of the geological environment affect the seismic signatures in this region. At present there are only a few limited studies on attenuation relations available for strong- and for weak-levels of ground motion in Alaska. Attenuation curves are being developed for intensity from an edited version of the existing data base. The problem of seismic amplification effects of short-period waves is being investigated for this region. A shallow reflection survey will be carried out in order to ascertain the location of the major discontinuities and to identify the possible existence of two Quaternary faults in the Anchorage area. Several other tasks are part of the overall objectives of this program. (a) A damage evaluation in the city of Anchorage, sustained from the 1964 Good Friday earthquake, is in progress. This information and local surficial geological data are planned to be used in order to ascertain any existing correlation between damage and geologic conditions in the area. (b) In order to obtain strong ground-motion

recordings, eight portable accelerograph systems have been deployed in the region. All available strong ground-motion recordings which have been obtained in the area have been digitized. (c) Geological mapping at 1:63,360 and at 1:25,000 scales, begun under previous projects, is in process of completion. In addition, a subsurface mapping program is under way, beginning with the construction of several geological cross sections through metropolitan Anchorage.

A deep geotechnical borehole, thus far extending to 232 meters in depth, is devoted to obtaining lithological and geotechnical information for vertical control. This control will be used to calibrate the subsurface geological cross sections. The data obtained from this phase of the project are also being used to construct a distribution model for physical parameters in order to evaluate theoretically the expected levels of ground motion in the near field. It is also contemplated to deploy a downhole triaxial short-period seismometer system extending from the surface to a depth sufficient that crystalline rock may be found. Several other efforts consist of cooperative endeavors with the Trans Alaska Crustal Transect program, the Alaska Seismic Studies project, the Alaska Division of Geological and Geophysical Surveys, and the Geophysical Institute of the University of Alaska in Fairbanks, Alaska.

SEISMICITY STUDIES

A set of maps showing seismicity of the Arctic and adjoining regions was released as part of an effort to gain an understanding, from the global-framework point of view, of the distribution of earthquake epicenters with magnitudes equal to or greater than 4.5 that have been located instrumentally in the 1960-1983 period of time. The set includes 12 Lambert equal area projections depicting earthquake hypocenters as functions of magnitude and of depth categories. Figure 1 portrays an example of such a map. In this map one can see very clearly areas of seismic quiescence.



1960-1983 $m \geqslant 4.5$

Figure 1.— Seismicity of the Arctic and Adjoining Regions for earthquake epicenters located instrumentally from 1960 through 1983, with magnitudes (m_b or M_s) equal to and greater than 4.5. [After "Seismicity of the Arctic and Adjoining Regions, 1960-1983", by A. F. Espinosa and J. A. Michael, USGS-OFR-MAP-84-376, 1984].

 1156 20130

A similar set of maps, showing seismicity of Alaska and the Aleutian Islands, was released as part of an effort to gain an understanding, from the regional-framework point of view, of the distribution of earthquake epicenters with magnitudes equal to or greater than 4.5 that have been located instrumentally from 1960 through 1983. An edited seismic data-base magnetic tape has been assembled for Alaska. This set consists of 11 Modified-Stereographic Conformal Projection maps at a 1:12,500,000 scale, each depicting earthquake hypocenters for a given magnitude range and for a given depth-of-focus range. Figure 2 portrays an example of such a map. In this map one can see very clearly areas of seismic quiescence.

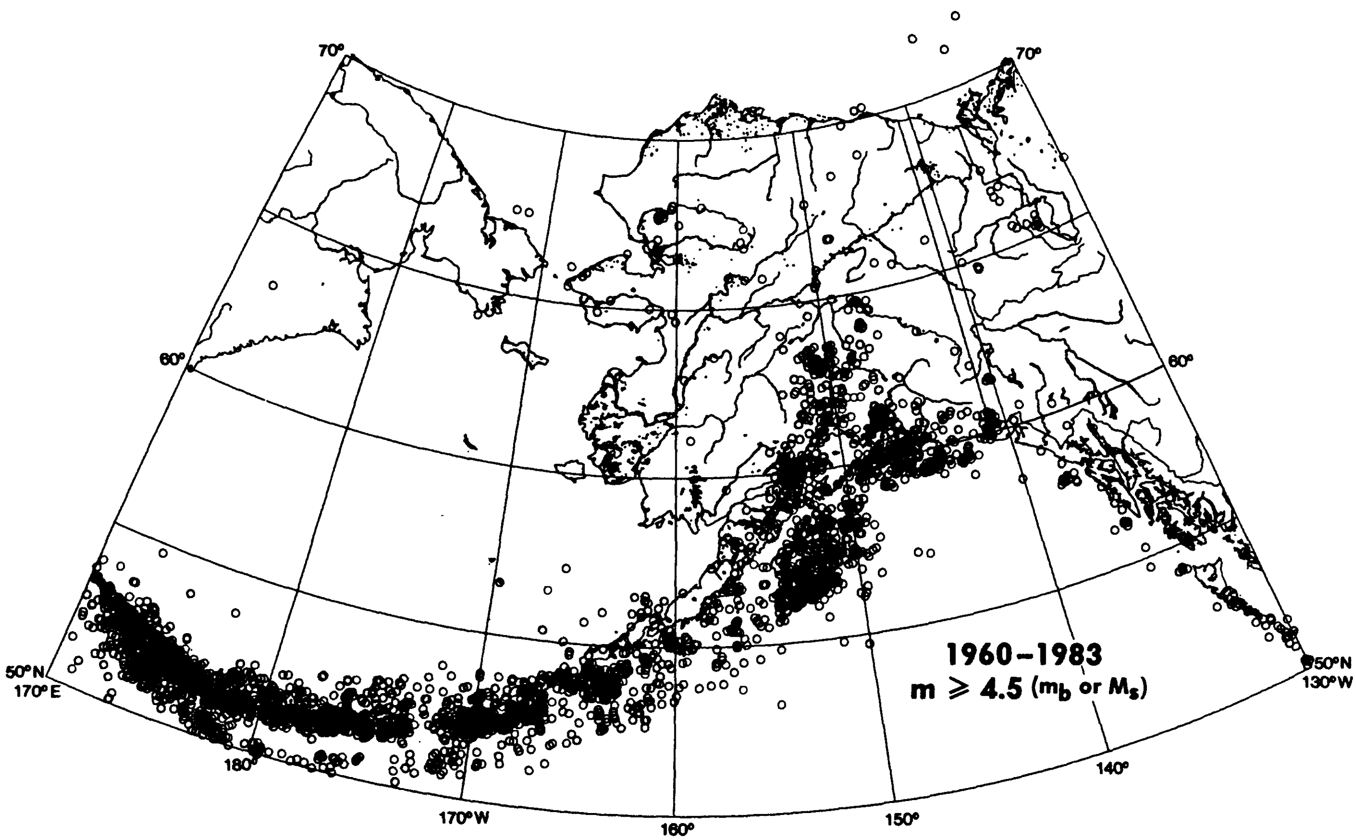


Figure 2.— Seismicity of Alaska and the Aleutian Islands for earthquake epicenters located instrumentally from 1960 through 1983, with magnitudes (m_b or M_s) equal to and greater than 4.5. [After "Seismicity of Alaska and the Aleutian Islands, 1960-1983", by A. F. Espinosa, USGS-OFR-MAP-84-855, 1984].

Other seismicity studies of the region which could affect Anchorage and vicinity are in progress. In figure 3, the left map shows all earthquakes which have been located from 1900 through 1984 and the right map shows only earthquakes for which a magnitude has been computed in the same period of time. On each map box 1 outlines the general area, and boxes 2, 3, and 4 are used in an effort to gain an understanding, from the local seismicity framework point of view, of the distribution of earthquake epicenters in the region. Some of the epicenters, located from the high-gain short-period seismic network data collected by the Alaska Seismic Studies Project, are being used in a comparative seismicity study of the regions shown as boxes 3 and 4. Figure 4 illustrates selected time and magnitude studies categorized according to the 4 boxed areas outlined in figure 3.

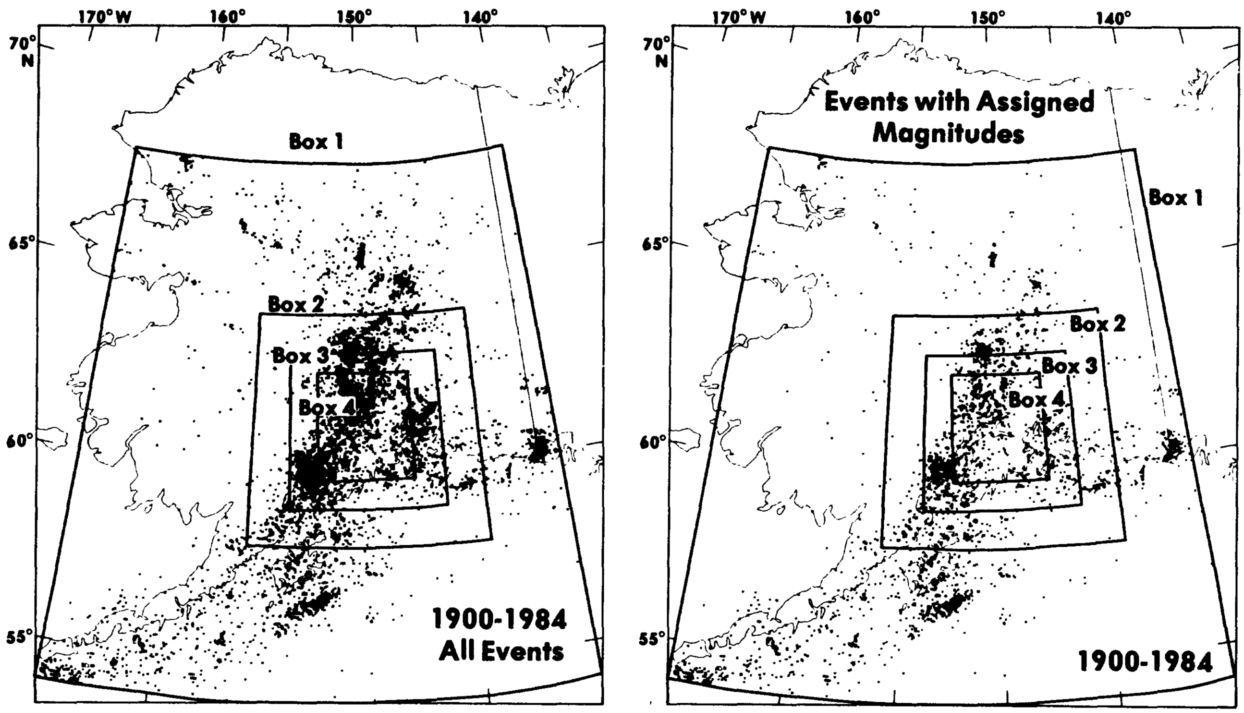


Figure 3.— Regional and local seismicity of Alaska for earthquake epicenters located from 1900 through 1984; *left*: all earthquakes located, and on the *right*: earthquakes for which there is an assigned magnitude. Boxes 1, 2, 3, and 4 are used to study the spatial distribution of seismicity and for comparative studies.

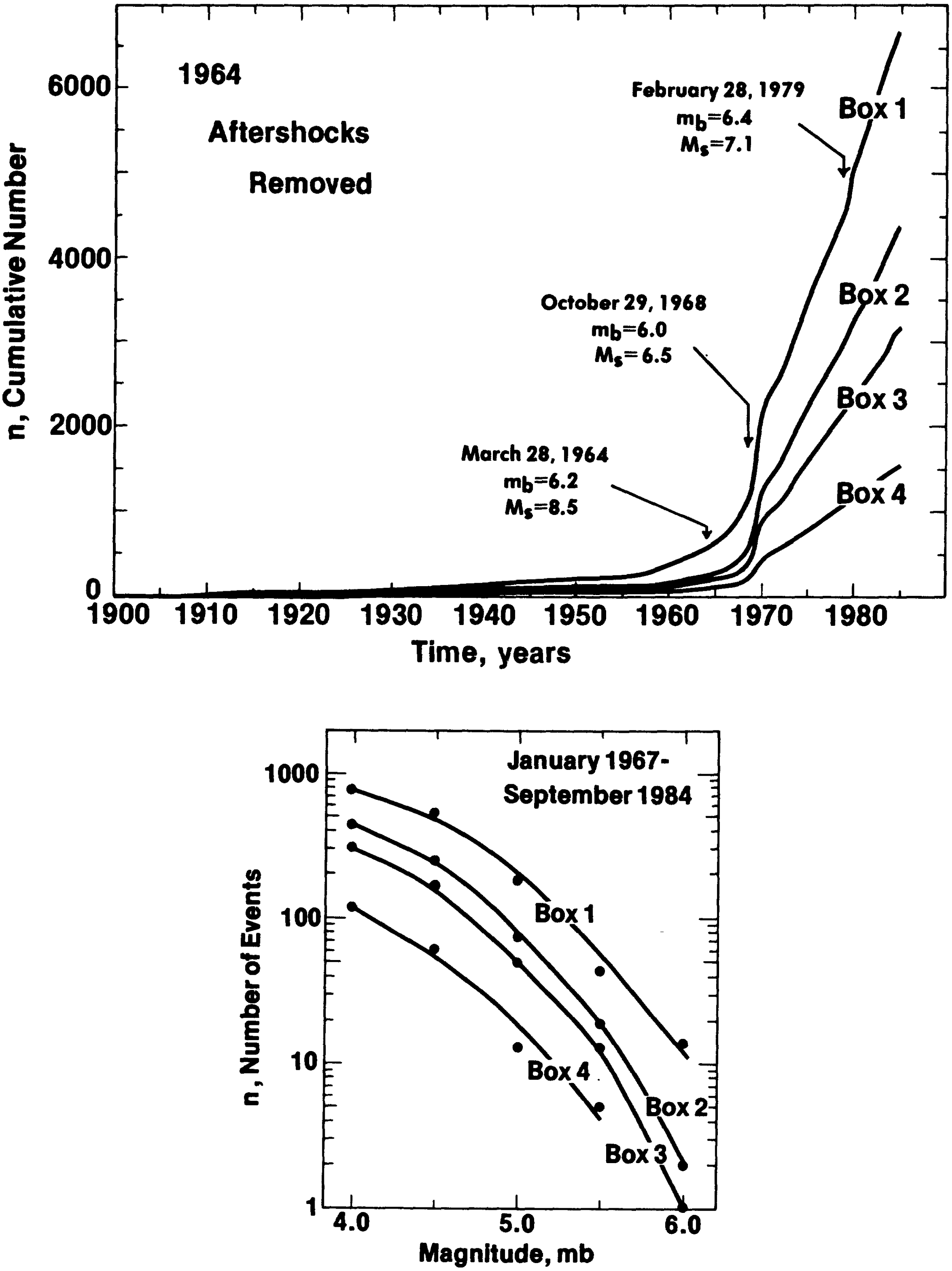


Figure 4.— Examples of some of the time and magnitude seismicity studies being done for the region. Box identifications refer to spatial seismicity distribution shown in the previous figure.

1157 20130

GEOMETRY OF A SUBDUCTION ZONE

A technique has been developed to map in three dimensions the geometry and attitude of the lithospheric Pacific plate as it collides with the North American plate and subducts. Such a 3-D visual display of how the mean-surface of the lithospheric Pacific plate behaves is achieved by using the instrumentally determined hypocenters for the region. The data bank used contains teleseismic instrument-determined hypocenters for earthquakes with magnitudes (m_b or M_s) equal to and greater than 4.5, from the years 1960 through 1984, from the map "Seismicity of Alaska and the Aleutian Islands," discussed in the preceding section. The resultng image yields a visual display of what could be considered a three-dimensional representation of a subducting plate based on seismological data for a given geographic region.

In composite figure 5 the upper part portrays a map of Alaska and adjoining regions as viewed at an angle of inclination of 20° from the higher latitudes (about 75° N.). Within this map a rectangular box is connected by vertical dashed lines to the lower part of the figure which contains 3-D displays of the mean-surface of the lithospheric Pacific plate. The intervening section, second from the top, shows the location of volcanoes in the region that have been active in Holocene time. The two most recently active volcanoes are identified by their names and the dates of the last activity.

The 3-D display portrays the direction of the Pacific plate motion by arrows and that of the North American plate by a large arrow labeled N. A. P. The Pacific plate subducts under the North American plate in Canada, Alaska, and in the Aleutian Islands region. This 3-D figure shows the contortion that the

Pacific plate (average thickness 50 km) is undergoing as it collides with the North American plate. It also shows an elbow or bend of the subducting plate with a north, slightly eastward, direction (under Canada) penetrating to a depth of about 50 km.

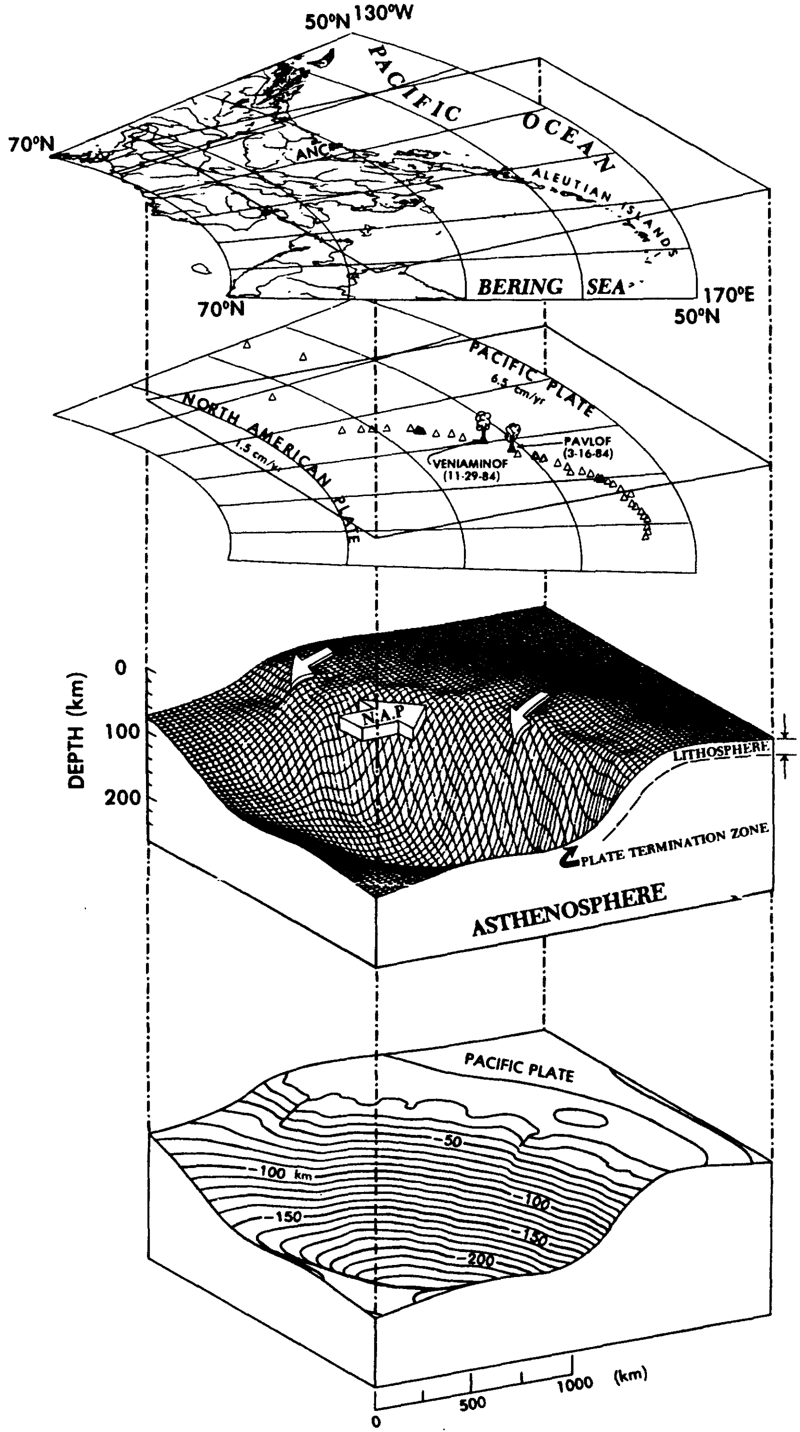


Figure 5.— A technique has been developed to map a plate subduction zone using the database from the "Seismicity of Alaska and the Aleutian Islands" map. A representation in three dimensions of the shape of the Lithospheric Pacific Plate as it subducts underneath the North American Plate is shown in this figure.

INTENSITY ATTENUATION STUDIES

The intensity data file in magnetic tape format has undergone an extensive editing process which has taken nearly one and a half years. From this database we have been able to construct the Modified Mercalli Intensity distribution for 14 earthquakes which have occurred in Alaska. An example is shown in figure 7, following page. Some of the isoseismal maps published earlier have been reviewed and revised.

The isoseismals for all the earthquakes occurring in Alaska have been digitized and are being used to determine some of the source parameters. This data-base is also being used to determine empirically the intensity attenuation for each of the earthquakes under study (fig. 6).

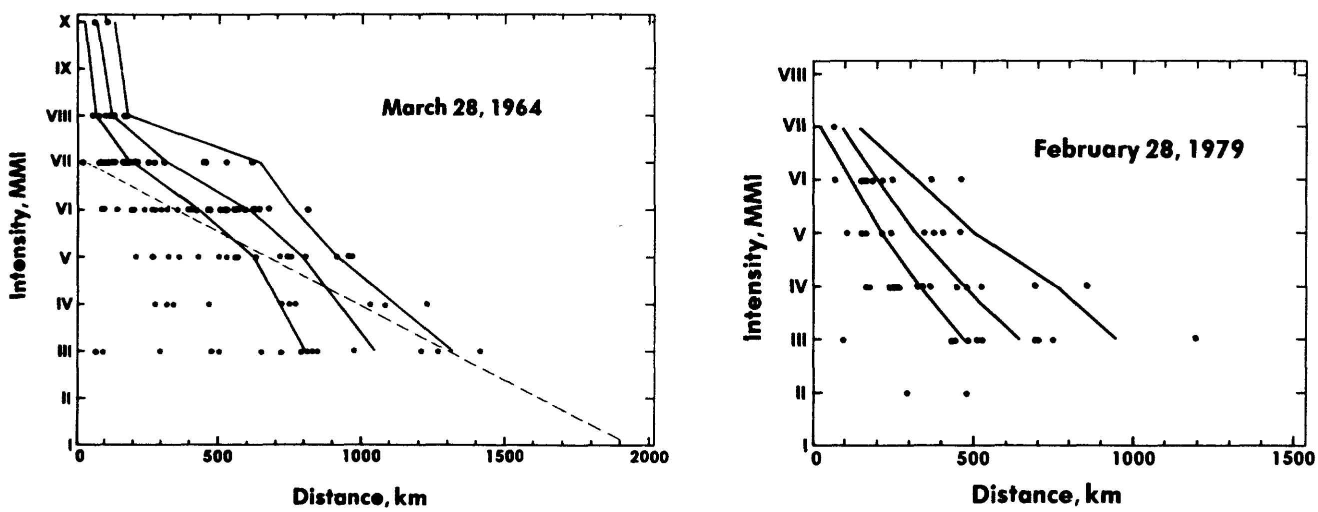


Figure 6.— Modified Mercalli intensity ratings as a function of epicentral distance for two earthquakes in Alaska. The dashed-line represents a univariate regression least squares fit to the observed data. The middle curve, from the three curves shown, represents the best fit to the observed data by a process being developed and tested.

11B6 20130

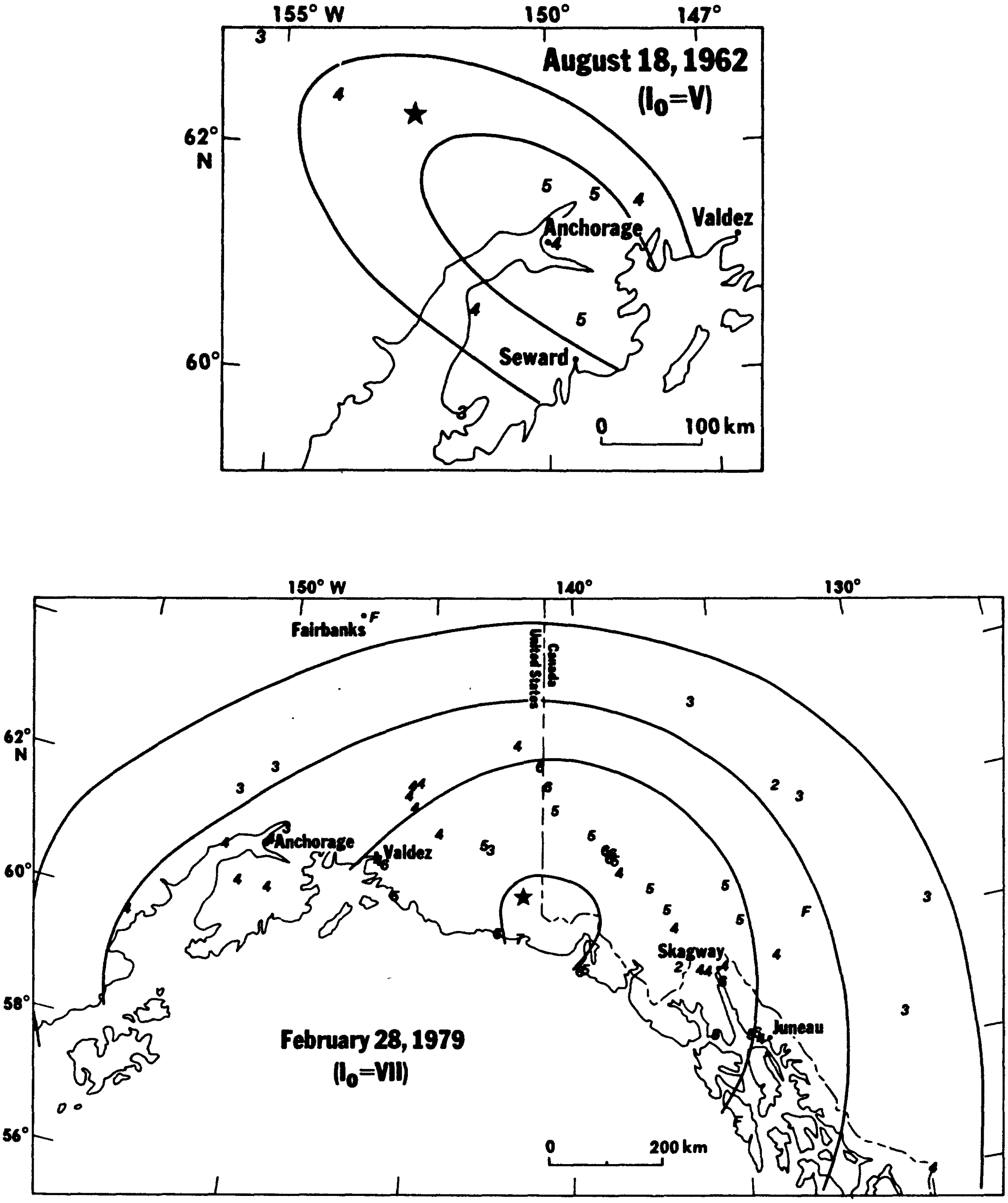


Figure 7.— Modified Mercalli intensity distribution for the earthquakes of August 18, 1962, and February 28, 1979. Numbers indicate the ratings assigned to each of the questionnaires and the solid star represents the epicenter of the event.

 1152 20130

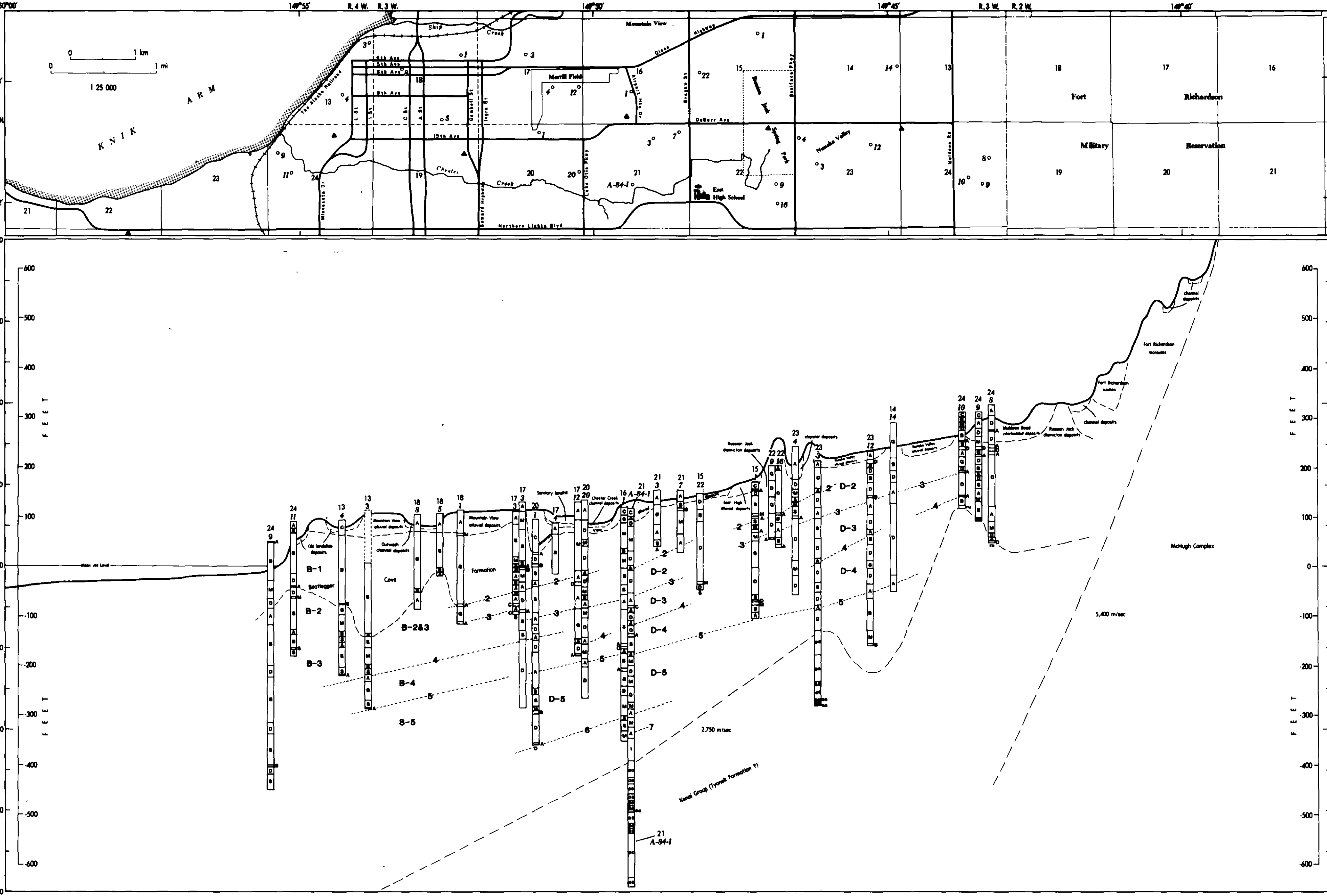
DAMAGE EVALUATION

A damage evaluation for the city of Anchorage is in preparation from a damage data survey performed after the 1964 earthquake. A total of 680 questionnaires were obtained in an east-west traverse along 15th Avenue and DeBarr Avenue in Anchorage. This information and local surficial geological data are planned to be used in order to evaluate transfer-function amplification curves in the area and to ascertain any existing correlation between damage and geologic conditions.

A preliminary result shows that 44 percent of the houses built on outwash gravel, 47 percent of the houses built on alluvial fans, and 50 percent of the houses built on ice contact deposits sustained damage. The area covered by the damage survey is shown in the upper part of figure 8. The geological cross section portrays subsurface conditions beneath the area of the damage survey. Strong-motion instruments have been deployed along this strip since July, 1984; their locations are shown as solid triangles on figure 8. A portable digital seismograph system will be deployed along this same strip for a period of two months; the planned locations for these instruments are shown on figure 8 as solid squares.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

OPEN-FILE REPORT 84-791
PLATE 1



EAST-WEST GEOLOGIC CROSS SECTION ALONG THE DEBARR LINE, ANCHORAGE, ALASKA

GEOLOGIC MAPPING

Mapping aspects of the project may be divided into four phases: (1) surficial geology mapping at 1:63,360 scale; (2) geologic mapping at 1:25,000 scale; (3) subsurface mapping at 1:25,000 and (or) smaller scales, and (4) other efforts. In the discussions that follow, reference is made to map areas identified on figure 9 by circled number.

1. The surficial geology mapping of what is now the entire Municipality of Anchorage was begun under a previous project; it then comprised the area of the Greater Anchorage Area Borough (Schmoll, workshop volume). This mapping was originally conceived as being published in three sheets, each comprising about four standard 15' topographic quadrangles, and covering respectively the northeastern (fig. 9, area 1), southeastern (fig. 9, area 2) , and western (fig. 9, areas 3-6) parts of the roughly triangular shaped Borough area. Because the western sheet has now been superseded by more modern, larger scale quadrangle maps, surficial geology mapping of most of this sheet will be converted to the larger scale and be incorporated into phase two. Consequently, the original mapping will now be issued as the northeastern and southeastern sheets, with the part of the western sheet not covered by larger scale maps (fig. 9, area 3), mainly the Anchorage A-7 quadrangle, issued separately. As an adjunct to this mapping, and to extend the concepts of the folio series of environmental geology maps, previously published for most of the metropolitan area, to the rest of the Municipality, a single geologic materials map of the entire Municipality is being prepared on the original three sheet basis at 1:63,360 scale.

1288 20130

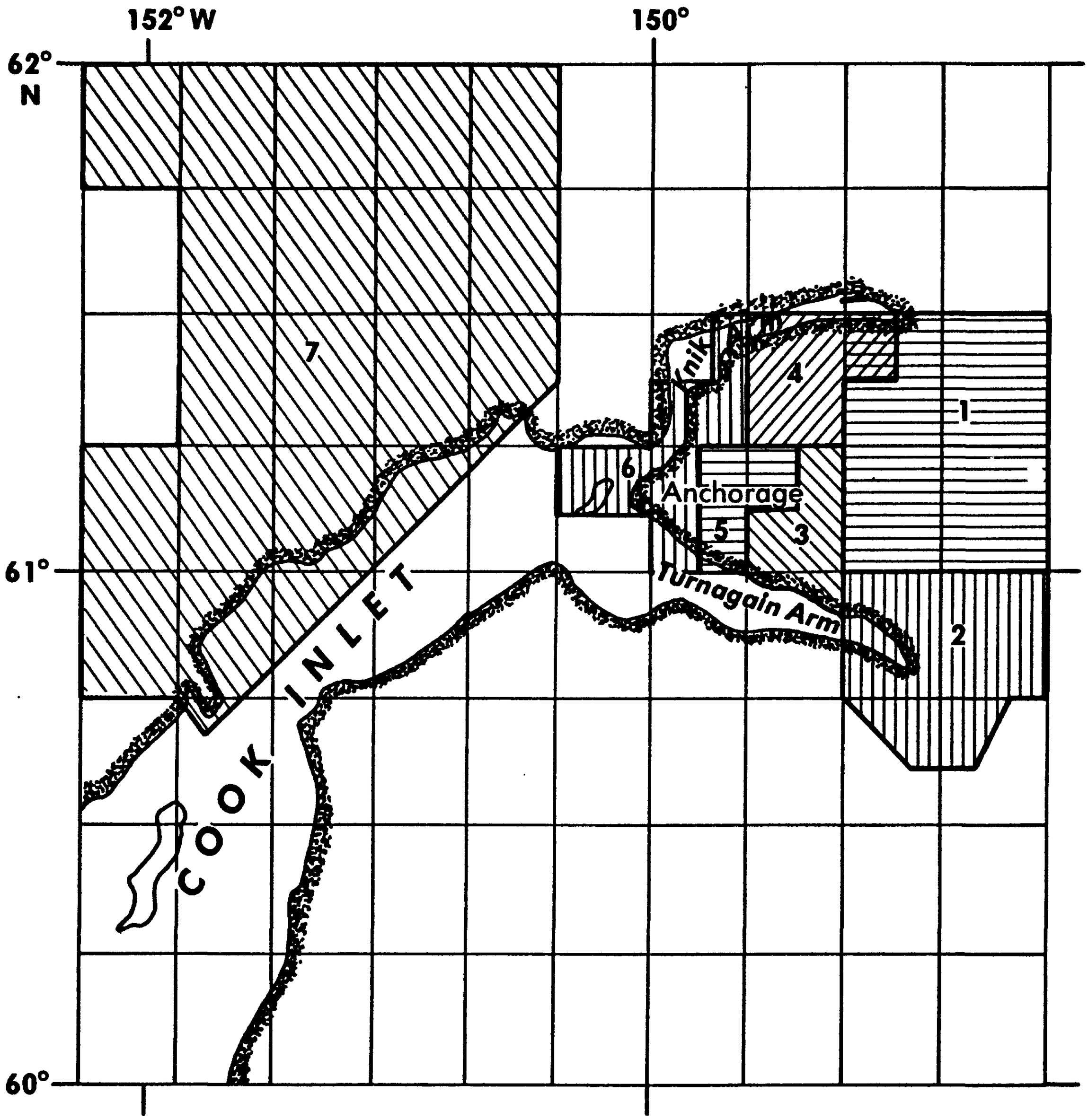


Figure 9.— Map showing locations where geologic mapping is in progress. Numbered areas are referred to in the text. The grid outlines the standard 1:63,360-scale (15′) topographic base maps.

1254 20130

2. The newer 1:25,000-scale topographic quadrangle maps cover most of the metropolitan area of the Municipality, including the part that extends northeast along Knik Arm to about Eklutna. Bedrock mapping in this area is presently in progress (fig. 9, area 4) or planned (fig. 9, area 5) by R. G. Updike and C. A. Ulery of the Alaska Division of Geological and Geophysical Surveys. This new mapping will be combined with the surficial geologic mapping noted above, to be upgraded to standards of the larger scale, to produce a series of about 8 geologic quadrangle maps. In addition, the long promised geologic maps for the rest of the metropolitan area, covered by the generalized map in the folio series (discussed in Schmoll, workshop volume), will be converted to about 6 additional quadrangle maps (fig. 9, area 6).

3. In a later phase of the project, after development of a number of subsurface geologic cross sections through the lowland parts of the metropolitan area, it is planned to produce a map portraying subsurface conditions. If possible this map will portray conditions extending from the surface down to the "basement" complex of metamorphic and igneous rocks that occur at the surface in the foothills bordering the east side of the metropolitan area, but that is buried as deep as 3,500 m at the west end of the area. The map will encompass parts of areas 5 and 6 shown in figure 9. Although a scheme for developing this map has been proposed, the feasibility of this scheme has yet to be established, and many of the details, including the level of interpolation that can be achieved from existing and newly acquired data, remain to be placed in a realistic format.

4. Other efforts, presently non-funded, may be devoted to completion of geologic mappng west of Anchorage (fig. 9, area 7), an area likely to be the site of

considerably expanded development in the near future.

GEOTECHNICAL DRILLING

This phase of the project is devoted to the acquisition of new data to supplement what is already available from existing drilling, mainly in the form of water-well logs. Because much of that data is of limited quality and shallow in depth, it is desirable to obtain additional high-quality data at carefully chosen sites to fill in critical gaps in existing subsurface knowledge. In 1984, the first hole was drilled and selectively sampled, in part as an experiment to ascertain the feasibility of undertaking such drilling at reasonable cost, and to expand existing experience in this activity acquired in drilling through similar rocks in the area west of Anchorage. The initial hole reached 232 m at a cost of $15,000, with limited but critical coring of the relatively soft Tertiary rock that underlies the unconsolidated Quaternary deposits beginning at a depth of about 155 m at the drill site. While this experiment was regarded as generally successful, further techniques need to be developed for obtaining better samples of the coarse-grained, nonhomogeneous Quaternary deposits which do not yield readily to conventional sampling or coring methods.

COOPERATION WITH THE TACT PROGRAM

As an adjunct to the main thrust of the project, selected activities have been undertaken in cooperation with the Trans Alaska Crustal Transect program. This work may be divided into two phases: (1) observation and sampling of cuttings obtained from the drilling of seismic shot holes; and (2) contributions to geologic mapping.

1. Mainly because of previous knowledge and the continued interest in the Quaternary glacial and volcanic deposits of the Copper River Basin, opportunity was taken to observe the drilling through these materials done in conjunction with TACT seismic lines. In 1984 operations at 16 drill sites were monitored, and a technical report was released on the observed results. A similar but more limited activity was conducted in 1985.
2. Also because of familiarity with the region, and the existence of unpublished geologic mapping in the files of project personnel, contributions have been made to the mapping of the Gulkana B-1 quadrangle, part of the swath of detailed geologic mapping across the Copper River basin and adjacent Wrangell Mountains undertaken in conjunction with the TACT program. Existing mapping, mainly in glacial and volcaniclastic deposits, was revised photogrammetrically, and brief field investigations to visit sites of uncertain identity on the basis of the photointepretation, were undertaken in 1984. The revised mapping has been prepared for publication.

EARTHQUAKE DAMAGE -- 1964 LESSONS LEARNED AND RELEARNED

by

Karl V. Steinbrugge
Structural Engineer
El Cerrito, California 94530

INTRODUCTION

The great Alaskan Earthquake of 1964 taught new lessons as well as repeated those learned from previous earthquakes and reobserved in subsequent ones. Perhaps "lessons learned" is too strong for all members of the design professions. It appears that a few of the concepts have not been well understood and/or applied in view of damage to some more recently constructed buildings.

In a setting such as this workshop it seems important to review several of the more important of these Alaskan lessons. The selected topics are based on personal knowledge from the field inspections and studies made by the author after the 1964 event. The intent is to raise questions for thought and discussion, and not necessarily solutions to specific problems.

INTENSITY -- USE AND MISUSE

Modified Mercalli intensities usually provide major inputs for studies of aggregate damage and potential life loss such as those developed for governmental vulnerability studies. Also, there are engineers and scientists who relate intensities taken from isoseismal maps to damage and to acceleration, sometime interpolating intensities to obtain building design values to 2 or 3 significant figures. In some instances, undue faith may be placed on isoseismal maps.

Figure 1 shows a snowman in the Turnagain section of Anchorage and quite close to a major landslide. The snowman survived the earthquake as did all wood frame dwellings beyond the landslide area. What is the intensity? Figure 2 shows the interior of a one story store across the street from the 4th Avenue landslide. A globe turned over, several items fell on the floor, and some shifted -- the author entered the store along with the owner upon his first return after the earthquake. What is the intensity? Compare this with Figures 3, 4, and 5. (For locations of these structures with respect to landslides and to each other, see map in pocket in Steinbrugge, et al, 1967.) These comparisons are not isolated instances.

The explanation for these field observations relates to the type of ground motion generally experienced in Anchorage. The predominant motion was about 0.5 seconds, thereby accentuating damage to taller structures which have longer natural periods.

No intensity map was drawn for Anchorage (Cloud, et al, 1967). Cloud states "The results of bringing together long- and short- period effects are not serious when attempting to rate moderate earthquakes. However, results are striking when attempting to rate major events, such as the Prince William Sound Earthquake, due to the greatly increased proportion of long-period effects to short-period effects. Effects in Anchorage, Alaska, offer a classic example.... The U.S. Coast and Geodetic Survey's solution to this problem was to assign a range of intensities rather than a single intensity..... "

This is not unique to Anchorage. For different soil conditions, earthquake magnitudes, distances from seismic energy release regions, and other parameters, isoseismal maps are not given in detail for the heaviest shaken areas -- see similarly prepared maps for 1952 Kern County (California), 1959 Hebgen Lake (Montana), and 1971 San Fernando (California).

This is not to say that isoseismal maps are useless -- far from it. Analysis applied in the context of the source data, that is, to the reports of effects on specific structures at specific sites are very useful when extrapolation for

Figure 1. Snowman at far right survived the 1964 Alaskan earthquake in Anchorage as did these wood frame dwellings. Behind the photographer were badly damaged dwellings in a landslide area.

Figure 2. Interior of a store across the street from the Fourth Avenue landslide in Anchorage. Stock on the shelves were little disturbed, and only several items fell.

Figure 3. Mt. McKinley building in Anchorage. The very large crack in the reinforced concrete bearing and shear wall was so wide that a hand could be placed through it from window to window.

Figure 4. The 1200 "L" apartment building in Anchorage. Almost an identical building to Figure 3, with almost identical damage in the second story.

Figure 5. One of 2 collapsed shear wall towers of the 6 story Four Seasons apartment house in Anchorage. Floors were stacked upon each other like pancakes. Prestressing wires which were not grouted shot out like missiles, with the arrow indicating where one struck a house.

Figure 6. Four Seasons apartment house in the course of construction. Steel columns with prestressed lift-slab floors. Minimal lateral force resistance to bending moments at column to floor connections, and thus no secondary or redundant resistance was present.

1257 20130

vulnerability purposes to other regions. However, numerical quantities assigned to isoseismal lines rather than to back-up data have very large uncertanties.

One misuse of intensity involves circular reasoning. A design professional may write to a building owner that the designed building will withstand an Intensity VIII earthquake. Modified Mercalli Intensity VIII states "Damage slight in specially designed structures...." After the event and if the structure were to be damaged similar to that shown in Figures 3, 4, and 5, then the designer could assert that the damage was "due to an Intensity IX" as defined by him, the most knowledgeable person on the structure. Yet all around the damaged structure may be differently designed undamaged structures, meeting the same building code. More will be said of this in later paragraphs on "Redundancy".

DAMAGE CONTROL AND LIFE SAFETY

The intent of earthquake resistive design as required by building codes is to protect life, and is only partially directed towards damage control. (There are certain exceptions, notably the code provisions for hospitals in California constructed since 1972.)

The basic philosophy behind the seismic provisions of most American building codes appears in the commentary on the fourth edition of the "Recommended Lateral Force Requirements" by the Seismology Committee of the Structural Engineers Association of California (1975). This publication states that the code intends buildings to "Resist major earthquakes of the intensity of severity of the strongest experienced in California, without collapse, with some structural as well as nonstructural damage." It goes on to state "In most structures it is expected that structural damage, even in a major earthquake, could be limited to repairable damage." By using certain types of flexible, but safe framing systems in certain occupancies, such as hotels, it is quite possible for a structure to suffer 50% property loss without serious structural damage.

Life was not lost in the buildings shown in Figures 3 and 4 and one can state that the intent of the code was met. Certainly, none of us can quarrel with the need for life safety, and this goal seems to be increasingly achievable.

The cost to repair the Mt. McKinley Building (Figure 3) was 40% of its replacement value and 30% for the 1200 "L" Building (Figure 4). Neither of these structures were functional (occupied) for a long period of time. Does the average design professional understand the code philosophy and is he willing to be named on the drawings for a building which may not be functional for many months? Does the owner understand this risk? Do disaster response planners rely on all modern earthquake resistive buildings to remaining functional?

REDUNDANCY

All buildings meeting the lateral force requirements may be code-equal but not necessarily truly equal. Certain structural types have redundancies inherent to them. As time goes on, some of these redundancies are eliminated by research which indicates that the redundancy is an extra cost which can be saved using new methods or material assemblies. Cost saving is normally true, but equivalent safety may not be true. Often the framers of building code provisions had in mind the kinds of construction then current, and could not have fully anticipate the future. Design forces, allowable stresses, minimums, and other judgment-determined factors are often in these unstated contexts and not understood by the researchers.

It is not the point to continue a long standing debate on equivalence vs. adequacy for code purposes, but rather to show the lessons learned in 1964 and repeated elsewhere.

Figures 3 and 4 are of poured-in-place reinforced concrete structures which were well designed and constructed for their era, not unlike many hundreds of other buildings in western United States. Both were structurally very similar. Each had one wall completely sheared in a lower story; each wall was both a shear wall and a bearing wall. The fracture was complete and an air gap separated the upper portion from the lower portion. Certainly, there was redundancy in the

 1287 20120

load carrying systems. Compare these with Figures 5 and 6.

Perhaps classic for redundancy were the multistory steel frame buildings in San Francisco at the time of the 1906 shock. None were designed to be earthquake resistive. All steel framing was encased in concrete for fire protection reasons, thereby giving significant uncounted lateral force resistance through composite action. All these steel frames survived excellently without the benefit of our modern design and construction concepts. A number of these buildings are still in use.

Inherent redundancy is often much less in precast concrete buildings due to connection difficulties. The designer may compensate for this, unless he believes that redundancy is unnecessary or he fully believes that the code is adequate in all cases. Quite evidently this can be a decision by the designer and yet meet the code.

Only a partial comparison can be made between poured-in-place and precast concrete in Anchorage. A total of 20 buildings with precast concrete tee-beam floors and roofs were examined by the author after 1964, although perhaps as many as 26 may have existed. A review of known performance shows that the largest completely undamaged building had a roof diaphragm area of 6500 square feet, which certainly is not large. Four collapsed or partially collapsed. While in some cases the damage can be attributed to the supporting hollow concrete block or other reasons, these same factors were involved with lighter material roofs and floors which were not damaged. It must be remembered that the low rigid one and two story buildings outside of the landslide area were almost always unaffected by the 0.5 second predominant ground motion, and precast stand out by contrast.

I have no quarrel with precast concrete; I do believe that the construction industry and design professionals continue to need a better understanding of this product.

Redundancy may also be viewed by type of failure. Shear walls failing in shear or by shifting along a cold joint usually does not cause collapse. Figures 7, 8, and 9 show movements along cold joints or x-crack failures, whereas shear

Figure 7. Slippage along an interior reinforced concrete shear wall in the Anchorage-Westward Hotel. Some bars snapped while others necked.

Figure 8. Similar to Figure 7, except at the West Anchorage High School.

1252 20130

Figure 9. Failure of shear walls (X-cracking) at the West Anchorage High School.

Figure 10. Note unfilled cell containing reinforcing bar. In Anchorage.

wall failures due to concrete splitting and turning over can be catastrophic as shown in Figure 5. While no design professional wishes to contemplate the failure of his design, many experienced designers consider the value of redundancy or its equivalent should the unthinkable occur.

WORKMANSHIP

Workmanship is a perennial problem throughout the world. It has been observed that shop workmanship is often better than field workmanship for a variety of reasons, including the better opportunity for inspection as well as working conditions.

Certain materials which are handled by individual workmen or very few persons and which may be quickly covered have been troublesome in the field. Falling into this category are unit masonry types such as hollow concrete block. Figure 10 is one such example found in Anchorage.

Figure 11 shows a problem at a cold joint in an otherwise monolithic reinforced concrete wall in Anchorage. The aggregate along the cold joint acted as ball bearings. Figures 7 and 8 also exhibit poor workmanship.

CITED REFERENCES

Cloud, Wm. K., et al (1969). "Distribution of Intensity, Prince William Sound Earthquake of 1964" in The Prince William Sound, Alaska, Earthquake of 1964 and Aftershocks, vol. II, parts B and C, pp.5-48.

Steinbrugge, Karl V., et al (1967). "Building Damage in Anchorage" in The Prince William Sound, Alaska, Earthquake of 1964 and Aftershocks, vol. I, part A, pp.7-217.

Figure 11. Concrete was not monolithic in this cold joint, and aggregate acted as ball bearings in this Anchorage building.

RECENT AND ANTICIPATED CHANGES IN UTILIZATION OF EARTHQUAKE HAZARD INFORMATION FOR SITING CONSIDERATIONS; ANCHORAGE, ALASKA

by

Barbara J. Sheinberg
Geologist;
Associate Planner,
Anchorage, Alaska

BACKGROUND

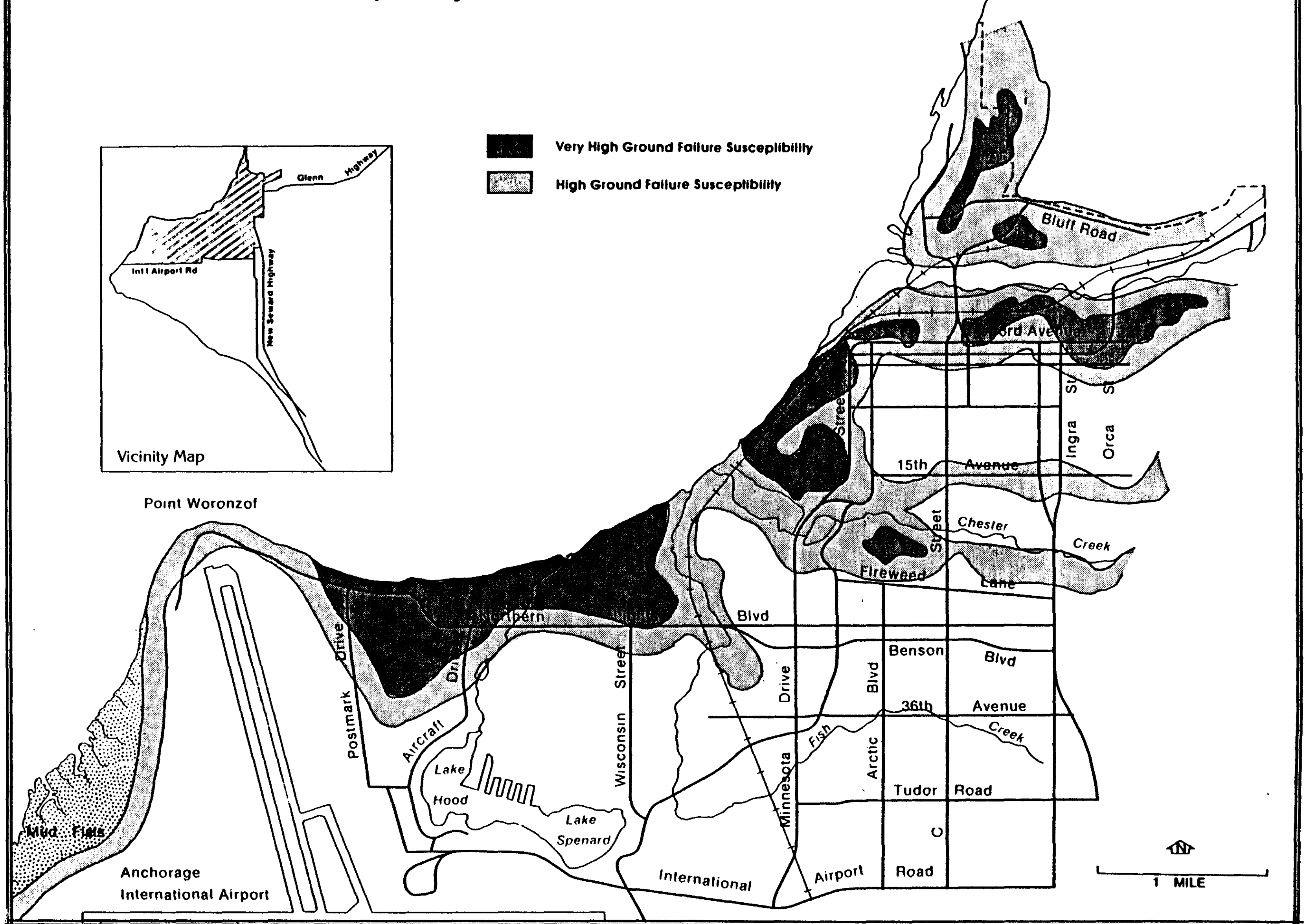
The title of this plenary session is "Current Alaskan Urban Development Which Requires Consideration of Earthquake Hazards - Siting Considerations for New Construction". This paper and discussion will focus on the historic absence in the use of siting considerations relative to earthquake hazards in the Municipality of Anchorage, Alaska and recent program changes attempting to address and remedy this situation. The reasons for recent program changes will be emphasized with recommendations and responsibilities assigned regarding how these changes have been accomplished. Technical information about earthquake hazards in Anchorage has existed for years. The data is continually being refined, but has been available for years in a complete enough form to meaningfully address siting considerations. In addition, articulate public policy towards utilizing earthquake hazard information in siting conditions has not recently changed. Key factors that have recently changed have been:

1. Recent rapid area population growth that has fueled pressure for land development in all city areas including on seismically hazardous lands (Figure One),

2. Increased awareness and understanding on the part of key decision makers about environmental processes and hazards, and

3. More effective communication on this matter between both scientists/technicians and government bureaucrats and within the bureaucratic structure itself.

Northwest Anchorage
Ground Failure Susceptibility



Source: Geotechnical Hazards Assessment Study, Harding - Lawson Associates 1979

These factors have resulted in recent Anchorage program changes including proposals for and actions toward:

1. Adoption of geotechnical site investigation requirements as local amendments to the Uniform Building Code (Municipal Title 23),

2. Initiation by the Municipality's Community Planning Department of an earthquake safety study (with anticipated end results of municipal plan and code changes).

   The four study phases are:

   a. Synthesis of seismicity and geotechnical hazard data to result in a contour map showing annual probability of exceeding (for example) 0.1, 1.0, 10 feet of ground displacement.

   b. A damage and risk evaluation including an inventory of Anchorage's existing to earthquake hazards in terms of dollars and lives at risk.

   c. Review of alternative hazard mitigation and reduction scenarious, to include evaluation of the costs and benefits of each to both the community and individuals. Resultant determination of community's acceptable level of risk.

   d. Translating results of Phase C above into recommended land use, building code and siting changes and implementation of these changes.

3. Adoption of an interim municipal review procedure (until earthquake safety study is completed and implemented) for all development proposals on land in Anchorage's most vulnerable earthquake hazard areas. Review and comment will be by Municipality's Geotechnical Advisory Commission.

4. Increased reliance by decision making bodies in Municipality on comments and advise of Geotechnical Advisory Commission.

IMPROVING TSUNAMI PREPAREDNESS IN ALASKA

by

George W. Carte'
Alaska Tsunami Warning Center
Palmer, Alaska 99645

INTRODUCTION

Before I can discuss improving tsunami preparedness in Alaska I will first address the degree of preparedness as I have observed it. Most communities under 600 population are not well prepared (Carte', 1984). Many of these same communities have the highest percentage of land in the potential tsunami hazard zone below 100 foot elevation. This evaluation is based on six factors: communications, written plan, public warning devices, local response agencies, evacuation sites, and availability of emergency equipment and services. Although improvements are suggested in every factor, I believe communications and written plans are most important and most lacking.

Some communities have planned development based on past experience or potential tsunami flooding. Entire towns were relocated after extensive damage in the 1964 tsunami. Yet some were rebuilt in the same location where heavy damage occurred. Unfortunately the tsunami hazard zone is not well defined for most areas of Alaska. Rough estimates have been made for evacuation purposes but detailed and reliable computations are needed for planning and zoning decisions.

A local, seismically-triggered, tsunami warning device is used in Hawaii. A recent evaluation points out many possible problems (Cox and Morgan, 1984). If the reliability of these triggers could be improved, they could help decrease the warning time for a local tsunami.

Ultimately, how well the system works depends on personal response, both from the local officials and the general public. Since most have little or no first-hand experience with tsunamis, education efforts are very important. The recent regional "Shaker" exercises conducted by the State and FEMA were very educational, but required extensive planning and logistics. Local drills are conducted by the State and visits are also made occasionally by ATWC.

RISK AND PREPAREDNESS IN ALASKA

About three-fourths of Alaska's population lives on or near the Pacific coast. All four of Alaska's largest industries depend on the sea. Fishing is the principal activity for most of the Pacific coastal communities. Floating logging camps and mills are mostly found in Southeastern Alaska. Oil platforms and terminals are found in Cook Inlet and Prince William Sound. A major part of the tourist industry involves sportfishing, sightseeing, and cruise ships to coastal Southeastern and Southcentral Alaska plus sport-hunting activities.

An assessment of tsunami preparedness in Alaska was done for 46 communities (Carte; 1984). All towns over 1,000 population appeared adequately prepared and 85% of those below 600 population had low or marginal preparedness. This assessment was based on the six factors that will be discussed next in this paper. It was also found that eight of the nine towns with the largest area subject to tsunami flooding were rated low or marginal. It appears that most of the smaller communities will need outside help to achieve some minimal level of preparedness.

The help needed by the smaller communities can and has come from many sources besides the State and Federal governments. Boroughs, neighboring larger communities, native corporations and private industry should all be included in planning. The Alaska Division of Emergency Services (ADES) is the lead agency responsible for this planning and coordination with help from the Federal Emergency Management Agency (FEMA). The Plan for Public Safety Services prepared for the Aleutian/Pribilof Islands Native Association includes a discussion of the tsunami hazard in that region (Messick, 1978). Such reports will have a positive effect of the level of preparedness.

COMMUNICATIONS AND WRITTEN ACTION PLANS

The universally acknowledged worst method of communication in a disaster is the telephone. The system immediately becomes overloaded besides everyone's best effort advising the public not to use their phone unless absolutely necessary. Even if not overloaded, earthquake damage in the epicentral region will likely cause equipment damage or satellite miss-alignment. Some small villages still have their common phone in a community center which is locked at night.

Thirty of forty-six communities studied receive their initial warning via telephone from a regional warning point. This is the only direct means for many smaller villages. Some towns also receive the message via teletype through local FAA/NWS offices. The only backup for most smaller communities is indirect or non-specific means such as radio or television. The National Weather Service via the NOAA Weather Radio, the Coast Guard via marine radio, and commercial/public broadcasters via the EBS system are all trained and ready to immediately broadcast warning messages.

The Alaska State-wide Satellite Television System is not yet utilized, although widely watched, especially in small communities. Its main shortcoming is dependence on the local satellite antenna and electric power. Electricity is not always available 24 hours a day in some smaller villages and often unreliable. The new Aspen State-wide computer network reaches most medium size communities not on the State warning phone system. The Aspen network potentially could be tied directly into the warning system.

What is most needed is non-satellite dependent and non-landline dependent communications. The State's proposed meteor burst system and high frequency radio network will begin to meet this need. Especially in small villages, receiving devices should be solar recharged and battery operated for minimum maintenance and maximum reliability.

Because of the infrequency of tsunamis a written plan is necessary to insure proper, timely action is taken. Most smaller communities do not have any written plans. Turnover of Village Public Safety Officers is frequent. Other key local officials may be fishing, logging or just out of town when the disaster strikes. The written plan needs local input. Although there will be some "broiler plate" in each plan it should be site specific and practical. Some local pride of authorship will help insure it is read and used.

 1356 20130

OTHER PREPAREDNESS FACTORS

The most common public warning devices are sirens, bells, or whistles. To be effective the signal for evacuation must be known, heard over the entire hazard area, and regularly tested. Evacuation maps and placards describing the signals and safe areas have been distributed in most of the highest risk communities by the ADES. Remotely activated sirens, such as used by the Kenai Peninsula Borough, would benefit several small communities on Kodiak Island, the Alaska Peninsula and Southeastern Alaska.

The local response agencies in the typical coastal community are a volunteer fire department, a health aid, and a Village Public Safety Officer (VPSO) or small police department. These are the ones who will direct evacuation, rescue, first aid, and initial recovery efforts. Public works departments, National Guard units, EMT's, and others become more common as the population increases. Yet in some very small villages there is no volunteer fire department. Since a small community cannot affort these services, individuals will have to be more self-reliant. Fortunately most residents of small villages are very resourceful. They could be aided by training in hazard awareness and emergency skills such as firefighting and first aid.

Most homes and stores in the very smallest villages are in the 100 foot hazard zone. As community size increases buildings begin to extend inland. An adequate evacuation site should be out of the hazard zone, easily accessible, and provide protection from the elements. Perryville has no nearby high ground and some communities have no buildings above the potential flooding level. Any site selection for future community centers, schools, health clinics, fire stations, etc. should be above the hazard zone or of tsunami resistant construction.

As would be expected, small communities will not have a significant common reserve of food, medicine, and emergency equipment. It would not be practical to stockpile these perishable supplies and expensive equipment. In the more remote villages, individuals have larger than normal food stocks and other supplies, if they are not lost to the earthquake or tsunami. ADES or Borough headquarters should list places with the highest risk and least resourcs to prioritize relief efforts.

LOCAL PLANNING AND RELIABLE RUNUP DATA

Some larger communities routinely consider earthquake hazards and tsunami hazards in planning and zoning. Old town sites at Afognak, Kaguyak, Chenega, Valdez and Portage were abandoned after extensive earthquake and/or tsunami damage in 1964. Yet Old Harbor was rebuilt in exactly the same place where nearly every building was destroyed in 1964. Kodiak rebuilt the water-front business district in the same location for economic reasons, and rejected the suggestions for only reinforced concrete or masonary, tsunami-resistant construction (Urban Regional Research, 1982).

There has been only 6 damaging local tsunamis in the last 87 years and no damage from tsunamis generated outside Alaska (Cox and Pararas-Carayannis, 1976). Because of the strong directional nature of tsunamis, Aleutian generated events have caused no damage in the Gulf of Alaska and vice versa. Even the well studied 1964 tsunami doesn't report positive and negative effects in parts of Southeastern Alaska.

With such meager historical data, it is even more important that we have emperical runup calculations done for Alaska as was done for the rest of the Pacific Coast States. In the early 1970's three of nearly 100 Alaska coastal towns were calculated by the Corps of Engineers (Houston and Garcia, 1974). This would allow for more reliable hazard zone predictions for evacuation and data to base zoning and planning decisions.

LOCAL TSUNAMIS WARNING SYSTEM

In November 1976 the Hawaiian Civil Defense Division and the Hawaii Institute of Geophysics installed a number of seismic triggers and designed to sound an alarm for an earthquake 6.5 or over (Adams et al, 1977). Specifically it will trigger for an acceleration of 0.06g which is estimated to be a Richter magnitude 6.5 at about 100 km. Therefore smaller events closer than 100 km would also trigger, plus the relationship between acceleration and magnitude is variable. Local instructions by Hawaiian Civil Defense say a public warning should only be issued if the trigger is activated and the earthquake has been felt by monitoring personnel (Cox and Morgan, 1984). To date no event has been large enough to activate the triggers.

Cox and Morgan (1984) feel the potential for false alarms is so great with the local triggers as to lower the confidence and effectiveness of the total tsunami warning system in Hawaii. They therefore recommend the triggers be abandoned or their threshold raised significantly to lessen the false alarms.

The main advantage to the local triggers is a more rapid warning for locally generated waves. In Alaska we instruct those feeling a very strong earthquake to evacuate the coastal areas immediately. How well that will be heeded is not known. If a tsunami is near a town with a siren system, the dispatcher on duty usually must receive permission from a superior or a warning over the State warning system befor activating the siren system even if the quake were strongly felt by the dispatcher. If there were a reliable trigger device this could significantly speed the local warning. Since Alaska is much more seismically active than Hawaii, possibly some triggers should be located in Alaska for testing purposes to better determine their actual response before they are considered for use in Alaska.

PREPAREDNESS EDUCATION AND EXERCISES

The ADES does a good job training local civil defense personnel in the moderate and large communities. Visits to coastal communities are made by ADES and ATWC personnel for education purposes. Bad weather, infrequent schedules, and high costs make visits to the smaller communities less common.

Local exercises are conducted by the State, but are usually only "desk top" type. The two regional "Shaker" exercises conducted by the State and FEMA were very educational, but required extensive planning and logistics. The Coast Guard at Kodiak conduct frequent local drills, including evacuation drills, and could be a model for the rest of the State. The city of Kodiak and the Kodiak Island Borough School District each have excellent written plans for the public and staff. Possibly VPSO training at the State Trooper Academy could include earthquake and tsunami preparedness.

Most exercises do not involve the private sector, yet a study of hurricane warnings suggests adequate preparedness depends on coordination between Federal, State, local, and private business (Carter, et al, 1979). Canneries are an example. Canneries can have a high concentration of often non-local workers right on the waterfront. The State could require a tsunami evacuation plan for major canneries and even yearly evacuation drills.

BIBLIOGRAPHY

Carte! G., 1984, "A Tsunami Preparedness Assessment for Alaska," Science of Tsunami Hazards, v. 2, n. 2, pp. 119-126.

Carter, T. M., J. P. Clark, R. K. Leik, 1979, "Organizational and Household Response to Hurricane Warnings in the Local Community," presented at the AAAS Annual Meeting, Houston, 1979, NHWS Report Series No. 79-01, 39 pp.

Cox, D. C., G. Pararas-Carayannis, 1976, "Catalog of Tsunamis in Alaska" (Revised 1976), NOAA, World Data Center A: Solid Earth Geophysics, Rpt. SE-1, 43 pp.

Cox, D. C., J. Morgan, 1984, "Local Tsunamis in Hawaii - Implications for Warnings," Hawaii Institute of Geophysics Rpt. HIG-84-4, 104 pp.

Houston, J. R., A. W. Garcia, 1974 "Type 16 Flood Insurance Study: Tsunami Predictions for Pacific Coastal Communities," U.S. Army Engineer Waterways Experiment Station, Tech. Rpt. H-74-3, 88 pp.

Messick, M. J., 1978, "Plan for Public Safety Services, Aleutian-Pribilof Islands," Aleutian/Pribilof Islands Association, Anchorage, AK, 198 pp.

Urban Regional Research, 1982, "Land Management Guidelines in Tsunami Hazard Zones," prepared for the National Science Foundation, Washington, D.C., 258 pp.

 1353 20130

AN ASSESSMENT OF EARTHQUAKE HAZARDS OFFSHORE SOUTHERN ALASKA

By

Yogesh K. Vyas

Exxon Production Research Co.

Houston, Texas

ABSTRACT

A careful assessment of earthquake hazards offshore S. Alaska is essential due to high seismicity along the Aleutian arc and its potential impact on the design of structures in the S. Bering Sea for oil and gas development. API RP 2A provides guidelines on earthquake hazards in the region suitable for the development of seismic input to the pre-lease sale planning. Significant progress has been made recently in the areas related to simulation of ground motion for giant earthquakes for which no strong motion records exist; input parameters for probabilistic hazard analysis of the region; site-response analysis procedures to account for effects of local soils, and processed strong-motion records for S. Alaska. Future improvements could be achieved through refinement of the simulation technology; updating seismic hazard maps for the region through systematic hazard analyses; calibrating the site-response analysis procedures accounting for the broad range of offshore soils; and upgrading the seismic instrument networks in S. Alaska to record large magnitude earthquakes. The recent progress together with the future improvements outlined in this paper would lead to specification of more accurate seismic input for site-specific and final design of offshore structures in the region.

I. INTRODUCTION

Over the past several years, industry and academia have been devoting a significant effort to establish an improved understanding of earthquake hazards offshore S. Alaska. The primary motivation for this effort is to develop more reliable input for future design of safe yet cost-effective, earthquake-resistant structures in the S. Bering Sea. This paper discusses some of the improvements made recently regarding the assessment of earthquake hazards in the region, and the areas of future improvements which would lead to specification of more accurate input for final design of structures in the region. The paper also discusses the general considerations involved with earthquake-resistant design of offshore structures as well as the overall procedure used for the development of design ground motions.

The Aleutian arc region is one of the most seismically active regions in the world. The primary cause of the seismicity is the intermittent relieving of stress which accumulates due to relative movements between the Pacific and the North American plates. Between 1938 and 1979, several earthquakes (Fig. 1) having moment magnitudes M_w 7-1/2 and larger have ruptured much of the interface between the N. American and Pacific plates. Most of the significant earthquakes have occurred in the shallow Benioff-zone situated between the Aleutian trench and the Aleutian islands. The largest of these earthquakes (Fig. 2) had a moment magnitude of M_w 9.2 (e.g., 1964 Prince William Sound earthquake), rupture lengths of several hundred kilometers with strong shaking lasting up to 4 to 6 minutes. The segments along the arc that have not ruptured in recent times are referred to as "seismic gaps". One such gap called the Shumagin Gap [1] is situated between two previous ruptures (Fig. 2) along the arc, M_w 9.1 of 1957 to the west and a M_w 8.4 of 1938 to the east. There is a high likelihood for a major earthquake to occur in this gap [2] during next few decades.

The deep portion of the Benioff-zone has also generated some significant earthquakes. Earthquakes are also associated with the volcanoes on the Aleutian islands. Furthermore, local faults in the back-arc of the Aleutian islands also have the potential to generate large earthquakes.

II. GENERAL EARTHQUAKE DESIGN CONSIDERATIONS [3]

Offshore structures are typically designed to meet both strength and ductility requirements. The strength requirements are intended to prevent significant interruption of normal platform operations and no damage to the platform. The strength level earthquake (SLE) design ground motions are generally associated with a return period of 200 years. The ductility requirements are to ensure that the structure will not collapse under a rare, intense ductility level earthquake (DLE) which is normally associated with a return period on the order of 1000's of years. The design ground motions should always be specified with the knowledge

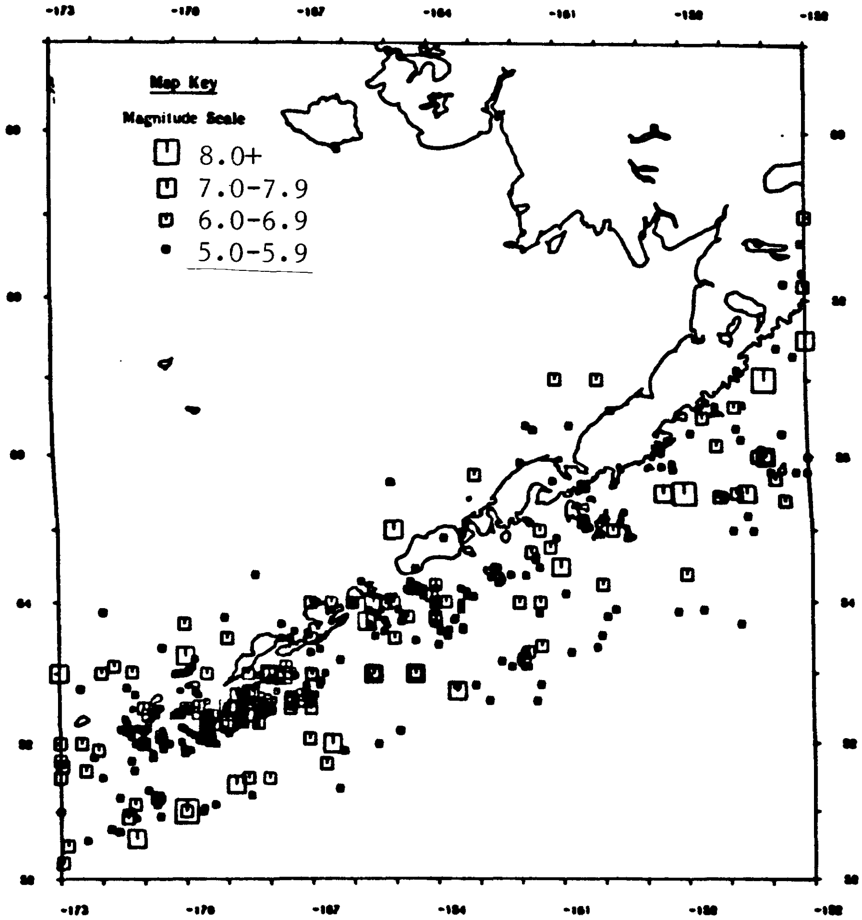


Fig. 1. Seismicity Map of Southern Alaska

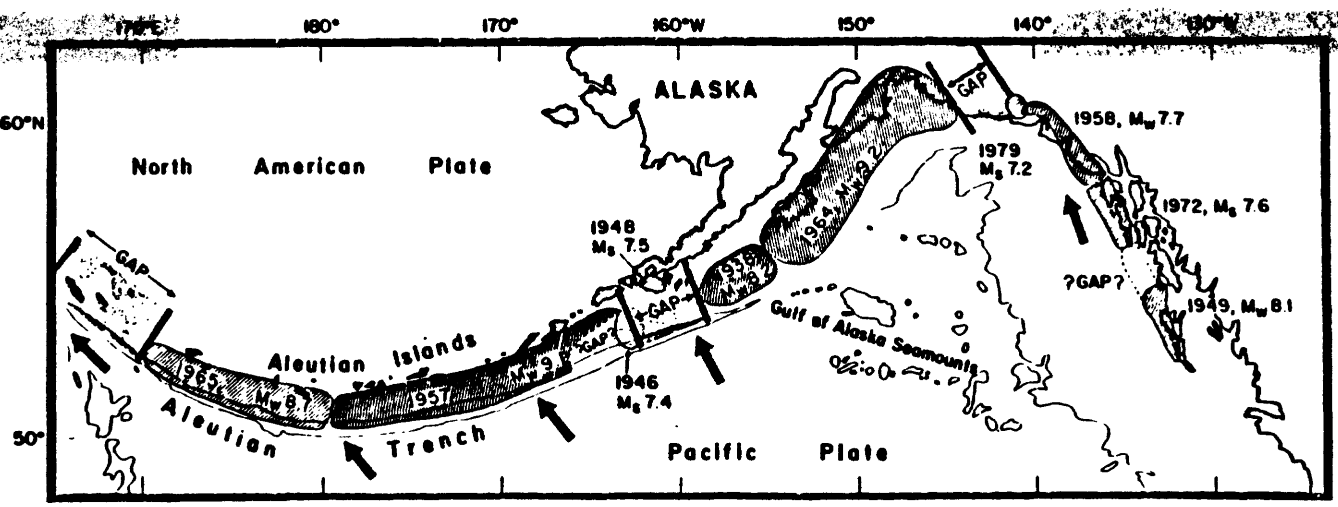


Fig. 2. Seismic Gaps and Rupture Zone of Major Earthquakes Since 1938 [1].

1352 20130

of the analysis procedures to be used for computing earthquake loads on the structure as well as the performance criteria (practice) used to ensure adequate resistance to the imposed loads.

Offshore structures are sensitive to long-period (>1 sec) ground motions. It is in this range that the soft offshore soils tend to amplify the ground motion. Thus, it is important not to rely solely on the peak ground acceleration (PGA) parameter for the design of an offshore structure. It is preferable to develop design ground motions using long-period ground-motion parameters such as response spectral velocity at long-period.

III. OVERVIEW OF SEISMIC EXPOSURE ANALYSIS PROCEDURE [3]

The procedures can be described (Fig. 3) in terms of the following four steps: (1) seismotectonic characterization, (2) seismic exposure assessment, (3) ground motion characterization, and (4) design ground motion specification. This approach for seismic exposure analysis is also endorsed by APIb RP 2A [7].

A. Seismotectonic Characterization

This step involves developing an understanding of the seismotectonic setting of the study region to explain where, why, and how often earthquakes occur in the region and characterizing the generation and propagation of ground motion. This step is divided into three parts: source evaluation, site evaluation, and source-to-site motion attenuation. Source evaluation results in a description of the potential earthquake sources in terms of their location, type of faulting, activity, and maximum magnitude. Site evaluation provides description of the local geology and soil conditions that might influence ground motion at the site. Source-to-site motion attenuation involves finding an appropriate relationship which characterizes the decay of ground motion as a function of the earthquake magnitude and source-to-site distance and possibly other parameters such as the focal depth, fault type and local soil conditions.

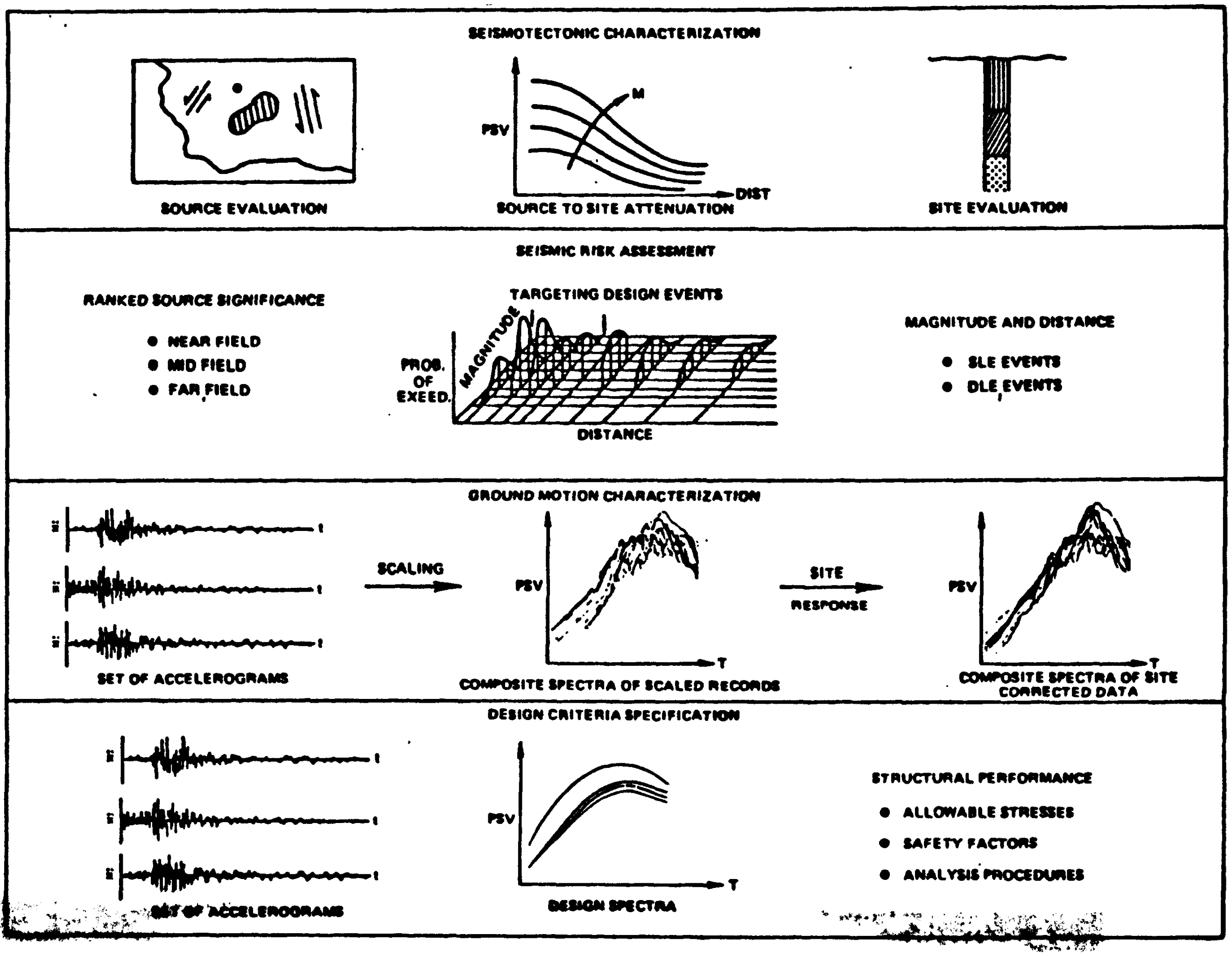


Figure 3.--Schematic Exposure Analysis Procedure

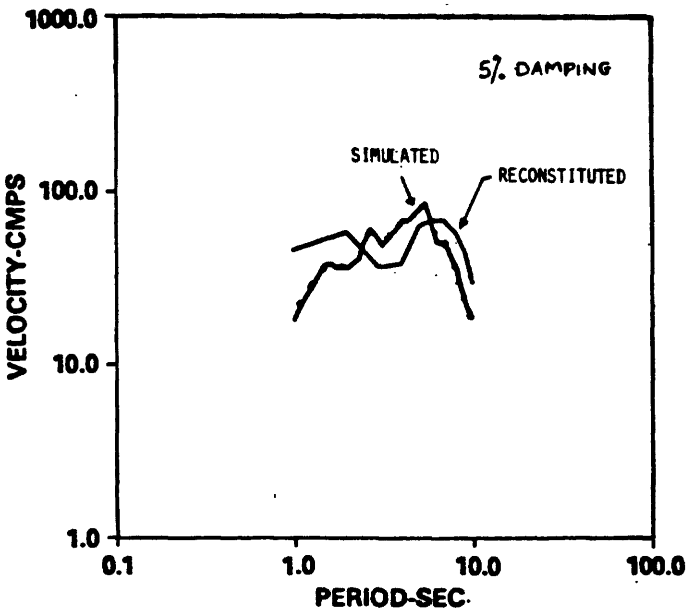


Figure 4.--Comparison Between Simulated and Reconstituted Motions for the 1964 Prince William Sound Earthquake. (At Anchorage Site).

14B5

B. Seismic Exposure Assessment

This step uses the information developed in the previous step to determine those earthquakes which are the most important sources of strong ground shaking in terms of magnitude and distance to the site. The strength level earthquakes (SLE) design events are selected using probabilistic seismic hazard analyses. The determination of the ductility level earthquake (DLE) design events involves a more deterministic assessment of the major earthquake likely to contribute most to ground motion at the site from various sources.

C. Ground Motion Characterization

This step involves developing estimates of ground motion for the events identified in the previous step. The process involves selecting and scaling accelerograms recorded during earthquakes similar to the design events. The effects of the local soil conditions are also explicitly accounted for. The result of this step is a set of ground motion records and a suite of response spectra which represent the design events associated with the SLE and DLE.

D. Design Ground Motion Specification

The final step involves synthesizing the results of the previous three steps and specifying the level of ground motoin for the SLE and DLE design events. Design ground motions are specified as smooth design spectra and associated sets of representative accelerograms. Development of the final specifications also takes into account the analytical procedures and performance criteria for structural design.

IV. EARTHQUAKE HAZARDS ASSESSMENT OFFSHORE A. ALASKA - RECENT DEVELOPMENTS AND FUTURE IMPROVEMENTS

The recent developments including the areas for future improvements in earthquake hazards assessment offshore S. Alaska are discussed below under the following sub-headings: (1) Giant Earthquakes, (2) Seismic Hazard Mapping, (3) Effects of Offshore Soils, and (4) Strong-Motion Records.

A. Giant Earthquakes

The DLE design motions for future sites in the S. Bering Sea would most likely to be dominated by the potential for giant earthquakes along the Aleutian arc. A giant earthquake can be classified as having a moment magnitude M_w of 8.5 or greater. The DLE design motions are normally developed by scaling accelerograms representative of the magnitude and source-to-site distance of the design earthquake and region's tectonic and geologic conditions. The lack of recorded strong motion data for such large earthquakes precludes such a direct approach. Exxon in collaboration with Caltech [4] has developed an analytical procedure to simulate motions for giant earthquakes. The simulated motions are obtained by mathematically summing up recorded motions a smaller-size earthquake several hundred times and constraining those motions by using seismological parameters of the giant earthquakes inferred from teleseismic records.

The soundness of simulation technology has been verified by testing it for two large earthquakes - the 1968 Tokachi-Oki earthquake (Japan) having M_w 8.2 [4] and 1964 Prince William Sound earthquake (Alaska) having M_w 9.2 [5]. In the former case, the overall shape and average response spectrum level of the simulations match those for the recorded motions. For the latter case, no actual strong motion records exist. However, a comparison between the response spectra for the simulated motions and the reconstituted motions (Fig. 4) for the event based upon the damage assessments and a tape recording of the sounds of the earthquake [6], shows similar gross characteristics.

For future site-specific design, it would be desirable to refine the simulation technology using any available strong-motion data for a truly giant earthquake. A suite of actual strong-motion records for such an event would allow a more accurate assessment of attenuation of ground motion especially for sites close to the source. To achieve this, it is important to maintain and if possible, upgrade the seismic instrument stations along the Aleutian islands to record data for such events.

Due to lack of long-term historic seismicity data, there is also a considerable uncertainty in the return intervals for giant earthquakes. One possible approach to decrease the uncertainty would be to conduct geologic dating studies of the sites along the Aleutian arc that have experienced giant earthquakes and have preserved evidence of the paleo-seismic records. Both historic and paleoseismic data base would allow more accurate specification of recurrence relationships for such earthquakes.

B. Seismic Hazard Mapping

API RP 2A [7] has published a seismic hazard map (Fig. 5) for Offshore Alaska. The S. Bering Sea region in this map has been classified as Zone 3 with an effective ground acceleration of 0.2 g. The Pacific segments south of the Aleutian Islands and along the Alaska Peninsula have been classified as Zones 4 and 5 with effective ground accelerations of 0.25 g and 0.4 g respectively. A design spectrum corresponding to a given effective ground acceleration can be obtained by scaling the normalized spectrum given in the SPI RP 2A.

The Woodward-Clyde Consultants have performed two very comprehensive studies - the 1978 [8] Offshore Alaska Seismic Exposure Study (OASES) and the 1982 [9] Outer Continental Shelf Environmental Assessment Program (OCSEAP). The former study was performed using a limited data base to provide input for the pre-lease sale planning for this region. Since then, the earthquake data base for the region has been updated significantly, perhaps making the OASES results obsolete though the overall methodology is still quite valid. Their more recent study used improved recurrence relationships for large magnitude earthquakes by explicitly accounting for their spatial and temporal variations. The focus of the study was more on the earthquake hazard in the Gulf of Alaska and thus a direct applicability to the S. Bering Sea is somewhat limited.

A more recent study [10] has also mapped the earthquake hazards in the Gulf of Alaska. No explicit account of the spatial and temporal variations was made of the recurrence for large magnitude earthquakes. Furthermore, the study employed ground motion attenuation equations derived from the

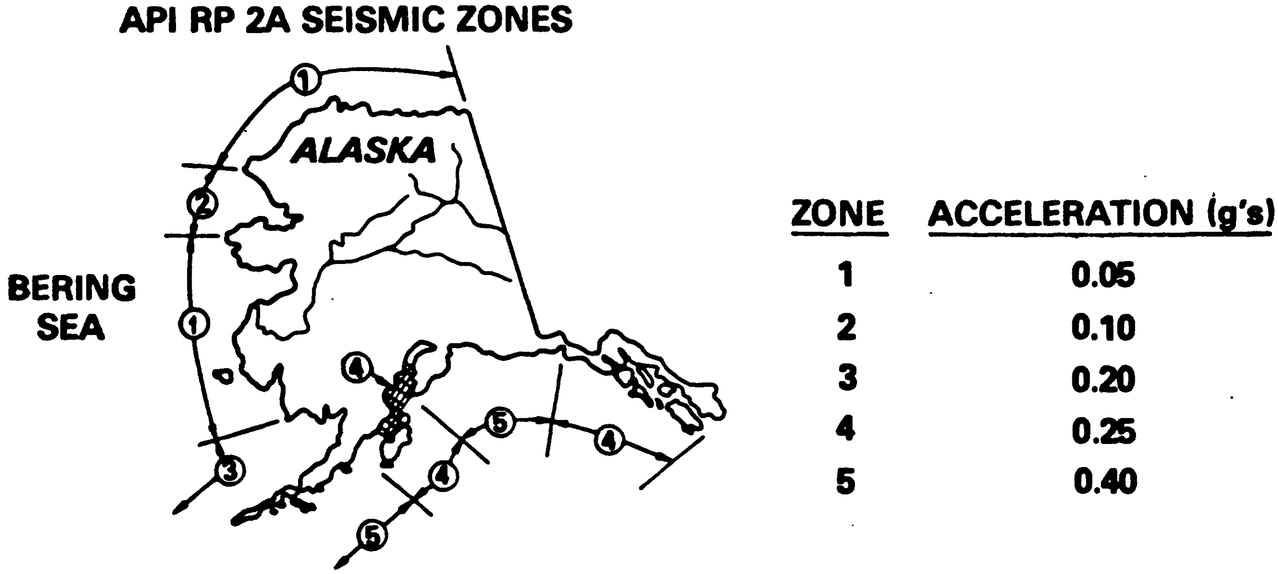


Fig. 5. Seismic Hazard Map for Offshore Alaska [7].

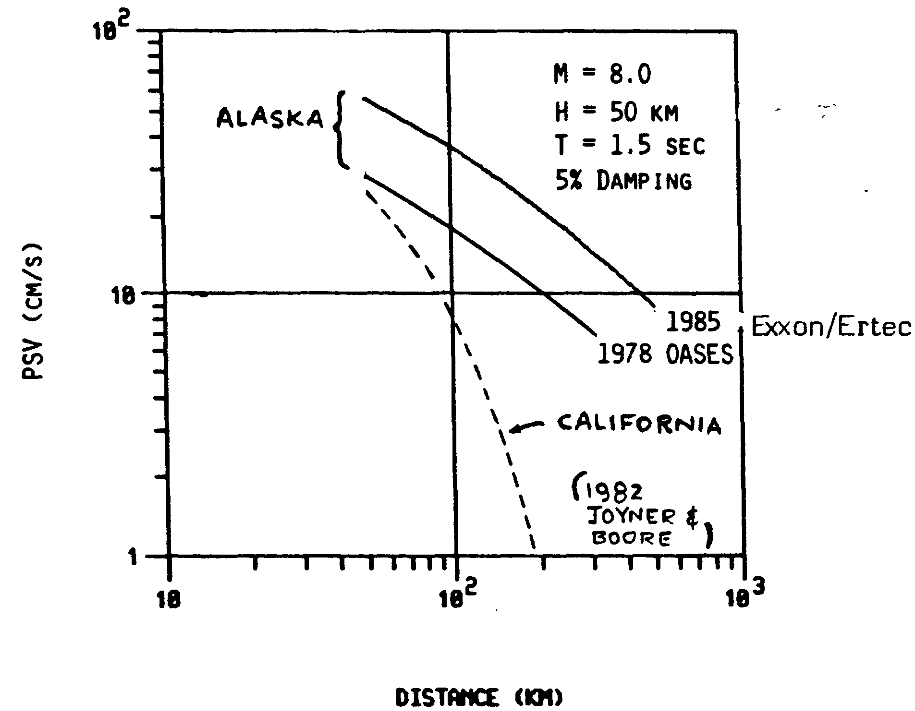


Fig. 6. Comparison Between Alaskan Subduction-Zone and California Attenuation Equations.

14B4 20130

California earthquakes and therefore not directly applicable to the subduction-zone earthquakes.

Some progress has been made toward establishing more relevant input for the seismic hazard analysis of the region. Through a joint effort of Exxon and The Earth Technology Corporation, improved ground-motion attenuation equations [11, 12] for the Alaskan subduction-zone earthquakes have been developed. The study used an extensive strong-motion data base largely made up of corrected accelerograms for the Japanese subduction-zone earthquakes but also for other subduction-zones around the Pacific rim such as Peru, Chile, N. Guinea, Mexico and Alaska. The near-source saturation effects in the attenuation equations for large magnitude earthquakes ($M_w > 8.0$) were defined using simulated accelerograms for such earthquakes. These newly derived attenuation equations predict lower rates of attenuation with distance (Fig. 6) than those for California [13]. The new Alaskan equations predict similar rates of attenuation as used in the OASES study except the actual levels of ground motions are higher for the former case.

Most of the recording sites onshore Japan are underlain by thin alluvium which may not be as favorable for the generation of long period surface wave energy as the deep, long sedimentary basins in the back-arc of the Aleutians. The effects of the back-arc geology may need to be accounted for in the attenuation equations. Future seismic hazard analysis for the region should use the improved attenuation equations as well as updated source and recurrence models. The possible effects due to local faults in the back-arc basin should also be investigated. Besides using input parameters more relevant to the Alaskan environment, seismic hazard studies should perform systematic parametric sensitivity anlaysis to identify uncertainties in the various input parameters as well as the design motions.

C. <u>Effects of Offshore Soils</u>

Soft offshore soils generally tend to amplify the long-period (<0.5 sec) ground motion and attenuate the short-period motions (<0.5 sec). Since the deepwater structures respond more to the long-period motions, the amplified motions would result in greater earthquake loads to be induced on the structures. There is a complete lack of significant ground motion records from the seafloor precluding an empirical approach generally adopted for onshore sites. Past efforts [14, 15] have attempted to acquire seafloor accelerograms offshore Alaska and elsewhere but due to lack of funding, such programs were not carried out for durations long enough to record motions for large earthquakes. API RP 2A provides guidance (Fig. 7) on effects of local soils, in form of normalized design spectra for rock, shallow and deep alluvium. For a more detailed assessment of effects of local soils one-dimensional site-response analysis procedures [16, 17] (Fig. 7) which have been applied for various site-specific studies [3] are preferred. The analysis involves both amplitude and frequency content modification of an onshore accelerogram by mathematically propagating it upwards through a soil model of the site under consideration. The soil model consists of a description of the site's layering, strength and stiffness parameters all of which are selected on the basis of offshore site investigation studies followed by laboratory tests on soil samples recovered offshore.

A systematic and comprehensive site-response analysis of various possible offshore scenarios would provide a very meaningful data base on effects of offshore soils. Such information could be verified using onshore data with appropriate adjustments for offshore application. Such a study should also examine cases where the basic assumption involved with one-dimensional analysis such as a vertically-propagating shear wave, is violated. Effects of other wave-types arriving at arbitrary angles of incidence need to be investigated. Effects of water overburden on vertical motions essentially comprised of compressional waves which would get transmitted through water also need to be accounted for. Finally, special cases where the lateral heterogeneities in the site geometry which may result in wave reflection and refraction causing amplification or deamplification of motions at the site need to be examined too.

D. Strong-Motion Records

The cornerstone of the earthquake criteria development and various empirical studies is the strong-motion instrument records. The Lamont-Doherty Geological Observatory (LDGO) has been operating the Shumagin Island network

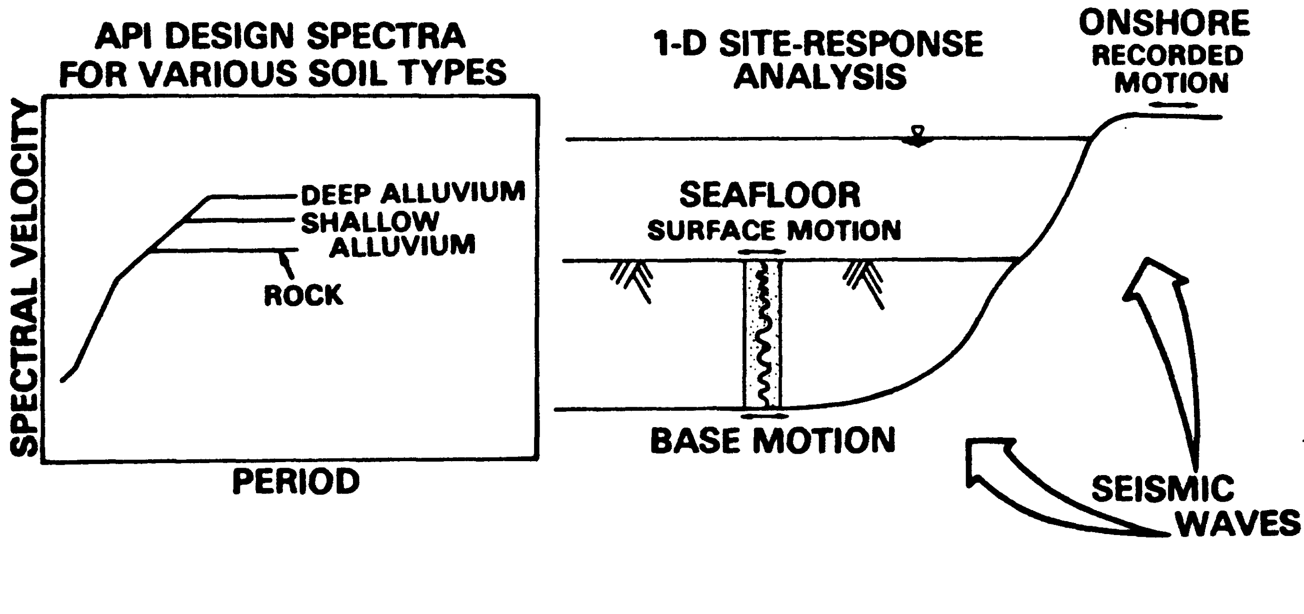


Fig. 7. Effects of Local Soils on Ground Motions.

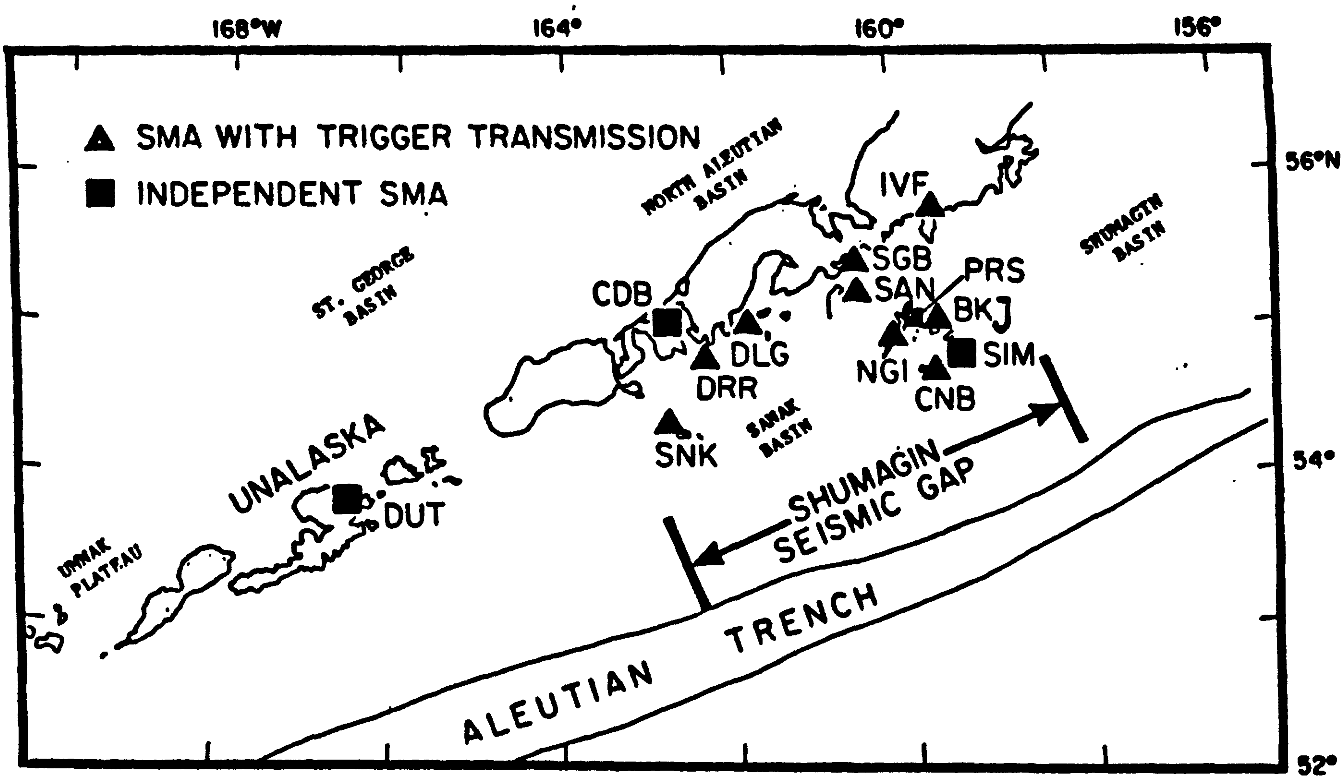


Fig. 8. Location of LDGO Operated Strong Motion Stations [18].

1456 20130

(Fig. 8) and has processed many strong-motion accelerograms recorded [18] during Alaskan Benioff-zone earthquakes. Such programs need to be continued and desirably the local networks should be expanded and upgraded to be able to record some of the large earthquakes likely to occur in the region. A special effort needs to be made in determining the site conditions at the recording stations in terms of its soil types, layering and the soil strengths as well as stiffnesses. Such information is very essential for site response analysis performed to account for effects of local soils that may be different from those at the recording site.

V. CONCLUSIONS

While significant progress has been made in the evaluation of earthquake hazards offshore S. Alaska, there is room for further improvements. The improvements in the areas related to calibration of simulation techniques for giant earthquakes, updating of seismic hazard maps, evaluation of the effects of offshore soils and upgrading of strong-motion instrument stations would allow specification of more accurate input for the design of safe and more cost-effective earthquake-resistant offshore structures.

REFERENCES

1. Davis, J., et al., "Shumagin Seismic Gap, Alaska Peninsula: History of Great Earthquakes, Tectonic Setting and Evidence for High Seismic Potential," Journal of Geophysical Research, Vol. 86, No. 85, p. 3821, May 1981.

2. Jacob, K. H., Hauksson, E., "A Seismotectonic Analysis of the Seismic and Volcanic Hazards in the Pribilof Islands-Eastern Aleutian Islands Region of the Bering Sea," NOAA Report No. 03-5-022-70, 1983.

3. Vyas, Y. K., "Development of Site-Specific Earthquake Design Criteria for the Santa Barbara Channel (SBC) Region, Offshore California," presented at the Specialty Seminars on Earthquake Engineering, Design of Offshore Structures, Stanford University, July 1984.

4. D. A. Coats and H. Kanamori, "Semi-Empirically Derived Long-Period Ground Motions Generated by Giant Earthquakes," Proceedings of the 8th World Conference on Earthquake Engineering, July 1984.

5. D. A. Coats, H. Kanamori, and H. Houston, "Simulation of Strong Motion from the 1964 Alaskan Earthquake," Earthquake Notes of the Eastern Section of the Seismological Society of America, Vol. 55, No. 1, March 1983.

6. Housner, G. W. and Jennings, P. C. (1972). Reconstituted Earthquake Ground Motion at Anchorage, The Great Alaskan Earthquake of 1964, Engineering, Printing and Publishing Office, National Academy of Sciences, Washington, D.C., pp. 43-48.

7. "API Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms," American Petroleum Institute, API RP 2A, Fifteenth Edition, 1984.

8. Woodward-Clyde Consultants, 1978. Offshore Alaska Seismic Exposure Study, prepared for Alaska Subartic Operators Committee (ASOC), March, 6 volumes.

9. Woodward-Clyde, 1982. Development and initial application of software for seismic exposure evaluation, vol. II, Seismic Exposure.

10. Thenhaus, P. C., and others, "Probalistic Estimates of Maximum Seismic Horizontal Ground Acceleration on Rock in Alaska and the Adjacent Connected Shelf." Vol. 1, No. 2, Earthquake Spectra, February 1985.

11. Vyas, Y. K., Crouse, C. B., and Schell, B. A., "Ground-Motion Attenuation Equations for Benioff-Zone Earthquakes Offshore Alaska," Earthquake Notes of the Eastern Section of the Seismological Society of America, Vol. 55, No. 1, March 1984.

12. Crouse, C. B., Vyas, Y. K. and Schell, B. A., "Ground Motion from Subduction-Zone Earthquakes," submitted to Bulletin of the Seismological Society of America, 1985.

 14B3 20130

13. Joyner, W. B., and D. M. Boore (1982). Prediction of earthquake response spectra, U.S. Geological Survey Open-File Report 82-977.

14. Steinmetz, R. L., et al, "Seismic Instrumentation of the Kodiak Shelf," Marine Geotechnology, Volume 4, No. 3, 1981.

15. "Seafloor Earthquake Measurement System," Ocean Industry, September, 1982, p. 221, a program conducted by Sandia National Laboratories for the Department of Energy/U.S. Geological Survey with supplemental funding from ARCO, Chevron, Gulf, Mobil and Shell.

16. Streeter, V. L., Wylie, E. B., and Richart, F. E., June., "Soil Motion Computations by Characteristics Method," Jou. Geot. Div., A.S.C.E. proc., V. 100, No. GT3, March 1974, pp. 247-263.

17. Lee, M. K. W., and Finn, W. D. L., "DESRA-2, Dynamic Effective Stress Response Analysis of Soil Deposits with Energy Transmitting Boundary Including Assessment of Liquefaction Potential," Soil Mechanics Series No. 38, June, 1978, Dept. of Civil Engineering, University of British Columbia, Vancouver, B.C.

18. Bevan, J. and Jacob, K. H., "Processed Strong-Motion Data from Subduction-Zones: Alaska," Lamont-Doherty Geological Observatory, Columbia University, Palisades, New York.

FEDERAL RESPONSE PLANNING IN ALASKA

By

Richard A. Buck

Federal Emergency Management Agency, Region X

Bothell, Washington

The 1980 vulnerability study was the beginning of the Federal Emergency Management Agency (FEMA) involvement in recent years in Alaska earthquake preparedness. In the first years the concern was with upgrading State and local preparedness and FEMA grants went in that direction. For the past two years we have been engaged in an effort to upgrade the Federal earthquake response prepapredness. Since FEMA does not have an office in Alaska and because of high travel costs, we contracted with Alaska Division of Emergency Services to work with the Federal agencies in Alaska and to come up with a plan.

It is highly unusual for a State agency to be cast in the role of assisting with Federal preparedness. This approach was taken for two reasons: (1) we had few practical alternatives; (2) Federal and State agencies have a unique relationship in Alaska. They are less inclined to be at odds with one another than Federal and State agencies in the lower 48. The "we" and "they" are distinguished by residence in Alaska or the lower 48.

We are happy with the progress of the plan. It is ready to be published. Essentially it follows the format used in the Puget Sound Federal Earthquake Plan, which was first published in 1977. The plan is based on three sets of premises. The first set deals with the nature of the problem. The second set is a belief about how effective organizations work, both in normal times and during disasters. The third is an assumption about the planning process.

First, what is the problem in Alaska from earthquakes? As a Federal disaster response agency we like to define the problem in terms of what types of assistance would be requested by State and local authorities after the maximum credible earthquake. The number of injured and homeless is a good indicator of the level of need. Table I compares the number of seriously injured and homeless from the four study areas on the west coast.

Table I

Seriously Injured and Homeless After a Great Earthquake

	Los Angeles	San Francisco	Puget Sound	Alaska
Injured	82,900	40,400	8,000	176
Homeless	182,000	57,500	23,500	2,000

From Table I it is clear that the overall magnitude of the problem from a national perspective is not overwhelming. The Federal government should have no trouble providing the assistance needed. That is not to minimize the effects on the people in Alaska. It is a great loss for a small population. Our perception of the problem tempers the amount of time and money we are willing to spend on response preparedness at the Federal level in Alaska. The problem is small enough that we should be able to handle it as we do the 25 to 50 major disasters that are declared in the U.S. each year. There will be some unique problems because of climate and remoteness. Those will be the subject of some special planning activities.

The second set of premises are described in a paper I wrote in 1983 for the National Earthquake Hazards Reduction Conference in Seattle. The concept is called "laissez faire disaster response." The term "laissez faire" was borrowed from economics to describe a system that operates without much central direction and where there is a good deal of competition between elements in the organization and among outside organizations. These conditions exist in government as well as the private sector. The organization chart may make it look like a centrally directed system, but if you look at how it really operates you normally will find an interlocking set of informal networks within the organization and between elements of other organizations which make it work day to day. If that is how it works day to day, the organization will function best in a disaster working the same way. Any attempt to reorder the organization to work along formal organizational lines will only reduce its ability to deal with the disaster problems. In a disaster the competition between elements will become fierce. The networks may also breakdown due to communications equipment degradation. However, as much as possible the disaster organization should follow the day to day organizational methods of operation. People work best in a system they are comfortable with and which seems familiar to them. Any special disaster procedures should build on the day to day ways; and not replace them. This is especially true when communications have broken down and centralized direction is even less possible. Our Federal response plan follows this philosophy. It expects agencies to use their normal formal and informal networks to get the job done. It institutes some special procedures to re-establish contact among the Alaska Federal agencies, State agencies and Federal agencies in the lower 48.

For instance, the plan sets up a coordinating center in the Federal building with an alternate at BLM's Campbell Lake District Office--where agencies can gather to coordinate operations and to which the State can direct requests for Federal assistance. It also establishes a communications plan to replace the normal telephone contact so vital in day to day business; but which will be denied us after the earthquake.

We have also looked at the kinds of problems the Federal government will be requested to assist with. The givens in this analysis were: (1) the State and local governments will continue to be in control of response; the Federal government will not be taking over the State and local functions; (2) the State and local governments and the private sector in Alaska are capable of handling most of the problems with which they will be confronted. An analysis was done to identify those special problems which might be beyond State and local capability. Table II lists those State/local deficiencies.

The Federal effort in dealing with the identified deficiencies to date has been minimal. It consists of identifying the agency with the best capability in dealing with each problem. This brings us to the third set of premises: incremental planning. Through administering a number of planning projects, I have come to the realization that the most grandiose planning schemes are doomed to failure. Most organizations change incrementally at a fairly constant rate. They are not capable of absorbing simultaneous systemwide changes.

Table II.

State/Local Response

Air Search & Rescue/Air Reconnaissance	Field Kitchens
Trained Medical Triage Teams	Damage & Hazard Assessment
Air Evacuation	Outsize Airlift
Fire Fighting Support	Resupply of Petroleum
Highway Clearance	Air Transportable Generators
Temporary Bridge Repair	
Demolition of Unsafe Structures	

So it is with disaster plans. Planners can dream up comprehensive systems which will optimize disaster response effectiveness in the abstract. But the real world operators of organizations will not buy the systems. We have found experience that it is not possible to address all the potential earthquake problems in a preparedness program. Therefore, we have selected out the key ones. Today, we do not have the resources devoted to planning to insure that every one of these needs can be handled by the Federal government in an effective way. By identifying the need and the agency with the capability, we at least have alerted certain Federal agencies of what might be expected of them in a major earthquake. This will allow them to take some preparedness steps to be better able to perform the function. At this time, we do not have the resources to assist them, or to prod them into taking action. One step at a time, however. This is the essence of incremental planning.

For the immediate future, the emphasis will be on maintaining the soon-to-be published plan. Beyond that, we will begin to study the best means of addressing the identified deficiencies in State and local response.

It should be noted that earthquake response planning also improves our ability to deal with other catastrophic events. I, in fact, prefer to call our efforts catastrophic disaster planning. At this time there is an earthquake response planning effort nationally, which endeavors to put the entire Federal government in a position to deal with large catastrophies. We have 25-50 major disasters declared in our country every year. But we have never seen the capacity of the Federal government really strained by any of these. We know the time will come--particularly in California--when a major earthquake will do just that. The progress on this national earthquake planning has not been impressive. So far, it has been along the lines of designing on the proper organization chart and assigning some functions--much like our Alaska program. Some day, I hope, it will move into real problem-solving, addressing just how resources from around the country will be brought to bear on a catastrophic disaster. This national plan is needed more for a problem in California than in Alaska. But Alaska will gain from the effort.

EMERGENCY PREPAREDNESS PLANNING IN ALASKA

by

Lloyd I. Turner

and

Jim Sey
Alaska Division of Emergency Services
Palmer, Alaska 99645

INTRODUCTION

Ninety-five percent of the population and industrial base of the State of Alaska lies in one of the world's most active seismic zones. During this century, the Pacific coastal and central regions of Alaska experienced 11 earthquakes of magnitude 8 or greater on the Richter Scale including the catastrophic Good Friday Earthquake of March 27, 1964. Although no one can predict precisely the location and timing of the next earthquake, scientists agree that sooner or later another major event will occur within the borders of the State. Due to the rapid growth in population that Alaska has experienced in recent years, an earthquake, similar to what occurred in 1964, could be far more destructive in terms of casualties and property loss.

As the agency charged with the overall responsibility for disaster planning and management at the State level, the Alaska Division of Emergency Services (ADES) is concerned about the earthquake threat within Alaska and has been actively involved in preparing the communities and residents of the State for such an eventuality.

The purpose of this paper is to acquaint the reader with the responsibilities and services that are provided by this Division and to provide a summary of the more important earthquake and tsunami preparedness programs that it has undertaken in recent years. The paper also discusses the Division's plans and programs for the immediate future and contains recommendations regarding areas or subjects where additional effort is required.

THE ALASKA DIVISION OF EMERGENCY SERVICES

ADES is a Division of State government within the Department of Military and Veterans Affairs. The authority for the establishment of ADES is contained in Alaska Statute 26.23.030. The mission of the organization is to develop and maintain a Statewide integrated emergency management system designed to protect life and property and to assist individuals and local governments to repair and recover from injury and damage caused by any type of disaster. In order to accomplish its mission, ADES has three primary responsibilities. The first is to work with and assist local governments and community organizations in planning and preparing for both natural and civil defense disasters. In accomplishing this goal, the Division conducts frequent training sessions and exercises in various communities throughout the State and also provides direct staff assistance to local governments in their planning and preparation efforts. The Division's second responsibility is to coordinate the immediate State response to save lives and preclude further damage to property when disaster strikes. In this role, ADES can call upon any other State agency for assistance. Finally, after the immediate threat is over, ADES is also responsible for coordinating the recovery efforts and providing assistance to communities and individuals in their rebuilding efforts through the use of various State and Federal programs.

THE DISASTER RESPONSE PROCESS

During any disaster situation, the initial response efforts is the responsibility of the individuals and communities directly affected by the event. Assistance will be made available as soon as possible from both the State and Federal sector if necessary; however, there is a time factor involved while forces are mustered, problems identified and priorities established.

If the community determines that the assistance required is beyond their local capability, the governing body of the community can request additional aid from the State. Under a typical disaster situation, ADES dispatches a response team to the scene to determine the extent of the emergency and to provide whatever immediate assistance may be required. A recommendation is also forwarded to the Governor regarding what, if any, additional assistance is required from the State government. Once the Governor has approved a disaster declaration, the full force of State resources can be brought to bear on the problem.

Depending upon the overall extent and impact of the disaster, the Governor can also request Federal assistance. Such requests are channeled through the Federal Emergency Management Agency (FEMA) to the President. If the President approves the Governor's request, a Federal Coordinating Officer is appointed from within FEMA and that officer is responsible for coordinating all Federal assistance to the disaster area.

Although the above process may appear cumbersome and time consuming, in actual practice it is not. Most State and Federal agencies have the statutory authority and responsibility to assist communities in preventing further loss of life or damage to property. Such assistance can be rendered without a formal declaration at either the State or Federal level. Additionally, in the event of a major disaster, it would be apparent from the outset that a catastrophe had occurred and the required declaration would be forthcoming immediately.

DISASTER ASSISTANCE PROGRAMS

There are a number of disaster assistance programs that are available through the State and Federal governments. The following is a summary of some of the Federal programs that could be applied within Alaska after the President has approved a disaster declaration:

Temporary Housing - Provides funding to individuals for temporary housing in the event their home has been destroyed or is unusable as a result of the disaster. Up to one year's temporary housing can be granted under this program.

Mini-Repair - Provides up to $10,000 for the repair of damaged homes to permit early occupancy of the residence.

Small Business Administration Loans - Provides low interest loans to individuals and businesses who have suffered personal or real property losses as a result of the disaster.

Individual and Family Grant Program - FEMA can provide financial assistance to individuals for the loss of personal property. The total amount of the grant cannot exceed $5,000. FEMA provides 75% of the funding for these grants and the State contributes the remainder.

Public Assistance Program - FEMA can also provide financial assistance to the State and its communities for the repair of damaged public facilities. This is also a 75%-25% matching program.

In addition to the Federal programs cited above, Alaska has several similar programs that are administered by ADES using State funds. These include the State Individual and Family Grant Program, the State Public Assistance Program and the State Disaster Loan Program. Funds for these programs are derived from the Disaster Fund which is a revolving $5,000,000 account. The Governor has the authority to appropriate up to $1,000,000 for any one disaster during the State fiscal year. Legislative approval is required in the event that the cost of any single disaster exceeds $1,000,000 or the total for all disasters during the fiscal year exceeds $5,000,000. At the present time there are 19 State declared disasters in various stages of completion. They range from the windstorm disaster that occurred in Southeast Alaska last winter to the recent flooding on the Yukon and Kuskokwim Rivers.

RECENT EARTHQUAKE AND TSUNAMI RELATED PROJECTS

Beginning in the last 1970's, ADES has undertaken a number of earthquake and tsunami related projects through funding provided by FEMA. The following is a summary of the more important activities that have been completed:

Greater Anchorage Area Earthquake Response Study - This study, which was completed in 1980, provides a comprehensive analysis of the effect that an earthquake, similar to the 1964 event, would have on the Greater Anchorage area. The report addresses casualty and damage estimates for various facilities and utilities. Although the study is primarily directed at Anchorage, it also includes a section on the effects that the follow-on tsunamis would have on coastal communities. In addition to ADES staff personnel, several engineering firms and recognized national consultants contributed to the information contained in the report. The document has been used extensively by ADES in its earthquake response planning efforts.

Tsunami Run-Up Maps and Warning Stick-ons - Although Anchorage suffered extensive damage and some loss of life the real "killer" in 1964 was not the earthquake, but the tsunamis that followed and devastated many of the coastal communities. To help communities prepare for a future tsunami event, ADES has recently completed potential run-up maps for 24 coastal towns ranging from Ketchikan in the Southeastern Region to Dutch Harbor/Unalaska in the Aleutian Islands. Samples of the maps that have been developed are available through ADES and will be displayed at the workshop. Technical experts for this project was provided by the Alaska Tsunami Warning Center. In addition to the maps which have received widespread distribution, ADES has also distributed warning signal stick-ons and informational brochures to the residents of the coastal communities.

Public Awareness - Public awareness is a vital and continuing requirement of any disaster preparedness program. During the past few years ADES has maintained an active earthquake and tsunami education program throughout the State. This includes frequent seminars and training sessions for emergency management personnel at the local level as well as awareness presentations for the general public including the school systems. Plans are under way to expand the Division's capability in this regards by using trained volunteers as guest speakers and instructors.

Disaster Volunteer Program - In 1983, ADES initiated a Disaster Volunteer Program within the Division. Since that time, approximately 40 individuals have been trained and are qualified to assist when an emergency strikes. These volunteers have proven themselves to be a highly motivated and capable adjunct to the full time, professional staff and were used extensively in the Southeast Windstorm Disaster of November 1984 and during the recent "Shaker II" Earthquake Exercise.

Training Exercises - During the past two years, ADES has become actively involved as a participant in Statewide training exercises. These exercises are designed to test the Division's response capability and procedures for both wartime and natural disaster emergencies. The most recent exercise, which was conducted in early April of this year, was "Shaker II." This was a three day earthquake and tsunami exercise based upon a scenario similar to 1964. Over 400 people participated and it involved all levels of government and every major community in Southcentral Alaska. The primary objective was to test current concepts, plans and procedures with the end goal being improved disaster response capability. Shortcomings in the State's ability to respond were identified and efforts are now under way to make the necessary changes and improvements.

One of the noteworthy findings of this exercise was that the overall disaster response capability within the State has improved significantly since 1964, and that ADES was much better prepared to manage a major disaster today than they were 21 years ago.

Federal Agency Earthquake Response Plan - Over the years, the Federal government has played an important role within Alaska. The assistance rendered by the Federal agencies in 1964 was vitally important to the overall recovery effort. Although there have been significant improvements in the response capability at the State and local level in recent years, Alaska would still count heavily upon the Federal sector for assistance if another major earthquake should strike the State. Recognizing the need for an effective Federal reponse, FEMA requested that ADES undertaike the task of developing a detailed plan for the Federal agencies to follow in the event that such a disaster again occurs. Although it is rather unusual for a State agency to develop a Federal plan, the cooperation received from all Federal agencies was outstanding. The plan was completed and distributed earlier this summer and it will be an effective tool in ensuring a coordinated response from all levels of government.

FUTURE ACTIVITIES

During the forthcoming Federal fiscal year, ADES has requested funding from FEMA to undertake a comprehensive review of the design and construction standards for State owned or leased buildings and facilities in the Greater Anchorage area. Buildings and facilities to be included in the review fall into two categories:

1. Those that are not required for emergency or recovery operations. The focus will be on buildings rather than facilities and will emphasize the need for designing and constructing buildings to minimize potential loss of life. Nonstructural hazards will be included in the review.

2. Those State owned or leased buildings and facilities that are critical for emergency and recovery operations. Such facilities require a higher standard of design than facilities indicated in 1. above. The continued functioning of critical equipment will also be addressed.

The overall purpose of this proposal is to:

1. Review current standards and perform a preliminary analysis of State owned or leased buildings and facilities in the Greater Anchorage area using these standards.

2. Determine what, if any, changes should be made in present standards.

3. Develop a plan of action to implement proposed changes in the current standards and to correct deficiencies in State owned or leased buildings and facilities.

The Division plans to work quite closely with representative from the scientific and engineering community in this vitally important undertaking and is hopeful that the end result will be an improvement in building seismic safety throughout the State.

In addition to the above, there are three other earthquake related projects that ADES will be involved with during FY 86. The first will be the development of an earthquake/tsunami disaster specific annex to the current State Emergency Plan that will detail the specific response actions required at the State level following such a catastrophic event. The annex will be patterned after the recently completed Federal Agency Earthquake Response Plan and it will address all seismically prone areas in Alaska.

The second project entails the development of an alternate location for the State's Emergency Operations Center (EOC) within the Greater Anchorage area. The present location of the primary EOC in Wasilla meets the needs quite adequately for most natural disaster situations and it is ideal for a civil defense emergency since it is out of the primary impact area. However, if a major earthquake strikes Anchorage, there is a need to have an alternate location closer to the damage scene. Efforts are presently under way to locate a suitable facility in closer proximity to the Municipality.

Although not directed specifically at the earthquake threat, ADES has developed a comprehensive communications package that would enhance the State's overall capability to respond to any major disaster. The system consists of additional high frequency, single side band radios and the Meteor Burst System, neither of which are affected by earthquakes. The Meteor Burst System operates by bouncing radio signals off reflecting trails left by burning meteors as they enter the atmosphere and the system provides hard copy messages in a matter of seconds. Although ADES was unsuccessful in obtaining funding for this project during the last Legislative session, every effort will be made to include it in the next budget cycle.

RECOMMENDATIONS

During the course of the workshop we anticipate that many worthwhile recommendations will be forthcoming from the participants, particularly in regards to scientific and engineering work that needs to be accomplished.

From an emergency management standpoint, there are two specific areas where we believe additional effort is required.

The first concerns the need for more research regarding tsunami run-up data. Extensive efforts have been made in the past to define the potential run-up that could be expected in our coastal communities from a distant source tsunami. Although additional refinements are possible and certainly desirable, the information presently available to ADES on distant source tsunamis serves our emergency management requirements relatively well.

Our primary concern at this time is the need for more information on the locally generated tsunami hazard since little or no warning can be given for such an event. Because of the lack of data on this phenomenon, we, along with the Tsunami Warning Center, have somewhat arbitrarily assumed that all coastal communities in the seismic zone have such a hazard and we have established the 100 foot elevation level as the minimum safe area. With the data currently available, it is the only prudent course to follow. However, any effort to more precisely define this threat would be welcomed not only by emergency managers but also by the communities since it would provide them with more accurate and realistic run-up information.

The second area where we believe additional effort must be expended is in regards to the private sector's involvement in our earthquake programs. Too often our audiences are limited to fellow professionals from the emergency management and scientific community. One of the key factors in California's success has been their ability to get the private sector interested and involved in their earthquake programs. The leaders in their statewide effort are not only emergency management specialists, engineers and scientists, but also include bankers, business leaders, media personnel, doctors, politicians, etc. We believe that one of our primary goals in the next few years should be to actively seek out and involve the private sector in our efforts within Alaska.

PRESENT PLANNING FOR AND MANAGEMENT OF SEISMIC RISK MITIGATION

Lidia L. Selkregg[1]

University of Alaska
Anchorage, Alaska

Introduction

In 1964 there was little knowledge of disaster planning. Concern over earthquake risk was not reflected in U.S. public policy and, as stated, the extensive work conducted by the National Academy of Sciences to document the 1964 earthquake set the stage for the development of comprehensive analytical seismology and risk mitigation studies. In the last 15 years several actions taken by Congress have led to the current commitment to risk prevention and mitigation.

On December 31, 1970, President Nixon signed Public Law 91-606, the Disaster Act of 1970. Section 203 (h) of the act requested that a full investigation be made to prevent or minimize loss of life and property due to major disasters. President Nixon stated in his 1972 State of the Union message to Congress on January 20, that the administration would consider new and accelerated activities aimed at reducing the loss of life and property from earthquakes, hurricanes, and other natural disasters. Prompted in part by the property losses resulting from the 1971 San Fernando earthquake, Congress enacted the Disaster Relief Act of 1974 (Public Law 93-288) to assist local and state governments in

---

[1] The research presented here was conducted under the National Science Foundation Grant CEE 8112632 (Earthquake Hazard Mitigation: Planning and Policy Implementation, The Alaska Case).

carrying out their responsibility of disaster mitigation and prevention. The act required that every state designate a lead agency and prepare a state emergency plan outlining the process for delivering federal aid and the framework necessary to coordinate state and local government action.

Seismic risk reduction was also the focus of the Earthquake Hazards Reduction Act of 1977 (U.S. Public Law 95-124). The purpose of this act was to reduce the risks to life and property resulting from future earthquakes through the establishment of an effective earthquake hazards reduction program. For the first time national concern for risk mitigation as a method to minimize death and loss of property was addressed. The act brought national attention to the development of earthquake-resistant design and construction and earthquake prediction, model codes, research, planning, and educational programs.

As a result of the Hazards Reduction Act of 1977, on July 20, 1979, President Carter signed an executive order that created the Federal Emergency Management Agency (FEMA) with the responsibility of coordinating disaster assistance programs. The intent of the act was to streamline emergency management programs and increase management efficiency in disaster preparedness, mitigation, relief, and recovery. The act also stressed the need for increased research in the area of disaster mitigation and prevention along with technical assistance to local and state governments. FEMA was established to consolidate the planning, mitigation, and assistance functions and responsibilities that were previously under several separate federal agencies, including the Federal Disaster Assistance Administration (FDAA) and the Federal Insurance and Hazard Mitigation Agency (FIHMA). The objectives were to centralize and institutionalize federal decision-making related to risk mitigation, prevention, and recovery and to assist state and local government in reviewing the local state of preparedness.

Under the authority of the act the principal agencies entrusted with the responsibility for performing research on prediction, mitigation, and prevention of seismic disasters are the National Science Foundation (NSF), the U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA). Since the Alaska earthquake of 1964 substantive research programs on earthquake hazards mitigation have been developed in seismology and geology by the USGS, in building standards by the National Bureau of Standards, in seismic analysis of nuclear power plants by the Nuclear Regulatory Commission, and in disaster relief by FEMA.

In the last five years the NSF, USGS and FEMA's interest has increased the number of professionals and scientists involved in earthquake-related sciences and technology in this country and abroad. This has led to sponsoring of workshops and conferences directed toward evaluating the process involved in risk assessment, hazard mitigation, disaster prevention, and disaster recovery--both short and long range. A new dimension in risk mitigation awareness has emerged with the involvement of planners, public administrators, sociologists, who along with engineers, seismologists and architects look for solutions to major public safety issues. However, research related to preearthquake planning and postearthquake recovery is still in its infancy. Research efforts seem to have focused mostly on the application of geological information in the allocation and development of special zones (microzonation) rather then looking at the total impact in a broader regional and urban context. Also limited is research related to the organization and institution entrusted with implementation of risk mitigation policies.

Measures and policies related to land use planning, site selection, design of foundations and structures, abatement of hazardous structures, and location and construction of critical facilities are not applied or implemented. Organizational fragmentation seems to dispense the effectiveness of even the best designed programs. Priorities and mandates of agencies and departments differ, communication of bureaucrats with their counterparts in other agencies often does not occur even when their responsibilities clearly overlap or interface.

Alaska Today

No doubt that the overall technical competence needed to insure safe development in earthquake-prone regions has been refined since 1964. In 1978 the state legislature passed the Alaska Disaster Act, which requires that the Division of Emergency Services study areas subject to shifting, subsidence, flood, or other catastrophic occurrences and recommends appropriate changes in zoning regulations, other land use regulations, or building requirements for areas susceptible to a disaster. The legislature passed the Alaska Coastal Management Act, which contains a section on geophysical hazards (GAAC 80.050) that directs districts (local governments) and state agencies to identify known geophysical hazard areas and areas of high development potential where geophysical hazards may occur. Development in these areas cannot be approved until siting, design, and construction measures for minimizing property damage and protecting against

1587 20130

loss of life have been provided. A number of public and private organizations directly or indirectly address problems of natural disaster. In addition, most of the communities have designated an emergency preparedness director and have developed civil defense-type plans.

Why then do many believe that another major earthquake in southcentral Alaska would have a drastic effect on people and property? Why have lands designated high risk in Anchorage been developed for industrial, commercial, and residential use? Earthquake hazard mitigation presents implementation problems that differ from those inherent in government programs to attack social and environmental ills. The threat from earthquakes is largely invisible and of low probability, though of great potential consequence.

Many people interviewed as part of this study conducted in 1983 were pessimistic about the prospects of improved risk mitigation efforts, and they often cited specific impediments, including technical issues of geology, land use allocation, government organization, and specific planning and management problems. Broader concerns were related to the obvious lack of implementation of well-known public safety measures. The issues most often referred to by the public, scientists, policy makers, and staff of various agencies related to political and organizational obstacles. The organizational obstacles often referred to include imperfect scientific information and defective theoretical approaches, ambiguous policy directives, and the difficulty of sustaining public interest in the issue. Political obstacles are even broader and more difficult to specify. They include leaders who lack knowledge, sympathy, or commitment to implementation, no firmly committed constituencies, and the problem of identification of the level of government responsible for mitigation.

Some of the most often mentioned obstacles are:

1. Accuracy, reliability, and availability of scientific geotechnical information. Geology and other relevant sciences in most cases, cannot tell with certainty when, where, or with what degree or severity an earthquake will occur. Thus, uncertainty is injected into the assessment of the actual risks. This ambiguity is the result of communication difficulties between the technical expert, the planner, and the layman citizen or public official.

2. Earthquake hazard mitigation in Alaska has been hampered by lack of understanding of how it relates to local, state, and national public policy decision making. Risk evaluation prevention and mitigation studies are isolated from the planning process.

3. Organization of the earthquake mitigation process lacks clarity. Much of this results from the absence of an overall understanding of how risks and geotechnical hazards should be placed in the policy process. Successful policy implementation is unlikely in a situation where precise policy directives are not present. The Alaska case is a hodge-podge of local planning and zoning, state land use, and federal policy statements, and planners and public officials report lack of communication among departments as the stumbling block to hazard mitigation Responsibility for geophysical hazard mitigation is spread among agencies and governmental organizations. Planning is done by another

department, and the issuing of building permits and codes and zoning enforcement is the responsibility of yet another.

4. Shortage of funds. Geophysical hazard mitigation and implementation programs are particularly vulnerable to budget cuts. Since hazard mitigation has little institutional presence and no constituency, it has difficulty making claims on resources.

5. Successful implementation is hampered by operational rules of administrative agencies which skirt or neglect geophysical risk mitigation. Except in the more complex projects, neither a licensed engineer nor a building official is required to consider siting in relation to geophysical risk. Nor does geophysical risk mitigation appear prominently in land use regulations. For example, the 1982 Anchorage Comprehensive Plan makes few references to seismic risk, and the ones which do appear are incidental and indirect. In short, the existing rules of responsible agencies usually don't support seismic risk mitigation. Formal and informal standard operating procedures generally do not include any regular incorporation of geophysical risk.

6. Planning and technical staff hired by federal, state and local agencies are rarely trained to deal with seismic risk as part of the environmental assessment process. Many consider mapping, storing, and displaying of physical data to be the end product rather than the process leading to assessment and implementation of mitigation measures.

 1651 20130

When communities seek outside assistance and have studies performed and maps prepared by consultants or turn to state and federal data bases, often they do not have staff with expertise to use the data and translate it into planning recommendations and administrative regulations policies.

7. The lack of statuatory support for geotechnical hazard mitigation measures reduces the probability that leaders in government and the bureaucracy will take these dangers into account. Leaders may lack skill or commitment to geophysical hazard mitigation. Agency heads and local government leaders often lack the managerial and political skills necessary to maximize what can be done within existing law.

8. Elected officials blame deficiencies of technical information and the absence of directions and assistance that they receive from staff and other levels of government. These excuses often make political resistance to mitigation measures. Officials often fail to pursue rational policy options for reasons which have to be judged as expedient rather than logical.

9. There is no constituency which supports seismic risk mitigation. Although property owners, bankers, environmentalists, land developers, neighborhood community councils, and other organized groups are all heavily represented on legislative, planning, zoning, and platting bodies, rarely seismic risk mitigation has received public attention.

Earthquake hazard mitigation lacks a constituency or support of recognizable interest groups.

10. Lack of coordination among local, state, and federal government involved in pre-paredness, mitigation, and recovery . Local and state governments have some capacity to deal with the consequences of disaster of all types. The federal role and responsibility in this area, however, is most significant and is recognized and established in legislation. This fact is based on the conception that coping with large-scale disasters is beyond the capacity of local government. The federal and state governments have thus assumed a critical role in disaster mitigation and response. In earthquake hazard mitigation, however, federal and state governments' roles have been minimal. This is true despite the fact that Alaska has a unique institutionalized history of coordination among federal, state, and local agencies on issues related to land use and economic development.

A PLANNING AND ADMINISTRATIVE MODEL FOR RISK AND MITIGATION

By

Lidia L. Selkregg[1]
University of Alaska
Anchorage, Alaska

Introduction

A review of present preparedness in the state conducted in 1982-83 reveals that if a major earthquake were to occur today, the state and its major communities would be no better prepared than on March 27, 1964. Little planning for risk mitigation has been done. In fact, as a result of increased population and development that occurred in upper Cook Inlet, many scientists, planners, and administrators believe that another earthquake would have even greater impact on commerce and people than in 1964. Destruction of transportation systems and commerce in Anchorage, the major city and distribution center in the state, would affect the entire state economy.

The Alaska experience exemplifies the need for improving methodologies in the preparation of regional and municipal plans for seismic risk areas. Also apparent is the need to educate planners and policy makers on the importance of this issue and of developing effective interdisciplinary/interagency management systems to insure the application of recommendations made in the immediate relief and long-range recovery process.

---

[1] The research presented here was conducted under the National Science Foundation grant CEE 9112632 (Earthquake Hazard Mitigation: Planning and Policy Implementation, The Alaska Case).

1654 00130

A planning model, that includes a "risk" component as an integral part of the comprehensive planning process, is presented as an answer to some of the basic problems encountered in assuring that risk mitigation becomes a part of future urban and regional development in Alaska.

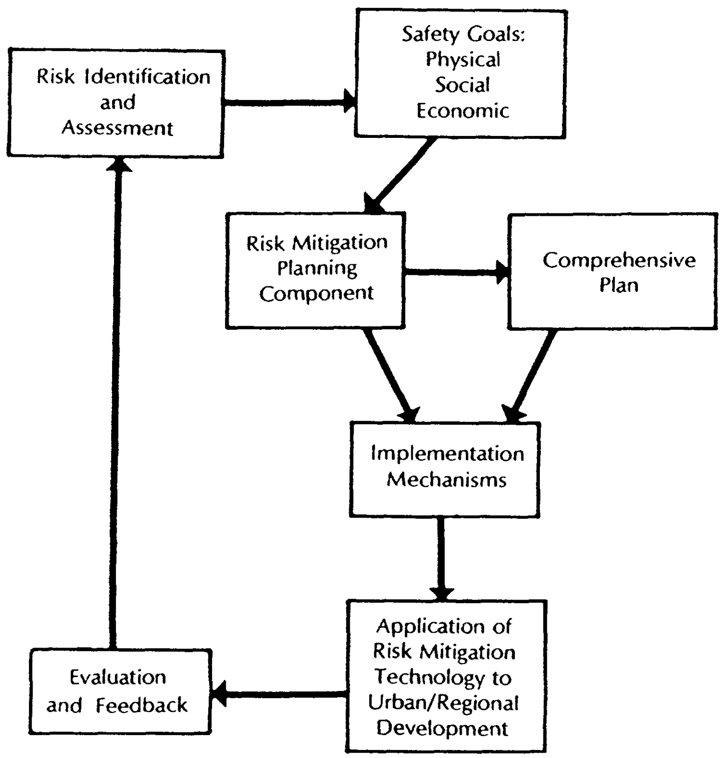
A Planning Model

The Alaska experience points out that efforts toward minimization of natural risks not only depend on the ability to delineate hazardous areas and evaluate the level of risk pertaining to potential use in those areas, but also on the ability to develop new planning methodologies that include a "risk component" as an integral part of the comprehensive planning process (Fig. 1). Areas of high risk were identified and mapped in all affected communitied immediately following the 1964 earthquake. Local governments, assisted by the U.S. Geological Survey, have prepared detailed environmental studies for various communities. Since then, the Municipality of Anchorage has conducted a special geotechnical hazard assessment study that, in addition to mapping seismic risk areas, has identified other hazards--wind, coastal erosion, snow-and rockslide areas, permafrost zones, and areas subject to glaciation. Many communities, in compliance with the Alaska Coastal Management Act, have prepared documents reflecting geophysical hazard zones; however, this information is not being used to develop comprehensive plans, and construction is taking place indiscriminately on steep slopes, wetlands, and on man-made fill.

This leads to the conclusion that present planning methodology does not insure successful application of disaster prevention and mitigation technology and

FIGURE 1

Risk Mitigation and Implementation Process



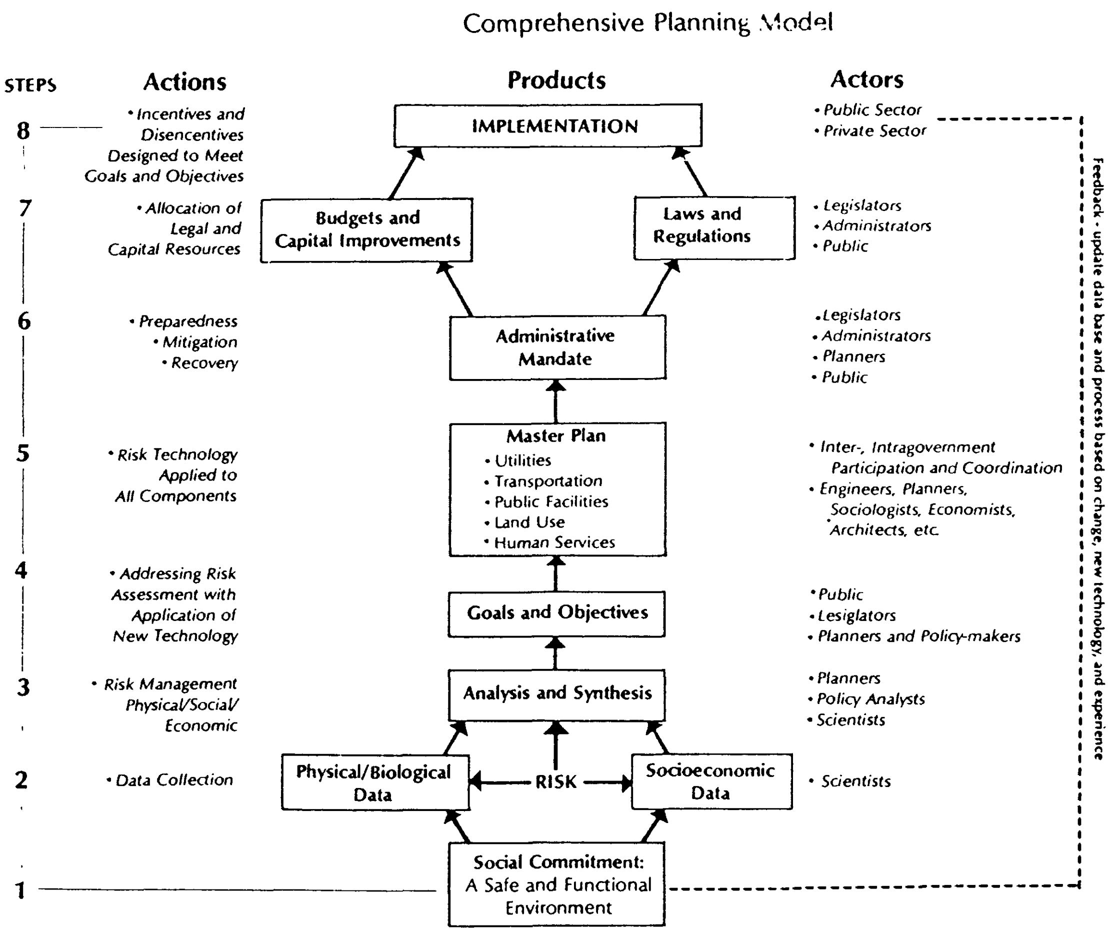
1684 20130

perhaps a new definition of comprehensive planning is in order. The present concept of planning as a process for setting goals statements without development of specific guidelines for implementation has resulted in sporadic and inconsistent application of technology directed to risk mitigation on the one hand and other technologies (also often misguided) directed to land use allocation, transportation, and utilities development on the other. A successful planning process must integrate comprehensive goals and objectives based on the understanding of the physical, social, and economic makeup of the urban system into a master plan for implementation through team building that relates all components of urban structure; utilities, transportation, public facilities, land use and human services.

Knowledge of risks must be applied to all components of an ongoing comprehensive planning process (Fig. 2). Implementation of goals and objectives must be adjusted in response to increased technical knowledge and to changes in the socioeconomic makeup of the area. Plans must be reliable and predictable guides for public and private development decisions. At present the general setting of goals without a defined implementation mechanism does not provide the guidelines needed to express the true intent of the goals. Risk consideration must be applied to all the components of a comprehensive development plan. To accomplish this, coordination and cooperation are indispensable. Inter- and intraagency coordination and use of common baseline data are critical when implementing plans through programs and projects.

A comprehensive regional/city development plan, tying together more specific components which focus on specifics, is needed to assess the impact of seismic

FIGURE 2



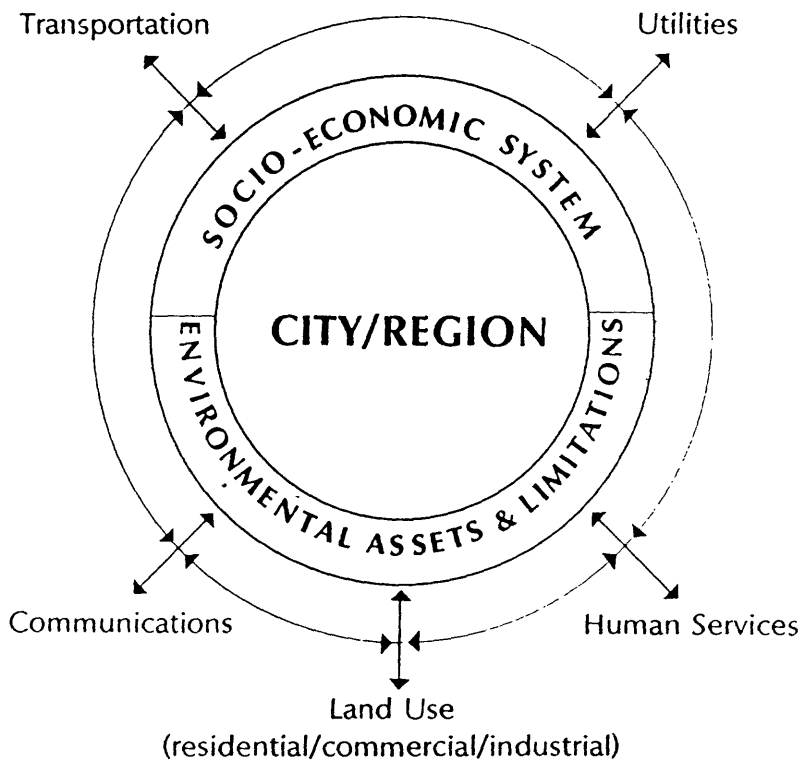
1655 20130

risk. A region or city exists as a function of its socioeconomic base and environmental assets and limitations (Fig. 3). The relationships of people and their environments change after a major earthquake. Preplanning for postearthquake reconstruction is needed to insure that an effective and rapid recovery occurs within the framework of the reestablishment of a strong socioeconomic system. Evaluation of the social and economic impact of a future seismic event could help identify potential infrastructure losses which could significantly disrupt the region. This would allow for preparation of long-range plans that would consider the potential effects of seismic risk. After a risk analysis is made, all facets of man-made environment should reflect awareness and application of risk mitigation components and should include an economic evaluation of cost when changes on established patterns are recommended. Effective risk mitigation, therefore, must take place before disaster strikes--when community participation and education of policy makers can take place. This would ensure that both the public and the legislators understand the multitude of topics involved in the planning process and the responsibilities that each has in promoting public safety.

To date, much of the planning and preparedness effort has been directed towards avoiding structual failure of individual buildings. Disruption that may result from failure of the urban infrastructure has been almost totally ignored. Fire could destroy a great part of a city because of failure of water systems. Rescue and long-range recovery would be affected by failure of transportation, communication, and utility systems. Because the city functions as an integrated network, the failure of one element logically would affect the function of the whole system. Moreover, disruption in a major component of a region/city

FIGURE 3

The City/Regional Infrastructure



1682 20130

infrastructure would affect the whole economy. Weakening of the economic base would in turn affect total recovery. The planners, public and policy makers in Alaska have not so far included consideration of these facts in planning the location of roads, ports, airports, major economic centers, schools, hospitals, utilities, and other basic services.

To accomplish this, coordination and cooperation are indispensable. Use of computers makes the storage, retrieval, and distribution of data easier and more accessible. Baseline data, however, must be updated on a continuing basis to insure that new information, methodologies, and concepts are used in preparation of comprehensive plans that include regulations directed to mitigation of seismic risk and set guidelines for postearthquake recovery. Public and private agencies must share the same reliable date to identify risks and establish programs responsive to specific development needs.

Evaluation of the recovery process that took place after the March 1964 earthquake emphasizes the importance of interrelating three planning phases--prevention, immediate relief, and long-range recovery--and use of the same physical and socioeconomic baseline data. Preventive measures were not considered or followed in the reconstruction in Alaska except where federal dollars were used for urban development in federally approved projects. To prevent this in the future, risk mitigation guidelines and methodologies must be in place before the disaster occurs.

Recommendations

Overspecialization and administrative division of specialized fields strongly influenced effectiveness of long-range recovery programs following the earthquake. Evident were conflicts on agency guidelines, timetables for implementation of programs, and funding of specific projects, which interfered with the continuity of the implementation process and diluted recommendations made after the disaster. Institutional changes will be necessary if interdisciplinary coordination is to be effective. Now is the time to evaluate the present conditions and chart a course of action to guide future seismic planning efforts. Public and legislative commitment and funding efforts should be directed to:

1. Research of seismic risk causes and effects

2. Effective emergency preparedness and public education

3. Application of risk mitigation technology to urban and regional growth and development

Implementation of these recommendations requires changes in the present methods of planning and management of risk mitigation programs at local, state, and federal levels. As stated, risk mitigation measures must be applied to the development of all capital improvements and selection of land use. Development of coordination among various departments at the municipal level would require a strong legislative and administrative commitment. An advisory body similar to the Anchorage Geotechnical Advisory Commission could assist the planning and zoning commissions, department heads, municipal assemblies and councils, and the mayor in establishing new guidelines for the application of risk prevention and mitigation methodologies.

At the state level, an Alaska commission on seismic safety should be established to provide a focal point for development of risk mitigation planning and implementation policies. Sufficient funds and personnel should be made available for its functions. The commission would also represent the state interests at the national level in advocating for risk mitigation and recovery programs. In addition it is recommended that a state joint legislative committee on seismic safety be established to deal with legislation needed to minimize the catastrophic effects of earthquakes.

Scientists, researchers, architects, engineers, planners, and public administrators need to build communication skills to inform the public and the policy makers of their findings. They must assume the social responsibility to educate the public as well as policy makers. Only with their assistance will society move toward achievements of the following critical goals:

1. Obtain a social commitment to risk mitigation

2. Support continued research of socioeconomic and physical/biological data.

3. Develop of institutional processes and strategies necessary for the synthesis and analysis of data and translation into achievable goals.

4. Develop guidelines for state and local seismic risk zoning and other land use controls.

5. Establish federal, state, and local incentive to assist with implementation of risk mitigation measures.

6. Prepare a socioeconomic impact statement regarding the effect of natural hazards on the community infrastructure.

7. Evaluate the legal implications and municipal liability of allowing construction in high-risk areas without proper mitigation measures.

SOCIAL EFFECTS & DISASTER RESPONSE

By

Richard A. Buck

Federal Emergency Management Agency

Bothell, Washington

After having worked with Karl Steinbrugge on the 1975 earthquake vulnerability study for the Puget Sound Area (which was similar in approach to the two preceding studies: L.A. and S.F.), I proposed some new approaches to the damage analysis. I first presented these ideas at a 1978 USGS research applications conference in Denver. The new approaches came from my observation of difficulties in using the 1975 Puget Sound Study for disaster response planning.

It is important at this point to express what we had intended to get out of the vulnerability analysis. The disaster agency at that time was the Federal Disaster Assistance Administration--whose sole responsibility was disaster response at the Federal level and assistance to State governments in preparedness for disaster response. We were not particularly interested at that time in earthquake hazard mitigation, beyond what could be done to save lives and protect property by effective immediate response to the earthquake. Therefore, we were looking for information that could be used directly by the local, State and Federal response agencies: emergency services, police, fire, public works.

In the 1975 study the damage projections were normally stated in terms of the number of destroyed structures or degree of damage to components in percent. This is excellent information, but to be directly useful to emergency responders it must be subjected to another level of analysis. That analysis would show the degree of degradation of systems in terms of loss of function and the amount of time required to restore the system. In other words, how many users would be out of service and for how long. With this information, the emergency responders have some idea of the requirements for emergency provision of services.

In the 1980 vulnerability analysis for Anchorage we attempted to implement some of the recommendations I made at that Denver meeting. Part of my proposal at the Denver meeting involved the process as well as the outcome of the analysis. I proposed that the process be more iterative in terms of the relationship of the scientists and engineers and the users of the data. In fact, it was proposed that the planning process move along simultaneously with the vulnerability analysis--rather than following it. The planners would use preliminary data from the study in their planning process; the preliminary data would stimulate various questions which the researchers could feed back into the final results. It was a frustrating experience, I think, for the researchers because they had to come face to face with the everyday difficulties involved in intergovernmental response planning. Response planning is inherently a messy process. It certainly slowed progress on the vulnerability analysis; but I think the tradeoff was worthwhile.

For electric power, natural gas and housing units, we applied the approach cited above; the second level of analysis. The engineers produced a damage profile--number of homes destroyed and damaged; number of breaks in lines and pipes; numbers and percentages of componenets of utility systems damaged or destroyed. The planners then worked with the utilities to get an analysis of the effects on function and restoral times. They worked with engineers and contractors to get home repair times and tied that in with utility restoration. Table 1 (attached) of the study shows the electric power and natural gas losses in terms of housing units without service, with restoral times in hours.

Between the instant of the earthquake and 24 hours the study projects the maximum loss of service. This will be a period of chaos and regrouping. Many employees of the utilities will be tied up immediately with their own family problems. There will be problems getting to their duty stations because of slides and blocked roads. As the employees report in, crews will be dispatched to begin restoration. Because of the extensiveness of damage, there will be little restoration of service during the first 24 hours. After that, the systems will be brought up to normalcy rapidly.

TABLE 1

ESTIMATED HOUSING UNIT DAMAGE AND LOSS OF UTILITIES

SHAKING/SLIDE

UNITS	PERCENT DAMAGED
690	60-100 (considered destroyed)
114	40- 60
172	20- 40
56,487	0- 20

ELECTRIC POWER LOSSES

UNITS	TIME
14,500	24 hours after event
7,250	48 hours
1,813	72 hours
700	96 hours
virtually all restored	120 hours

NATURAL GAS LOSSES

UNITS	TIME
281	24 hours after event
187	48 hours
93	72 hours
15	96 hours
virtually all restored	120 hours

1751 20130

My immediate conclusion on seeing this data was that it did not look like power and natural gas would be much of a problem. By 96 hours after the event the table shows only 700 households without power; these are the homes too damaged to live in anyway, so at 96 hours after the diaster electric power is not a problem in general for emergency responders. I have no problem with this data. My experience in the Coalinga earthquake leads me to believe that power restoration will be rapid.

The natural gas service losses, I believe, are more questionable. First, very little loss is projected. Second, the repairs would be rapidly made. The Coalinga experience causes me to question this. Restoration of the natural gas system was the most expensive problem in Coalinga; and it took about a month. The problem was not so much breaks in the gas mains. The problem was breaks in service connections to damaged homes and businesses and the problems inherent in re-energizing the system once the gas had been turned off. Service connections had to be repaired or capped off. The system was re-energized section by section after purging; which was expensive and time consuming. In Anchorage, gas services have seismic shut off valves. There is a good chance that every pilot light in the city will have to be relighted. I believe based on what I saw in Coalinga that the utility was over-optimistic in gas outage numbers and restoral times. In Coalinga, the gas problem did not impact on people in a critical way. It was the dead of summer in the San Joaquin Valley. Heat was the last thing anyone needed. Lack of heat would even have been tolerable in winter there. But what about Anchorage in January or February?

The next step in analysis was to look at the need for temporary shelters based on physical damage and loss of utility services. The top of Table 1 gives the damage profile for housing units. Not a lot of major damage, except in slide areas. Table 2 (attached) gives the housing losses over time based on the combined causes--stated in terms of the number of people needing temporary shelter or longer term temporary housing. The small numbers seeking shelter during the first 24 hours is function of the priod of chaos and the inability of responders to either provide shelters or let people know where to go for shelter. During this period, people will make do themselves or with the help of their neighbors. Two days after the event people now are able to seek

TABLE 2

ESTIMATED FAMILIES/PERSONS NEEDING PUBLIC SHELTER OR HOUSING ASSISTANCE

DAYS AFTER EVENT	SHAKING/SLIDE S	SHAKING/SLIDE W	UTILITIES S	UTILITIES W	UNIT TOTAL S	UNIT TOTAL W	PERSONS S	PERSONS W
1st 24-hours	69	69	173	173	242	242	774	774
2	100	122	260	744	360	866	1152	2771
3	100	122	130	190	230	290	736	928
4	100	122	65	72	165	194	528	621
5	100	122	-0-	-0-	100	122	320	390
6	100	122	-0-	-0-	100	122	320	390
7	100	122	-0-	-0-	100	122	320	390
8*	200	225	-0-	-0-	200	225	640	720
9	300	325	-0-	-0-	300	325	960	1040
10	350	375	-0-	-0-	350	375	1120	1200
11	400	425	-0-	-0-	400	425	1280	1360
12	450	460	-0-	-0-	450	460	1440	1472
13	475	490	-0-	-0-	475	490	1520	1568
14	500	500	-0-	-0-	500	500	1600	1600
15	525	525	-0-	-0-	525	525	1680	1680
16	550	550	-0-	-0-	550	550	1760	1760
17	575	575	-0-	-0-	575	575	1840	1840
18	600	600	-0-	-0-	600	600	1920	1920
19	620	620	-0-	-0-	620	620	1984	1984
20	630	630	-0-	-0-	630	630	2016	2016
21	640	640	-0-	-0-	640	640	2048	2048
22	650	650	-0-	-0-	650	650	2080	2080
23	660	660	-0-	-0-	660	660	2112	2112
24	677	677	-0-	-0-	677	677	2166	2166
25	677	677	-0-	-0-	677	677	2166	2166
26	677	677	-0-	-0-	677	677	2166	2166

*Disaster Assistance Center Opens

S - Summer W - Winter

shelter, and some have been set up by the Red Cross and others. You can see that at day 2 there is a great difference between the summer and winter figures. Why? Heating needs. The house may have no damage, but the loss of utilities essentially makes it unlivable. For a four day period we see a tremendous need for immediate shelter. After day four, the need drops off because of the restoration of utilities, but raises again on day 8. This rise does not have a physical cause, so much as governmental and psychological cause. The government's apparatus for providing is in place by day eight. The people who have been making do with damaged homes--living in them even in fairly undesirable circumstances, now are seeking temporary housing. Living in a damaged and perhaps minimally-heated house becomes intolerable, especially now that government assistance is available and the prospect of better quarters appears.

We see in the housing area a combination of disciplines coming together to project the housing needs over time. This is information really useful to emergency services. To arrive at these projections you must have an estimate of damage to structure and utilities, a knowledge of what minimally acceptable housing would be for people, and information about probable government aid programs. When we began this project we knew how to get at the first two. The second (the level of toleration of minimal housing conditions) required research. One research project to help us get the answer was a random sample telephone survey of the Anchorage area. The survey endeavored to judge the self-sufficiency of people in Anchorage. The survey did not get at the survival skills base. But it did ask questions about material survival equipment and supplies: e.g., alternate heating sources, sleeping bags, camp stoves, food supplies. We found that only about 1/4 of the households in Anchorage had adequate survival gear. The average is brought down considerably by apartment dwellers. As a whole apartment dwellers in Anchorage are not any better prepared with survival gear than their counterparts in Seattle.

I believe that in the Anchorage Study we were resonably successful in bringing the psychological, organizational and governmental factors to bear on the damage analysis--melding the physical science and behavioral aspects. I have questioned the natural gas analysis as being too optimistic. The housing estimate used a survival survey which only looked at equipment and supplies. The mental state of preparedness is probably more important. We hoped that the survival gear inventory would be an indicator of mental preparedness. We had neither the time nor money to examine survival skills and attitudes directly.

The survival skills and attitudes is an area most in need of research--particularly as it applies to surviving in extremely cold and unforgiving weather. Organized governmental response in an earthquake cannot be expected to be effective the first 24 hours after an earthquake. The earthquake damages or destroys the very resources needed for governmental response. Communications are down, road access is blocked, command centers are damaged, hospitals are damaged and medical supplies destroyed. For the first 24 hours the response will mainly be people in neighborhoods helping each other. Their effectiveness will be the primary variable leading to a high or low count in the number of deaths and the intensity of suffering.

LEGAL LIABILITY PROBLEMS IN EARTHQUAKE PREPAREDNESS

by

John H. Wiggins
John H. Wiggins Company
Redondo Beach, California 90277

Liability for inappropriate or no action on the subject of earthquake preparedness can take several forms: (a) professional, (b) corporate, (c) public, and (d) personal.

Losses due to liability actions in the courts have recently caused many insurers to vacate the marketplace. Those companies who have decided to remain have raised rates to, in some cases, over 1000%, lowered limits of liability and raised deductibles. This action has been taken because of large and unpredicted court awards throughout the nation.

In 1960, 20% of every dollar that was reserved for paying losses went to pay legal defense costs. In 1983 the percentage had risen to 50%. This change has indicated quite clearly that Americans are willing to expend great sums on legal battles blaming others for their problems. When the next major earthquake occurs, it is my guess that we shall see similar liability problems that have happened in other areas.

Persons and corporations are virtually naked with respect to the law and the literature at length. Essentially, the question boils down to the questions of whether or not the hazard was "known." If so, were appropriate "actions taken." If not, why not and if so, were they taken prudently.

Personal and corporations are virtually naked with respect to the law and the brief questions posed above. Public bodies are, to a certain extent, insulated because of their discretionary authority to make policy decisions, even though those decisions may be "unwise".

The Alaska Supreme Court has consistently applied the policy/operational distinction in analyzing whether a decision is discretionary. The discretionary function exception applies to governmental decisions entailing planning or policy information. Decisions regarding execution or implementation of policy are not entitled to immunity. Thus, a problem arises where earthquake risk is concerned. The decision not to have a policy in the face of uncontroverted evidence may take a municipal body out of the discretionary realm. The decision on an operational level to "do nothing" in the face of knowledge that shows the risk to be higher than any other action may cause legal problems down the road.

Professional liability appears to me to be of great concern. I have therefore chosen to outline the situation as I see it.

I. <u>Current Condition</u>

A. Increased dependence of society on sophisticated technology.

B. Increased awareness of the need for recognition of uncertainty involved with technology and technological abilities.

C. Increased recognition by the citizenry and government of the need for technological, risk balancing input in society-level decision-making.

D. Increased awareness of design professionals/scientists of the role their work plays in shaping quality of life today and prospects for life tomorrow.

E. Recognition that projects or programs depend on interaction of large numbers of professional, lay and government personnel.

F. Recognition that technology placed at the disposal of nontechnical sectors without further input or constraints or monitoring by technological sector can, and already has, caused unforeseen, unwanted effects of global proportions before non-technological sector recognizes problem.

G. Increasing proclivity of legislatures and judiciary to affix legal responsibility for injury to anyone upon someone.

H. Proclivity of professionals to avoid talking and speaking out in public regardless of responsibility.

I. Need for consequences of actions to be identified by all sectors of society.

II. General Legal Principles

A. Requirement to perform at not less than the norm of competance and performance of the particular professional group.

B. Requirement that norm of group not stand at less than some "reasonable" level.

C. Determination by non-members of professional group of what norm of group must be in order to be "reasonable."

1. Legislative definition of "reasonable" norm.
   a. Paucity of technologically qualified legislators.
   b. Historical ineffectiveness of technological sector to unite with one voice.
   c. Lack of high-level, continuous lobbying by technological sector.
2. Judicial definition of "reasonable" norm.
   a. Jury's historical role in determining what shall be reasonable (really law-making rather than fact-finding) when no other definitions are available.
   b. General lack of technical expertise of juries, judges, and lawyers.
   c. Anti-technology attitudes of lay public.
   d. Limitations on time and scope of inquiry in educating a jury.
   e. After-the-fact effect of jury's determination that norm of technological group was "unreasonable."

D. Non-uniformity of definitions of group's responsibility

1. Fifty state legislatures.
2. Multitude of Federal agencies.
3. Developing international agencies.
4. Multitude of identifiable technical disciplines.
5. Multiple professional groups purporting to represent given disciplines
6. Poor communication and lack of reciprocal recognition of judicial decisions as to groups' responsibility.

E. Application of strict liability doctrine of responsibility.

1. Reasonableness and conformity to norm not relevant.
2. Issue restricted to question of whether work was "defective."

a. On question of "defectiveness of work," same unknowns as questions of "unreasonableness" of standard of conduct.

III. <u>Areas of Protection</u>

A. Expensing liability as a cost to customer.

1. Malpractice and errors or omissions insurance.

a. Cost

b. Availability

c. Competitive disadvantage incurred vis-a-vis non-insuring members of group.

d. Time lost in cooperating with carrier in defense of actions.

e. Judgments in excess of policy limits.

f. Large deductibles and cancellation policies.

B. Statutes limiting length of exposure to suit after completion of work.

1. Non-uniformity of legislation.

2. Possible constitutional infirmity as "special" legislation.

3. Some exposure for at least some period of time.

4. Risk of legislative repeal or judicial overturning.

C. Performng to code minimums.

1. Inadequacy and antiquation of existing codes - no rationale, no norms for uncertainty, no norms for criteria or specification acceptance, etc.

2. Knowledge of technological sector of code inadequacies.

3. "Minimum" required performance not necessarily "reasonable" performance.

4. No statute or flat judicial decision that adherence to code requirements will prevent liability.

5. Lack of any code requirements in many areas.

6. Time lag between development/application of new technology and recognition of it in code legislation.

D. Shifting risk/responsibility to owner.

1. Owner normally hires design professional as "expert" to advise and recommend to him, and he is generally unwilling and unqualified to make decisions out of his own area of expertise.

2. No settled doctrine that agent is protected vis-a-vis third party tort claimants by mere fact that he faithfully carried out owner's instructions, right of indemnification back over against owner is probably best that design professional could salvage.
3. Severe proof problems in proving that owner was fully informed by design professional of all the risks and was capable of intelligent decision.
4. No assurance that owner will be financially responsible, or even, still in area when injured plaintiff sues.

E. Shifting responsibility to legislative bodies of government.
   1. Government officials historically immune from suit for alleged errors as to matters involving the exercise of discretion.
   2. Courts historically defer to legislature's action under police power, inquiry confined to whether power to act existed and not as to whether power was exercised in wisest manner.
   3. Legislature has prospective power to create right of action (new tort) and to restrict or eliminate tort law; legislature can define what shall be "reasonable" standard of conduct or "Balanced Risk" standard of conduct.
   4. By making codes directive and by providing that no right of action shall exist against professionals whose design, etc., conforms to code directions, legislature can insulate design professionals from liability when the improbable* but possible, catastrophe or problem does in fact occur.
      a. Legislature must be fully informed of, and comprehend the risks so that in setting the requirements its action truly involves exercise of judgment and discretion in balancing the risks between laymen, professionals and governmental administrators.
      b. Straight, sweet-heart legislation aired purely at protecting design professionals, without reference to realistic requirements of performance, may be constitutionally suspect as forbidden "special" legislation.

---

* Accepted Level of Risk

c. Codes must do more than merely lay down a lower bound of performance; they must deal with joint roles of design professional and owner in a unified manner and must define and require "reasonable" performance.

d. Legislation should directly reveal bases and purposes of legislation, so that courts are not permitted to speculate as to legislative intent.

e. Cost of risk can then be spread over entire tax base through mediums of government disaster relief and/or catastrophe insurance programs.

IV. Conclusions and Recommendations

A. Formation of group to push concept of utilizing technological input on legislation which can apply Balanced Risk Concept.

1. Identify highest priority areas.
2. Formulate plan of action.
   a. Changes at local levels, percolating upward or,
   b. National legislation, percolating downward.

B. Professional insulation through Balanced Risk Contracts.

C. Development of pool of information, expert witnesses, etc., to be tapped in interim by counsel for design professionals being sued; too many decided cases in favor of unlimited liability of design professionals will make remedial legislation much more difficult.

GEOLOGIC-HAZARDS MITIGATION IN ALASKA: A REVIEW OF FEDERAL, STATE, AND LOCAL POLICIES[1]

by
R.A. Combellick
Alaska Division of Geological & Geophysical Surveys
Fairbanks, Alaska

INTRODUCTION

Many processes that are responsible for Alaska's scenic beauty and abundant resources are also responsible for the wide variety of physical conditions and natural hazards that challenge the human presence. Earthquakes and volcanoes are as active in Alaska as anywhere else in the world, the climate is severe, topographic variation is extreme, and thousands of miles of coastline are exposed to the open ocean. Thus, Alaska is subject to major earthquakes, volcanic eruptions, landslides, snow avalanches, floods, tsunamis, and many local or chronic hazards, such as permafrost, that can be costly for property owners over a long period of time. Effective mitigation efforts have greatly reduced these costs in other states.

Although the number of major natural events in the recent past is high, few events have significantly affected the general public because of Alaska's relatively sparse population and vast, thinly inhabited areas. Major events will continue to occur intermittently as in the recent geologic past, and with increasing development, the probability will increase that people, businesses, property, and critical facilities will be affected.

Experience in other states demonstrates that local ordinances are among the most effective means of mitigating natural hazards. State governments generally provide guidelines, technical information, and the requirement or incentives for local adoption of risk-reduction measures. All municipalities in Alaska have zoning authority that can incorporate hazard-mitigation measures. Flood-plain-management ordinances have been adopted in at least 20 cities and boroughs. Other hazards have been only generally addressed. A few local governments have recently begun to independently act on specific issues of local concern. Most major municipalities have adopted the Uniform Building Code published in 1982 by the International Conference of Building Officials (ICBO). Although this code provides detailed requirements for earthquake-resistant design and construction, it does not provide comprehensive construction and siting requirements for other hazards.

The purposes of this report are fourfold: 1) review geologic-hazard issues in Alaska from an historical perspective; 2) discuss various approaches to hazard mitigation; 3) evaluate hazard-mitigation programs in other states (their strengths, weaknesses, and applicability in Alaska); and 4) review existing state, federal, and local programs dealing with hazards in Alaska. This report also includes a summary of policy recommendations developed in September 1985 during an interagency workshop on earthquake hazards in Alaska. Because major programs of disaster preparedness and

[1] Alaska Division of Geological & Geophysical Surveys Special Report 35, 1985 (71 p.). Copies available from DGGS, 794 University Ave. (Basement), Fairbanks, AK 99709. Cost $3.

response already exist and operate under the Division of Emergency Services and local agencies, these activities are not discussed in detail. This report focuses primarily on activities that reduce the likelihood of injury or damage from natural hazards. Greater emphasis on knowledge of the hazards, public awareness, and effective mitigation measures will reduce vulnerability to hazards and consequently reduce dependence on postdisaster response and relief.

NATURAL DISASTERS IN ALASKA

From 1964 to 1981, there were seven presidential declarations of disaster in Alaska, an average of one every 2.5 yr. These natural disasters included one major earthquake, three floods, one heavy rain and landslide, one severe freeze, and a major fire during a severe freeze. Although a total of about $76 million in federal aid was provided, it was far short of the total estimated damages. For example, of the $350 million estimated damages that resulted from the 1964 Great Alaska Earthquake in 1964, about $56 million in federal aid was provided. Except for restoration work performed directly by the U.S. Army Corps of Engineers, the remaining burden fell on state and local governments, private businesses, and individuals. Following the Chena River flood in Fairbanks in August 1967 (fig. 1), which resulted in damages that totalled about $84 million (Péwé, 1982), the federal government provided $7.3 million in direct financial aid (Federal Emergency Management Agency, 1982).

In addition to disaster declarations by the President, for which federal relief funds are available, the Governor of Alaska is authorized to make disaster declarations for which state relief funds are provided, generally through the Alaska Division of Emergency Services (ADES). State funds may supplement federal-relief funds for presidentially declared disasters, but more often are used to provide relief after events that are not declared disasters at the federal level. From January 1978 to February 1982, no disasters were declared in Alaska by the federal government, but the Governor made 14 disaster declarations, an average of 2.5 every year. Relief funds authorized by the Governor ranged from $14,000 to $505,000 per disaster and totalled slightly more than $2 million for the 4-yr period. These figures are not necessarily all the funds expended; they do not reflect all expenditures through agencies outside ADES, but provide an estimate of the magnitude of state expenditures used to respond to natural disasters.

State expenditures for disaster relief are likely to increase as development extends into areas once considered remote and marginally suitable for development. Because many major natural events have occurred in remote areas where property damage was small, they are not commonly recognized as manifestations of continuing processes that will eventually affect developed areas. In 1912, a major volcanic eruption near Mt. Katmai was about 24 times larger than the 1980 eruptions of Mount St. Helens in terms of volume of magma ejected (Decker and Decker, 1981). A giant landslide-induced seiche occurred in Lituya Bay during an earthquake in 1958. The seiche stripped all vegetation to an elevation of 1,740 ft on the mountain opposite the slide and resulted in two deaths, even though Lituya Bay is only seasonally inhabited by a few people (figs. 2a,b). In 1946, a 100-ft-high tsunami hit Unimak Island, destroyed the lighthouse at Scotch Cap, and killed five people; in addition, it killed dozens of people and inflicted extensive property damage

Figure 1. Aerial view of downtown Fairbanks, Alaska, during the Chena River flood. Photograph by U.S. Bureau of Land Management, August 16, 1967.

1786 20130

Figure 2. (a) View of Lituya Bay, Alaska, September 16, 1954. (b) The same area after the July 9, 1958, earthquake (Richter magnitude 7.9) that triggered a massive rock slide at the head of the bay (arrow). The resultant wave stripped vegetation to an elevation of 1740 ft on the hillside opposite the slide (August 9, 1958 photo). Photographs by D.J. Miller, U.S. Geological Survey.

elsewhere on the Pacific coast. In 1899, an earthquake of Richter magnitude 8.4 occurred near Yakutat Bay that elevated the coastline as much as 49 ft (Tarr and Martin, 1912).

Although many of these events are unusually devastating, they are not unique; they are the episodic results of ongoing natural processes that will continue to produce similar destruction in Alaska. For example, at least 40 of the more than 80 volcanoes in the Aleutian Islands and Wrangell Mountains have erupted at least once during the past 200 yr (Miller, 1976). Four giant waves have occurred in Lituya Bay since the mid-1800s (Miller, 1960); at least six tsunamis over 30 ft high have struck the Alaska coast during the last 100 yr (Cox and Pararas-Carayannis, 1976), and 15 great earthquakes (MJ7.8) have occurred in Alaska since 1899 (Meyers, 1976), an average of one every 5.5 yr.

The population of Alaska increased dramatically in the late 1960s and early 1970s and continues to grow at a steady rate (fig. 3). Undoubtedly, human exposure to natural hazards will increase substantially as the population grows and occupies larger areas. More events will be declared disasters at the state and federal levels because they affect more people. A corresponding increase in casualties and expenditure of public funds for disaster relief can be expected unless continued precautions are taken to reduce vulnerability to hazards.

Recent changes in federal policy add to the burden of disaster recovery on state and local governments and individuals, as the people in Fort Wayne, Indiana, discovered after their spring 1982 flood. Because of recent policy changes, federal grants to local governments for repair of public facilities are limited to 75 percent of the total cost of damages; state and local governments are responsible for the remainder. Also, federal disaster-relief loans to individuals and businesses are no longer available at low-interest rates (Federal Emergency Management Agency, oral commun., 1983). Loans issued at less than the conventional interest rate are only available to applicants who cannot qualify at the conventional rate. Thus, many people in Fort Wayne faced interest rates of about 16 percent on their disaster loans, as opposed to the 3 percent charged Alaskans in 1964 after the Great Alaska Earthquake.

Lessons from the 1964 Great Alaska Earthquake

The Great Alaska Earthquake of March 27, 1964 (Good Friday), provided an unprecedented opportunity to assess several conditions and effects: 1) the soundness of construction methods; 2) the effects of state and local land-use practices under conditions of severe ground shaking; 3) the effectiveness of disaster response; 4) the approaches to postearthquake recovery; and 5) the subsequent impact on land-use regulation and construction practices. Unfortunately, many lessons from this event have not been taken seriously. Because of the increased population and accelerated construction in high-risk areas, Alaskans are more vulnerable now than they were in 1964. Selkregg and others (1970; 1984) reviewed planning and regulatory factors that relate to the 1964 earthquake and its aftermath. Their reviews, summarized below, underscore the desirability to assess hazard-mitigation measures in Alaska.

When the 1964 Great Alaska earthquake occurred, there was no state-development plan and there were very few controls on land use and construction in Alaska. Very little state assistance was available to local communities to prepare their own comprehensive development plans and implement zoning

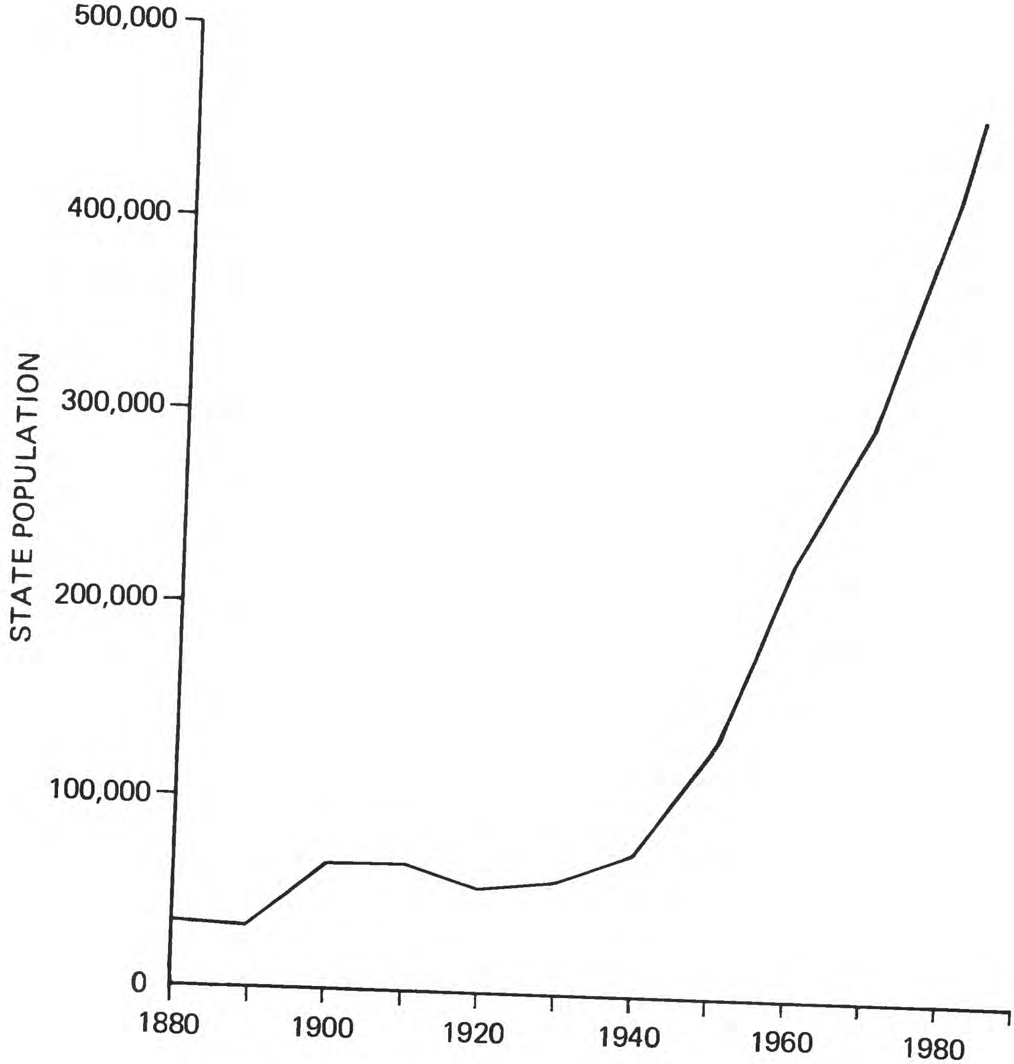


Figure 3. Population growth in Alaska, 1880 to 1982. Data from Rollins, 1978, and Alaska Department of Labor, 1983.

controls. In addition, few state or local efforts had been made to collect basic data on geologic hazards in developing areas. Consequently, very little had been done to mitigate the effects of earthquakes or other geologic hazards. This situation not only accounted for much of the damage that occurred, but made it nearly impossible to make intelligent, defensible decisions for improvements during reconstruction. Reconstruction practices varied widely throughout the affected region, and many hard-hit areas were allowed to redevelop to preearthquake standards and conditions.

Anchorage was the only city in the affected region that adopted the ICBO Uniform Building Code before 1964, and many large buildings constructed according to that code withstood the severe shaking. A few buildings moved more than 11 ft without substantial damage except to utilities. However, local development plans and zoning ordinances did not consider potential hazards, and some heavily developed residential and business areas were affected by major destructive ground displacements. One of the few reports that contained geologic-hazards information on the Anchorage area before 1964 identified areas of poor foundation materials and slope instability (Miller and Dobrovolny, 1959). Although the report was available 4 yr before the earthquake, it was apparently not used in local planning. Many unstable areas identified in the report failed during the earthquake, which resulted in millions of dollars in damage to homes, businesses, and utilities.

Soon after the earthquake, several groups began to technically evaluate the affected area. The groups included an Engineering Geology Evaluation Group established by the Alaska State Housing Authority (ASHA); a federal Scientific and Engineering Task Force appointed by a special presidential commission; a panel of architects and engineers also appointed by the commission; and the U.S. Army Corps of Engineers. High-risk areas were identified, based on unstable soils and proximity to steep slopes. Recommendations were made to prohibit or severely restrict construction in high-risk areas or to limit high-risk areas to offstreet parking, parks, and other low-density purposes. A strong plea was made to improve planning and zoning and adopt and enforce building codes. Many local people objected to the recommendations because they thought the recommendations would further disrupt an economy already seriously impacted by the earthquake, despite arguments that the project would provide much-needed renovation in parts of the Anchorage business district and the chance to implement sound redevelopment plans.

Pressures were great to rebuild Anchorage to its preearthquake status as quickly as possible. Ultimately, the recommended urban-renewal projects, which originally included all areas identified as high risk, were reduced to only those areas that were directly damaged by the earthquake; adjacent unstable zones were excluded. The Corps of Engineers extensively studied the Turnagain Heights landslide area where many homes and utilities were destroyed (fig. 4). They reported that the slide material would continue to be subject to 'substantial differential movements' and 'locally large distortions during future earthquakes.' Accordingly, they concluded that construction of any type should be prohibited on the slide material. Although ASHA originally recognized a high-risk area that extended far inland from the slide scarp, its final redevelopment plan for Turnagain Heights reflected the strong public resistance to urban renewal and limited the proposed project to the area on the seaward side of the scarp that had failed during the earth-

Figure 4. During the Great Alaska Earthquake of March 27, 1964, homes were destroyed by a massive landslide in Turnagain Heights subdivision, Anchorage. U.S. Army photograph, courtesy of Alaska Earthquake Photograph Archives (archive no. TRN-35).

quake[2]. The ASHA adopted the Corps of Engineers' recommendations and recommended that the high-risk area be redeveloped for park and recreation purposes only. However, the Anchorage City Council decided not to adopt the plan and began to accept applications for building permits in the slide area.

Similarly, the L Street slide area in downtown Anchorage was designated as high risk and recommended for limited single-family residential construction and recreational open space. The council again decided not to adopt the recommendations. Permits were issued to rebuild existing buildings and erect new structures on the slide and in the adjacent high-risk area. Large, high-occupancy buildings continue to be constructed on and near the slide (fig. 5).

The approach to postearthquake reconstruction in Valdez contrasted markedly with Anchorage. Valdez and its marine facilities were seriously damaged by a tsunami and submarine slide caused by the earthquake (fig. 6). Because of earthquake hazards posed by rebuilding Valdez in the same location, the residents voted to move the entire town to a new location near Mineral Creek (fig. 7). The new site is naturally protected against tsunamis, and the soil is stable. The move, endorsed by the federal task force, paved the way for major assistance by the U.S. Office of Emergency Preparedness and Corps of Engineers. A new mayor and city council were elected to carry out the move, and an aggressive new planning and zoning commission was appointed. The Uniform Building Code was adopted, a comprehensive redevelopment plan was developed by a private contractor, and the entire town was relocated by the fall of 1967.

A major improvement in state disaster preparedness was made when a comprehensive disaster act was passed in 1977. Under this act, the newly created Division of Emergency Services (DES) initiated major disaster-preparedness plans and programs to improve the ability of state and local agencies to respond to disasters. This improvement in response capability is not matched by a complementary program of predisaster measures for proper land-use and construction practices to reduce the likelihood of injury or property damage.

In completing its eight-volume analysis of the 1964 earthquake and its aftermath, the National Research Council (1973) observed that if the earthquake had occurred in a more densely populated area during work and school hours (the event was at 5:36 p.m.), it could have resulted in 50 times as many deaths and 60 times as much property damage. The council concluded that improved hazard mitigation is possible only through research and meaningful regulation, which serve as a basis for improved design, construction, and land-use decisions, and better containment of disasters. Both require improved knowledge of the hazards, adequate warnings, and dependable response and recovery plans.

HAZARD MITIGATION

Advance planning and preparation are essential to prevent or minimize adverse effects from natural hazards and respond to disasters when they occur. The first step in this effort is to learn as much as possible about

[2] Subsequent engineering analyses in unaffected areas inland from the Turnagain Heights landslide demonstrated that the sediments responsible for failure (Bootlegger Cove Formation) have a safety factor of only 0.85 (Seed and Wilson, 1966), which indicates an unsafe condition because the material is not strong enough to withstand anticipated loads.

Figure 5. Buildings in unstable areas on and near the L Street slide in downtown Anchorage. This slide (and others) was triggered by the earthquake that occurred March 27, 1964. Photograph by R.A. Combellick, May 22, 1982.

Figure 6. Old Valdez townsite after a tsunami destroyed port facilities and most of the downtown area on March 27, 1964. Photograph by J.B. Townshend, April 1964, courtesy of Alaska Earthquake Photograph Archive, Townshend collection no. 74B.

Figure 7. New Valdez townsite near Mineral Creek, 3.5 mi northwest of old townsite. Photograph by Steve and Delores McCutcheon, summer 1970.

1855 20130

natural processes and their potential effects. The second step is to use that information to develop measures that reduce the likelihood of injury and damage to persons and property at risk from the hazard. The third step is to develop the means to quickly respond to a disaster, restore public order, and remove the threat of further injury or damage. Hazard mitigation encompasses activities that reduce the likelihood of property damage or personal injury from a natural event. Disaster preparedness acknowledges that, particularly with major events, there will be property damage and personal injury that cannot be prevented through hazard mitigation. Therefore, disaster preparedness creates mechanisms to respond to the disaster, enables an orderly recovery, and distributes financial losses. Response preparation normally includes plans, facilities, and programs for evacuation, search and rescue, communication, shelter, food, police protection, debris removal, rapidly deployable protection works (such as sand-bag levees), and restoration of lifelines and critical facilities. Hazard insurance and disaster-relief funds (the latter supported by taxes) are the most common means of distributing financial losses. In this report, relief funds and insurance are considered functions of disaster preparedness rather than mitigation because they do not reduce the overall cost of a disaster; they simply distribute those costs among taxpayers and insurance buyers. Although hazard insurance and disaster relief cannot substitute for adequate safety measures, they can be effective tools for mitigation if they include the proper incentives, such as reduced insurance rates for taking specified loss-reduction measures or requirements for taking such measures as a condition of eligibility. Disaster response puts disaster-preparedness plans and other postdisaster activities into effect to restore order and facilitate recovery. This report emphasizes hazard mitigation and does not discuss disaster preparedness and response in detail except where improvements can be made to promote mitigation.

The first two steps in the hazard-mitigation process, hazard evaluation and risk assessment, are prerequisites to the third step, risk reduction. Reliable information on natural processes and their associated risks is essential to determine appropriate risk-reduction measures. Inadequate information can result not only in inadequate or misguided measures, but can contribute to overdesign and overregulation.

Hazard Evaluation

The objective of hazard evaluation is to produce five kinds of information:

1. Descriptions of natural processes and controlling factors that relate to the hazard.
2. Location and extent of potentially affected areas.
3. Probability and frequency of occurrence.
4. Probable severity (for example, magnitude, intensity, and duration).
5. Expected physical effects.

Understanding the natural processes and controlling factors that relate to a hazard is essential for determining the location and extent of potentially affected areas, probability and frequency of occurrence, probable severity, and expected physical effects (fig. 8). Earthquakes are a good

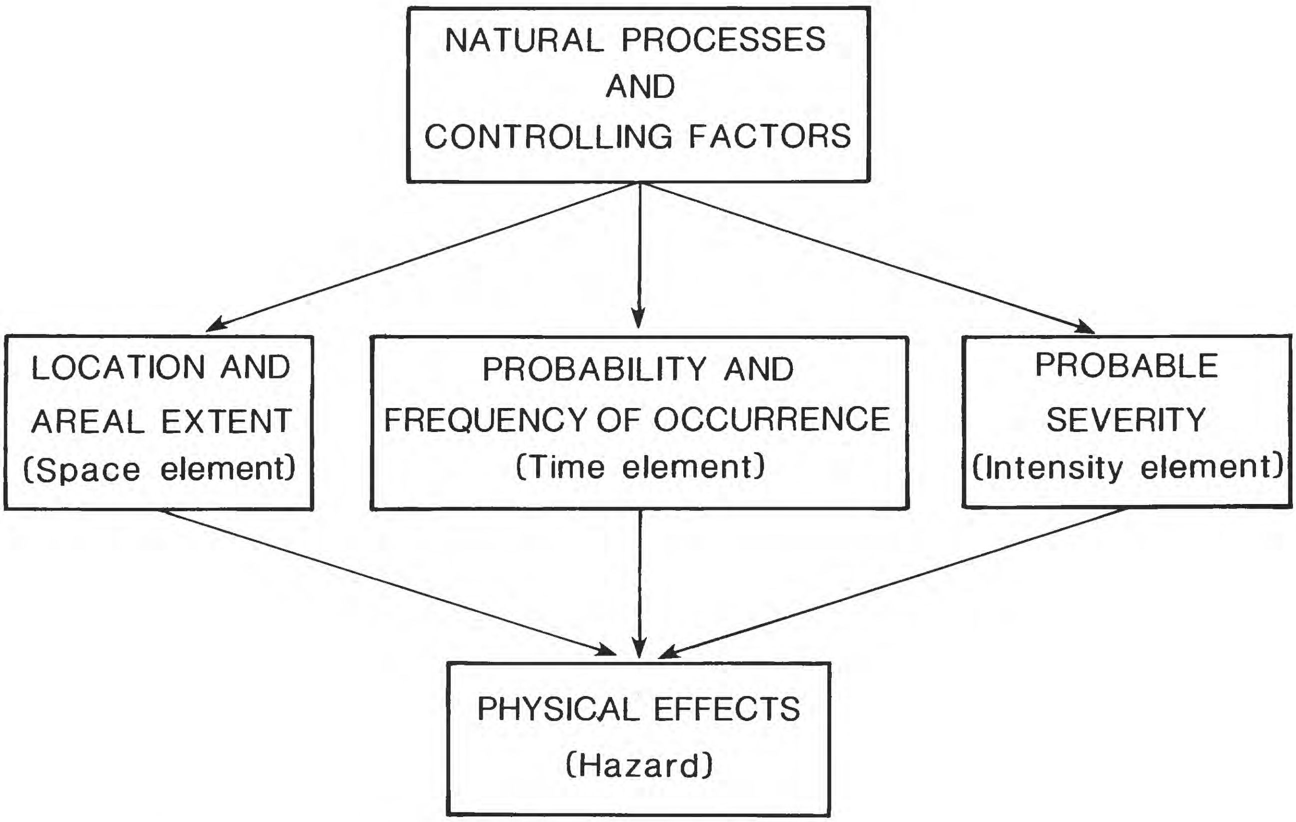


Figure 8. Flow diagram of study objectives in hazard mitigation.

example of a hazard for which persistent data collection has led to successful hazard mitigation in many parts of the country. As a result of continuous global and regional seismic monitoring and geological and geophysical studies over the past few decades, geoscientists are gradually developing a better understanding of the processes that control the distribution, occurrence, intensity, and effects of earthquakes. In California, commitments by federal and state agencies to long-term, continuous monitoring of earthquakes have contributed to an increased level of confidence in identifying areas of high earthquake hazard and improved knowledge of earthquake effects (for example, strong ground motion). Both factors have been used extensively and successfully in regulating land-use and improving earthquake safety in new and existing buildings.

The scale and complexity of processes determine the difficulty of evaluating associated hazards. Generally, the larger the area over which the processes operate and the greater their complexity, the less 'mappable' the hazards are because of the difficulties in delineating areas likely to be affected. Often, high cost and limited technology preclude accurate delineation of areas of high exposure and definitive predictions or forecasts of events. This condition poses legal problems in hazard mitigation, particularly in land-use regulation, because of limited technical defensibility of the boundaries of designated 'hazard areas.'

Significant geologic hazards in Alaska are listed in table 1. The 'mappability' of these hazards is based on the presence of physical features that provide a basis for areal delineation of the hazard at scales appropriate for land-use planning. For secondary hazards, mappability is based on the relative ease of delineating areas susceptible to secondary effects. For example, areas in which the intensity of ground shaking is likely to exceed given levels are very difficult to accurately delineate; hence, this primary hazard of earthquakes has low mappability. Areas that are likely to experience ground failure as a result of the given intensity of ground motion are easier to delineate; hence, ground failure, as a secondary effect of earthquakes, has higher mappability. 'Prediction capability' for catastrophic events (table 1) is based on the presence of recognizable conditions that warn of an impending event within a definite time period so that people can be evacuated and other preparations can be made.

To a large degree, legal defensibility of hazard-related land-use regulations is related to mappability. A map adopted for regulatory use is subject to legal scrutiny; thus, the boundaries or contours depicted on it and data used to derive them must be defensible in court. Historically, two additional factors have heavily influenced court decisions and often override problems of scientific defensibility: 1) the potential loss associated with the hazard (for both life and property); and 2) the degree of restriction posed by the regulation. On the one hand, land-use regulations related to highly destructive hazards, such as floods or earthquakes, have fared better in courts than those that relate to less destructive hazards, such as soil creep or lightning. On the other hand, regulations do not fare well if they are so restrictive that they infringe on fundamental liberties or do not clearly relate to the promotion of public health and safety. Generally, if a rational relationship exists between a regulation and the promotion of public health and safety, the regulation will be upheld in court. On this basis, many regulations have survived court tests, even when there were disagreements within the scientific community about the validity of the data used as criteria for the regulation (Baker and McPhee, 1975).

Table 1. Significant geologic hazards in Alaska.

Potentially catastrophic geologic hazards

Event	Causative processes	Primary hazards	Secondary hazards	Mappability[a] Zone of primary hazards	Mappability[a] Zone of secondary hazards	Prediction capability[b]
Earthquake	Crustal displacement Volcanic eruption	Strong ground shaking Fault displacement Subsidence or uplift	Ground failure Avalanche Tsunami (can also be caused by earthquakes outside Alaska) Seiche	L-M	M-H	L
Rapid mass movement:						
Snow avalanche	Snow accumulation on steep slopes and subsequent modification by drifting, melting, and precipitation (also a secondary effect of earthquakes)	High dynamic pressure Burial	Air blast	H	H	M
Slide (landslide, rockslide, rock fall, slump)	Natural or artificial slope oversteepening, overloading and/or reduction of material strength, usually by water saturation (also a secondary effect of earthquakes, volcanic eruptions, coastal erosion, and river erosion)	Ground displacement (both vertical and horizontal) High dynamic pressure Burial	Flooding following temporary damming of stream by slide deposit Tsunami or seiche	M	H	M
Flow (mudflow, debris flow, debris avalanche, slushflow avalanche)	Excessive rainfall or rapid snowmelt in areas of steep slopes and loose surficial materials (soil, vegetation, rock; also a secondary effect of volcanic eruptions)	Ground displacement High dynamic pressure Burial	Flooding following temporary damming of stream by flow deposit	M	H	M

[a]Mappability
- H - Probable location of future events can be shown on large-scale maps (1:63,360-scale or larger).
- M - Variations in relative intensity or severity of hazard can be shown on large-scale maps, but not the location of future events.
- L - Variations in relative intensity or severity cannot be shown on large-scale maps.

[b]Prediction capability
- H - Individual events can be predicted with sufficient accuracy and warning time to evacuate area.
- M - Although individual events cannot be reliably predicted, conditions favorable for their occurrence can be forecast in time to issue warnings and evacuate area if necessary.
- L - Neither individual events nor the conditions favorable for their occurrence can be predicted reliably enough to allow for adequate response.

Table 1. (con.)

Event	Causative processes	Primary hazards	Secondary hazards	Mappability[a] Zone of primary hazards	Mappability[a] Zone of secondary hazards	Prediction capability[b]
Volcanic eruption	Buildup of magma and gas under pressure within or beneath the earth's crust, followed by upward migration via conduits and fissures to the Earth's surface	Lava flow Pyroclastic flow Nuée ardent (glowing avalanche) Directed blast Ash fall Volcanic bomb Earthquake Noxious gas	Mudflow (lahar) Debris avalanche Tsunami Acid rain Lightning Forest fire Landslide	M	M-H	M
Flood	Cloudburst Prolonged rainfall Rapid snowmelt River ice jam Glacial outburst (release of subglacial or englacial water) Coastal storm surge Also a secondary effect of earthquakes, volcanic eruptions (tsunami), and mass movements	High dynamic pressure in area of high-flow velocity Submerence of large areas Excessive siltation	Erosion and deposition Water-supply contamination	H	H	M-H
		Chronic or localized geologic hazards				
Soil instability:						
Creep	Solifluction or gelifluction Frost creep Slow downslope movement of nonsaturated soils on steep slopes	Differential downslope movement of ground surface	- -	H	- -	- -
Heave	Frost heave Swelling of clay-rich soil by absorption of water	Differential vertical movement of ground surface	- -	M	- -	- -
Subsidence	Soil compaction Settling as a result of melting of ice-rich permafrost or seasonal ground ice Shrinking of clayrich soils during drying	Differential vertical movement of ground surface	- -	M	- -	- -

Table 1. (con.)

Event	Causative processes	Primary hazards	Secondary hazards	Mappability[a] Zone of primary hazards	Mappability[a] Zone of secondary hazards	Prediction capability[b]
Coastal erosion	Waves of sufficient energy to remove sediment or rock faster than it is replenished Tsunami Tidal current Artificial disruption of longshore sediment transport (jetty, breakwater, sand mining) Storm surge	Land removal	Landslide caused by slope oversteepening	H	H	- -
River erosion	Flow of sufficient velocity and capacity to remove material from riverbank Migrating or shifting channel Artificially induced (for example, sand-and-gravel mining from riverbank) Also a secondary effect of floods (see above)	Land removal	Landslide caused by slope oversteepening	H	H	- -

Risk Assessment

Ultimately, the impact of a disaster on individuals and public resources depends on the success of hazard mitigation. The number of casualties, amount of public-relief funds disbursed, and time required for recovery are reduced if mitigation efforts are successful. The effects of a disaster cannot be predicted accurately and are generally anticipated in terms of risk, that is the probable level of damage or loss given the probability of an event (hazard) occurring and its predicted effects. Disaster preparedness must be capable of responding to the 'calculated risk' (the estimated total risk for any given level of mitigation; fig. 9). 'Residual risk' is the difference between calculated risk and 'acceptable risk' (risk that can be accommodated without undue hardship). Residual risk represents the range of unacceptable risk that can be reduced by proper management.

If the potential physical effects of a hazard are known, the risk can be estimated based on the types of facilities present or planned, cost of replacement or repair, whether or not people are likely to be present, and the socioeconomic impact of damage. Obviously, there is no direct risk from a hazard, such as a landslide, if there are no facilities or people in the affected area. Similarly, the risk of locating agricultural land or parks in the path of a potential landslide is lower than for locating a hospital or power plant in the same location. The task of economists, planners, developers, designers, and regulators is to use the hazards information provided by scientists and engineers to derive associated 'calculated risks' and then select appropriate risk-reduction and disaster-preparedness measures. A comprehensive treatment of risk assessment for natural hazards is given by Burton and others (1978) and White and Haas (1975).

Risk Reduction

Given adequate information about geologic hazards and the risks they pose, different risk-reduction approaches are possible: 1) land use, 2) construction technology, 3) protection works, and 4) warning systems.

Land use

Land-use approaches to risk reduction involve decisions about where certain types of facilities can be built. The greatest power for effective land-use planning and regulation for most facilities is concentrated at the local-government level, where most construction is regulated under authority delegated by the state. Generally, the planning body of the local government prepares a comprehensive land-use plan that serves as a base for specific zoning ordinances. Natural hazards are just one of many considerations that may affect land-use-planning and zoning decisions. If the hazard is severe, separate hazard zones may be identified to limit land use to low-density or recreational purposes. If the hazard is localized and manageable on a site-specific basis, certain siting and design practices may be prescribed. Some local governments, primarily outside Alaska, use hazard-overlay maps to add qualifiers to existing zoning categories without changing their primary designations. In all cases, local governments have provisions that allow flexibility in cases where the ordinance imposes an undue hardship or where a specific use that is not normally allowed can be permitted because it meets

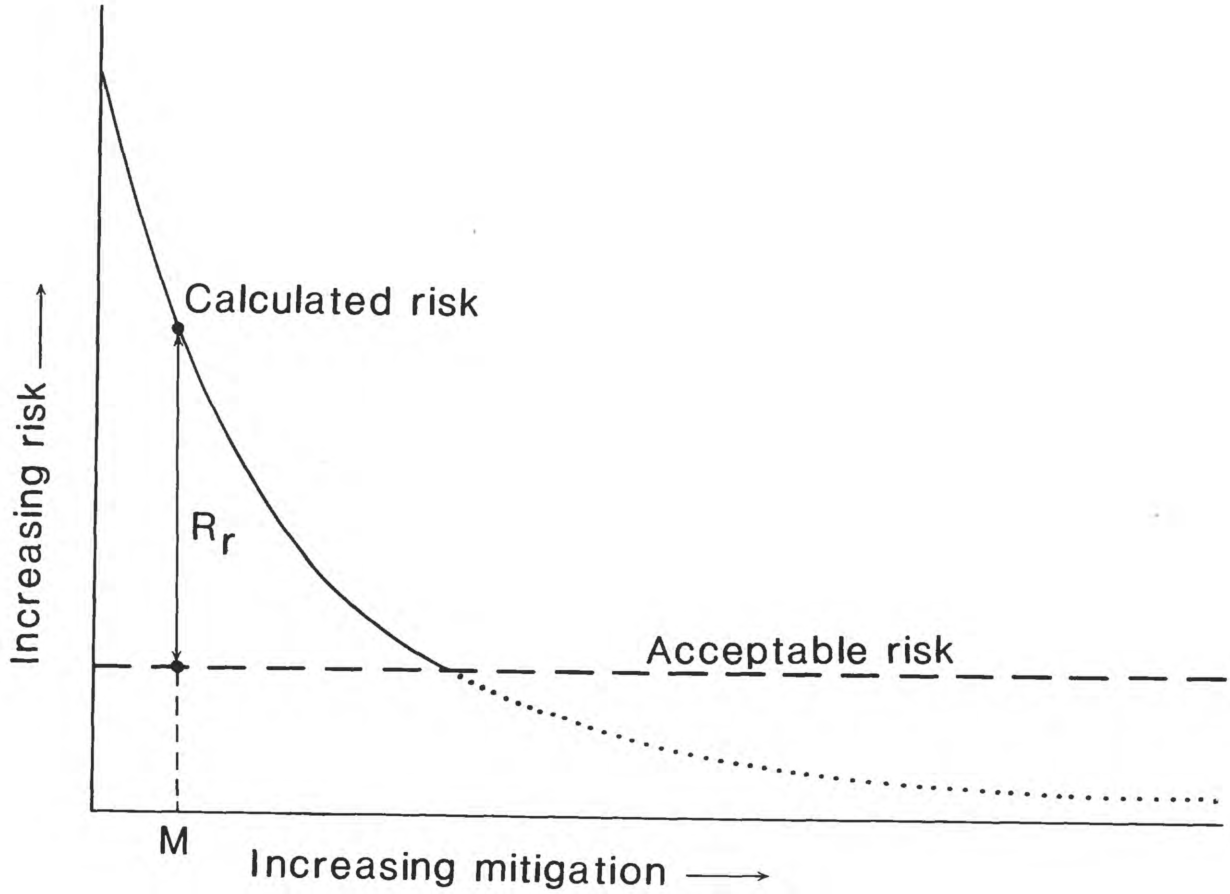


Figure 9. Relationship between risk and hazard mitigation. The residual risk (R_r) is the difference between calculated risk and acceptable risk for a given level of hazard mitigation (M). Modified from Woodward-Clyde Consultants, 1980b, fig. 1-1.

the standards intended by the ordinance. Where land is already in use, zoning changes generally apply only to new construction.

Hazards information can be used by individual builders to select safe sites for construction, for example, based on location of unstable slopes or ice-rich permafrost. At the state level, hazards information can be used in statewide and regional land-use plans to develop zoning regulations for state land and in site selection for state buildings and major public or critical facilities.

Construction Technology

Proper design and construction of facilities are effective in reducing vulnerability to many hazards. The most stringent regulatory measures are used in the design and construction of critical facilities. For most noncritical facilities, the power for implementing regulatory measures is at the local level. Typically a local government adopts the ICBO Uniform Building Code by ordinance and deletes or adds provisions as it deems appropriate for its jurisdiction. Sometimes, design and construction standards are incorporated into the zoning ordinances, such as minimum floor elevations in flood areas, but these are in addition to a building code that applies to the entire jurisdiction. Most states require local governments to adopt a building code and usually specify the Uniform Building Code (UBC). The State of Alaska currently does not require local governments to adopt a building code, although it gives them the authority to do so. Most major municipalities in Alaska have adopted modified versions of the Uniform Building Code. At least one municipality, the Fairbanks North Star Borough, has not yet adopted a building code.

Hazard-related design and construction requirements are not comprehensive in the Uniform Building Code. The latest version (International Congress of Building Officials, 1982) contains design requirements for wind and earthquake loads (sec. 2312) and guidelines for excavations, construction on expansive soils, grading, drainage, and erosion control to be implemented largely at the discretion of local building officials. A major limitation of the earthquake regulations in the code is that they provide design requirements only for the structural integrity of buildings under the forces of earthquake shaking and will not necessarily alleviate major foundation failures, building displacements, or misalignments that result from earthquake-induced ground failure. This omission could mislead local authorities or building designers who follow the code rigorously to expect the resultant structure to be safe from earthquakes; in fact, the structure may be built on sensitive or liquefiable soils that could cause failure from major ground displacements even before shaking reaches the level for which the structure was designed. A building so designed would probably maintain its structural integrity; however, risk of injury from falling and sliding objects is still very high if major ground failures are involved and, unless the building can be realigned, it could be a total loss.

For earthquake design, the Uniform Building Code incorporates an 'importance factor' that depends on the type of facility proposed and specifies design criteria based on the seismic zone in which the facility is located (fig. 10). Buildings with assembly rooms for 300 or more persons require earthquake-design forces 1.25 times the normal value. For 'essential facilities' (hospitals, fire and police stations, and disaster centers), the factor is 1.5. Some state governments have legislated special design and con-

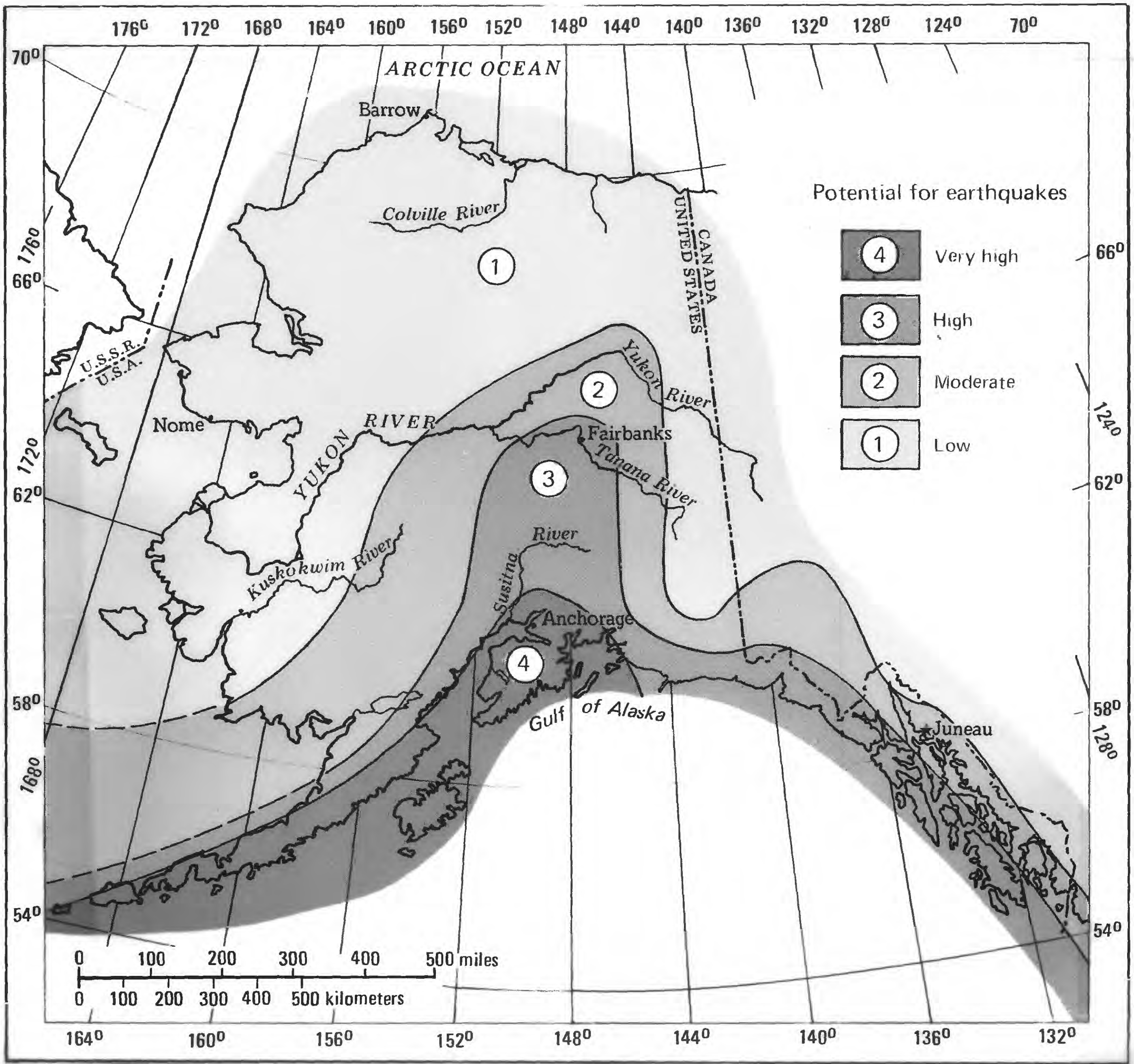


Figure 10. Seismic-zone map from the Uniform Building Code (International Congress of Building Officials, 1982). Seismic hazard is lowest in zone 1 and highest in zone 4.

1985 20130

struction requirements for such facilities beyond the provisions of the Uniform Building Code. State agencies (or federal agencies for federally supported projects) have authority to establish standards and review proposed designs and construction practices on a project-specific basis for some major public facilities, such as hydroelectric dams. Some specific approaches used in other states are discussed later in this report.

A problem in hazard-related design is that the magnitude of an event a structure should be capable of withstanding (the 'design event') is difficult to assess. The conservative approach is to design for the 'maximum credible event,' or the largest event possible considering the known natural processes or conditions in an area. For example, in a seismically active region, the maximum credible event could be a Richter magnitude 9.0 earthquake. The design cost for a Richter magnitude 9.0 earthquake may be unreasonably high for many facilities, especially if the probability is low that the event will occur during the design life of the facility. These costs may approach or even exceed the total financial loss that could result from the maximum credible event if no measures are taken. A more common approach is to design for the 100-yr event, which is often termed the 'maximum probable event.' Flood-hazard maps typically show elevations of the '100-yr flood,' a flood that can be expected to occur once every 100 yr. The type of facility will also help determine the design event. In California, the Division of Safety of Dams (DSD) requires that dams be designed so that no major amount of water is released if the maximum credible earthquake occurs.

Intensity of ground shaking at the site is the most important factor in earthquake-resistant design and depends on factors such as the distance of the site from the expected earthquake, the magnitude of the earthquake, the degree of attenuation of shaking with distance from the epicenter, and whether the site is on bedrock or sediment. Intensity of ground shaking can be expressed in terms of peak ground acceleration, duration, ground displacement, spectral velocity, or numerous other parameters. Thus, for design purposes, the maximum probable or maximum credible event must be one or more of these parameters, rather than just magnitude.

Protection works

A limited number of hazards can be mitigated by protection works and other structural and corrective solutions. The most common protection structures are flood-control dams and diversion works, which can substantially reduce the need to relocate existing facilities and impose new zoning restrictions to prevent disaster (fig. 11).

Although flood-protection works have successfully controlled flood hazards in many areas, two potentially serious deficiencies must be considered. First, if the protection works fail, the hazard can be much more severe than before the works were built because large volumes of water are suddenly released and the diversion works can inhibit flood water draining from the protected area. Second, protection works can promote increased development in the 'protected' area and, if the protection fails, damage and injury will be much more extensive.

Protection works have also been used successfully to control slope instability and coastal erosion. Techniques for stabilizing landslides are developing rapidly and proving to be increasingly successful. As a result, many areas in southern California that were formerly avoided because of

Figure 11. Floodgate in the Chena Lakes Flood Control project, about 20 mi east of Fairbanks. The structure limits water flow to 12,000 ft^3 per sec, which is less than one-fifth the amount that flooded Fairbanks in 1967. Photograph by U.S. Army Corps of Engineers.

landslide hazards are no longer considered unfit for development (Leighton, 1982). Because many landslides are triggered when they become water saturated, internal-drainage systems are frequently successful, as in the Pacific Palisades area. However, not all landslides can be controlled in this manner, and other protection or stabilization methods are often prohibitively expensive. For coastal-erosion problems, jetties and breakwaters often reduce erosion in one area, but promote erosion or deposition in adjacent areas because the longshore transport of sediment is disrupted. Other protective or corrective approaches to risk reduction include firebreaks, riprap, use of vegetation for slope stabilization, and anchoring of loose structures.

Protection works and corrective measures are often necessary because land was improperly developed. Sound land-use planning and regulation and proper selection and preparation of construction sites are the best ways to avoid expensive postdevelopment measures that may have limited success.

Warning systems

Warning systems are both risk-reduction and disaster-preparedness measures. They help reduce the hazard to people by providing time to evacuate an area of impending disaster and simultaneously initiate disaster-response activities. Although short-term warning of an impending event can reduce risk of personal injury during a disaster, it generally does not reduce the hazard to fixed structures and property. Warnings are possible only if reliable hazard predictions can be issued and communication is dependable, or if adequate time lapses between an event and its effects (table 1). For example, if a major tsunami is generated by an earthquake beneath the south Pacific Ocean, there is ample time to issue warnings to Alaskan coastal communities.

Warning potential for river floods is high because predictive techniques for weather conditions that produce heavy rainfall are relatively effective, and often there is time to warn people downstream once a flood begins. Prediction of volcanic eruptions is improving rapidly, but requires constant localized seismological monitoring and measurements of ground deformation. Warnings are less effective for snow avalanches and landslides. Typically, areas susceptible to these hazards are identified and studied to determine when conditions exist that could trigger mass movements; however, it is not possible to reliably predict individual events. Although advances are being made in earthquake prediction, it will probably be a long time before they are reliable.

Combinations of approaches

No single approach to risk reduction is universally effective. In most situations, a combination of approaches is most effective, and the circumstances will dictate which methods should be emphasized. For example, in developed areas, substantial changes to zoning ordinances are unreasonable; therefore, protection works or more stringent building codes should be emphasized. Old buildings may need to be refurbished to meet new standards. The best combination of risk-reduction measures depends on the level of jurisdiction (local, state, or federal), the types of facilities involved, the extent and type of development, and the expected hazards. A balance between land-use and building-technology approaches has proven most effective. Many local jurisdictions outside Alaska use both a strong hazards-related zoning

 1958 20130

ordinance and a building code. If adequately enforced, this approach can alleviate many problems. Zoning ordinances can be used to prohibit or restrict construction of certain types of facilities in unstable areas. Facilities that are allowed in these areas must be built according to the building code.

The following examples illustrate how combined risk-reduction approaches are commonly used in specific applications.

Subdivisions

Most local jurisdictions, including those in Alaska, establish subdivision regulations by ordinance to provide guidelines and requirements for dividing large parcels of land into smaller lots for resale. In addition to the standard requirement that developers submit plans and plats that describe proposed layouts of lots, utilities, and transportation routes for review and approval by the local planning commission, subdivision regulations sometimes deal with localized geologic hazards. Rather than impose a priori restrictions on land use and construction within subdivisions, local jurisdictions may require, through subdivision regulations, that the developer identify hazards such as unstable soils, steep slopes, snow-avalanche zones, and areas prone to flooding. The developer must describe how these hazards can be avoided through appropriate land use or construction alternatives approved by the planning commission.

Excavations and grading

Many local governments establish site-development ordinances to prevent hazards caused by improper grading that could promote slope instability or inhibit drainage. A permit may be required for specific types of grading and excavations. Some provisions of this type are included in chapter 70 of the Uniform Building Code (International Conference of Building Officials, 1982).

Commercial facilities

Major new commercial facilities tend to attract residential development and, if improperly located, can inadvertently promote growth in hazardous areas. Therefore, if major shopping and business centers are located away from hazardous areas, community risks will be reduced.

Places of assembly

Special measures are often necessary for facilities, such as schools, auditoriums, churches, and other large buildings that are intended for large groups of people. The objectives of hazard mitigation for these structures are to allow safe exit and protect occupants from injury. One highly successful measure is the Field Act in California, which regulates construction and remodeling of schools. Other successful measures are the earthquake regulations in the Uniform Building Code that require design loads to be increased by 25 percent for buildings that will be used by at least 300 people.

Lifelines and critical facilities

Some facilities are essential to public health and safety and require special consideration in hazard mitigation. These critical facilities would pose a major danger to the public if damaged or must remain functional during and after a disaster for public safety or essential economic activities. Included in this category are hospitals, police and fire stations, detention facilities, disaster centers, dams, nuclear and other power plants, chemical plants that handle toxic materials, water supplies, sewer systems, power lines, highways, railroads, airports, and communications systems. Schools and other places of assembly are often considered critical facilities because of the large number of people that would be affected in a disaster. Key considerations are that critical facilities must provide for safety of occupants and, in most cases, must continue to perform some or all functions. Thus, more stringent hazard-mitigation measures are required. Special building standards and site-selection procedures are needed for these facilities. Effective hazard mitigation for these structures requires periodic review during site selection, design, construction, and operational phases of the projects. This process generally must be established through federal and state legislation and regulations that specify permitting and regulatory authorities, responsibilities and rights of the contractor(s), and review functions of various agencies.

The Hazard-mitigation Process

Hazard mitigation consists of four major steps: 1) collection of geologic data, 2) hazard evaluation, 3) risk assessment, and 4) risk reduction (fig. 12). The success of this process depends on effective public education. Government policy in hazard mitigation cannot be developed and implemented without support by an informed public. The most effective hazard mitigation occurs when informed individuals make wise decisions about where and how they build.

Roles of Different Levels of Government

Because most development is regulated by local governments, local risk-reduction practices have the greatest potential for success. Large public-works projects and construction of critical facilities are often regulated at the state level, where hazard-management policies are most appropriate. Because many hazards transcend the boundaries of local governments, adjoining local jurisdictions need to coordinate with each other to prevent conflicting plans and regulations. For example, flood-plain management or diversion practices in one community could affect other communities downstream, or zoning for major commercial facilities in one jurisdiction might promote development in hazardous areas of an adjacent jurisdiction. All regulatory activities of local governments are performed under authority granted by state government. Therefore, states need to provide legislation, clear policy guidelines, and adequate information for local governments to develop hazard-related ordinances.

In Alaska, local land-use policies are the responsibility of borough governments. Because boroughs occupy sizable land areas (larger than most counties in the contiguous states), the scale of borough land-use plans is

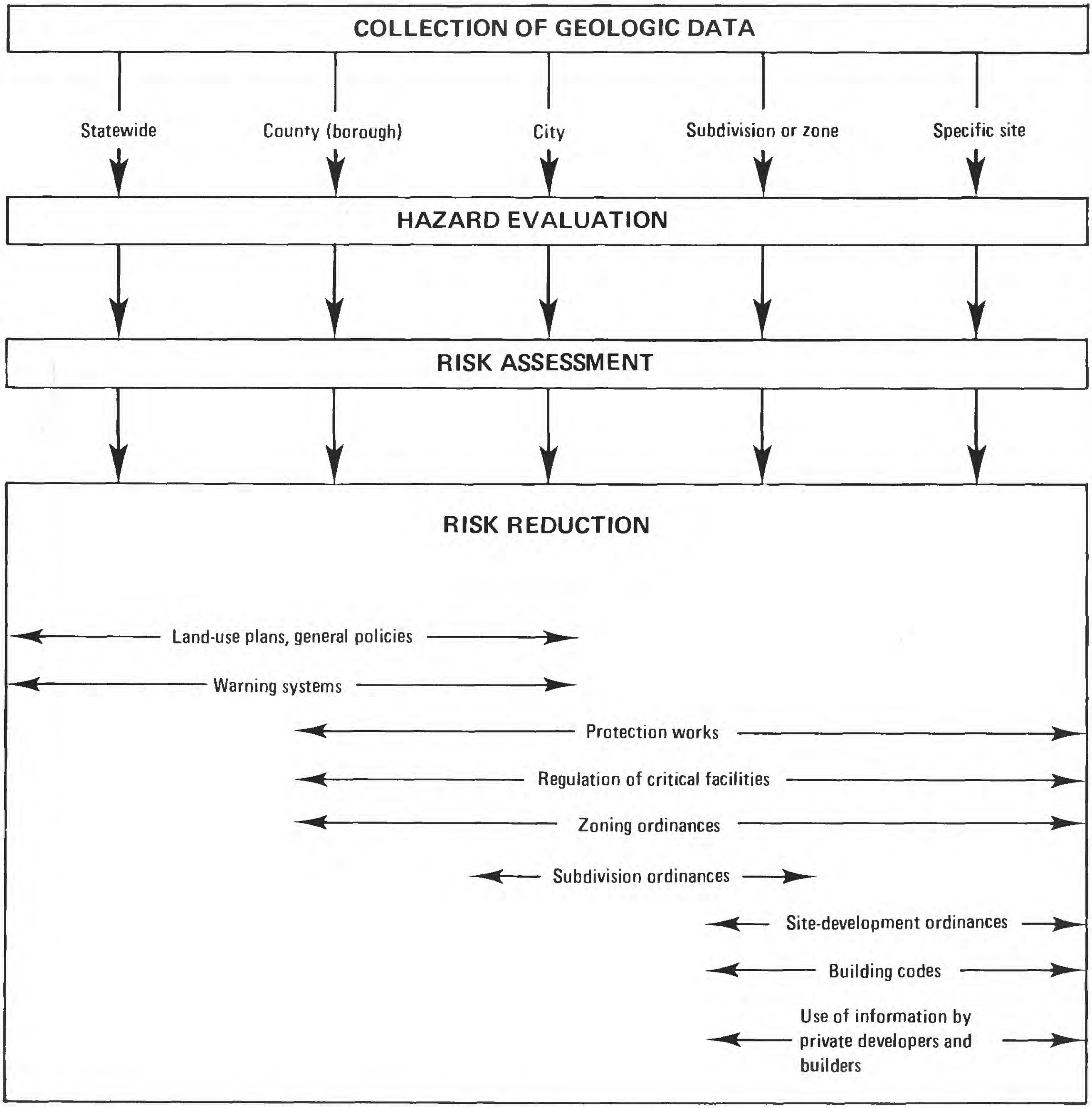


Figure 12. The hazard-mitigation process.

1955 20130

ideal for incorporating geologic-hazards considerations. However, only 25 percent of Alaska is subdivided into boroughs; therefore, when problems arise in areas outside the organized boroughs, coordination between borough and state or federal governments is necessary.

Because federal, state, and local governments have different levels of financial and personnel resources and different management responsibilities, their roles in hazard mitigation are also quite different (table 2). Local governments generally do not have the financial resources or personnel to conduct major geologic-hazards studies, particularly for large-scale and potentially catastrophic hazards like earthquakes and volcanic eruptions. State geological surveys are equipped to conduct these types of studies, publish information on hazards that affect the state, and provide technical assistance to local governments. Other state agencies can assist with land-use plans, ordinance development, building-code enforcement, and other risk-reduction measures. The federal government assists states by providing topical information on geologic-hazards processes, performing research, and mapping on a regional scale. State and federal governments have disaster-relief funds to assist communities if a disaster occurs. Availability of federal disaster-relief funds is becoming increasingly contingent on effective state and local risk-reduction measures that follow a disaster.

GEOLOGIC-HAZARD-MITIGATION PROGRAMS IN OTHER STATES

Twenty-seven states, including Alaska, have adopted some form of legislation that authorizes or requires measures for geologic-hazard mitigation. The comprehensiveness and effectiveness of hazards legislation vary widely among these states and depend on how strongly the statutes are worded and how actively they are implemented. In some states, hazards legislation is ineffective because it authorizes measures that are never implemented. Of the 27 states with hazard-mitigation legislation in effect in 1982, 13 (including Alaska) adopted the Example State Disaster Act published by the Council of State Governments (1972). The disaster-prevention section of the act calls on the Governor and the state Division of Disaster Emergency Services to study disaster-prevention matters, land uses, and construction in the state and to recommend measures to reduce or prevent harmful consequences of a disaster. The Council of State Governments Disaster Act does little to mitigate hazards because it is primarily disaster-preparedness legislation. The act relies on follow-up legislation, policies, and development of agency programs to be effective for hazard mitigation. Only a few states have enacted programs in which hazards considerations are integral to land-use, development, and construction policies. The most common approach at the state level is enactment of legislation that initiates development of local mitigation programs and broad state policies and sets up state regulation of certain facilities.

Hazard-mitigation programs in California and Colorado were reviewed to determine whether they could serve as models for similar programs in Alaska. Both states have significant geologic hazards that are similar to those in Alaska and have tested their programs over longer periods than most other states. Information used in this review includes state statutes and regulations, published reports, and numerous discussions with individuals involved with the programs at state and local levels.

Table 2. Suggested roles of federal, state, and local governments in hazard mitigation and disaster preparedness. Modified from Council of State Governments, 1979; Hays and Shearer, 1981; and Nichols and Campbell, 1971.

	Federal governments	State government	Local government
Policy	Long-term national goals and policies Financial assistance for state and local governments to develop policies and programs	Enabling legislation for local governments Statewide goals and policies Statewide land-use plans Establish interdisciplinary councils to recommend public policy Financial assistance to local governments	County (borough) land-use plans
Research	Support topical research on geologic processes and regional mapping of hazards Support engineering and socioeconomic studies Support permanent monitoring (for example, earthquakes) at regional scale Conduct postdisaster studies	Support research on geologic hazards in the state and mapping of hazards at local to statewide scales Support long-term monitoring at statewide scale Conduct short-term postdisaster studies in cooperation with federal government	Perform or require local studies of specific hazards
Technical services	Supply geologic data, small-scale regional maps, and information Provide assistance to state and local governments	Supply geologic data, large-scale maps, and information to local governments and public Provide technical assistance to local governments	Assemble and evaluate data relevant to local hazards issues

Table 2. (con.)

Risk reduction	Develop model building codes and land-use plans Provide financial support for local land-use plans Support development of risk-reduction building technology Protection works (for example, U.S. Army Corps of Engineers) Issue predictions and warnings	Develop guidelines for local risk-reduction measures Develop model zoning ordinances Establish laws and regulations for siting and design of lifelines and critical facilities Set hazard-mitigation requirements for construction projects using state capital funds or loans Protection works Evaluate predictions, issue warnings, and advise as to appropriate response	Adopt and enforce zoning and site-development ordinances, building codes, and subdivision regulations
Disaster preparedness	Federal disaster-relief funds and loan programs Provide advice and financial incentives for state and local preparedness plans Maintain major response capability (for example, U.S. Army National Guard, Corps of Engineers) Offer or subsidize hazard insurance	State disaster-relief funds Disaster-preparedness plans and programs Public education Assistance to local governments in developing preparedness plans	Local preparedness plans Public education with emphasis on individual preparedness

1983 20130

California

Hazard-mitigation programs in California are largely an outgrowth of public reaction to natural disasters, beginning with legislation that was developed after the St. Francis Dam failed in 1928 (Campbell, 1976). This approach has been responsible for a wide variety of seemingly unconnected special-purpose programs. For example, school construction has been strictly regulated for earthquake safety under the Field Act since 1933, when an earthquake extensively damaged schools in Long Beach. Similar standards for hospitals (Hospital Seismic Safety Act) did not appear until after the 1971 San Fernando earthquake when extensive damage occurred and dozens of people were killed at four major hospitals and many other medical facilities. In recent years, California has begun to develop more farsighted, coordinated programs in anticipation of future events.

Surges in public emotion that follow disasters have been responsible for the episodic development of hazards-related legislation in California. Two consequences are the need for extensive corrective action by the legislature on hastily prepared bills and, until the early 1970s, the lack of comprehensive, well-prepared legislation. A high percentage of hastily prepared bills were passed by the Legislature during the emotional aftermath of disasters. Lulls between disasters allowed sufficient time to prepare good legislation, but were also periods of apathy during which few good bills were passed (Slosson, 1975).

Despite this erratic process, many successful programs that address specific problems were developed. In recent years, Californians and their legislators have begun to support more advanced planning and well-prepared, long-range legislation like the Alquist-Priolo Special Studies Zones Act and establishment of the Seismic Safety Commission.

Many lessons can be learned from the history of hazard-mitigation programs in California. The lessons are particularly applicable to Alaska, which is in a position similar to that of early 20th-century California. Economic development is still in its youth, one major damaging earthquake has occurred, and the likelihood is high that additional events will occur (as they did in California) that will take a progressively greater toll of lives and property unless the disaster potential is reduced. Ironically, the 1964 Great Alaska Earthquake inspired the establishment of California's Joint Committee on Seismic Safety, which in 1974 became the Seismic Safety Commission (Campbell, 1976).

The major state legislative programs that relate to geologic-hazard mitigation in California, their development, and some of their strengths and weaknesses are reviewed below.

State Planning and Zoning Law: General plan

In 1927, California passed legislation that allows local governments to prepare a general plan to document their land-use and development policies. In 1955, the general plan became a state requirement for all counties and cities, and two 'elements' (land use and circulation) were addressed (California Government Code, secs. 65300-65302). By 1971, seven more elements were added, including a 'seismic-safety element' and a 'safety element' required by amendments that were passed soon after the San Fernando earthquake. Also in 1971, the most significant feature relating to implementation was added: the requirement that all zoning ordinances and subdivision approvals be consistent with a jurisdiction's general plan.

State law requires the Governor's Office of Planning and Research to prepare, adopt, and periodically revise state guidelines to assist local governments in preparing their general plans. These guidelines constitute California's official interpretation of the planning law and give detailed instructions and suggestions on content, format, and procedures (California Office of Planning and Research, 1980).

As new elements were added to requirements in the general plan, local governments were given deadlines for their preparation and adoption. All seismic-safety and safety elements were to be completed by 1976. As of January 1977, 81 of the 412 cities and 19 of the 58 counties had not adopted a seismic-safety element (California Seismic Safety Commission, 1977a). Only the housing element requires an update every 5 yr. However, the guidelines strongly encourage thorough review and revision of all elements at least every 5 yr to reflect new conditions and public attitudes.

Various portions of each general plan must be submitted to appropriate state agencies for review. For example, a copy of the adopted seismic-safety element and associated technical data must be submitted to the state Division of Mines and Geology (DMG). With one exception (unrelated to hazards), state agencies do not have approval authority over general-plan elements. The purpose of submitting review copies is to inform state agencies that have responsibilities related to certain aspects of the general plan and to provide those agencies with an opportunity to suggest revisions or improvements.

The seismic-safety element of the general plan must consist of an "identification and appraisal of seismic and geologic hazards, such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to effects of seismically induced waves such as tsunamis and seiches." The safety element must describe proposed features for community protection from those hazards. Flooding must be addressed in other elements of the general plan, including the land-use element (which identifies areas subject to flooding) and the conservation element (for conservation aspects of flood control). State guidelines note that the division of the general plan into separate elements "is more a product of the incremental nature of the legislative process than a conscious design." Thus, local planning commissions are encouraged to combine the seismic-safety and safety elements into one section devoted to the hazard issues. Plans for implementing the Alquist-Priolo Special Studies Zones Act, described below, must also be included in the general plan if all or a portion of the local jurisdiction lies within one zone.

Only 1 yr after all seismic-safety elements were due to be completed, the California Seismic Safety Commission (SSC) (1977a) reviewed the seismic-safety requirement and found that it had already begun to produce positive effects. However, SSC recognized that it could be a long time before a major earthquake tested the requirement's effectiveness. The seismic-safety requirement forced local identification of earthquake problems, formulation of related policy, and significantly impacted land-use decisions. When a questionnaire was sent to four cities and four counties, most jurisdictions responded that information generated by the seismic-safety requirement provided important seismic and geologic data for decisionmakers at all levels of government and increased the awareness of planners, public-works officials, building departments, and elected representatives of seismic and geologic problems related to land-use planning. The review committee concluded that, despite some weaknesses, the seismic-safety requirement produced very significant benefits in the interest of public safety.

One weakness of the planning law is that the state is unable to ensure that general plans or their individual elements are adopted and periodically updated. No penalties are prescribed for failure to complete a general plan, nor are financial incentives given. However, any property owner, resident, state agency, state attorney general, or any aggrieved party may sue to enforce the requirement for adoption of a general plan and consistency of subdivision approvals and zoning. The courts may issue a writ of mandate for compliance with the requirement or set aside city or county approval of an action that is inconsistent with the plan. Apparently, court action is the only means of ensuring compliance (J.L. Mintier, oral commun., 1982).

Another weakness is that no single agency is responsible for reviewing the adequacy of general plans. Seismic-safety elements are submitted to the Division of Mines and Geology (DMG) for possible review, but approval is not required. Also, DMG comments concentrate on the technical adequacy of geological and geophysical information and do not address application of the information to planning (J.L. Mintier, oral commun., 1982). The California Seismic Safety Commission (1977a) found a wide variation in content and quality of plans. Although SSC conceded that variation in content and organization is inevitable, and to a certain extent desirable, it concluded that lack of checks on quality allowed the adoption of many seismic-safety elements that contain misleading or erroneous information. Consequently, questions are raised about the validity and effectiveness of seismic-safety elements in a planning document.

After a general plan is adopted, implementing it through such means as revising existing zoning laws, updating building codes, and conducting safety inventories of existing buildings is difficult. Although the law requires that actions such as subdivision approvals and zoning changes be consistent with the general plan, it cannot ensure that new actions stipulated by the plan are implemented. Mintier and Stromberg (1982) surveyed seven jurisdictions and found that the safety element has not functioned successfully as a planning document. For example, all seven jurisdictions had adopted policies in their general plans that called for an inspection and rehabilitation program for hazardous buildings, but none have implemented their programs. Instead, the seismic-safety element has been most effective as an educational tool for planners and elected officials and as a broad mandate for local governments to learn about the geology of their areas and to mitigate hazards through project reviews.

Alquist-Priolo Special Studies Zones Act

The Alquist-Priolo Special Studies Zones Act was passed in December 1972 and became effective as part of the California Public Resources Code (secs. 2621 to 2630) in March 1973. As of 1980, the act had been amended four times. The law requires the State Geologist to delineate special-studies zones (normally 1/4 mi wide or less) that encompass all 'potentially and recently active' faults that constitute a possible hazard to structures from surface faulting or fault creep. Before any 'project' (defined by the law) within a special-studies zone is approved, cities and counties must require a geologic report that defines and delineates any hazard of surface fault rupture.

Project approvals and geologic reports must comply with policies and criteria set by the State Mining and Geology Board (SMGB). The act also requires that sellers of real property located within a special-studies zone disclose that fact to prospective buyers. Table 3 summarizes responsibilities and functions under the act.

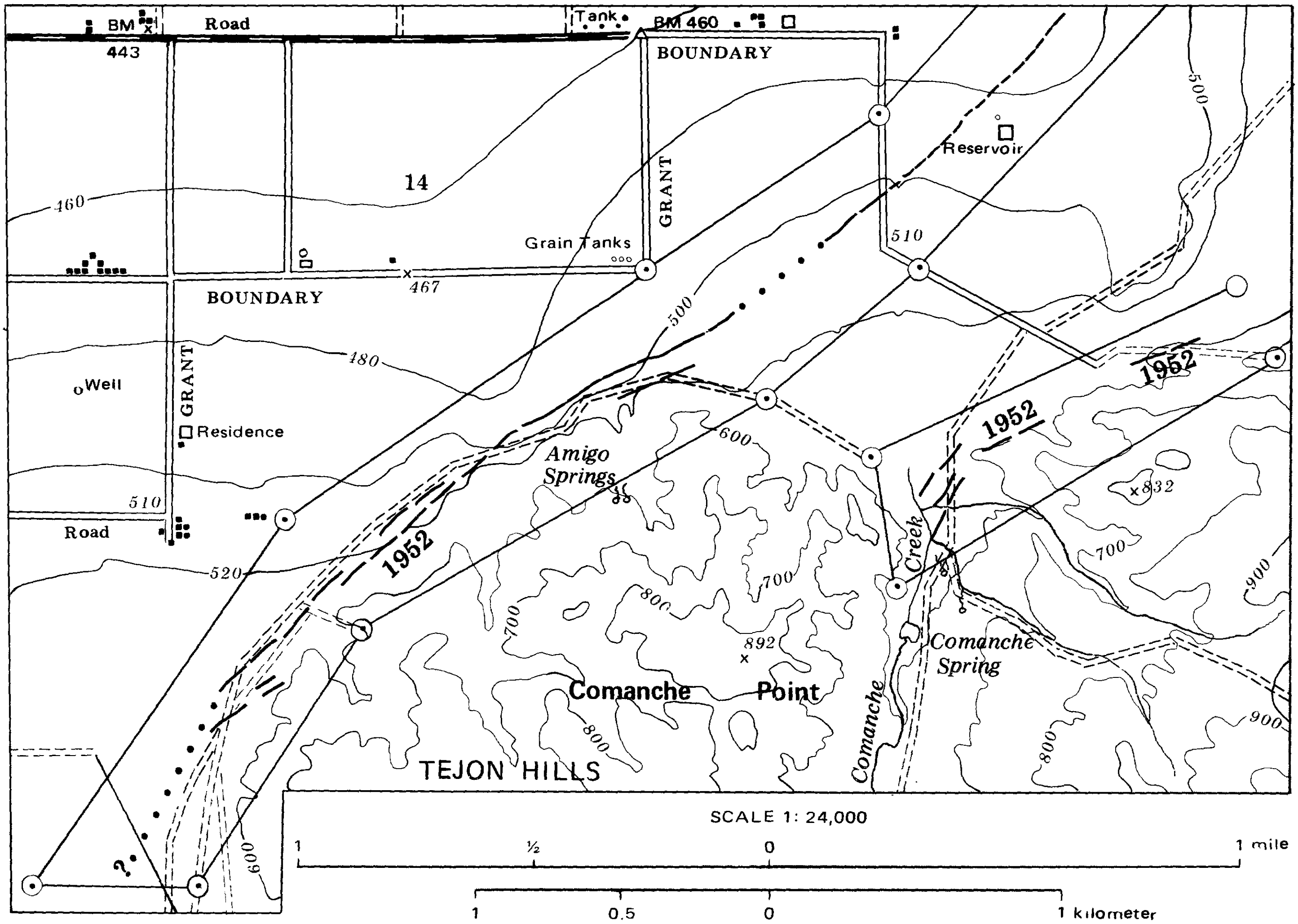
According to the law, a 'project' is any new real-estate development or structure intended for human occupancy, with the exception of single-family wood-frame dwellings that do not exceed two stories and alterations that do not exceed 50 percent of the structure's value. The SMGB defines an active fault as one that shows evidence of surface displacement within the last 11,000 yr (Holocene time). To delineate special-studies zones, the State Geologist defined a 'potentially active' fault as one that shows evidence of surface displacement during the last 2 m.y. (Quaternary time), and included 'recently active' faults in the 'potentially active' category.' Since January 1, 1977, special-studies zones have been delineated based only on faults that show evidence of activity during Holocene time.

The DMG produces maps that show special-studies zones on U.S. Geological Survey 1:24,000-scale topographic base maps (fig. 13). An ongoing fault-evaluation program selects faults that can be located in the field with sufficient precision and confidence to indicate that site-specific investigations required by law will be successful. Positions of the special-studies zones are controlled by the positions of mapped fault traces. Zone boundaries are straight-line segments that join locatable features on the ground. The zones have a total width of about 1/4 mi except where there are closely spaced, parallel fault strands in which case the zone may be wider. As of January 1, 1980, 288 special-studies-zone maps had been issued; 24 of these had been revised. Approximately 24 counties and 69 cities are affected (Hart, 1980). The DMG is required to review new geologic and seismic data to revise existing zones or delineate new ones.

Local governments are responsible for determining, through requirements placed on the developer or builder of projects within a special-studies zone, whether a potential fault hazard exists for proposed structures and their occupants. Fault information shown on DMG special-studies-zone maps is not intended to be sufficient for this purpose. Along with the permit application, the developer or builder must submit a report prepared by a geologist registered in the State of California that addresses potential surface fault displacement through the project site. As required by SMGB policies, the city or county must then retain a registered geologist to review the report for adequacy. The city or county must approve the report before a permit is granted. The policies of SMGB prohibit construction of structures for human occupancy within 50 ft of an active fault. Therefore, to be eligible for a permit, a builder or developer must prove there are no active faults within 50 ft of the proposed project. The board has set 50 ft as the minimum standard, and encourages cities and counties to impose more restrictive criteria for large or critical structures.

The DMG has found that the investigative methods, documentation, report quality, and validity of conclusions are inadequate in many fault-evaluation reports (Hart and Wagner, 1975; Stewart and others, 1977). Although not required to do so by law, DMG published guidelines for the evaluations and a suggested outline for the reports (Hart, 1975).

Implementing the Special Studies Zones Act at the local level has additional problems, some of which remain unresolved. Most difficulties result



EXPLANATION

Potentially active faults

1952

Faults considered to have been active during Quaternary* time; solid line where accurately located, long dash where approximately located, short dash where inferred, dotted where concealed; query (?) indicates additional uncertainty. Evidence of historic offset indicated by year of earthquake-associated event

Special-studies-zone boundaries

These are delineated as straight-line segments that connect encircled turning points that define special-studies-zone segments

*Beginning with maps issued January 1, 1977, special-studies zones have been delineated only for those faults considered to have been active during Holocene time.

Figure 13. Example of a Special Studies Zones map. These maps are published by the California Division of Mines and Geology in accordance with the Alquist-Priolo Special Studies Zones Act of 1972. Modified from Hart, 1980, p. 7.

Table 3. Summary of responsibilities and functions under the Alquist-Priolo Special Studies Zones Act (Hart, 1980).

State Geologist

1. Delineates special-studies zones; compiles and issues maps to cities, counties, and state agencies.
   a. Preliminary maps for review.
   b. Official maps.
2. Reviews new data.
   a. Revises existing maps.
3. b. Compiles new maps.
   Approves requests for waivers initiated by cities and counties.

State Mining and Geology Board

1.
   Formulates policies and criteria to guide cities
2. and counties.
   Serves as Appeals Board.

Cities and Counties.

1. Must adopt zoning laws, ordinances, rules, and regulations; primary responsibility for implementing act.
2. Regulate specified 'projects' within special-studies zones.
   a. Determine need for geologic reports before project development.
   b. Approve geologic reports before issuing development permits.
   c. May initiate waiver procedures.
3. May charge reasonable fees for administrative costs.

Other

1. Seismic Safety Commission - advises State Geologist and State Mining and Geology Board.
2. State Agencies - prohibited from siting structure across active fault traces.
3. Disclosure - prospective buyers of any real property located within a special-studies zone must be notified of that fact.

from lack of clear definitions and requirements and from inconsistencies between SMGB policies and the Special Studies Zones Act. For example, the law is not clear about what basis is used to establish property values of buildings proposed for alteration to determine if a geologic report is required (based on 50 percent of the value). Whether 'structures for human occupancy' include warehouses, studios, and buildings added to an existing facility, or if the requirements apply to expansion of existing uses and changes in occupancy is not clear. Policies of SMGB prohibit building any structures for human occupancy within 50 ft of an active fault, whereas the Special Studies Zones Act exempts certain structures (for example, single-family dwellings) from that requirement. Many problems could be resolved by amending the act and revising SMGB policies (California Seismic Safety Commission, 1977b).

More serious implementation problems arise because the Special Studies Zones Act imposes uniform, statewide requirements that do not allow flexibility for local differences in government, level of development, and conditions that preclude accurate delineation of surface fault traces. For example, how can the trace of a suspected active fault be located in an urbanized area that has no predevelopment aerial photography and is largely covered by fill? Where faults must be located by remote-sensing methods, such as seismic and magnetometer surveys, it is generally not possible to date the displacement or accurately extrapolate the surface trace. Many local governments alleviate uncertainties in clarity, definition, and application of the law by imposing their own more restrictive ordinances. For example, if the setback is increased to 100 ft, the surface trace of a fault that has no surface expression can be approximately mapped because it incorporates a 50-ft margin of error beyond the setback required by SMGB. To alleviate uncertainties in how the law is applied to individual properties that lie partially within a special-studies zone, one city adjusted zone boundaries to follow property lines and street centerlines so that lots originally crossed by a zone boundary are now entirely within the zone (California Seismic Safety Commission, 1977b).

Requirements imposed by the Special Studies Zones Act and by board policies created a considerable demand for registered geologists. Two registered geologists are required for all new projects in every special-studies zone in every city and county affected by the act. One registered geologist prepares the report for the developer or builder, and the other reviews it for the permitting body. Many local governments regard this requirement as excessive and have recommended that they be allowed to hire one geologist to prepare a report for the entire portion of a special-studies zone that transects their respective jurisdictions and that DMG provide the review. Because of the scarcity of registered geologists, some people believe that it is impractical and not in the public interest to require that the reports be reviewed by registered geologists. One city geologist found that "many geologists preparing reports are unaware of recent trends in fault analysis, rely on inappropriate methods of investigation, and restrict themselves too tightly to a site, referring only to published regional data rather than using field-checked air-photo interpretation" (California Seismic Safety Commission, 1977b).

The disclosure requirement presents implementation problems and is not clear about responsibility for its enforcement. Most local governments assume the state is responsible for enforcement, but a few have clarified their own policies and procedures for disclosure. Most cities and counties do not know whether a seller discloses to prospective buyers that the subject property lies within a special-studies zone. Many sellers and real estate agents are unaware of the requirement, even though they may be aware of the act. One county requires the owner to sign a statement, recorded with the deed, that acknowledges the potential hazard, but only for new projects that require a geologic report under the Special Studies Zones Act. Enforcement of the disclosure provision for property that does not require a report is much more difficult because a permit is generally not involved, and the county is therefore unaware of a sale until after it is recorded. Apparently the only real compliance incentive is the threat of possible court action against the seller if an unnotified buyer suffers losses from fault damage (California Seismic Safety Commission, 1977b).

A major concern among property owners has been the potential impact of the Special Studies Zones Act on property values and development interests. Some cities and counties have in turn expressed concern about possible liability for lots declared 'unbuildable.' Although there apparently are no documented cases of financial loss due to the act, one would expect such losses to occur when property intended for construction is purchased, later included in a special-studies zone, and found to be located on an active fault. After the initial loss, however, subsequent investments in the property should not be affected because restrictions on property use would not change (California Seismic Safety Commission, 1977b).

The Special Studies Zones Act has successfully restricted development along mapped active faults in California. Its effectiveness in reducing the hazard from surface fault rupture has not been tested because no damaging surface ruptures have occurred in a special-studies zone since the law went into effect. Whether particular faults are active or inactive is often disputed, because the age of most recent displacement is based on interpretations on which competent geologists may disagree, especially when there is insufficient conclusive evidence. When a geologic report is accepted, a jurisdiction reduces its liability if it takes the conservative position and regards faults of questionable age as active and imposes the setback requirement for an active fault.

Locating boundaries of special-studies zones has often been a problem for local agencies. Some landmarks that were used to identify turning points no longer exist because they were based on old topographic maps or were not field checked (California Seismic Safety Commission, 1977b). Once turning points are located, boundaries are rarely challenged, even though they represent no identifiable geologic boundary between areas of greater and lesser hazard. This approach to mapping hazard areas has generally been upheld by court decisions in many states, as long as there is a rational relationship between delineation of the hazard area and the promotion of public safety (Baker and McPhee, 1975). Boundaries that can be easily located by the enforcing agency are preferable to boundaries that follow natural discontinuities in hazard severity. Special-studies zones only delineate areas where fault-evaluation reports are required and do not themselves impose *a priori* restrictions on land use. Therefore, precise geologic data to defend boundaries is not needed.

Field, Garrison, and Green Acts: School buildings

California's Field Act (Education Code, secs. 39140 to 39156 and 81130 to

2088 20130

81146) is one of the best known and documented success stories in geologic-hazard mitigation. The Field Act resulted directly from public reaction to the extensive damage inflicted on schools in Los Angeles County during the Long Beach earthquake of March 10, 1933 (Richter magnitude 6.3). Although accurate figures are not available, about 70 schools were demolished and many more severely damaged (fig. 14). Assemblyman Don Field introduced the bill, which quickly passed both houses of the state legislature and was signed into law on April 10, 1933, exactly one month after the earthquake.

The Field Act regulates new construction of primary and secondary schools and community colleges to ensure conformance with minimum design standards for protection of life and property during an earthquake. Alterations or additions that exceed $20,000 are similarly affected. The Garrison Act was enacted in 1939 and amended by the Greene Acts in 1967, 1968, and 1974, to require that schools built before 1933 be inspected and, if judged unsafe, rehabilitated to Field Act standards or abandoned.

The Field Act has several requirements:

1. Plans for construction or alteration of school buildings must be prepared by registered architects or structural engineers.
2. Plans must be reviewed and approved by the Office of the State Architect, Department of General Services, before a construction contract is awarded to ensure that the plans meet standards of the state building code (ICBO Uniform Building Code by reference).
3. Construction must be continuously inspected by registered inspectors to ensure compliance with approved plans.
4. The design architect or structural engineer must observe the construction and prepare any necessary design changes.
5. All parties (designers, contractors, and inspectors) must file reports (under penalty of perjury) that verify compliance with the approved plans.

Because the act references the state building code (part 2, title 24, California Administrative Code), it does not impose its own standards for school-building design, and therefore remains flexible to accommodate changes in the code as earthquake-engineering technology advances. In effect, the Field Act simply strengthens uniform implementation of the code for school construction by placing strict design-review and approval responsibility and inspection enforcement in the hands of the State Architect. The law requires a filing fee of 0.6 to 0.7 percent of the estimated construction cost ($250 minimum) to defray the state's costs of implementing the law.

Other provisions of the Education Code (secs. 39002 to 39002.5 and 81033 to 81033.5) require geologic and soils-engineering studies of prospective school sites located within a special-studies zone (Alquist-Priolo Act) or an area designated geologically hazardous in the local general plan. A copy of the report must be submitted to the Department of Education. The site selection is not approved if the construction effort required to make the school building safe for occupancy is economically unfeasible.

The Field Act has proven its effectiveness through several damaging earthquakes since 1933. During the Kern County earthquake of 1952 (Richter magnitude 7.7) and the San Fernando earthquake of 1971 (Richter magnitude 6.4), many buildings not built to Field Act standards completely collapsed, but nearby school structures built in compliance with the law survived nearly undamaged (Campbell, 1976; Mann, 1979).

Figure 14. John Muir School, Long Beach, California, damaged by the March 10, 1933, earthquake (Richter magnitude 6.3). Photograph by W.L. Huber.

2058 20130

When Mann (1979) reviewed the Field Act and related laws for the Seismic Safety Commission, he concluded that the only major problem is that early (pre-1950) schools built to comply with the Field Act may no longer conform to modern standards because of frequent upgrading of building codes. The Field and Garrison Acts contain no provisions for periodic inspections and possible rehabilitation of schools that once complied with the law. Although many early structures are probably safe, Mann (1979) recommended that selected schools built from 1933 to 1950 be inspected by the Office of the State Architect and professional societies.

School boards faced with building a new school are concerned that Field Act requirements will make construction prohibitively expensive. In response to their concern, Mann (1979) compiled information from design professionals and estimators and showed that the total added cost of materials, labor, inspections, fees, and paperwork related to Field Act requirements historically has been a maximum of 5 percent of the total construction cost. This increase is partially offset by lower insurance rates available for schools that comply with the Field Act. In addition, because of the high probability of exposure to a significant earthquake during the 50-yr design life of any school in California, the relatively minor additional investment during construction is likely to prevent major earthquake-related repairs. With one exception, no school built to Field Act requirements has been damaged by an earthquake to the extent that major repair was necessary. However, the damage rate for schools built before 1933 is 25 to 75 percent.

Perhaps the only other major drawback of the Field and Garrison Acts is that they do not apply to all educational facilities or other important public facilities (J.F. Meehan, oral commun., 1982). Universities, for example, are not subject to the acts. Hospitals were not placed under similar requirements until after the San Fernando earthquake in 1971. The Riley Act, which was also enacted in 1933, requires most other buildings to be constructed to comply with the state building code, but does not impose strict enforcement and review procedures as prescribed for schools by the Field Act. The review provision is probably primarily responsible for the Field Act's success. A study by Woodward-Clyde Consultants (1980a) concluded that "the superior performance demonstrated by public schools constructed under Field Act standards appears to be a product of both the formalized review process and the appropriateness of policy standards. The superior performance is also a product of the sound judgment exhibited by reviewers; this is related to sufficient scope of review, a high level of expertise of reviewers, and a high degree of independence of reviewers."

Hospital Seismic Safety Act

After many medical facilities were severely damaged during the San Fernando earthquake in 1972 (fig. 15), the Hospital Seismic Safety Act (California Health and Safety Code, beginning with section 15000) was enacted. This act requires enforcement and inspection procedures similar to those of the Field Act for construction and alteration of hospitals. New construction of hospitals must conform to provisions of the latest edition of the ICBO Uniform Building Code. An important difference from the Field Act is that the Hospital Seismic Safety Act requires, beyond protection of life and property from the immediate dangers posed by an earthquake, that hospitals be capable of continuing services to the public after a disaster. Additional requirements

Figure 15. Olive View Hospital, Sylmar, California, damaged by San Fernando earthquake on February 9, 1971 (Richter magnitude 6.4). Photograph courtesy of National Oceanic and Atmospheric Administration.

2081 2080

for fire safety and equipment anchorages are imposed. According to Woodward-Clyde Consultants (1980a), practical standards used to fulfill these requirements are that the design should permit safe exit after the maximum credible earthquake and continued function after the maximum probable earthquake (see app. B).

Implementation of the Hospital Seismic Safety Act is different than for the Field Act because of the additional safety requirements and because hospital construction is regulated by the Office of Statewide Health Planning and Development (SHPD). The Office of the State Architect, Department of General Services, reviews designs and inspects structures as under the Field Act, but under contract to SHPD, which coordinates all reviews and enforces the act. A Building Safety Board within SHPD serves as an advisory body and acts on appeals and waivers. To cover the cost of administering the act, SHPD is authorized to collect a filing fee not to exceed 0.7 percent of the estimated construction cost.

Construction plans for work that affects hospital structural elements must be accompanied by a geologic- and engineering-investigation report that evaluates the potential for earthquake damage. This site assessment can be waived by SHPD if judged unnecessary and not beneficial to public safety. The Department of General Services (generally the State Architect) provides independent review of the geologic data by a registered engineering geologist or DMG as part of its basis for approving or rejecting the plans.

The Hospital Seismic Safety Act authorizes SHPD to review hospital operations to ensure that the hospital is adequately prepared to resist earthquake damage. The act does not specifically provide for inspection of structural elements, nor does it require upgrading of older hospitals that are seismically hazardous. Amendments to the act (chapter 303, 1982) authorize SHPD to inspect any hospital for hazardous conditions and order it vacated if it violates applicable building standards. Although upgrade policies that affect hospitals may also be contained in general plans and implemented at the local level, very little local action has been taken (Woodward-Clyde Consultants, 1980a).

Besides lacking policy for upgrading existing hospitals, the Hospital Seismic Safety Act has a potentially serious limitation regarding the requirement for continuing hospital services after an earthquake. The ability to provide uninterrupted medical services strongly depends on lifelines and other external critical facilities, such as roads, electric power, natural-gas lines, water, and sewer. Seismic-safety requirements for these facilities do not exist to the degree imposed on hospital buildings under the act. It is questionable whether a hospital could continue to function for a long period after a major earthquake that would probably disrupt some or all of these services, even though the building conforms to the strictest earthquake-safety standards. Although the Veteran's Administration requires its hospitals to be capable of operating independently of external facilities for at least 4 days, no similar requirement is included in California's Hospital Seismic Safety Act (Woodward-Clyde Consultants, 1980a).

Riley Act

The Riley Act (Health and Safety Code, secs. 19100 to 19183) regulates construction of most other buildings in California that are designed for human occupancy and do not have their own specific legislation. The only exclusions are buildings located outside city limits and not intended for human occupancy, one- and two-family dwellings outside city limits, farm buildings, and certain labor-camp buildings in unincorporated areas.

The Riley Act was signed into law in 1933 and originally required that all buildings, other than those listed above, be constructed to withstand lateral design-wind and earthquake forces of 2 to 3 percent of the total vertical design load. Amendments in 1965 and 1974 changed the lateral-force requirements to comply with the state building code (part 1, title 24, California Administrative Code), which is based on the latest edition of the ICBO Uniform Building Code. A 1979 amendment allows local governments to assess the earthquake safety of existing buildings and identify permissible corrective actions. Structures governed by the Field, Garrison, or Hospital Seismic Safety Acts and all state-owned buildings are specifically excluded from the 1979 provisions. The latest amendment in 1980 authorizes local governments to require installation of earthquake-sensitive gas-shutoff valves in public buildings as a fire deterrent.

Although design and construction standards for buildings under the Riley Act are similar to standards of the Field and Hospital Acts (all use the ICBO Uniform Building Code), review and enforcement requirements are not nearly as stringent. City and county governments are responsible for enforcing new construction under the Riley Act through their own ordinances and procedures, some of which are prescribed by the Uniform Building Code. The 1979 amendments for reconstruction of hazardous buildings authorize local governments to assess earthquake safety and establish reconstruction standards. This provision applies only to unreinforced masonry buildings constructed before building codes were adopted that require earthquake-resistant design; in effect, the Riley Act assumes that all newer buildings are safe.

Two important provisions alleviate major concerns of local governments that want to initiate programs for building rehabilitation. One provision grants local governments immunity from liability for earthquake damage based on any action taken or not taken to assess or upgrade old buildings. The other provision recognizes the high cost of rehabilitating old buildings to meet codes that must be met for new buildings and allows local governments to enact their own building standards to improve seismic safety and still be economically feasible.

Because the Riley Act does not require centralized review and therefore has not produced centralized records, its effect in reducing earthquake hazards to buildings in California is difficult to assess. The present concern over the earthquake safety of many buildings constructed in California before and after 1933 suggests that the Riley Act has not been entirely successful. Although the act is enforced by local agencies, the quality of review and inspection varies (Woodward-Clyde Consultants, 1980b). Contributing factors include qualifications of building officials, competence of inspectors, personnel and funding limitations, interpretation of the building code, and familiarity of the building official with the type of project involved. Building officials in California are not required to meet any standard minimum qualifications. According to the Woodward-Clyde study, many building officials assume that building designs, soil reports, and geologic-hazard reports are adequate because they are prepared by registered professionals who are familiar with the code's requirements. Funding limitations often prevent local agencies from hiring competent professionals to perform reviews and from contracting to have reviews performed externally.

Elected local officials play a large role in determining the degree of building-code enforcement by establishing budgets and setting work priorities. One survey of local building departments showed that 40 percent of the respondents believed that their elected local officials are sympathetic to weaker enforcement of building regulations, and 70 percent felt that local-government management has little or no concern about earthquake risk (Olson and Scott, 1980; International Conference of Building Officials, 1980). The survey concludes that roughly half of the local building departments in California operate with little support from elected officials and management. Judging from these surveys, the attitudes of many local elected officials in California apparently do not reflect public concerns for seismic safety. Two recent surveys in California showed strong public support for stringent seismic-safety measures. In one survey (Turner and others, 1979), 65 percent of the respondents strongly favored public expenditures to enforce building codes for seismic safety. The second survey (Turner and others, 1980) showed that 75 to 80 percent of the respondents favored laws to strengthen or vacate hazardous buildings.

Dam Safety Act

Design, construction, alteration, operation, and removal of nearly all nonfederal dams in California (concrete and earth-fill) are under the authority of the Dam Safety Act (California Water Code, secs. 6000 to 6501). The only exemptions are dams smaller than the jurisdictional size specified by the act, based on height and storage capacity. The Dam Safety Act is another example of response to public reaction that followed a major disaster. In 1928, the St. Francis Dam in southern California failed and caused extensive property damage and about 420 deaths. The new law put all nonfederal dams under state supervision if they were built or proposed to be built across a natural watercourse. State involvement includes extensive reviews of design and construction elements to ensure safety. After the 1963 failure of the Baldwin Hills Dam in Los Angeles, which was not built across a natural watercourse and therefore was exempt from state supervision, the act was amended to include offstream dams.

The Division of Safety of Dams (DSD) in California's Department of Water Resources (DWR) administers the Dam Safety Act and is required to authorize and supervise all aspects of dam construction, alteration, operation, and removal. Not only does DSD perform these functions for state-jurisdictional dams; it also reviews federal hydroelectric and flood-control dams under the Memoranda of Understanding with the Federal Energy Regulatory Commission and the U.S. Army Corps of Engineers.

For state-jurisdictional dams, the Dam Safety Act and associated regulations require state-of-the-art design and construction standards. Before construction can begin, an application must be filed with DWR, accompanied by detailed design plans, specifications, and the results and supporting data from regional and site-specific geologic and engineering studies. The DSD conducts extensive geologic and engineering reviews, and sometimes retains outside consultants to assist with the review of major critical projects. As part of the review process, DSD may conduct site inspections and observe field studies.

Dam construction or alteration may begin after DSD formally approves the design plans and supporting data. To ensure that approved plans are followed and unforeseen problems are recognized and resolved, DSD frequently inspects sites during construction and reviews the required owner-performed inspections and tests. After the dam is built, a use permit is required before the reservoir can be filled. After filling, the dam and reservoir are inspected and evaluated at least annually during operation. The use permit can be revoked at any time if DSD finds a condition that indicates the dam or reservoir is unsafe and constitutes a danger to life and property. Fees that are collected with the initial application (before the design review begins) and annually during the operational phase provide $200,000 to $300,000 to the state general fund each year to partially offset costs of the dam-safety program.

The DWR is also responsible for site selection, design, construction, operation, and maintenance of State Water Project facilities. A Consulting Board for Earthquake Analysis was established to assist DWR in seismic design and participate with DSD in design reviews. The DSD annually inspects and evaluates state dams and nonstate-owned jurisdictional dams; the consulting board conducts an extensive review every 3 to 5 yr. As part of the safety program for state-owned dams, DWR also installs and operates strong-motion instruments to monitor earthquake effects. One or more instruments is installed on or near each dam at sites recommended by the design engineers for maximizing structural response. These data are combined with data from instruments not owned by the state to determine possible damage to existing dams and provide seismic-design information for future dams. The instrumentation program is conducted by the Earthquake Engineering Section of DSD and is funded entirely through state water-use fees. Seismic instrumentation of dam sites has provided some of the best strong-motion data available anywhere for recent earthquakes.

The DWR requires high performance standards for dams, although design standards are not fixed. This approach promotes improvements in design techniques as technical knowledge improves. Each selected design must meet established minimum performance standards that are more conservative than for most other types of structures. For example, the design must ensure that no major amount of water is released from a reservoir as a result of the maximum credible earthquake or the 1,000-yr flood. The Dam Safety Act makes the owner and operator of a dam or reservoir legally responsible for the dam's safety and specifically protects the state from liability for damages that result from failure after approval, enforcement of orders, regulation, or measures taken to prevent failure (W.W. Peak, oral commun., 1982).

As with the Field and Hospital Acts, success of the amended Dam Safety Act in reducing geologic and seismic hazards to dams and reservoirs is largely attributed to its strict, centralized review procedure. The approach to dam reviews, however, is much different because of the size and uniqueness of dam projects. In contrast to schools and hospitals, for which definite design codes must be followed and standard, proven designs are typically used, each dam presents totally new problems for which great flexibility in design must be allowed. For this reason, dam-safety reviews require expertise in several disciplines and a high level of independent thinking (Scott, 1981). Thus, DWR uses experienced staff as well as private firms contracted for external reviews. Geologists and engineers in DWR must meet minimum qualifications and participate in continuous technical training, including extensive educational programs in earthquake engineering. Many review tasks of the department are performed by reputable private consulting firms with the best expertise in their fields. The review processes of DWR are considered to be objective, independent, and thorough (Woodward-Clyde Consultants, 1980b).

Although dams and reservoirs are subject to strict hazards-safety regulations under the Dam Safety Act, other elements of the water-supply system are almost totally unregulated with regard to geologic hazards. Most water-distribution facilities, including aqueducts, pumping stations, treatment facilities, and local distribution networks, are built and operated by municipalities and are generally self regulating. The remainder, serving 20 to 25 percent of California's population, are owned by private companies regulated by the Public Utilities Commission. However, there are no general policies regarding protection of these facilities from natural hazards (Woodward-Clyde Consultants, 1980a). Because aqueducts and water-distribution lines frequently must be placed across active faults or within sediments subject to failure during earthquakes, they are highly susceptible to damage. Possible serious effects of damage, as demonstrated during past earthquakes, include loss of adequate water supply for fighting fires, contamination from damaged sewage facilities, and disruption of water supply to medical facilities for treating disaster victims. Except for the Dam Safety Act, there are no state policies regarding protection of water-supply facilities from natural hazards (W.W. Peak, oral commun., 1982).

The dam-safety program in California has not only been a model for other states, but has also had a major impact on federal dam-safety programs. Because of its major recent influence in the federal Auburn Dam and Warm Springs Dam projects, California helped demonstrate the inadequacy of the review process for many federal dam projects and was instrumental in causing improvements at the federal level (W.W. Peak, oral commun., 1982).

Just as the hazards-mitigation policies of the Field and Hospital Acts could be expanded to improve the safety of other buildings for public occupancy for which similar policies do not exist, the Dam Safety Act could be applied to other critical facilities in California and elsewhere. Presently, California does not have a formal review process for other critical facilities, although the Seismic Safety Commission has strongly encouraged such review. The SSC defines a critical facility as "any structure housing or serving large numbers of people, or otherwise posing unusually high hazards to public health and safety in the event of damage or malfunction" (Scott, 1981). In addition to dams, schools, and hospitals, the definition includes nuclear reactors, liquified-natural-gas terminals, petroleum-storage facilities, fire and police stations, disaster centers, communication and transportation facilities, utility lifelines, electric generating plants, prisons, coliseums, and large office buildings.

Strong-motion Instrumentation Program

Technology for design of earthquake-resistant buildings is derived largely from information about the forces and deformation induced in structures by ground motion during earthquakes. Reliable information of this type can be obtained only by measuring motion in buildings and on nearby ground during earthquakes. Lack of such data continues to hamper advancement of earthquake-design technology, despite major nationwide expansions in strong-motion instrumentation. The 1964 Great Alaska Earthquake produced limited information useful for seismic design because there were no strong-motion instruments in the area to record ground motion and building response.

In addition to providing data essential for improving earthquake-resistant design, quantitative measurements of ground motion are important to develop a better understanding of earthquake processes, improve prediction capabilities, aid regional planning, and assess applicability of data to other areas.

Because strong-motion data are important for improving earthquake-resistant design, a requirement was added to the Uniform Building Code in the mid-1960s that all buildings with more than six floors be instrumented with strong-motion-recording devices. Many California cities immediately adopted the provision. However, problems and inadequacies soon became apparent. There generally were no provisions for continued instrument maintenance, many areas were neglected because instruments were concentrated in areas of high-rise buildings, and instrument locations prescribed by the code frequently proved inadequate. For example, during the 1971 San Fernando earthquake, all deaths occurred in buildings with fewer than six stories, and instruments located at sites in buildings as prescribed by the code (one at ground level, one on a middle floor, and one at the top) often produced unusable data because the effects of structural details and resonant properties of the buildings were not considered. The ground-level instrument produced no building-response data, and the instrument on the middle floor often was located at a nodal point where response was minimal. The highest instrument often produced the only usable data, but recorded only the horizontal components of motion (California Division of Mines and Geology, 1976).

The California Legislature recognized the need for statewide planning, coordination, and standardization to obtain quantitative ground-motion information from earthquakes. The Strong-motion Instrumentation Program (SMIP) (Public Resources Code, secs. 2700 to 2708) was signed into law in October 1971, with the objective of "acquiring strong-motion instruments and installing and maintaining such instruments as needed in representative geologic environments and structures throughout the state." The Division of Mines and Geology is responsible for organizing and monitoring the SMIP with advice from the Seismic Safety Commission. Under the program, DMG purchases, installs, and maintains instruments throughout the state and processes the resulting data. Funds to operate SMIP come from an application fee levied on all building permits in the state. The fee, collected by cities and counties, is 0.007 percent (7¢ per $1,000) of the proposed facility's total value as determined by the local building official. Local governments deposit the collected fees in the Strong-Motion Instrumentation Special Fund of the State Treasury to be used exclusively for the program. A city or county may be exempted from collecting the fees if it has adopted an ordinance that requires accelerograph installation and has at least one building under its jurisdiction that was instrumented in accordance with the ordinance before January 20, 1972. Fees are not collected from projects that do not require a city or county permit. Thus, state and federal construction projects and those requiring only state or federal permits are exempt from the fee requirement.

The SMIP is funded entirely by fees collected by cities and counties, including instrument purchases, field logistics for installation and maintenance, salaries, and data processing. Because the budget is affected directly by the construction industry, it varies from year to year. The program is adjusted to respond to revenue fluctuations; for example, the number of instruments purchased and installed each year is increased or decreased. The overall financial health of the program has been excellent despite downturns in the construction industry because fees have generated more revenue than originally anticipated. Although annual revenue was initially projected at $250,000, it grew rapidly to well over $400,000 in the first few years and is now about $1 million per yr (California Division of Mines and Geology, 1976; T.M. Wootton, oral commun., 1982). Although additional funds were needed for unanticipated data processing and instrument maintenance, the purchase and installation of instruments were accelerated. The program's goal is to install 1864 accelerographs by the year 2035, at which time the building-permit fee will be reduced to a level sufficient to maintain a monitoring program. Instruments will be distributed equally among free-field sites (away from man-made structures), buildings, structures other than buildings, and utility systems (T.M. Wootton, oral commun., 1982).

The SMIP uses structural information available for a building and its location relative to faults when it installs accelerographs and recording systems rather than using the standard minimum installation prescribed by the Uniform Building Code. This procedure maximizes the results by anticipating the building response. Most installations have a 13-channel capability that can record up to four strategically placed instruments that measure three directional components.

Data generated in the SMIP are being used to improve building designs and update codes. For example, one instrumented building that was constructed in compliance with existing codes failed during the 1979 Imperial Valley earthquake. Because the accelerographs recorded the earthquake motion and failure of the building, they provided invaluable data to analyze the building's structural response and determine design flaws responsible for failure (T.M. Wootton, oral commun., 1982).

Many local programs do not comply with the standards of the state program because of the exemption granted to cities and countries that had adopted pre-1972 ordinances that required installation of accelerographs. Those that had adopted a program were using unreliable building locations prescribed by the Uniform Building Code. Unfortunately, the exemption applies to most major cities. To partially alleviate this problem, the legislature enacted an amendment in 1975 that allowed, but did not require, an exempted city or county to apply to rescind its exemption.

Another possible weakness with the SMIP is that many major or critical facilities that require state or federal rather than local permits are exempt from the program. This situation does not necessarily mean that state- and federal-regulated critical facilities are not being adequately instrumented, but it may mean that some are not financially supporting a program from which they benefit greatly. A few of these facilities, such as dams in the State Water Project, are instrumented under separate programs with their own sources of funds and are contributing to the strong-motion data base in California. The earlier Advisory Board to the SMIP (now replaced by the Seismic Safety Commission as advisory body to the program) solicited the input of the California Water and Power Earthquake Engineering Forum and the Public Utilities Commission to determine appropriate accelerograph installations for many critical facilities and lifelines systems. The SMIP has since included many of these structures in its installation program (T.M. Wootton., oral commun., 1982).

A third potential weakness is the possible lack of sufficient funds to process and interpret strong-motion records from a major earthquake, a contingency not addressed in the legislation. In the absence of a legislative solution, the Office of Strong-motion Studies has proposed two ways to deal with this problem. First, the program has a continuous reserve of controllable funds to purchase and install new instruments; these funds could be diverted, if needed, after a major earthquake. Second, after planned installations are completed and the program enters its operational phase, revenues will exceed expenses and thus allow a contingency reserve to accumulate. Once an adequate reserve is attained, fees could be reduced to a level necessary for program maintenance (California Division of Mines and Geology, 1976).

Other programs in California

In 1975, a Surface Mining and Reclamation Act (SMARA) was enacted in California to prevent adverse environmental impacts of surface mining, restore mined areas to a condition compatible with other uses, balance mining interests against other land uses, and eliminate residual hazards to public safety. The SMARA requires the State Mining and Geology Board to develop policies and guidelines for reclamation of mined land, which then must be implemented by lead agencies (generally local governments). The State Geologist is required by SMARA to classify areas based on their mineral potential (areas that contain little or no mineral deposits, areas that contain significant mineral deposits, and areas that contain mineral deposits of unknown significance). This information is used by SMGB to establish policies and land-use priorities for mineral-resource areas. Local governments are required to balance land use between development and resource extraction and to issue surface-mining permits consistent with SMGB policies.

A reclamation plan must be submitted to the local agency before a permit can be issued. Potential geologic hazards that result from surface-mining and reclamation practices represent one of several issues that must be addressed by the plan. Proposed approaches to soil-erosion control, flood control, disposal of mine waste, slope gradients, backfilling, erosion, and drainage must be described in the plan and must be consistent with SMGB policies before a permit is issued. The plan is reviewed only by the local agency. A copy of the plan must be submitted to the California Division of Mines and Geology, but DMG does not have approval authority. The SMGB encourages local agencies to integrate the requirements of SMARA with other required planning and review procedures, such as the general plan (California Division of Mines and Geology, 1979).

Another statute that requires local-government action in land use and development is the California Environmental Quality Act of 1970 (CEQA). This law requires local agencies to review, for environmental effects, all public and private projects over which they have discretionary authority. State guidelines for implementation specifically include geologic and seismic hazards as environmental effects and direct local agencies to examine such hazards in their assessments. Any issue in the assessment that may have a significant effect, including exposing people or structures to major geologic hazards, must be addressed in an environmental-impact report. For many new critical facilities that do not carry their own review requirements (as for dams and hospitals), CEQA is the chief means to ensure that geologic and seismic hazards are considered in siting and design (Mintier and Stromberg, 1982).

The Subdivision Map Act (1907) is the oldest land-use law in California. Among other provisions that establish procedures for filing and approval of parcel maps, this law requires studies to evaluate possible expansive soils and flood hazards in tract developments of five or more lots, unless waived by the local building official. These studies can provide the developer and local building official with information necessary to take proper precautions against soil and flood hazards. The California Division of Real Estate may refuse approval if a subdivision is threatened by floods. As with implementation of the general plan and Riley Act, the Subdivision Map Act relies on diligence, adequate funding, and competence of local officials to be successful. Expansive soil is one of the most costly geologic problems nationwide but, ironically, one of the easiest and cheapest to correct. The benefit-cost ratio of measures to reduce losses from expansive soils can be as high as 20:1 (Alfors and others, 1973). This hazard can be dealt with adequately at the local level, such as through the Subdivision Map Act.

In 1981, an Earthquake Education Act signed into law in California provided $250,000 to develop public-education programs about earthquake preparedness and response. The Seismic Safety Commission was required to develop these programs within 2 yr, then test the programs in communities and schools in several counties. In 1984, a law was passed that authorizes the statewide implementation of the new curriculum. Another 1984 law requires all California schools that have an enrollment of 50 or more students to develop earthquake disaster plans and conduct regular drills.

In 1981, a Mobile Home Safety Act was passed that requires state certification of anchoring devices for mobile homes. Manufacturers of the devices must submit results of physical tests of their products for review by the Department of Housing and Community Development and demonstrate that they meet minimum engineering standards for earthquake safety.

Statutory authority for California agencies engaged in geologic-hazard mitigation

All hazards programs in California are administered by a state agency, although for many programs the enforcement power is largely delegated to local governments. Agencies that have wide-ranging responsibilities for geologic-hazards mitigation are the Division of Mines and Geology (DMG), the State Mining and Geology Board (SMGB), and the Seismic Safety Commission (SSC). In broad terms, SSC is an advisory body and SMGB a policy-setting body. The DMG collects, analyzes, and disseminates information on the state's geology according to SMGB policies and (for earthquake issues) the advice of the SSC. Many other agencies are involved in hazard-mitigation programs but have narrower responsibilities. The roles of these agencies, such as the Office of Planning and Research, Office of the State Architect, and Division of Safety of Dams, are described in preceding sections on statutory programs.

Division of Mines and Geology

Sections 607 and 2201 to 2205 of the Public Resources Code established the Division of Mines and Geology under the direction of the State Geologist and outlined its authority. With regard to hazards, "the State Geologist may...conduct, with city and county governments or federal agencies, large-scale geological investigations to identify and provide timely delineation of geological hazards in and adjacent to metropolitan areas..."(sec. 2205h). Within this authority, DMG routinely studies geologic hazards throughout the state and publishes the results in bulletins, special reports, county reports, and maps for use by local governments and the general public.

2052 20130

Other statutes require DMG to perform specific additional functions. For example, the Strong-motion Instrumentation Program was established by separate legislation that requires DMG to organize and monitor the program. The Alquist-Priolo Special Studies Zones Act requires DMG to delineate special-studies zones that encompass potentially active faults. Mineral-resource zones must be delineated by DMG (under the Surface Mining and Reclamation Act) to set priorities and policies for balancing local land use and developing reclamation plans. State planning law requires local agencies to submit copies of their approved general plans to DMG for review.

Most funding for DMG activities comes from yearly appropriations by the legislature through the general fund. The funds designated for the Strong-motion Instrumentation Program are directly offset by local-government deposits to the SMIP Special Fund from permit fees. Otherwise, appropriations to DMG are not itemized by project except for occasional special projects (T.E. Gay, oral commun., 1982). The State Geologist manages the budget to conduct programs under authority granted to DMG and according to policies and priorities set by SMGB. The Urban Geology Master Plan for California (Alfors and others, 1973) was prepared using funds from the Department of Housing and Urban Development.

State Mining and Geology Board

The State Mining and Geology Board has existed in some form as an advisory body for state geologic issues since the 1880s. It evolved into an informal policy board for the Division of Mines and Geology until 1975, when the legislature gave the board specific policy-setting duties in the Surface Mining and Reclamation Act. Complementary legislation in 1975 (secs. 660 to 678 of the Public Resources Code) formally established SMGB as a policy-making body for DMG and set its overall statutory authority.

The SMGB consists of nine members who represent the public interest; they are appointed by the Governor and are not employed by the state. Minimum qualifications of members are set by statute and are intended to represent a broad range of technical and planning fields that include geology, mining engineering, soils engineering, seismology, mineral resources, ecology, landscape architecture, and local government. A chairman is appointed by the Governor from among the members, and a paid executive officer and staff are appointed by the board. Board members hold staggered 4-yr terms and receive $100 compensation for each day the member is engaged in official board duties (up to $4,000 per yr).

In addition to developing surface-mining and reclamation policy, SMGB "shall also represent the state's interest in the development of geological information necessary to the understanding and utilization of the state's terrain and seismological and geological information pertaining to earthquake and other geological hazards. General policies for the Division shall be determined by the Board." The SMGB nominates a candidate for State Geologist, who is appointed by the director of the Department of Conservation and administers the board's policies as chief of the Division of Mines and Geology.

In effect, SMGB assumes much of the load usually borne by state legislatures and administration in setting policies and priorities for the activities of a state geological survey (D.W. Sprague, oral commun., 1982). The advantage is direct public influence on survey activities by independent public representatives. The possible disadvantages are the additional 'layer of bureaucracy,' a working relationship that may hamstring the survey, and difficulties identifying which policy issues are appropriate for board action as opposed to those that can be effectively resolved within the survey. There is also a potential problem regarding division of responsibilities in earthquake-hazard issues between SMGB and the Seismic Safety Commission. Although SSC has an advisory role and SMGB has a policy-setting role, the difference is often not distinct; whether two separate bodies are justified where subject areas overlap is questionable. On issues related to seismic hazards, however, SMGB and SSC appear to cooperate on an informal basis to minimize duplication. In at least one instance, legislation has formally established SSC as a policy-setting body for a DMG function. In 1975, the legislature abolished a separate board formerly established for the Strong-motion Instrumentation Program and transferred advisory and policy authority to SSC. The SMGB no longer issues policy for DMG management of the strong-motion program.

Seismic Safety Commission

The Seismic Safety Commission (SSC), established by the California Legislature in 1974, was an outgrowth of two advisory groups that were active in earthquake-related issues. The legislature's Joint Committee on Seismic Safety (1969-74) and the Governor's Earthquake Council (1971-74) recommended formation of a permanent organization with broad powers in earthquake-hazard reduction. The SSC was established by sections 8890 to 8899.5 of the Government Code as an advisory body to coordinate the various earthquake-related programs of state, federal, and local agencies. Amendments to the Seismic Safety Commission Act in 1976 abolished the Strong-motion Instrumentation Board and Geological Hazards Technical Advisory Committee and transferred their functions to SSC. In 1984, the legislature removed the sunset clause on SSC's enabling legislation, effectively making SSC a permanent commission.

All but two of the 17 members of SSC are appointed from the public by the Governor to represent the fields of seismology, geology, soils engineering, structural engineering, architecture, fire protection, public utilities, mechanical engineering, city and county government, insurance, social service, and emergency service. One member is appointed from the State Senate and one from the State Assembly. Members have staggered 4-yr terms and receive only travel expenses and per diem for their work. The SSC appoints a paid executive director who hires technical and clerical staff. Total funds expended by SSC in FY 1980-81 were $396,569, of which $31,000 was for direct support of SSC and the remainder for contracts and staff support to conduct special projects and prepare reports (California Seismic Safety Commission, 1981).

Responsibilities and powers of SSC are diverse, but are basically restricted to earthquake-hazard-reduction issues. Its statutory mandates are to set goals and priorities in the public and private sectors; recommend program changes to state and local agencies and the private sector to reduce earthquake hazards; review postearthquake reconstruction practices; gather, analyze, and disseminate information; encourage research; sponsor training for enforcement and technical personnel; help coordinate seismic-safety activities of all levels of government; advise the State Mining and Geology Board on seismic-safety aspects of the Special Studies Zones Act; and advise the State Geologist on the Strong-motion Instrumentation Program. To carry out its functions, SSC reviews proposals, drafts legislation, conducts public hearings, and enters into contracts for special studies as a basis for issuing its recommendations. Much of SSC's work is performed by or under supervision of specially appointed task committees. Figure 16 summarizes the functions of SSC and illustrates its relationships to the Division of Mines and Geology, the State Mining and Geology Board, and other agencies.

In practice, SSC helps coordinate about 30 seismic-safety programs that involve 52 state agencies. Total program expenditures during the past few years range from about $13.7 million in FY 1980-81 to $18.1 million in FY 1978-79. In addition to its ongoing advisory and coordinating functions, SSC reviewed numerous programs, such as the Hospital Seismic Safety Act, Field and Garrison Acts, and seismic-safety-element requirement (General Plan) and, as a result, recommended changes and drafted legislative amendments to increase their effectiveness. The SSC was instrumental in initiating state review of the federal Auburn Dam and Warm Springs Dam projects and establishing memoranda of understanding with federal agencies for future dam reviews (California Seismic Safety Commission, 1981).

After damaging earthquakes in California, members of SSC or its staff generally visit the site to observe the damage, evaluate disaster response, and issue recommendations for policy or program changes for particular problems made apparent by the events. Because of high public concern over the Livermore Valley earthquake of January 1980 and its possible implications for seismic safety of plutonium facilities at the Lawrence Livermore Laboratories, SSC conducted public hearings and initiated an independent review of the facility.

Recently, SSC created a Hazardous Buildings Committee to develop a model local ordinance for hazards mitigation of older buildings and recommended that seismic safety of state-owned buildings be evaluated. The Southern California Earthquake Preparedness Program (SCEPP) is a significant cooperative program with local government. The program is funded by the state and federal governments and involves five southern California counties. The objectives of SCEPP are to produce an operational prediction and warning system, establish earthquake-hazard-reduction plans, develop public-awareness programs, assess earthquake vulnerability, and conduct tests to improve plans and systems. The SSC has overall management responsibility for SCEPP and has appointed a policy advisory board to provide project direction. In 1984, the legislature authorized funding to extend SCEPP and initiate a similar program in the San Francisco Bay area (R.A. Andrews, oral commun., 1984).

A formal coordinating and advisory body for nonearthquake-related hazards does not exist in California. The SSC has reviewed some statutory programs and their implementation problems, but has focused primarily on earthquake-related issues. Legislation that established SCEPP in 1980 also broadened the authority of SSC to all natural hazards, but the demands of earthquake-hazards work have prevented the commission from devoting significant effort to other hazards. The State Mining and Geology Board provides policy and advice to the Division of Mines and Geology on other hazards, but not to other state agencies and only in a limited fashion to local governments (D.W. Sprague, oral commun., 1982).

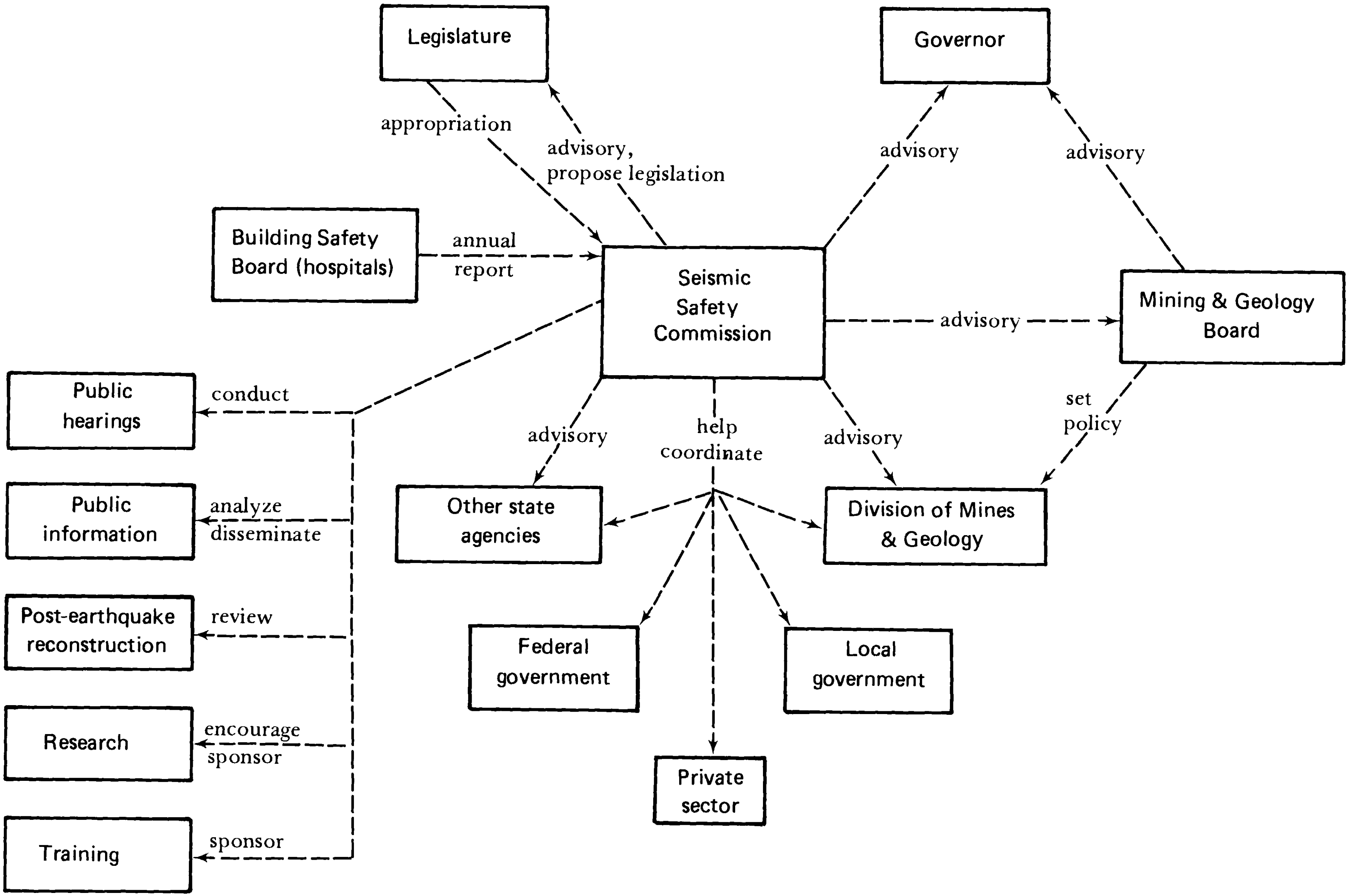


Figure 16. Functional relationships between the Seismic Safety Commission and other organizations and activities in California.

2154 20130

State Board of Registration for Geologists and Geophysicists

A State Board of Registration for Geologists and Geophysicists is responsible for examining and registering applicants who perform professional geological or geophysical work in California. Originally established for registration of geologists only, the board was created through legislation in 1968 (secs. 7800 to 7807, California Business and Professions Code) because of considerable problems that developed when unqualified persons performed geologic work required by various local agencies. In the early 1960s, city and county governments began adopting ordinances that required geologic reports in proposed subdivision areas where a geologic hazard was known or presumed to exist. The proliferation of such ordinances occurred after Los Angeles County lost a $6 million lawsuit that resulted from movement of the Portuguese Bend landslide. The movement was initiated by construction of a county road (Campbell, 1976). The new ordinances created an immediate and considerable demand for geologists. Unfortunately, many unqualified people took advantage of the demand, which resulted in serious inadequacies and wide variation in report quality.

To protect homeowners and subdividers who were responsible for meeting report requirements, cities and counties established qualifying boards to determine who were qualified geologists and stipulated that only reports prepared by approved professionals would be acceptable. With separate boards in each jurisdiction, each with its own qualifying criteria, geologists were forced to take numerous examinations and pay fees to several boards to practice in different areas of the state. Eventually, geologists demanded action from the state.

In 1968, legislation created the Board of Registration for Geologists and set minimum qualification requirements. The board developed its own regulations to establish procedures and fees. In 1972, the law was amended to include geophysicists, with similar requirements regarding background and experience. All geological or geophysical reports required under state and local laws must now be prepared by or under the supervision of a state-registered geologist or geophysicist. Optional certification in a specialty (such as engineering geology) is also provided under the statute.

Basic requirements for registration as a geologist are graduation with a major in geology or completion of at least 30 semester units in geologic science, of which at least 24 units are upper division or graduate courses; a minimum of 7 yr of professional geologic work that includes at least 3 yr under the supervision of a registered geologist or 5 yr "in responsible charge of professional geological work"; and successful performance on a written examination. Credit is given for experience through undergraduate training (½-yr credit for each year of training up to 2 yr), graduate training (year for year), and teaching (year for year if teaching load is at least six units per semester). Credit for training and teaching may not exceed 4 yr toward the 7-yr requirement. Minimum qualifications for registration as a geophysicist are equivalent to those for a geologist.

The primary objectives of state-level professional registration of geologists and geophysicists are to protect the public from unqualified persons and provide comparable professional standards throughout the state (a benefit for the public and professionals). Some professionals also believe it has helped to establish comparable pay scales for engineering geologists and registered engineers.

2158 20130

The registration program in California has been subject to two major criticisms. First, registration does not necessarily protect the public from unqualified persons. Someone who once meets the qualifications for registration may not have the opportunity to keep up with rapid advances in knowledge and techniques in certain areas or maintain his or her original proficiency in that area. As an example, a city geologist in California found that "many [registered] geologists preparing reports are unaware of recent trends in fault analysis, rely on inappropriate methods of investigation, and restrict themselves too tightly to a site, referring only to published regional data rather than using field-checked air-photo interpretation" (California Seismic Safety Commission, 1977b). Inadequate report preparation by registered geologists and geophysicists is a significant problem, and only an adequate peer-review process is capable of detecting poor reports and producing improvements. When the Division of Mines and Geology reviewed geologic and seismic reports of a hospital site, only 31 of the initial 71 reports were accepted (Amimoto, 1974). The percentage of unacceptable reports has decreased markedly since the Division published study guidelines and the professional community became familiar with the requirements. However, many reports must still be revised. Apparently, the key to ensure acceptable geologic reports is a clear statement of the report requirements combined with an adequate review process. The requirement that the reports be prepared by registered geologists may not be necessary.

The second major criticism is that the law discriminates against academic personnel, who in many cases may be better qualified to perform certain types of work than many private consultants because they are more apt to keep up with new developments (Troxel, 1982). The law does not count research as qualifying experience, and many professors are not allowed by their employers to perform services that might be considered consulting. Because no more than 4-yr credit can be granted for teaching and a professor can rarely accumulate more than 3-mo consulting experience each year, at least 16 yr are needed to acquire the necessary experience.

Colorado

Although there is less natural-hazards legislation in Colorado than in California, the Colorado state government and many local jurisdications are very active in hazard mitigation. Most activity is attributable to state land-use-planning laws, a subdivision law, and a state geological survey that is very active in hazard issues. Hazards are a major focus of state planning and subdivision laws that were developed in the early 1970s. During the 1960s, population growth in Colorado was tremendous, and new subdivisions were virtually unregulated. Development expanded from relatively safe, flat areas into narrow, flood-prone valleys and onto steep mountain slopes. Serious property damage from geologic processes in mountain subdivisions contributed to the overall problems of rapid development and short-lived land-sale schemes. These practices produced many unhappy customers and generated demands for stricter regulation of land use and development. Destructive floods on the South Platte River in 1965 and 1969 reinforced the demand to consider geologic processes in land-use decisions.

Legislative action on land-use problems and geologic hazards began in 1969 when the Colorado Geological Survey (CGS) was established. In 1971, a Land Use Commission was established and given broad advisory, coordination, and review responsibilities. A stringent subdivision law [Senate bill (S.B.) 35] that requires evaluation of geologic factors was enacted in 1972. Finally, two important statutes regulating local land use were passed in 1974: House bill (H.B.) 1034, a Local Government Land Use Control Enabling Act that authorizes cities and counties to consider geologic hazards in any land-use decisions; and H.B. 1041, an act that concerns "areas and activities of state interest" and empowers local governments to designate geologic-hazard areas and requires that these areas be administered in accordance with state guidelines. Except for dam review and inspection, Colorado does not have statutory programs for state review and permitting of other special facilities as California has for schools and hospitals. Instead, the Colorado Land Use Commission has authority to review almost all development activities and issue cease-and-desist orders on behalf of the Governor for any development believed to pose a serious public hazard. The commission coordinates technical reviews among other state agencies, including the CGS, as part of its review function.

Unlike California, there is no state building code in Colorado, nor is there a state requirement for local adoption of building codes. Local governments have the authority to establish codes, and many have adopted the ICBO Uniform Building Code. The extent to which these jurisdictions adopt and implement provisions of the Uniform Building Code that relate to seismic and geologic hazards in Colorado was not studied.

Colorado Land-use-planning Laws

Colorado cities and counties did not acquire broad authority to plan and regulate land use until 1974, when the General Assembly passed the Local Government Land Use Control Enabling Act [H.B. 1034, Colorado Revised Statutes (Rev. Stat.) 29-20]. The act also mentioned certain considerations, including geologic hazards, that could be used as a basis for land-use decisions. However, the act did not prescribe conditions, requirements, procedures, or schedules for adopting local land-use plans; its only intent was to grant land-use regulatory authority to local governments.

In a companion bill passed the same year (H.B. 1041, Colorado Rev. Stat, 24-65.1-101, and those that follow), local governments were given the authority to identify and designate 'matters of state interest' (activities or areas having state significance). A major category of 'areas of state interest' is natural-hazard areas, which could include geologic hazards, flood hazards, and wildfire hazards. Legal definitions were given for most of the nine specific geologic hazards: avalanches, landslides, rock falls, mudflows, unstable or potentially unstable slopes, seismic effects, radioactivity, ground subsidence, and expansive soil and rock. However, local designations are not restricted to these nine hazards.

House bill 1041 required the state Department of Local Affairs to conduct a statewide program to designate natural-hazard areas or other matters of state interest by June 1976. The General Assembly appropriated enough money for the department to grant $25,000 to each participating county. To qualify for the grant, the county had to designate flood-, wildfire-, and geologic-hazard areas, as well as other matters of state interest. In addition, the Colorado Land Use Commission is authorized to formally request local governments to designate matters considered by the commission to be of state interest. If the local government fails to act, the commission may seek court action. Although local designation of matters of state interest is optional under the law, the state has considerable power to see that it is done. However, this power is limited because the courts make the final decision, presumably based on their judgment of whether an activity or area is important enough to the public welfare to warrant state involvement (P. Schmuck, oral commun., 1982).

Before a matter of state interest is designated, a local government must hold public hearings and submit the proposed designation to the Land Use Commission for review. Geologic-hazard designations are reviewed by the Colorado Geological Survey. Neither the CGS nor the commission have approval authority over local designations, but both may issue recommendations for revision, which the local government can either accept or reject. Once the designation is adopted, the local government must develop guidelines and regulations for its administration consistent with state criteria. Generally, guidelines for geologic-hazard areas are contained in local zoning ordinances. In H.B. 1041, state criteria for geologic-hazard areas specify that "all developments shall be engineered and administered in a manner that will minimize significant hazards to public health and safety or to property due to a geologic hazard." Additionally, H.B. 1041 requires CGS to develop model geologic-hazard-control regulations to serve as compulsory guidelines for local governments. The resulting publication (Rogers and others, 1974) provides definitions, descriptions, criteria for recognition, consequences of improper use, and mitigation procedures for each hazard, plus identification procedures, recommended professional qualifications for geologists and engineers who prepare reports, and suggestions to local governments for administering geologic-hazard areas. The appendix of the report contains a model geologic-hazard-control regulation that demonstrates application of suggested procedures. The CGS is also required by H.B. 1041 to provide technical assistance to local governments concerned with designation and development of guidelines for geologic-hazard areas (W.P. Rogers, oral commun., 1982).

After a matter of state interest, such as a geologic-hazard area, has been designated by a local government or after the Land Use Commission has formally requested that a local government issue a designation, no development is allowed in the area until local guidelines and regulations for its administration have been developed and approved. The law specifies that, as part of its administration, a local government must require a permit for any development in a designated hazard area. A permit can be approved only if the proposed activity complies with local-government guidelines for administration of the area.

A model local geologic-hazard-area regulation developed by the Colorado Land Use Commission and the CGS (Colorado Land Use Commission, 1976) specifies acceptable hazard-mitigation techniques for issuing a permit in a designated geologic-hazard area. For example, in designated avalanche areas, structures that support snow in the starting zone, avalanche deflection, or protection in the runout zone are considered acceptable mitigation techniques, but artificial release of avalanches with explosives or artillery is not. Similarly, the model regulation lists earthquake-resistant design according to the ICBO Uniform Building Code as an acceptable mitigation technique in designated seismic areas. Mitigation measures are not required to issue a permit for certain 'allowable uses' in geologic-hazard areas, such as agricultural uses, certain industrial-commercial uses (loading and parking areas), and public and private recreational uses such as parks, golf courses, and nature preserves.

Results from detailed technical studies of the hazard and documentation of proposed mitigation techniques are required by the model regulation as a basis for review of the permit application. These studies must be performed by a qualified professional geologist or registered professional engineer. Although geologists are not registered in Colorado, a separate bill, H.B. 1574 (1973), sets the minimum qualifications for geologists who prepare reports or maps required by law. According to the model regulations, the local government must solicit and consider recommendations from CGS on the permit application; however, compliance with the recommendations is not mandatory.

Table 4 summarizes functions of local and state agencies in implementing H.B. 1041 with regard to geologic-hazard areas. House bills 1034 and 1041 constitute the Colorado equivalent of the General Plan Law in California. Designation of geologic-hazard areas and development of guidelines for their administration are analogous to the 'seismic safety' and 'safety' elements in the General Plan, respectively. The major difference is that local master plans (as they are called in Colorado) are not required in California, nor are designations of geologic-hazard areas. As of September 1981, 26 of 63 counties had adopted a master plan (Colorado Land Use Commission, 1981). Information on how many of these counties had designated geologic-hazard areas was not available.

Colorado planning law has some of the same weaknesses as the General Plan and Special Studies Zones laws in California. House bill 1041 does not provide state government with a direct means to enforce the requirement that local governments administer matters of state interest in accordance with state and local guidelines, such as standardized review procedures (P. Schmuck, oral commun., 1982). Although the Colorado Geological Survey reviews designations of geologic-hazard areas and geologic reports prepared for permit applications, its recommendations are not compulsory and approval is not required. Other than the 'courtesy review' of designations and guidelines that local governments are required to solicit from the state, there is no other review requirement such as the California requirement in the Special Studies Zones Act that the local permitting authority must obtain an independent review of geologic reports by a registered geologist. The CGS often identifies and resolves potential problems in their reviews, but only to the extent that a local government or developer is willing to accept the recommendations (W.P. Rogers, oral commun., 1982).

Colorado H.B. 1041 and other similar bills that introduce special permit requirements can be an unnecessary burden to developers and builders because of additional applications, required supporting materials, and delays. Often different permits duplicate requirements for supporting materials. The Colorado Land Use Commission has issued a permit-application form that local governments are required to use for development in areas of state interest (Colorado Land Use Commission, 1976). Even though a local government may have taken measures to incorporate the requirements of H.B. 1041 into its existing master plan and zoning procedures, at least two permit applications must be filed: one for the local zoning permit and one for the designated area under H.B. 1041. This problem could be eliminated by allowing local governments to incorporate the requirements of state laws into their own permitting procedures (P. Schmuck, oral commun., 1982).

Table 4. Functions of local and state agencies regarding geologic-hazard areas under Colorado House bill 1041 (1974).

LOCAL GOVERNMENT

1. Designates geologic-hazard areas, among other 'matters of state interest,' in accordance with guidelines from the Colorado Geological Survey and Land Use Commission.

2. Holds hearings and solicits state recommendations on permit applications for development in geologic-hazard areas.

3. Grants or denies permits for development in geologic-hazard areas in accordance with established guidelines.

4. Receives recommendations and technical assistance from the Colorado Geological Survey and Land Use Commission to designate and administer geologic-hazard areas.

5. Sends recommendations on geologic-hazard areas to other local governments and the Land Use Commission.

6. On request of the Land Use Commission, acts on designations of specific geologic-hazard areas.

COLORADO DEPARTMENT OF LOCAL AFFAIRS

1. Conducts statewide program to identify geologic-hazard areas and other matters of state interest (before June 30, 1976).

2. Oversees and coordinates state technical assistance to local governments.

3. Provides financial assistance as authorized by law.

COLORADO LAND USE COMMISSION

1. Issues formal requests for local governments to take action in specific geologic-hazard areas.

2. Provides assistance, guidelines, model land-use regulations, and forms to be used for local designations of geologic-hazard areas, permit applications, and permits.

3. Reviews or delegates review of designations of geologic-hazard areas proposed by local governments.

4. Submits recommendations to local governments for modifying proposed designations of geologic-hazard areas.

5. Issues written notices to county boards of commissioners on any activity believed to constitute a serious hazard to the public safety, followed by written cease-and-desist orders on behalf of the Governor if the county fails to take action.

2182 20130

Table 4. (con.)

COLORADO GEOLOGICAL SURVEY

1. Develops guidelines and model local regulations to designate and administer geologic-hazard areas.

2. Sends recommendations to local governments and the Land Use Commission to designate geologic-hazard areas based on current information.

3. Provides technical assistance to local governments concerning designation of geologic-hazard areas.

One difficulty of administering geologic-hazard areas at the local level is reconciling hazard-area designations with other zoning ordinances. Hazards represent only one of many zoning considerations. Jefferson County, one of the most populated counties in Colorado, solved the problem by creating a separate Geologic Hazard Overlay District (G-H) zoning designation (J. McCalpin, oral commun., 1982). As its title implies, the G-H district is superimposed on other zone districts and its regulations supplement those of the underlying district. The G-H zoning resolution states that "when the regulations of this district conflict with any provision of the underlying zone district, the provisions of the Geologic Hazard Overlay District shall control; otherwise, the provisions of any underlying district shall remain in full force and effect." A G-H district may be designated for any of six different types of hazards. Guidelines for district administration basically follow the model geologic-hazard-area regulation issued by the state Land Use Commission that specifies the types of geologic and hazard-mitigation information required with permit applications. The guidelines also reference CGS criteria (Rogers and others, 1974) as the primary source for geologic-hazard identification and mitigation procedures.

Colorado land-use laws, particularly H.B. 1041, have been effective in encouraging consideration of geologic hazards in local planning and incorporation of positive hazard-reducing land-use requirements in zoning ordinances. Virtually all heavily populated counties have designated and are administering geologic-hazard areas. One exception, surprisingly, is the City and County of Denver, which has elected not to participate in the program. Many smaller communities are actively participating. The town of Vail has incorporated avalanche-hazard areas into its zoning ordinances, which has had a substantial impact on development. The initial hazard-assessment studies used as a basis for the zoning in Vail helped improve public awareness of the issue and produced positive responses from many developers. Builders who avoid hazardous areas, or use such areas for recreation, or use avalanche-resistant designs, have generally received support from the public; but those who are indifferent to avalanche hazards often elicit critical and antagonistic public response that can jeopardize their ability to obtain financing (Ives and Krebs, 1978).

Effectiveness of the hazard-area-designation program (H.B. 1041) in preventing damage or injury from natural hazards is difficult to assess because of the lack of centralized records on individual cases. Open-space and low-density uses have been effective in reducing damage from floods and avalanches in many areas of Colorado. Colorado lacks other major catastrophic geologic hazards that affect large areas, such as frequent large earthquakes, which would provide more visible evidence on the effectiveness of hazard-mitigation measures.

Subdivision law

One of the strongest responses by the Colorado legislature to public pressure that resulted from uncontrolled development in the late 1960s was passage of a stringent subdivision law (S.B. 35, 1972). Because many problems of rapid growth in mountainous areas are related to geologic hazards, S.B. 35 requires that geologic conditions of an area be evaluated before a subdivision is approved by a county. The law applies to all division of land into single parcels of less than 35 acres within a county jurisdiction. Apparently the reason for having a maximum applicable parcel size of 35 acres was that larger parcels allow enough flexibility in land use that owners can avoid geologic hazards (W.R. Junge, oral commun., 1982). A county may elect to apply the same requirements to subdivisions that contain parcels of 35 acres or larger. Also, two or more counties may form a regional planning commission to implement the requirements of S.B. 35.

Major provisions of the Colorado subdivision law that relate to geologic hazards are listed below.

1. Every county must require that subdividers submit data, surveys, analyses, and studies of relevant site characteristics, including topography, lakes, streams, geology, potential radiation hazards, and soil suitability.
2. The Board of County Commissioners must distribute copies of preliminary subdivision plans and accompanying information on site characteristics to appropriate state agencies, including the Colorado Geological Survey, for evaluation of geologic factors that have a significant impact on the proposed use. State comments and recommendations are normally due in 24 days.
3. No subdivision may be approved until the required studies and plans have been submitted, reviewed, and found to meet 'sound planning and engineering requirements.'
4. No county may approve a preliminary or final plat unless hazardous conditions that require special precautions have been identified and proposed uses are compatible with these conditions.

The Colorado Geological Survey reviews all submitted information for geologic hazards and has had a major impact on subdivision plans and approvals. One weakness noted by CGS personnel is that they often do not know whether their recommendations have been implemented. Enforcement of S.B. 35 requirements is entirely at the county level, and some of the same problems exist as noted earlier for local implementation of the Riley and Subdivision Map Acts in California, including variability in the quality of documents approved for subdivisions and the degree to which subdividers are required to modify their plans to make them more compatible with known geologic conditions. However, the requirement in Colorado S.B. 35 that subdivision plans and supporting information be submitted to state agencies for review allows for much more state input to the subdivision process than in California, thereby upgrading the overall quality of the review process and providing some standardization.

The most serious weakness of the Colorado subdivision law is that it applies only to counties. Incorporated municipalities are not required to adopt subdivision regulations or follow the procedures set forth in S.B. 35. The City and County of Denver, for example, is immune from the subdivision law. The decision to exempt municipalities from the law apparently resulted from inadequate legislative support for state involvement in municipal-level regulatory processes to the degree called for in S.B. 35. Although the law has been successful in regulating development in mountain areas where there are many serious problems associated with steep slopes, it exempts a major percentage of subdivisions in the state that could be subject to equally serious problems (for example, mine-related subsidence, flooding, and ground-water depletion in the urban environment). Some proposed subdivision areas have been annexed into an adjacent municipality to avoid the requirements of S.B. 35 (W.R. Junge, oral commun., 1982).

A disclosure law was enacted recently (S.B. 13, 1983) that applies to all residential development. The developer must analyze the hazard potential and disclose any potential problems to prospective homebuyers. Because there is no requirement for state review or for submitting copies of disclosure statements to the state, there apparently is little means of review or enforcement other than the threat of litigation for not disclosing known hazards. It is too early to determine the effectiveness of this new law.

State-level project reviews

Major construction projects in Colorado that include many critical facilities are reviewed by the Colorado Geological Survey and other agencies to determine the adequacy of siting, design, construction, and, in some cases, operation to reduce potential dangers to the public from geologic hazards. With the exception of dams and certain state capital-construction projects, state-level review is not mandatory. However, basic information (for example, project type, location, size, or cost) for all proposed projects that receive state or federal financial assistance through grants or loans is routinely provided to the CGS through the Colorado Clearinghouse. The Clearinghouse was established to implement the provisions of the federal Office of Management and Budget (OMB) Circular A-95, which provided all states with the opportunity to review and comment on federally supported projects.[3] The CGS may request a geologic report for any project that it believes is potentially dangerous to the public because of geologic hazards. Most applicants comply with the request and respond favorably to survey recommendations. If a significant problem is revealed and is not resolved by the builder, state or federal funds may be suspended. During 1981, CGS performed about 700 reviews through the Colorado Clearinghouse (W.R. Junge, oral commun., 1982).

The CGS reviews proposed capital-construction projects of other state agencies through memoranda of understanding or policy letters. Most state construction projects are supervised by the Colorado Division of Capital Construction, which is required to submit reports on soils and geology for review by CGS under a formal memorandum of understanding. Other agencies that

[3] OMB Circular A-95 was rescinded and replaced by Presidential Executive order 12372 in July 1982. Although Executive order 12372 changed some procedural elements, the state review process remains intact.

do not have formal agreements with CGS may request review of construction projects and are strongly encouraged to do so by the Governor. Compliance with CGS recommendations is not mandatory, but most agencies respond favorably to the reviews (W.R. Junge, oral commun., 1982).

A program for review and inspection of dam construction and operation in Colorado exists under the State Engineer's Office and is similar to the dam-safety program in California. For proposed dams over 10 ft high or with a greater than specified capacity, plans and specifications supported by a geotechnical report must be submitted for review. The State Engineer's Office employs geotechnical engineers to review these reports and may contract with private consulting firms for all or part of a review. During construction, an independent third party may be required to inspect the dam and report to the State Engineer's Office to ensure that construction complies with approved plans and specifications. The State Engineer's Office is required to inspect every operational dam under its jurisdiction annually. Because of staff and funding limitations, this requirement has been impossible to meet. Colorado has over 2,200 dams; of these, the State Engineers Office can only inspect about 400 each year. Consequently, most dams are inspected once every 4 to 5 yr, unless a potential problem is brought to the attention of the State Engineer's Office. This weakness in the inspection program may be partially responsible for recent dam failures in Colorado. Many dams built before review procedures and construction standards were established are nearing the end of their safe, useful life. In July 1982, an earthfill dam at the headwaters of the Big Thompson River failed and caused several deaths and substantial damage to the Estes Park area. State inspection of the dam was overdue and was scheduled for later in 1982.

Other major projects and critical facilities in Colorado are not subject to rigorous formal review and strict approval procedures as are some facilities in California. However, through the Clearinghouse, CGS can review and comment on many projects. A major weakness of this procedure is that only state- and federal-funded projects are recorded by the Clearinghouse. Unless controlled by local laws or unless a local government requests a review by CGS, privately funded power facilities and buildings for public occupancy, for example, may not be reviewed for geologic hazards (W.R. Junge, oral commun., 1982).

Minimum qualifications for professional geologists

Under H.B. 1574 (1973), any geologic report that is required by law for a state or local agency or commission in Colorado must be prepared by a 'professional geologist.' There is no formal registration procedure for geologists in the state, but the law defines a professional geologist as "a person who is a graduate of any institution of higher education which is accredited by a regional or national accrediting agency, with a minimum of 30 semester (45 quarter) hours of undergraduate or graduate work in a field of geology and whose postbaccalaureate training has been in the field of geology with a specific record of an additional 5 yr of geologic experience to include no more than 2 yr of graduate work." Beyond these basic qualifications, selection of an appropriate professional to prepare geologic reports is left to the discretion of the person or agency who contracts the work and to the personal judgment of professionals who accept the work. Guidelines issued by the Colorado Geological Survey (Junge and Shelton, 1978) recommend that professional geologists who prepare reports for review by a state or local agency have education and experience in civil engineering, ground-water geology, Quaternary geology, geomorphology, and interpretation of aerial photographs.

Lack of formal registration for professional geologists in Colorado avoids the so-called club atmosphere to which many people in California object, but raises some question about consistency in judgment and evaluation when persons are selected to perform geologic work. Financial incentives may affect a geologist's judgment in accepting work for which he or she may be only marginally qualified. However, H.B. 1574 also eliminates the tendency to select a person for geologic work solely based on registration, and forces the contracting party and the consultant to evaluate professional qualifications based on the specific project. Because the requirement for educational and professional experience is more general, and a shorter experience period is required than in California (5 yr instead of 7 yr), built-in biases against some types of professionals (educators, for example) are reduced.

Statutory authority for the Colorado Geological Survey

In the mid-1960s, Colorado was one of only three states that did not have a state geological survey, and the incidence of serious geologic problems associated with development of its mountain regions was rapidly increasing. Recognizing the need for state action on geologic issues, many professional geologists worked through the American Institute of Professional Geologists and the Association of Engineering Geologists to develop a meaningful charter for the Colorado Geological Survey (CGS). Legislation was enacted to put the charter into effect and establish the Survey as a division in the Department of Natural Resources in February 1969.

Similar to the California Division of Mines and Geology, the legislation establishing CGS (Colorado Rev. Stat. 34-1-101 and those that follow) outlines its general statutory authority and responsibilities. Other statutes, such as H.B. 1041 (land-use-planning law) and S.B. 35 (subdivision law), prescribe specific functions consistent with the charter. The provisions of Colorado Revised Statutes 34-1-103 stipulate that "the Colorado Geological Survey shall function to provide assistance to and cooperate with the general public, industries, and agencies of state government, including institutions of higher education, in pursuit of the following objectives, the priorities of which shall be determined by mutual consent of the state geologist (chief of the division) and the executive director of the Department of Natural Resources." Some stated objectives relate to geologic hazards: "(a) to assist, consult with, and advise existing state and local governmental agencies on geologic problems..., (c) to conduct studies to develop geological information..., (g) to evaluate the physical features of Colorado with reference to present and potential human and animal use..., and (i) to determine areas of natural geologic hazards that could affect the safety of or economic loss to the citizens of Colorado." The statute requires the State Geologist to fulfill these objectives and to "work for the maximum beneficial and most efficient use of the geologic processes for the protection of and economic benefit to the citizens of Colorado."

With this charge, and because Colorado lacked any requirements to consider geologic information in land-use planning and development, a major task of CGS has been public education. Many people in Colorado objected to the use of geologic information as an infringement on their personal and property rights. Landowners and developers feared that geologic-hazard information would decrease property values and that the cost of geologic studies would outweigh the benefits. Public talks, testimony to legislative committees, newspaper articles, publications, conferences, and workshops were used to show how geologic information can save money, shorten development time, promote more efficient development, and provide a better product for the consumer (J.W. Rold, 1978). The CGS became involved in several important and controversial issues, such as proposed development in an area of known mudflows and avalanche hazards near Marble and a hazard assessment in mountain canyons after the Big Thompson River flood in 1976. These issues heightened public awareness of geologic problems, demonstrated the importance of using geologic information in development decisions, strengthened the credibility of CGS, and were major factors in the enactment of S.B. 35 and H.B. 1041 (W.P. Rogers, oral commun., 1982).

As in California, the annual legislative appropriation for the CGS is not itemized by project except for occasional short-term special projects. The State Geologist and the Executive Director of the Department of Natural Resources mutually determine the task priorities of the survey, and the State Geologist manages the budget accordingly. A basic philosophy of CGS is to place a relatively low priority on research and general geologic mapping and a high priority on problem-oriented tasks that benefit the public directly. Thus, the emphasis is to technically assist local governments, inform the public, prepare maps and reports for the 'prudent layman,' and address specific issues and problems of public concern (W.R. Junge, oral commun., 1982).

In 1983, the General Assembly reduced funding for CGS to the salary of one full-time professional. Without funding from other sources, CGS would no longer be able to perform most of its statutory functions. However, new legislation allows CGS to perform work on a reimbursible basis; this mechanism has allowed CGS to continue many of its functions. Although CGS no longer performs some routine reviews in conjunction with Colorado planning and subdivision laws, it continues to review projects for other state agencies on request and addresses specific problems in local areas. The work is paid for by federal or state agencies, local governments or, in some cases, private companies. The work performed by CGS is restricted by its statutory authority, which remains unchanged, and the survey may not perform consulting work that competes with the private sector (W.R. Junge, oral commun., 1982).

Other States

Most approaches to hazard mitigation in other states are similar to measures adopted by California and Colorado. Variations exist primarily in emphasis, comprehensiveness, and the degree to which authority and responsibility are delegated to local governments. Many successful state programs use hazard-specific measures and emphasize problems that most concern the state. Massachusetts, for example, requires state review of proposed projects in coastal areas that could alter land that is subject to tidal action, coastal erosion, and flooding. Minnesota has adopted a statewide building code that emphasizes flood-proofing requirements (Baker and McPhee, 1975).

State-level approaches to reduce loss potential from geologic hazards fall into two categories: 1) legislation and regulations that impose strict state controls on land use and building methods; and 2) planning legislation that transfers authority and responsibility for zoning and regulation of most construction to local governments. In both cases, programs generally rely heavily on a state geological survey or a similar agency that evaluates hazards on a regional basis, provides public information and technical assistance, and technically reviews planning documents and proposed facilities. Planning legislation has been emphasized over strict controls in recent years, particularly with increasing public desire for local autonomy. Strict state-level controls are reserved for very severe or regional problems that are beyond the capabilities of a local government if a disaster occurs and for critical facilities that affect large numbers of people or the continued operation of which is essential. Dams and hospitals are examples of facilities for which construction is strictly regulated at the state level in many states.

Hawaii and Maine are among the few states that have adopted statewide zoning regulations that specify the types of activities and construction permitted within each zone and incorporate hazards considerations into the zoning process. In Maine, one type of state zone is a 'protection zone' that regulates development on flood plains and steep slopes. Planning legislation has been enacted in lieu of strict statewide controls in Oregon and Wisconsin. Seven separate laws in Oregon's 'land-use package' establish requirements for local land-use planning, which must incorporate hazards considerations. The Wisconsin law encourages local flood-plain zoning but allows the state to impose its own zoning laws if the local government fails to do so. In Mississippi, a statewide building code has been enacted that local governments may modify to suit local conditions and preferences (Baker and McPhee, 1975).

Many states have established temporary or permanent commissions to advise the Governor, state agencies, the legislature, and local governments on land-use matters or hazards-related issues. In 1977, a temporary Seismic Advisory Council was established in Utah to recommend a program of seismic-hazard evaluation and mitigation to the Governor and legislature. The council disbanded when its mission was completed in 1980 (Carter, 1983).

Most states have a geological survey that collects geologic data and provides public information and technical assistance on hazards to local governments, developers, and individuals. Local governments use this information and sometimes perform their own studies to support hazards-related land-use plans and zoning ordinances that they develop on their own initiative. The Utah Geological and Mineral Survey has a Hazards Section that identifies and maps geologic hazards throughout the state as required by state code. Similarly, the Illinois Geological Survey identifies hazards and brings them to the attention of local property owners, city governments, or regional planning bodies and advises other agencies on hazards issues that affect their various functions.

FEDERAL HAZARD-MITIGATION PROGRAMS IN ALASKA

Many hazard-mitigation and disaster-preparedness programs that affect Alaska exist at the federal level. Federal programs emphasize disaster relief, regional studies, basic research on causal factors and processes, development of prediction capabilities and warning systems, and improvement of design standards and construction technology. Some major programs that benefit, or could benefit, Alaska are discussed in this section.

Disaster Relief

The federal Disaster Relief Act of 1974 (Public Law 93-288) provides financial assistance to state and local governments when the President declares an area a disaster or emergency. Under the program, the Federal Emergency Management Agency (FEMA) administers grants from the President's Disaster Relief Fund. Other agencies, such as the Small Business Administration and Farmer's Home Administration, provide disaster-relief loans.

Alaska has been a major recipient of financial assistance from the President's Disaster Relief Fund. From 1961 through 1979 (the President's fund existed before the Disaster Relief Act was passed in 1974), Alaska received about $76 million from the federal government to assist in recovery from major disasters. The 1964 earthquake and 1967 Fairbanks flood accounted for 83 percent of Alaska's total FEMA receipts as of 1979. From 1961 to 1970, Alaska's per-capita share ($221.81) was the largest of any state (Office of Emergency Preparedness, 1972). However, contributions from the President's Disaster Relief Fund generally cover only a small portion of the total damages. Assistance from the Disaster Relief Fund for recovery from the 1964 earthquake, for example, only amounted to about 16 percent of the total estimated damages. Although the U.S. Army Corps of Engineers performed much of the reconstruction at federal expense, a major share of the burden for disaster response and recovery was and remains at the state and local levels.

Although some improvements have been made in recent years, a major deficiency with disaster-relief and insurance programs in general is that eligibility for benefits is often not contingent on implementation of risk-reduction measures. For this reason, many programs have discouraged hazard mitigation by failing to offer the proper incentives and rewarding lack of foresight. Unconditional availability of disaster assistance probably grew out of the notion that disasters are 'acts of God' and cannot be prevented or mitigated; therefore, everyone should be equally eligible for assistance.

The Disaster Relief Act of 1974 established some conditions of eligibility for federal disaster loans and grants to encourage hazard mitigation at the state and local levels. As prerequisites for financial assistance, the law requires that postdisaster reconstruction or repair financed with federal relief funds must conform with applicable codes and standards, and that hazards from similar future events in the affected area must be evaluated and appropriate mitigation measures must be adopted. These requirements apply only to postdisaster actions and still do not affect eligibility based on predisaster mitigation.

Some of the most significant advances in promoting hazard mitigation in conjunction with federal disaster relief have been in the area of flood hazards. The National Flood Insurance Program not only offers a means to distribute financial losses, but also provides positive incentives for flood-hazard reduction. Communities must meet certain requirements to participate in the program, and state governments assist by coordinating programs within their borders. To qualify for federally subsidized insurance, the community must adopt prescribed land-use controls and construction standards for areas potentially affected by the 100-yr flood. For example, the lowest floor of a structure must not be below the level of the 100-yr flood or storm-surge height unless adequate flood proofing is provided.

A Flood Disaster Act was passed in 1973 to improve incentives for community participation in the National Flood Insurance Program. This act increased available insurance coverages and prohibited federal financing of projects in flood areas unless the community participated in the program. The latter prohibition includes projects financed by federally insured banks and savings-and-loan associations. Community participation has increased dramatically since the Flood Disaster Act was passed. In Alaska, state-backed mortgage-loan financers also require flood insurance in the 100-yr-flood area as a prerequisite for loan approval.

Regional Studies

Several federal agencies perform research and map areas that provide useful information for describing geologic hazards on a regional scale. Most notable are programs of the U.S. Geological Survey (USGS) that produce topographic and geologic maps and evaluate regional seismic activity. These programs assess regional problems and identify areas that require more detailed study. They are not generally adequate for site-specific decisions or local land-use planning because map scales are small and subject treatment is general. Although regional geologic quadrangle maps (1:250,000 scale) are available for most of the continental United States, large areas of Alaska have not been mapped at this scale. In addition, geologic hazards are not generally identified on geologic quadrangle maps. The maps provide approximate ages and brief descriptions of bedrock units and surficial deposits, but must be interpreted to infer potential geologic hazards. Map information must be supplemented by additional studies and more detailed data to produce hazards maps that are useful for planning.

The USGS has primary responsibility for regional earthquake-hazard studies under the Earthquake Hazards Reduction Program (EHRP) established by Public Law 95-124 in 1977. This is the largest long-term federal program devoted to earthquake-hazards mitigation in the United States. The National Oceanic and Atmospheric Administration (NOAA) manages the Alaska Tsunami Warning Center in Palmer where 15 seismographs are monitored in Alaska and around the northern Pacific Ocean. Other short-term projects are funded by various federal agencies to evaluate the seismicity and seismic hazards of specific areas in relation to activities for which they have management responsibility. In recent years, the Department of Energy has funded regional seismograph networks to determine geothermal-energy potential and earthquake hazards on the Alaska Peninsula. The Bureau of Land Management (BLM), through NOAA, has provided major funding for seismograph networks to determine earthquake hazards to oil development on the Alaska continental shelf. The BLM-NOAA program provided about $1 million annually to operate seismic networks in Alaska and analyze the data. However, this and most other hazards-related funds were phased out by the end of fiscal year 1982.[4] The Department of Energy has reduced its funding for seismic studies in Alaska.

[4] The fiscal year for the federal government is October 1 through September 30.

2288 20130
VR

As a result, many seismograph stations have been dismantled, and more will be removed if adequate support is not maintained (Davies, 1983).

Although EHRP is a large national program with broad scope, it sets no goals or policy to establish long-term, minimum seismograph networks nationwide or map earthquake hazards at minimum scales in all areas of high seismic risk. The USGS share of funding under the national program has been about $30 million annually since 1978. Distribution of funds among the four major elements of the USGS program (fundamental studies, earthquake prediction, induced seismicity, and hazards assessment) has remained relatively constant, with about 50 percent going to fundamental studies and hazards assessment. Under these two programs, the USGS operates limited seismograph networks and studies earthquake hazards in selected regions. Limited funding for these program elements on a national scale has forced the USGS to concentrate on heavily populated areas that have sufficiently high seismic activity to generate useful data in a reasonably short period, and that are relatively accessible so that the cost of obtaining data is not excessive (R.A. Page, oral commun., 1982). Alaska has received about 4 percent of the annual USGS budget for the earthquake-hazards-assessment portion of the national program, compared to 31 percent for California, 17 percent for the southeastern United States, 16 percent for the northeastern United States, and 13 percent for the central Mississippi valley (Hamilton, 1978). The only seismic instrumentation in Alaska supported by the EHRP is a small network on Adak Island that provides data to develop earthquake-prediction capabilities and a network operated by the USGS in southern and southeastern Alaska. The balance of Alaska funding goes to studies of earthquake-related ground instability in the Anchorage area, measurement of crustal deformation in two areas that are thought to have potential for major earthquakes in the near future, and interpretation of seismotectonic processes in southern Alaska from geologic and seismologic data (Hays, 1979; Reed, 1981).

From FY 1980 through FY 1984, USGS objectives and anticipated funding for its portion of the EHRP remained unchanged from previous years (Hays, 1979). Although it has been argued that EHRP has given only minor support to Alaska because other agencies (mainly DOE and BLM-NOAA) have substantially funded seismograph networks in Alaska, there are apparently no plans to shift more support to Alaska to compensate for the loss of funding from other agencies.

Basic Research

A major activity of the USGS is basic research into processes and factors that affect the distribution, frequency, and severity of geologic hazards. Although much of this work is performed by USGS personnel, some funding is provided to universities, state governments, and private consultants. The National Science Foundation (NSF) also supports basic research related to geologic hazards. Information from these studies is used by federal, state, and local agencies, engineering firms, architects, and planning consultants to improve hazards-mapping and prediction capabilities, assess risks, and develop better approaches to hazard mitigation.

About 40 percent of the Earthquake Hazards Reduction Program is basic research. As part of its share of the program, The USGS evaluates the earthquake potential of seismically active areas, assesses earthquake hazards, develops earthquake-prediction capabilities, and provides data on

(Page 334 follows)

earthquake occurrences and strong ground motion. The NSF supports research on fundamental earthquake causes and processes and engineering approaches to mitigate earthquake effects (Hamilton, 1978, Schnell and Herd, 1983).

The USGS will probably expand its research on landslides under a proposed National Landslide Hazard-reduction Program. The program's major goals are to determine the geologic, topographic, and hydrologic conditions that contribute to slope failures; determine factors that lead to changes in stability; analyze past failures to develop prediction capabilities; and recommend methods to mitigate landslide damage (U.S. Geological Survey, 1981). How much of this program will be performed in Alaska is unknown, but the research results should apply to mapping landslide hazards and improving risk-reduction methods in the state.

Two other hazards-related programs of the USGS in Alaska are the Arctic Environmental Studies Program and the Volcanic Hazards Program. The principal goal of both programs is to develop a better understanding of geologic processes in Alaska so that their potential effects in developing areas can be determined. The Arctic Environmental Studies Program obtains base-line geotechnical data for land-use planning in transportation corridors and other developing areas. The program also studies problems that arise during operation of the Trans-Alaska Pipeline System to provide a basis for avoiding or minimizing similar problems to other proposed facilities. The Volcanic Hazards Program studies volcanic deposits to determine the history and style of volcanic eruptions. A small part of this program monitors seismic and geochemical changes that may provide clues to future activity (Reed, 1981).

Prediction and Warning

The federal government supports numerous programs to advance technology for predicting major events. The weather-prediction program of the National Weather Service of NOAA is the oldest and most familiar. A major objective of this program is to improve capabilities of predicting weather-related catastrophies, such as floods and hurricanes.

About half of the USGS share of the Earthquake Hazards Reduction Program (25 to 30 percent of the total national program) is devoted to development of prediction capabilities. The largest effort is in California, although the results will apply in many other parts of the country (Hamilton, 1978). Prediction techniques developed in California may have limited application in Alaska because of differences in the seismotectonic processes responsible for major earthquakes in the two states.

Techniques for predicting volcanic eruptions are improving, especially with the large quantity of data provided by the eruptions of Mount St. Helens. Much of this progress has been made under the USGS Volcanic Hazards Program, which continues to study volcanoes in the United States and other parts of the world. This program includes studies of four volcanoes in the Cook Inlet region (Mt. Iliamna, Mt. Redoubt, Mt. Spurr, and Hayes Volcano), Mt. Edgecumbe in southeastern Alaska, and several volcanoes along the Alaska Peninsula and Aleutian Islands (T.P. Miller, oral commun., 1985). Internationally, there has been some success in predicting volcanic eruptions, and warnings are being issued based on these predictions. The ability to predict an eruption currently depends on historic information about a volcano's eruptive style, internal structure, and seismic activity, and on the geophysical and geochemical signals that normally precede an eruption. The principle is the same for predicting other types of events: success depends on the delay between onset of the event at depth (as indicated by renewed seismic activity, for example) and the surface eruption. Volcano research by the USGS in the Cook Inlet area is not necessarily aimed at predicting eruptions of Cook Inlet volcanoes, but provides data to develop predictive models.

Prediction capability will be a principal objective of the proposed National Landslide Hazard-reduction Program, which will expand existing USGS landslide-research activities. Timing, geologic setting, mechanisms, rates, and extent of past slope failures will be studied to determine how these factors can be used to predict future failures.

The success of warning systems depends on timely and accurate predictions of events or recognition of conditions that indicate a high probability that a hazardous event will occur. Because predicting an event's onset and location is not yet possible for many hazards, warning systems often depend on prediction of the time and place of impact after an event begins. For example, flooding can often be predicted only after a cloudburst has begun, and warnings must be issued and acted on during the limited time available as the flood develops. Similarly, the federal government has developed warning systems for hurricanes and tornados that are based not on predictions of occurrence, but on estimates of the time and place of impact once the storm has started.

Tsunami-warning systems are highly successful and effective, at least for tsunamis that originate at a distance, because many hours may pass after the tsunami is generated and before the waves reach a distant shoreline. In Alaska, the major difficulty in issuing tsunami warnings is inadequate communications with many small, remote communities in vulnerable coastal areas. The Alaska Tsunami Warning Center, operated by the National Weather Service in Palmer, issues warnings for the entire northern Pacific Ocean. The Alaska Division of Emergency Services assists by improving communications capabilities and supplementing public-education programs to instruct coastal residents on how to respond to warnings and how to recognize the signs of a local tsunami.

Snow-avalanche warning systems use weather forecasts and observations of snowpack conditions to determine the danger of avalanche activity rather than to predict or warn of individual events. The Alaska Avalanche and Fire Weather Forecast System (AAFWFS) was established by the federal government and the State of Alaska and began operation in 1980. The U.S. Forest Service (USFS) is lead agency for the program, and the Alaska Department of Public Safety was designated to represent the state and coordinate program participation by other state agencies. Objectives of the AAFWFS are to aid fire-suppression agencies in their management of resources and fire-related activities; provide mountain-weather and snow-stability forecasts to evaluate hazard levels; maintain an atlas of avalanche occurrences and paths; identify hazard zones to develop zoning regulations; and conduct a public-awareness program about avalanche dangers and accident prevention.

The fire-weather-service function of AAFWFS helps the National Weather Service prepare daily and spot fire-weather forecasts from April 15 to September 15 of each year. From September 15 to April 15, the AAFWFS provides mountain-weather and snow-stability forecasts that allow users to evaluate hazards and make scheduling decisions. Responsibilities for other avalanche-related activities are delegated by state legislation (Alaska Stat.

18.76.010) to the Department of Public Safety, which in turn has delegated some of the tasks to other state agencies. Federal participation in the program consists of monetary contributions from the BLM and USFS and support through the services of federal personnel.

The USGS has developed a system for notifying state and local governments, other federal agencies, and the public of potential or imminent dangers from geologic hazards. A notice is formalized as a Geologic Hazard Warning when a situation poses a risk greater than normal and warrants considerations of a timely response to ensure public safety (U.S. Geological Survey, 1984). A Geologic Hazard Warning is accompanied by copies of scientific papers or reports that provide the basis of the notification, descriptions of the known geologic and hydrologic conditions, and an offer to provide appropriate technical assistance to affected state and local governments. Whenever possible, warnings are accompanied by estimates of the time, place, and magnitude of the expected event and descriptions of possible geologic or hydrologic events.

The original Federal Register announcement of the hazard-notification system (U.S. Geological Survey, 1977) points out that the system does not have a nationwide capability to issue notifications of hazardous conditions wherever and whenever they may exist. It also does not relieve state governments of the responsibility to keep apprised of potential hazards. States may request an evaluation of a potential hazard by the USGS for possible issuance of a notice, watch, or warning. The notice also clearly divides the responsibility among federal, state, and local governments:

> "The U.S. Geological Survey recognizes that providing earth-science information, in accordance with its expertise, is only the first of the inputs needed by state and local governments and the public in mitigating the effects of geologic hazards. The actual adoption of the most effective mitigation measures by local authorities will result from a cooperative effort by agencies at all governmental levels and by non-governmental organizations and the public. Decisions for adoption of such mitigation measures should be based upon a broad range of earth-science, engineering, and socio-economic information;" and

> "...recommendations or orders to take defensive actions are issued by officials of state and local governments, where the police and public safety authority rests in our governmental system."

Construction Technology

Most major advances in construction technology and design standards continue to come from private industry. In a few areas, such as seismic design, the federal government conducts programs to develop standards for its own facilities and promote improvements in state and local building codes. The U.S. Army Corps of Engineers, Bureau of Reclamation, and the National Bureau of Standards are responsible for most of this work within the federal government. In addition, NSF supports research in seismic engineering as part of EHRP. Most research addresses methods to determine design events, analyze the response of soil and structures, determine the potential for failure of slopes, embankments, and foundations, and develop technology for earthquake-resistant construction (Schnell and Herd, 1983).

STATE AND LOCAL GEOLOGIC-HAZARD PROGRAMS IN ALASKA

The most significant progress in dealing with geologic hazards in Alaska has been in disaster preparedness. Enactment of a comprehensive disaster act in 1978 established the Alaska Division of Emergency Services and began a program that has significantly improved disaster preparedness at state and local levels. Although the Alaska Disaster Act addresses hazard mitigation, progress in this area has been limited. Local planning for flood hazards is improving, primarily in response to federal eligibility requirements for flood insurance and through assistance provided by the Alaska Department of Community and Regional Affairs.

Limited progress has been made to develop land-use-planning and construction standards at state and local levels as a means of reducing losses from other geologic hazards in Alaska, particularly for hazards that are potentially catastrophic. However, state funding for engineering-geology and seismic-monitoring programs beginning in FY 1984 indicates some interest in such programs.

Disaster Preparedness, Warning Systems, and Protection Works

In 1977, the Alaska Legislature and Governor adopted the Alaska Disaster Act (Alaska Stat. 26.23), based on the Example State Disaster Act by the Council of State Governments (1972). This law expanded the former State Disaster Office into a new Division of Emergency Services (DES) in the Department of Military Affairs and gave it broad responsibilities in disaster preparedness. These responsibilities include (from Alaska Stat. 26.23.040) such actions as preparing a comprehensive state emergency plan, assisting local governments in designing their emergency plans, distributing emergency food and supplies, establishing public-information programs, and arranging for public and private facilities during emergencies. In preparing the state emergency plan, DES is responsible for recommending land-use and building regulations to reduce the impact of disasters.

The Alaska Disaster Act also provides for community disaster loans, grants to disaster victims, temporary housing, and removal of debris. The Governor is required to consider steps for disaster prevention, and appropriate state departments are required to identify areas vulnerable to disasters and study ways to reduce the dangers. However, disaster preparedness is emphasized, and functions that relate to hazard mitigation are primarily advisory.

A state emergency plan prepared by DES in accordance with the Alaska Disaster Act was adopted in 1978 and spells out disaster-response and planning functions of local, state, and federal government agencies that concern floods, forest fires, earthquakes, tsunamis, volcanic eruptions, and 'utilities emergencies.' Although most assigned responsibilities address disaster preparedness and response, some relate to predisaster mitigation. For example, one responsibility assigned to local governments that concerns earthquakes is "land-use planning and seismic building codes to minimize the adverse effects of earthquakes on the community." However, because the emergency plan is not incorporated in state regulations, it lacks the force of law to require local governments to carry out this responsibility. The plan goes into effect when the Governor declares a disaster, which is too late to implement predisaster mitigation. In effect, the emergency plan is an advisory document and, although valuable as an action plan during a state emergency, does not mandate predisaster hazard mitigation by other state agencies or local governments.

Warning systems and related communications facilities are hazard-mitigation functions for which DES has major responsibility and has made substantial contributions in recent years. The DES coordinates with the federal Tsunami Warning Center in Palmer to issue timely warnings by providing and maintaining communications facilities throughout the state. The capability to communicate tsunami warnings to remote coastal areas is improving as the communications system is upgraded and expanded. In conjunction with its involvement in the Tsunami Warning System, DES conducts public-education programs in coastal villages to instruct residents on how to respond to warnings and how to recognize and respond to indications of local tsunamis for which warnings are not possible (D. Thomason, oral commun., 1982).

The ability of DES to fulfill its statutory responsibilities is limited by its funding. Funding for day-to-day operations has been barely sufficient to maintain a small staff at its headquarters office in Palmer and at a few field locations around the state. Only when a disaster is declared by the Governor does DES acquire and administer substantial funds for disaster-response operations. One responsibility that has suffered because of limited funding is assistance to local governments for preparing emergency plans (D. Thomason, oral commun., 1982).

The State of Alaska has major statutory responsibility for the Alaska Avalanche Warning System, which is part of the Alaska Avalanche and Fire Weather Forecast System (AAFWFS). Various state agencies participate in the avalanche-warning system or contribute information according to personnel and budgetary capabilities. Because of funding limitations, the proposed organization has never been fully staffed (Johnson, 1982). The program director and an avalanche specialist must contribute their time subject to the priorities of other duties. Two meteorologist positions are provided by the Alaska Railroad (a prime user of the warning system), and weather and snowpack information along the Seward Highway is generally provided by the Seward Highway Avalanche Project (SHAP), which is operated by the Alaska Department of Transportation and Public Facilities. The University of Alaska Arctic Environmental Information and Data Center operates the Alaska Avalanche Forecast Center, which maintains a statewide data base of weather, snow-stability, and avalanche occurrence data, including a special data base for SHAP (Fredston and Sweet, 1985). The Alaska Division of Geological and Geophysical Surveys has prepared avalanche atlases more or less independently of the joint program. Funding limitations eliminated the position to provide information and avalanche forecasts for the Juneau area (Johnson, 1982).

For these reasons, the Alaska Avalanche Warning System is only partially meeting its statutory responsibilities. Users and participants cite inadequate funding, absence of structure or direction, inexperienced staff members, lack of guidance from knowledgable avalanche specialists, and poor integration with user needs as reasons for the program's poor performance (Johnson, 1982). The USFS recommended that the entire program be taken over by the State of Alaska under the management of a single state agency.

Alaska statutes have some provisions for protection works through state participation in flood-control projects (Alaska Stat. 35.07.010). Under this law, state government assumes 90 percent of the nonfederal costs of federally approved flood-control projects that include planning, land acquisition, construction, and maintenance. If the project is to protect facilities under state responsibility (for example, highways, roads, parks, or fish and game facilities), the state assumes all nonfederal costs.

In 1977, H.B. 425 was introduced in the Alaska Legislature to establish an erosion-control fund in the Department of Community and Regional Affairs, but was not passed. The fund would have been used to support grants to municipalities of up to $25,000 to cover 80 percent of the total cost of an erosion-control project to protect public property. In the absence of an ongoing erosion-control fund as proposed in 1977, some communities have obtained state financial assistance for erosion control by special appropriation. Application for the funds is made to the Legislature in the same manner as for other capital-improvement projects.

Alaska Planning Law and Local Land-use Regulation

The Alaska Constitution establishes two levels of local government, cities and boroughs, that are classified according to such factors as population, geography, economy, and transportation. Organized boroughs are designated as first, second, or third class, and cities are designated as first or second class. First-class boroughs and cities have the most powers of self government. An organized borough and all cities within it may unite to form a unified municipality with all powers of first-class cities and boroughs. Currently, there are 11 organized boroughs in Alaska that comprise 25 percent of the state's total area and contain 95 percent of its population. The remaining 75 percent of the state's area is designated the unorganized borough. Of the 11 organized boroughs, three are unified municipalities (Anchorage, Juneau, and Sitka), one is first class (Fairbanks North Star Borough), six are second class, and one is third class (Haines).

Requirements and powers for planning and zoning are delegated by the legislature (Alaska Stat. 29.33) to cities and boroughs based on their class. First- and second-class boroughs must provide planning and zoning on an an areawide basis, but may delegate planning and zoning powers to cities in their jurisdictions. Planning and zoning are optional for third-class boroughs. In the unorganized borough, first-class cities must, and second-class cities may, provide planning and zoning. The Alaska Land Act (Alaska Stat. 38.05) requires the state Department of Natural Resources to provide planning and zoning in the unorganized borough outside cities that provide their own and in third-class boroughs if planning and zoning are not provided by the borough. The state owns and classifies some land within organized boroughs, but is required by state law (Alaska Stat. 35.30.020) to comply with local planning and zoning ordinances to the same extent as other landowners.

To fulfill the planning and zoning requirement, first- and second-class boroughs must have a planning commission of at least five members. The commission must prepare a comprehensive plan for systematic development in the borough, zoning ordinances to implement the plan, and a subdivision ordinance (Alaska Stat. 29.33.080). State law provides very generalized guidelines for these plans:

> "The comprehensive plan is a compilation of policy statements, goals, standards, and maps for guiding the physical, social, and economic development, both private and public, of the borough, and

may include, but is not limited to, the following: statement of policies, goals, standards, a land use plan, a community facilities plan, a transportation plan, and recommendations for plan implementation" (Alaska Stat. 29.33.085).

The planning commission must review the plan at least once every 2 yr and make recommendations to the borough assembly, which must "regulate and restrict the use of land and improvements by districts" in accordance with the plan.

The Alaska Division of Municipal and Regional Assistance (DMRA) in the Department of Community and Regional Affairs provides financial and technical assistance to local governments on request to partially offset budgetary and personnel limitations they face in preparing the required comprehensive plans. The DMRA coordinates the National Flood Insurance Program in Alaska and has been instrumental in having many communities comply with the program by helping them prepare flood-plain regulations. Other hazards are not systematically addressed by DMRA in its planning-assistance program (C.L. Miller, oral commun., 1982).

State financial assistance for planning is available to first- and second-class boroughs and first-class cities in the unorganized borough through grants and revenue sharing. The DMRA provides special-purpose grants on a funds-available basis and administers annual revenue-sharing funds to help pay for general municipal services. Boroughs that provide land-use planning receive $2 per capita annually from this fund.

Alaska's present land-use laws and the federal Alaska National Interest Lands Conservation Act of 1980 were influenced by recommendations of a Joint Federal-State Land Use Planning Commission that was established by the legislature in 1972 and was replaced by the Alaska Land Use Council in 1980. Most recommendations were related to resource development, preservation of lands in state and federal management systems, and land exchanges and disposals to satisfy terms of the Statehood Act and Alaska Native Claims Settlement Act. Few specific recommendations regarding geologic hazards resulted from the Commission's work. However, one recommendation for state-land policy outlined "primary public interests in retaining state lands in public ownership," which included "to restrict development in hazardous areas" (Joint Federal-State Land Use Planning Commission, 1979).

Geologic hazards in local planning and zoning

Alaska law neither requires nor encourages consideration of geologic hazards or any other specific issue in local comprehensive plans or ordinances, except through the Alaska Coastal Management Program. Because federal law requires adoption of land-use controls by communities in flood-hazard areas as a prerequisite to participate in the National Flood Insurance Program, most affected cities and boroughs in Alaska address flood hazards in their planning and zoning. Although local governments have authority to address other hazards, few do. Most local governments that have addressed geologic hazards have taken a broad approach and group hazards with other considerations, such as habitat preservation for creating generalized open-space districts. Some comprehensive plans identify specific local hazards and provide guidelines to develop or preserve affected areas.

The Municipality of Anchorage has adopted a comprehensive Flood-plain Regulation (ch. 21.60, Anchorage Municipal Code), as have 17 other cities and boroughs, to comply with the eligibility requirements of the National Flood Insurance Program. In addition, the municipality has adopted a Residential Alpine/Slope District in its Zoning District Regulation (sec. 21.40.115, Anchorage Municipal Code) to collectively consider a number of environmental factors, one of which is geologic hazards. Permitted uses are restricted to single-family dwellings, accessory structures, and certain conditional uses subject to approval by the planning department. Minimum lot sizes and dimensions are determined according to the slope of the lot. Although the statement of intent of the Residential Alpine/Slope district declares that "creative site design and site engineering are essential" to ensure proper development, the district regulations do not establish design and engineering standards or procedures to implement this requirement. In early 1985, the municipality initiated a natural-hazard risk assessment of the Anchorage area to provide a possible basis for strengthening hazard-mitigation policy in the zoning-district regulation.

Zoning regulations in the Fairbanks North Star Borough (FNSB) (sec. 18.44.010, FNSB Code of Ordinances) include two zones that make minor references to hazards. The General Agriculture zone, intended primarily to preserve and develop agricultural uses, "may also be applied to lands containing soils which are not able to support intensive structural development..." In this application, the zone is generally used in areas of ice-rich permafrost or steep slopes. Uses are restricted primarily to one- and two-family residences, parks, schools, churches, facilities with few employees, livestock, and agriculture (not all-inclusive). An Outdoor Recreation zone was created to encourage open-space uses and specifically mentions providing floodways along the Chena River. Most development is prohibited in the Outdoor Recreation zone, unless directly related to recreation. The FNSB has also adopted comprehensive Flood Plain Building Regulations (ch. 15.04, FNSB Code of Ordinances) to comply with eligibility requirements of the National Flood Insurance Program. In 1984, the FNSB began a comprehensive revision of its zoning ordinance. The new ordinance will contain a flood-plain 'overlay zone'; no other substantial changes concerning geologic hazards are planned.

Land-use controls that are recommended in a comprehensive plan are not effective unless zoning ordinances are adopted to implement them. Further, a zoning ordinance for mitigating hazards is not effective unless hazardous areas are identified, maintained with a conservative approach to variances and conditional uses, and enforced. Although some local governments in Alaska have addressed geologic hazards in their comprehensive plans and, to a lesser extent, in zoning ordinances, implementation has been limited. Some factors that hamper implementing local hazard ordinances in Alaska are general public resistance to land-use controls; lack of technical background and concern about geologic hazards on borough planning commissions, assemblies, and staffs; lack of public information on potential hazards and associated risks; low awareness of potential legal liabilities of local governments with regard to injuries or property damage caused by natural hazards; and lack of sufficient enforcement personnel.

The Anchorage Coastal Management Plan and Comprehensive Development Plan, both of which are referenced by title 21 (Land Use Regulation), describe extensive areas of known or suspected hazardous lands and recommend policies and controls for their proper management. Adoption of the proposed measures and their application to the identified hazardous areas have been limited, particularly in areas of high development. Technical reports and planning documents available before the 1964 earthquake identified many hazardous areas that were affected by major earthquake-induced ground failures in 1964; yet most hazardous areas are still zoned for residences or businesses. With the exception of Earthquake Park, all other areas along the shoreline in the Turnagain Heights area west of Fish Creek that failed during the 1964 earthquake and areas next to the headwall scarp are still zoned R-1 (single-family residential). In 1977, a memorandum and proposed ordinance were submitted on request to the Municipal Assembly by the municipal Department of Law. The memorandum and ordinance recognized the potential hazards to public safety and welfare in the Turnagain Heights slide area and the potential liabilities to the municipality if another earthquake occurred. The proposed ordinance placed a 1-yr moratorium on further development in the slide area to allow analysis of data and preparation of plans for future development; the ordinance was not approved by the Assembly (L.L. Selkregg, oral commun., 1982).

In 1982, the Anchorage Assembly passed an ordinance that formally recognizes the Anchorage Geotechnical Advisory Commission as an advisory body to the municipality. This group of professional geotechnical engineers and geologists existed for several years as an ad hoc organization that provided informal recommendations and information to the municipality. Now the Commission is occasionally requested to provide formal input to the Assembly on matters related to zoning ordinances and building codes. Formal recognition of the Commission indicates the Assembly's increased awareness of the need to consider geologic-hazard issues.

In the Fairbanks North Star Borough, land-use controls receive strong public opposition, particularly in areas outside the City of Fairbanks. Another basic problem is the limited awareness among planning personnel and elected officials of potential geologic problems and associated legal liabilities (S.B. Hardy, oral commun., 1983). To improve geologic-hazards mitigation in local planning requires improved public information on hazards in a form appropriate for land-use planning and the availability of technical expertise to the borough planning staff. An additional problem is the limited capability of the borough to enforce zoning laws. One borough employee is responsible for all zoning inspections outside the cities of Fairbanks and North Pole where development is scattered over an area roughly the size of New Jersey. With about 1,000 homes constructed in 1982, adequate zoning enforcement has become nearly impossible.

State Land-use Planning and Classification

The Alaska Division of Land and Water Management in the Department of Natural Resources is responsible for land-use planning and classification in the unorganized borough outside first-class cities. State-owned land within organized boroughs is also classified by the state, but is subject to additional restrictions under borough ordinances. State land may be conveyed to private parties, native corporations, cities, or boroughs after it has been classified. After state disposal, land-use restrictions generally conform to the original classification, but may be modified by the covenant of sale and may expire after a specified period.

State land-planning and classification regulations [Title 11, Alaska

2252 20130

Administrative Code, ch. 55, secs. 10 to 80 (11AAC 55.010-55.280)] do not address land-use management of hazardous areas. Several existing classifications could be applied because they restrict or prohibit high-density or residential uses, but only one land class (Greenbelt Land) specifically applies to hazardous areas (flood plains).

Alaska Coastal Management Program

A separate planning process that affects development in coastal areas was established by the Alaska Coastal Management Act of 1977 (Alaska Stat. 46.40). This law initiated statewide and district coastal planning to address development and conservation of coastal resources and coordinated planning in coastal areas, policies for resolving use conflicts, and public participation with local, state, and federal agencies in coastal-zone management. Funding assistance is provided by the federal Coastal Zone Management program. When the state Coastal Zone Management plan was completed in 1979, Alaska became eligible to receive increased federal funding to administer the program and provide assistance to local governments in preparing district plans. Many local districts have completed their coastal-management plans and more are being prepared. The Department of Community and Regional Affairs oversees and assists in preparing district coastal plans; the Office of Coastal Management administers the overall state program.

After state and district coastal-management programs were adopted, the Alaska Coastal Management Act requires affected municipalities and state agencies to administer land and water uses in conformance with their plans. At the local level, zoning regulations must be adopted, and permits and variances that are consistent with the plan must be approved. At the state level, uses or activities under state jurisdiction that are consistent with state and local management plans and with other state laws and regulations that govern the activity must be approved. Under the federal Coastal Zone Management Program, state and local governments may review federal activities for compliance with approved coastal plans.

State regulations developed under the Alaska Coastal Management Act establish minimum standards that must be met by state and district programs (6 AAC 80) and guidelines to prepare plans (6 AAC 85). Among issues that must be addressed are 'geophysical-hazard areas' in the coastal zone:

> 6 AAC 80.050. GEOPHYSICAL HAZARD AREAS. (a) Districts and state agencies shall identify known geophysical hazard areas and areas of high development potential in which there is a substantial possibility that geophysical hazards may occur. (b) Development in areas identified under (a) of this section may not be approved by the appropriate state or local authority until siting, design, and construction measures for minimizing property damage and protecting against loss of life have been provided.

The state coastal-management plan does not delineate geophysical-hazard areas. This is recognized as an ongoing task of state agencies, primarily the Division of Geological and Geophysical Surveys, that requires continual data evaluation and mapping to identify geophysical hazards in 'areas of high development potential.' District coastal-management plans delineate geophysical-hazard areas and recommend measures for their management, but as the state plan recognizes, "it will be impossible for districts to thoroughly assess each hazard area and devise detailed standards for any conceivable use." The state plan obligates developers to conduct studies needed to determine appropriate siting, design, and construction standards. Districts and state agencies are expected to have enough general data to know when to require such studies from developers. In practice, however, data are often insufficient in an area. Although geophysical-hazard areas are continually being identified for the state and district programs, no requirements exist to periodically update coastal-management plans.

Subdivision Law

In Alaska, subdivision platting responsibilities and powers are delegated to cities and boroughs in the same manner as planning and zoning. The borough planning commission, or a separate borough platting board, has jurisdiction over the form and size of subdivisions, dimensions of lots, and arrangement of utilities, transportation, and other public facilities. The platting board must publish a subdivision ordinance with rules and regulations to implement this power. State statutes require that the platting board approve a plat before work can begin on a subdivision, unless a waiver is granted under special circumstances. The plat must show survey points, boundaries, calculations and angles used in the survey, and other information that may be required by ordinance (Alaska Stat. 29.33.160 to 29.33.180). If the subdivision will have a central well, water samples must be submitted to the state Department of Environmental Conservation for analysis, but there are no state requirements to collect geologic or soils data for review. Except for state residential-land disposals and other areas under state jurisdiction, all reviews, permits, and additional platting standards are the responsibility of local government.

The Municipality of Anchorage and the Fairbanks North Star Borough have incorporated limited hazards considerations in their subdivision regulations. Anchorage subdivision regulations contain provisions for subdivision design that implement the requirements of the R-10 (Residential Alpine/Slope) District in the zoning regulations: "Subdivision design in the R-10 District shall take into consideration known areas susceptible to landslide, mud and earth flow, talus development, soil creep, solifluction or rock glaciation, avalanche chutes, runouts or wind blast. Each lot or tract zoned R-10 shall include a building site which is not within such a known susceptible area" (sec. 21.80.120, Anchorage Municipal Code). Properly implemented, this regulation requires developers to provide suitable building sites on each lot in a hazardous area. However, because the requirement applies only to the R-10 district, known hazards in subdivisions that are not zoned R-10 are not addressed, such as the Turnagain Heights slide area, which is zoned R-1.

Title 17 subdivision regulations in the Fairbanks North Star Borough code take a more generalized approach to hazards: "In those areas where the planning commission has been presented with evidence to the effect that the preliminary layout, if approved and developed, would tend to result in a hazard to persons or property, or if evidence has been presented which tends to indicate that damage to properties lying beyond the boundaries of the proposed subdivision may occur, the planning commission may impose more restrictive standards than those already established in other sections of these regulations" (sec. 17.20.020). Property impairment caused by disturbance of unstable soils is cited as one type of damage to which this regulation applies. In practice, this section of the borough subdivision regulations is seldom, if ever, used to apply more restrictive development standards. A more common practice is to change the zoning designation to one with a larger minimum lot size so that each lot contains a variety of siting alternatives (S.B. Hardy, oral commun., 1983).

Siting, Design, and Construction

The State of Alaska and some borough governments make limited use of building codes and other standards for site selection, design, and construction of public and private facilities. Some standards require consideration of geologic factors and use of appropriate construction technologies to minimize the danger from any hazardous condition. Specific requirements of building standards and the way they are implemented depend largely on the type of facility and whether its construction is under local or state jurisdiction. Standards are less strict for small private structures than for large public facilities, and the review and permitting process is different if the code is enforced by the state rather than the borough government. Review procedures for siting and design plans and for inspecting the project during construction are critical to successfully implement building codes and standards.

State and local building codes

The State of Alaska does not require local governments to adopt a building code, although it does give them the authority (Alaska Stat. 29.10.213). As part of the fire-prevention regulations in the state public-safety code, the state has adopted many sections of the ICBO Uniform Building Code (UBC) "to regulate all occupancies and buildings" (13 AAC 50.020). This regulation applies to all commercial, industrial, business, institutional, and public facilities in the state, and to residential buildings of four or more units. A municipality may be exempted from code requirements if the municipal government has enacted satisfactory ordinances for review and approval of building plans and specifications. Sections of the UBC adopted by the state public-safety code include earthquake regulations (sec. 2312), but do not include sections that deal with soils, foundations, and slopes (UBC, chs. 29 and 70).

Building plans and specifications must be submitted to the state fire marshal for review, unless review responsibility has been transferred to the local government. The fire marshal's review concentrates on design aspects that affect fire safety. Consequently, plans and specifications are not reviewed for earthquake safety. Other than this chapter in the public-safety code, there is no statewide building code.

Some boroughs and cities in Alaska have adopted the UBC by ordinance, usually with amendments, to regulate construction in their jurisdictions. In most cases, UBC sections that deal with potential geologic problems are adopted in their entireties with minor changes, including section 2312 (Earthquake Regulations), chapter 29 (Excavations, Foundations, and Retaining Walls), and associated appendixes.

In the Municipality of Anchorage, the UBC applies to all construction in the area formerly known as the City of Anchorage (Borough Service Area 30);

2388 20130

the remainder of the borough is exempt from the UBC. Section 2312(1) of the UBC was reinstated in 1983, with amendments; it requires installation of accelerographs in certain large buildings to record ground motion during strong earthquakes. The municipal building department reviews building designs and soils-investigation reports for compliance with minimum requirements of the UBC. As long as the proposed design meets minimum requirements of the UBC, the building department has no local authority to decline a permit, even if it believes there is a potential hazard that is not adequately addressed by the UBC (R. Watts, oral commun., 1982). For example, although the UBC requires that a building be designed to resist stresses produced by lateral forces during an earthquake, it does not require that the building site be analyzed to determine the potential for earthquake-induced ground failure. Consequently, a building could be designed to withstand earthquake shaking, but fail as a result of permanent differential movements of the ground on which it is built.

The City and Borough of Juneau has adopted the hazard-related sections of the UBC and, in some areas, has strengthened the requirements. For example, an additional factor that increases the design load according to building height must be included in the equation for determining design lateral-shear forces during earthquakes (sec. 19.06.010, City and Borough of Juneau Code of Regulations). For tall buildings, the resulting design load could be as much as 2.2 times that determined from the original equation in the UBC. Another change is an addition to chapter 29 of the UBC (Excavations, Foundations, and Retaining Walls) that partially compensates for the lack of adequate site-investigation requirements and gives the building official more power to ensure site safety. The addition requires that a qualified engineer submit an engineering report and recommendations for any proposed construction on soils that may have inadequate bearing capacity. The building official may incorporate the recommendations into the permit approval and any other requirements deemed necessary to ensure the stability and safety of the proposed structure.

Construction in the Fairbanks North Star Borough is not regulated by a building code. The City of Fairbanks, however, has adopted the UBC with no substantial amendments relating to potential geologic problems.

Local goverments differ in their approaches to adopting and implementing hazard-related building codes in Alaska. Their approaches reflect various backgrounds and attitudes of local elected officials and building departments rather than variations in severity of geologic problems in different areas of the state. For example, a UBC requirement to install earthquake accelerometers in large buildings in Anchorage was temporarily deleted when builders objected to the cost, but was later readopted (L.L. Selkregg, oral commun., 1983).

Adoption of a statewide building code or a state requirement for local adoption of codes is probably not the best solution to improve the role of building codes in reducing losses from geologic hazards in Alaska. The greatest need is to improve awareness by elected officials and the public of potential hazards and reasonable ways to reduce risks. The Anchorage Geotechnical Advisory Commission occasionally presents recommendations to the Municipal Assembly and meets with members of the planning department to discuss its recommendations and help resolve specific problems. If similar advisory services were available to local governments on a statewide basis, local implementation of hazard-related building codes would probably improve.

Another need is to improve the capability of local building departments to implement codes through adequate review of building plans and specifications for compliance with the geologic- and seismic-engineering requirements. In addition to sufficient funding to maintain adequate staffs, local governments would need to hire or contract reviewers and building inspectors who have had training or experience in earthquake and geologic engineering.

Critical facilities

The only critical facilities whose construction is regulated by the State of Alaska with specific regard to geologic hazards are dams and health facilities. Until 1981, construction of school buildings was subject to state review and approval of engineering reports, plans, and specifications under the Health and Social Services code (7 AAC 22.100). However, this regulation was not enforced, at least during the last several years of its existence (R. Goldberg, oral commun., 1982). In January 1981, the Governor transferred many inspection and enforcement functions, including regulation of school facilities, to the Department of Environmental Conservation (Executive order 51). The new regulations developed by DEC eliminated all state review and approval of engineering reports and construction plans for schools.

Construction of health facilities remains under the jurisdiction of the Department of Health and Social Services. Plans and specifications must be submitted for review, approval, and licensing by the department and must conform to codes and standards prescribed in the Health and Social Services code (7 AAC 09.050). In addition to the Uniform Building Code, the regulations require compliance with local building codes and special earthquake provisions and require submission of site surveys and soil investigations when notified by the department (7 AAC 09.060 and 7 AAC 09.090 - 09.110). The earthquake provisions require a seismic-investigation report to accompany the site survey and soil-investigation reports on new health-facility construction projects in UBC seismic zone III (which includes zones III and IV in later editions of the UBC). Plans and specifications for structural renovations of health facilities are also required to conform with the lateral-force provisions of the UBC. Nonstructural items such as book stacks and equipment must be properly secured to prevent or minimize undesired movement.

Plans and specifications for health facilities, along with supporting information, are reviewed by architects in the Division of State Health Planning and Development. Requirements and procedures are similar to those in California under the Hospital Seismic Safety Act. However, one requirement of California law that is not included in the Alaska regulations is that geologic and structural-design data be reviewed by professionals who are qualified in those fields. Although the difference may appear to be minor, the credibility of the review process is determined to a large degree by the technical expertise of the reviewers and has the greatest impact on the effectiveness of hazard-mitigation programs. In California, this is most apparent with regard to schools (Field Act) and health facilities (Hospital Seismic Safety Act; Woodward-Clyde Consultants, 1980a). Whether lack of this requirement in Alaska affects the adequacy of health-facility reviews for potential geologic hazards was not determined. Although the Division of State Health Planning and Development does not employ geologists or geotechnical engineers, this aspect of the review can be contracted to private firms (R. Goldberg, oral commun., 1982).

 2358 20130

Dam construction is regulated under the Natural Resources code (11 AAC 93) that contains requirements to consider geologic and hydrologic factors in dam safety. Requirements for information that must be submitted to the Department of Natural Resources (DNR) for review depend on the size of the proposed dam. For dams that are higher than 20 ft or have a storage capacity of 100 acre-ft or more (classified as large dams), an evaluation of earthquake effects (if it is in UBC zone III or IV), a seepage analysis, hydrologic data, geologic and foundation information, and procedures used to develop design criteria and construction specifications (11 AAC 93.170) are required. The same procedures and supporting information are recommended, but not required, for medium-size dams. Dams under 10 ft high or that have a storage capacity less than 50 acre-ft (classified as small dams) do not need DNR review or approval beyond granting the state water-appropriation permit.

Permit applications for dam construction are reviewed by engineers in the Division of Land and Water Management (DLWM) for compliance with applicable dam-safety and construction regulations. The DLWM does not employ engineering geologists or seismologists to review geologic or earthquake information but can contract private consulting firms (S.F. Mack, oral commun., 1982).

The present dam-safety and construction regulation is only 6 yr old and has had little opportunity to be tested. No reviews for large dams have been conducted since the regulation went into effect in December 1979. Most large dams, which are generally hydroelectric, are regulated by the Federal Energy Regulatory Commission (FERC), which has its own requirements and review procedures for siting, design, construction, and operation.

The major difference between the dam-safety program in Alaska and its counterpart in California is that Alaska regulations do not specify minimum performance or design standards to mitigate geologic hazards to dams. The absence of these standards may contribute to uncertainty about what criteria will be used for granting or denying permits, especially when complex geologic, seismologic, and engineering problems are involved. Because of the complexity and uniqueness of each dam installation, design standards must remain flexible to accommodate and promote improvements in design technology. However, dams could be required to meet certain minimum performance standards without compromising design flexibility. An approach that has been successful in California is to require minimum performance under certain adverse circumstances. For example, California law allows no major release of water from a dam as a result of a maximum-credible earthquake or 1,000-yr flood. Performance standards for other natural events could also be included.

Public facilities and state-funded capital-improvement projects

Design and construction of most state facilities are the responsibility of the Department of Transportation and Public Facilities (DOT/PF). Although DOT/PF usually obtains engineering-geology data during a project, there are no specified building codes or design standards set by state law to minimize potential effects from geologic hazards and no requirement to identify hazards before a project begins. State law does require state agencies to comply with local ordinances to the same extent as other landowners (Alaska Stat. 35.10.025 and 35.30.020); thus many state facilities are subject to local building codes.

The only state capital projects that are routinely reviewed by the Division of Geological and Geophysical Surveys (DGGS) are those that receive federal funding and are thus circulated through the state Clearinghouse (see following section). In other states, interagency agreements often establish review procedures among several agencies for proposed state capital-construction projects. The state geological survey is generally one party to the agreement and is given responsibility to review potential geologic hazards. Such a procedure has not yet been established in Alaska between DGGS and other agencies like DOT/PF and the Alaska Power Authority that are responsible for capital-construction projects. The DGGS is occasionally asked to participate in reviews on a project-specific basis where major concerns develop regarding the geology of proposed construction sites, but does not budget specifically for this service.

Local construction projects financed with state capital funds are also not subject to state siting and design standards, except under the Alaska Coastal Management Program. When a local government receives state funds for capital-improvement projects, state regulations do not stipulate that geologic hazards be evaluated or that siting and design meet minimum requirements for hazards safety.

Project reviews by state agencies

State agencies may review and comment on many proposed actions by state and federal agencies and projects that are regulated, licensed, or funded under state and federal laws. A brief description and location map of the proposed project or action is distributed to appropriate agencies, and reviewers can usually request additional pertinent information. The DGGS reviews many of these proposals to identify potential geologic hazards and conflicts with known mineral or construction-material resources.

Project reviews by DGGS fall into five categories: 1) federally funded or licensed projects for which descriptions are circulated by the state Clearinghouse under Presidential Executive order 12372 (see footnote 3); 2) projects in the coastal zone that require a federal permit (usually from the Corps of Engineers) and must comply with the Alaska Coastal Management Program; 3) disposals and exchanges of state-land parcels under the Alaska Land Act; 4) state selections of federal land under the Alaska Statehood Act; and 5) projects under the jurisdiction of other state agencies that request reviews by DNR on a largely informal basis. Of these five categories, only projects regulated by the Alaska Coastal Management Program must be reviewed against a state hazard-related development standard. Because hazard-related development standards do not exist for other projects, the use of geologic-hazards information is left to the discretion of the approving authority.

Two additional problems faced by DGGS in reviewing for geologic hazards are the limited geologic information for many areas of the state and limited number of personnel. Reliable large-scale geologic maps exist for most areas of other states, but are available for only about 7 percent of Alaska (fig. 17).

Professional registration

The few state and local laws in Alaska that require consideration of geologic hazards in siting and design generally require submission of geologic or soils-engineering reports, but are not specific about the professional qualifications of those who prepare them. Other state laws establish a state board of registration to set minimum qualifications and require engineers to register in Alaska. The state does not require professional registration of geologists, but provides optional certification for those who desire it. State certification is automatic if the applicant is certified as a professional geologist by the American Institute of Professional Geologists (Alaska Stat. 08.02.011). Certification requirements include a baccalaureate degree in geology or major subdivision, 5-yr experience (partial credit given for graduate degrees), and sustained record of high professional and ethical standards, as attested to by five professional geoscientists, at least three of whom are members of the Institute.

Geologic reports currently have a minor role in siting and design regulations, so lack of a registration requirement probably has little impact on building safety in Alaska. If hazard-mitigation programs are expanded at state and local levels to include requirements for geologic reports, registration or certification of geologists may become important because more unqualified persons will be tempted to take advantage of the increased demand for professional services. However, judging from the problems and controversy that have developed over the registration program for geologists in California, a similar elaborate registration program in Alaska may not be feasible. A stipulation that geologists who prepare reports required by state and local laws be certified according to the existing procedure (Alaska Stat. 08.02.011) and that they provide evidence of training or experience in the type of work required for the report, should be adequate to protect the public from unqualified persons and yet be flexible enough to avoid undue restrictions. For instance, this procedure would allow many qualified out-of-state geologists who currently practice in Alaska to continue making their services available without having to pass a separate state qualifying examination.

Research and Technical Services

State-supported research on geologic hazards in Alaska takes place by two mechanisms. The DGGS is the primary state agency responsible for preparing maps and reports for the public on geologic resources and hazards and for providing technical assistance to local governments and other state agencies on geology-related matters. Most funding for DGGS comes from the annual state operating budget, although a limited amount also comes from federal agencies, such as the USGS. The second mechanism is through the University of Alaska. Until FY 1983, most of the university's funding for research, including geologic hazards, came from the federal government. In FY 1983, when the federal share of research receipts at the university dropped to 36 percent, the State of Alaska became the university's dominant funding source (University of Alaska, 1983). Another funding mechanism, discontinued by the Legislature in 1984, was the Alaska Council on Science and Technology (ACST). The ACST was one means by which researchers at the University of Alaska could obtain state funding and was also a funding source for some nonuniversity scientists and research organizations.

Division of Geological and Geophysical Surveys

The Alaska Division of Geological and Geophysical Surveys, as it now exists, was established by the Legislature in 1972 as a division of the

Department of Natural Resources. State statutes require DGGS to "conduct geological and geophysical surveys to determine the potential of Alaskan lands for production of metals, minerals and fuels; the locations and supplies of ground waters and construction materials; the potential geologic hazards to buildings, roads, bridges and other installations and structures; and...other surveys and investigations as will advance knowledge of the geology of Alaska" (Alaska Stat. 41.08.020a). Specifically, the law requires DGGS to "....collect, record, evaluate, archive, and distribute data on seismic events and engineering geology of the state; identify potential seismic hazards that might affect development in the state; and inform public officials and industry about potential seismic hazards that might affect development in the state" (Alaska Stat. 41.08.020b). The Engineering Geology Section of DGGS has primary responsibility for collecting data and publishing reports on engineering geology and seismic and geologic hazards. The Water Resources Investigations Section publishes surface-water maps and reports that include streamflow hydrographs, runoff, and flood-plain maps to evaluate flood hazards. The Minerals Investigations and Geologic Mapping Sections produce mineral-potential maps and general-purpose geologic maps that are also useful for identifying geologic hazards and locating sources of construction materials.

An ongoing task of DGGS is to prepare large-scale maps of surficial geology. These maps are currently available for only about 7 percent of the state (fig. 17). Because most construction not only takes place on recently deposited sediments, but also makes extensive use of these sediments (primarily sand and gravel), DGGS prepares surficial-geologic maps with three objectives: 1) to locate sources of construction materials; 2) to provide engineering-geologic information for construction and land use; and 3) to advance knowledge of the geologic history of Alaska. Such maps have been prepared for portions of the lower Matanuska Valley and Susitna valley, the Kenai lowlands, and the Anchorage bowl; maps are being prepared for the Haines-Skagway area, the Chugach Mountains, and parts of the North Slope at scales of 1:63,360 and 1:24,000. Additional maps are planned for other developing areas and transportation corridors.

The DGGS has begun to prepare special-purpose reports and maps on engineering-geologic problems of selected areas that are of particular concern. Recently published examples include a comprehensive report on geologic hazards in the Fairbanks area (Péwé, 1982); an atlas of snow-avalanche paths along the Seward Highway (March and Robertson, 1983); subsurface-structure maps of the Bootlegger Cove Formation beneath Anchorage (Ulery and Updike, 1983); a report on the potential for earthquake-induced liquefaction in the Fairbanks-Nenana area (Combellick, 1984); and a report on liquefaction-susceptibility analyses of sediments in Knik Arm and upper Turnagain Arm (Updike, 1984). Reports in preparation include an engineering assessment of the Turnagain Heights landslide area in Anchorage, an engineering-geology map of southwest Anchorage, and an atlas of snow-avalanche paths along the Richardson Highway.

In FY 1984[5], the Legislature established a statewide seismic-hazard program within DGGS. This program was primarily initiated because of a major decline in federal support for earthquake monitoring in Alaska and because long-term, continuous monitoring of earthquakes is essential for seismic-hazard evaluation. The program supports seismograph networks and building

[5]The fiscal year for the State of Alaska is July 1 through June 30.

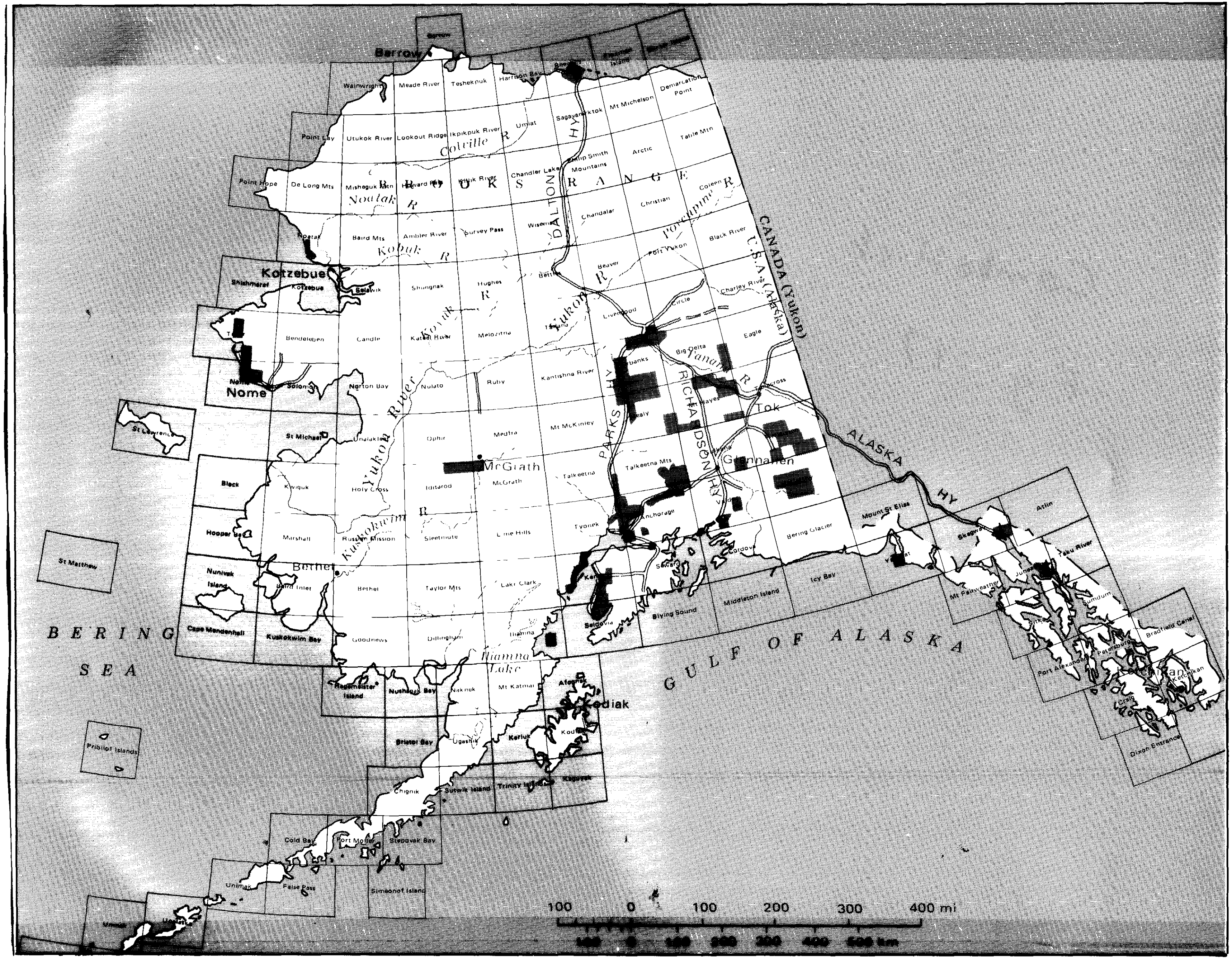


Figure 17. Areas of Alaska for which surficial-geologic maps were available in 1983 at scales useful for detailed land-use planning (1:63,360-scale maps or larger).

23B2 20130

instrumentation to directly monitor earthquakes, compile and analyze old and new data, and publish quarterly and annual earthquake bulletins. State funding of these seismograph networks, which are operated mainly by the University of Alaska in some of the most seismically active regions of Alaska, partially compensates for a recent dramatic decrease in federally supported networks. Only one network, which is operated by the USGS in south-central and southeastern Alaska, is supported by the federal government. Seismologic studies of some areas, particularly in interior regions away from major seismic regions, must still be based on limited existing data. For many areas of the state, reliable earthquake data either do not exist, or are available over such a short or discontinuous time period that they are inadequate for evaluating earthquake hazards (J.N. Davies, oral commun., 1982).

Occasionally DGGS is asked to participate on review panels or in special studies that involve other state agencies or local governments to address geologic problems associated with a major facility or hazard. One recent example is DGGS's participation on a geotechnical committee to make recommendations on the Pillar Mountain landslide near Kodiak that was identified by the USGS and Alaska Department of Transportation and Public Facilities (DOT/PF) in 1977. The geotechnical committee was formally established by a resolution passed by the Kodiak Island Borough and City of Kodiak in 1978. Another example is DGGS's involvement in site evaluation for the new state office building in Anchorage in response to a request from the Office of the Governor. Public institutions, private companies, and the general public also request information and assistance from DGGS.

University of Alaska

In FY 1983, the University of Alaska received about 53 percent of its total research funding from the State of Alaska. Approximately 43 percent of the total was from the state general appropriation to the university and the remaining 10 percent was from state research contracts on specific topics (University of Alaska, 1983). During FY 1982 and the first half of FY 1983, the Geophysical Institute, which performs most of the university's research on geologic and geophysical hazards, received approximately 36 percent of its total operating funds from the state. However, state research contracts for specific topics, including geologic hazards, constituted only about 7 percent of the institute's budget (University of Alaska Geophysical Institute, 1982), and less than 2 percent was for research on geologic hazards.

The federal government provided over 60 percent of the university's research funding until FY 1982. A major part of the federal funding was for studies of geological and geophysical hazards associated with oil development on the outer continental shelf. Many of these projects, particularly those dealing with earthquake hazards, also provided useful data for coastal and interior areas of the state. Federal funding for geologic-hazards projects has been largely terminated, with the exception of limited support to study sea ice and permafrost.

When federal reductions severely impacted university-operated seismograph networks in Alaska, the state appropriated about $140,000 for the Geophysical Institute to operate one regional network in FY 1983. The support came from a $20 million 'impact fund' created by President Reagan to provide relief to programs affected when federal responsibilities were transferred to the states. This was a one-time appropriation that maintained the seismic

 2383 20130

network through June 1983. In July 1983, the Geophysical Institute began to receive partial support for its seismic networks through the DGGS seismic-hazard program, funded by special appropriation in FY 1984. In FY 1985, the seismic-hazard program was incorporated into the state operating budget at a reduced level.

Alaska Council on Science and Technology

By September 1982, the Alaska Council on Science and Technology (ACST) had provided $632,935 for geologic-hazard studies out of a total of $3,035,641 spent on research activities since the council was formed by the Legislature in 1979. Snow avalanches, earthquakes, volcanoes, permafrost, and coastal-flooding hazards were studied. The ACST also convened two workshops to assess the status of research on hazards in Alaska and make recommendations for improved federal and state policy on supporting hazards studies (Alaska Council on Science and Technology, 1980a,b). The Legislature terminated funding for ACST at the end of FY 1984.

Two major problems prompted ACST workshops on hazards: the reductions in federal funding for hazards studies and the lack of state policy on hazard mitigation. State research funding for ACST was distributed among many scientific disciplines, and the amount available for hazards studies was inadequate to compensate for the major cutbacks in federal funds. The ACST supported short-term projects to address specific topics but, without state support, was reluctant to fund projects like seismograph networks that require long-term commitments to be cost effective. The Working Group on Alaskan Seismology recognized the advantage of state participation in federally funded earthquake-hazard-evaluation programs and recommended immediate state action to fund earthquake studies and develop a comprehensive state policy for seismic safety (Alaska Council on Science and Technology, 1980b). Some subsequent funding decisions made by ACST and the FY 1983 special appropriation made by the Legislature from the 'impact fund' were based on these recommendations, but no long-term state policy for hazard mitigation has been adopted.

CONCLUSIONS

Major geologic events will continue to occur in Alaska and, with increased development, affect more people and property. Earthquakes, volcanic eruptions, landslides, snow avalanches, floods, and related occurrences, such as tsunamis, seiches, mudflows, and secondary ground failures, are inevitable. The extent of property damage and injury associated with an event will depend not only on its location and severity, but also on how well the potential effects have been anticipated during planning and development. Although more continuous or localized processes like thaw settlement, soil creep, frost heave, and erosion may not be as disastrous, they may be just as costly over the long term unless susceptible areas are identified and potential problems are considered in selecting construction sites and designing facilities.

Although the State of Alaska has significantly improved its disaster-response and disaster-relief capabilities since the 1964 earthquake, there is a need to consider possible improvements in hazard mitigation (measures to reduce the potential for property damage and injury from natural events and, consequently, to reduce dependence on disaster relief). Technology is available to delineate natural hazards, determine their severity, and reduce their potential effects on people and property. On the basis of this review of national and state policies, 10 issues are proposed for considering possible improvements in hazard-mitigation policy in Alaska:

1. Policy guidance and coordination of state and local hazard-mitigation programs.
2. Availability of basic technical information on hazards for land-use planning and construction.
3. Continuation of federally funded hazards studies that are being terminated or substantially reduced.
4. Incentives and guidelines to consider geologic hazards in local plans and ordinances.
5. Hazard mitigation in siting, design, and construction of critical facilities.
6. Hazard mitigation in siting, design, and construction of many state-funded public facilities.
7. The relationship between hazard-mitigation and eligibility for disaster-relief funds.
8. Capability of state agencies to provide adequate technical services, assistance, and project reviews on geologic hazards for other agencies and local governments.
9. Standards of experience and education for geologists who prepare reports required by state or local laws for siting or designing facilities.
10. State capability to issue formal notices of serious geologic hazards and to coordinate the response by state and local agencies.

Successful hazard-mitigation programs in other states can serve as models for new or improved programs in Alaska. Certain attributes of federal programs that have suceeded in promoting hazard mitigation could also be incorporated in state programs. However, new programs in Alaska must be tailored to the state's unique political structure, demography, social attitudes, and existing laws. For example, a statewide building code may not be a reasonable approach to hazard mitigation in Alaska because many local governments are not equipped to establish rigorous review procedures or inspection programs for their jurisdictions. Regulation of all construction in the vast remote areas of the unorganized borough would be logistically impossible. On the other hand, regulation of the construction of critical facilities and certain state-financed projects in hazardous areas is feasible.

Hazard-mitigation programs in California and Colorado were reviewed to determine their possible applicability in Alaska. These two states were chosen because of their extensive, successful programs and because their geologic environments and problems are similar to those in Alaska. Many factors contribute to the success of hazard-mitigation programs in California and Colorado and of some federal programs:

1. Strong policy guidance and coordination by a single state agency or commission.
2. Availability of adequate technical information to identify and evaluate hazards and determine design standards.
3. Encouragement of better awareness and appreciation of hazards among local officials through incentives or requirements to consider hazards in local comprehensive plans and ordinances.

4. Protection of local governments from damage liability for actions taken in good faith to mitigate geologic hazards.
5. Availability of guidelines and criteria to recognize and mitigate hazards at the local level.
6. Centralized and standardized review of design and construction plans and supporting information for certain critical facilities and most public facilities.
7. Appropriate, clearly defined design and performance standards for facilities subject to review for hazards safety.
8. Adequate training and experience of reviewers in geology, hydrology, seismology, or engineering, depending on the review task.
9. Inclusion of incentives or requirements for hazard mitigation as part of disaster-relief programs.
10. Ability of programs to be self supporting through special permit or license fees (as with the California Strong-motion Instrumentation Program).

RECOMMENDATIONS FROM THE WORKSHOP ON EVALUATION OF REGIONAL AND URBAN EARTHQUAKE HAZARDS AND RISK IN ALASKA

The U.S. Geological Survey conducted a workshop in Anchorage, September 5-7, 1985, to assess the current state of knowledge of earthquake hazards in Alaska and advances in mitigation and preparedness since the 1964 Great Alaska Earthquake. Participants included seismologists, geologists, planners, emergency coordinators, policymakers, and educators that represent all levels of government, the private sector, and academia.

Workshop participants discussed the 10 issues that were proposed in the conclusions of this report for possible improvements in hazard-mitigation policy. Nine recommendations were unanimously adopted to address these issues.

Recommendation 1 - Alaska Natural Hazards Safety Commission

That a commission be established by the Legislature to provide policy guidance for the Governor and Legislature and help coordinate agency programs in natural hazards. Specific duties of the proposed commission (to be administered by the Office of the Governor) include recommending goals, priorities, and policies for hazard mitigation in the public and private sectors; developing legislation; disseminating public information; assisting in coordinating hazard-mitigation activities at all levels of government; and evaluating and issuing hazard warnings. Members should represent state, federal, and local governments and the private sector in the fields of geology, seismology, hydrology, geotechnical engineering, structural engineering, planning, and emergency services. A bill to establish the Alaska Natural Hazards Safety Commission was introduced in the Alaska Senate on May 6, 1985 (app. A).

Recommendation 2 - State Policy for Hazard Mitigation

That the Governor and Legislature develop policies for hazard mitigation in Alaska that establish long-term commitments and goals:

A. Recognition of state responsibility for the safety of its citizens from major natural hazards and for taking reasonable measures to reduce the loss of life, injury, and property damage.

B. A commitment to ensure long-term financial support for hazard monitoring, mapping, and mitigation, including funding for local governments to develop and maintain risk-reduction programs.

C. A statement of the roles and responsibilities of state and local governments in hazard mitigation that outlines the hazard issues to be relegated to cities and boroughs vs. those of statewide significance (for example, critical facilities and regional hazards) for which state government will retain responsibility.

D. A declaration of state-agency responsibilities and duties for collecting and disseminating technical information on hazards; providing technical, planning, and legal assistance to local governments; regulating construction of critical facilities; reviewing design plans for state-regulated facilities; administering local planning-assistance funds; helping prepare local disaster-preparedness plans; evaluating hazards to state facilities; and managing state hazard-monitoring programs and hazard-warning systems.

Recommendation 3 - Hazard-monitoring Program

That the state establish and support a program that ensures availability of basic data needed to evaluate geologic hazards. Included in the proposed program is a minimal network of seismic-monitoring devices to complement those of the federal government. Support for periodic instrument maintenance, transmission of seismic records to processing facilities, and processing and cataloging of data is necessary. Support for scientists to respond quickly to a significant event, collect data, and evaluate immediate dangers is also necessary.

Although operation of the overall hazard-monitoring program will require a long-term financial commitment, hazard-evaluation studies can be conducted on a project-specific basis. State commitment to a hazard-monitoring program will ensure that data are available for hazard evaluation when needed.

Recommendation 4 - Amendments to the Municipal Code (Alaska Stat. 29) and Other Statutes to Promote Local-government Action in Hazard Mitigation

That amendments authorize or require consideration of geologic hazards in local comprehensive plans, building codes, and ordinances; provide for state financial and planning assistance to help local governments exercise this authority; reduce liability of local governments from hazard-related damages based on lawful actions taken to mitigate hazards; and require that state agencies provide guidelines and technical assistance.

Recommendation 5 - State Regulation of Construction and Major Alteration of Critical Facilities

That critical facilities be reasonably protected from threat by natural processes. Because public health and safety are state responsibilities, state regulation of construction and major alteration of critical facilities is necessary. Existing regulations for safety of dams and health facilities from geologic hazards should be reviewed to be consistent with this recommendation, and new legislation or regulations should be considered to address other important facilities.

Programs to reduce the vulnerability of critical facilities to geologic hazards have four essential components:

A. Requirements for geologic and engineering investigations of the proposed site to evaluate potential geologic hazards and determine maximum probable and, in some cases, maximum credible events.

B. A requirement that siting and design plans for construction or major alteration consider the identified hazards in accordance with design or performance standards established by law for the type of facility in question and that plans be prepared by registered architects or structural engineers.

C. A requirement for central review and approval of the plans and reports by a designated state agency according to facility type (for example, regulation of hospital construction by the Division of State Health Planning and Development, dams by the Division of Land and Water Management, critical utilities by the Alaska Public Utilities Commission, or airports by the Department of Transportation and Public Facilities). The review and permitting agency should have the authority to establish interagency or external boards of consultants to assist in the review process or require independent review by a registered structural engineer and a certified professional geologist.

D. A requirement for verification by site inspection that construction complies with the approved plans.

Recommendation 6 - Hazard-mitigation Requirements for Certain Capital-construction Projects

That capital-construction projects financed by the state be subject to minimum standards to protect life and property from geologic hazards. These requirements should apply to construction projects that are performed directly by or under the supervision of state agencies and local construction projects that are financed with state capital-improvement funds. State policymakers, on the advice of the proposed Natural Hazards Safety Commission (Recommendation 1), should determine which projects are subject to these requirements. Regulated projects should include state-funded facilities that pose a significant risk to public safety if damaged. Examples include state-office buildings, state-financed municipal-office buildings, state-financed indoor-recreation facilities, and state-financed housing complexes. Examples of state-funded facilities that may not be subject to these regulations include warehouses, grain-storage facilities, roads, and parks. Critical facilities constructed with capital-improvement funds should be subject to the more stringent requirements and state-level review proposed in Recommendation 5.

Before a regulated facility is constructed or has major structural alterations, a geologic and engineering site analysis is necessary to identify potential geologic hazards and determine how safe the site is for the proposed use. In addition, a review of design and construction plans is necessary to verify that they conform with applicable codes and ordinances and that identified hazards have been adequately considered. The state agency or local government that administers the project should be responsible for implementing the requirements and reviewing and certifying the reports and plans before construction.

Recommendation 7 - Conditional Availability of Disaster-relief Funds to Promote Hazard Mitigation

That state statutes that provide community disaster relief in the form of grants or loans include positive incentives or requirements for hazard mitigation. Unconditional availability of relief funds for declared disasters may act as an incentive against mitigation measures. There are two general ways in which these incentives or requirements can be applied.

A. Increase state disaster-relief benefits available to local governments that adopt comprehensive hazard ordinances.

B. Require that local governments incorporate hazard-mitigation measures in postdisaster reconstruction to minimize damage from similar future events as a condition for receiving disaster-relief funds.

Recommendation 8 - Improved Capabilities for State Agencies to Provide Technical Assistance to Other Agencies and Local Governments in Hazard Mitigation and Disaster Preparedness

That appropriate state agencies be provided with sufficient funding and flexibility to respond to requests from other agencies and local governments for technical or planning assistance, including performance of routine reviews and participation in special review boards. Flexibility of project budgets (including the establishment of contingency funds) is necessary to provide for unanticipated needs. State agencies that request the assistance or participation of other agencies on review boards may compensate for services through reimbursible services agreements.

Recommendation 9 - State Hazard-notification System

That the state adopt a hazard-notification system to supplement that of the U.S. Geological Survey. Appropriate state agencies should recommend issuance of notices and supply supporting information to the proposed Natural Hazards Safety Commission (Recommendation 1). The Commission should review the recommendations, evaluate possible socioeconomic consequences, and advise the Governor, Legislature, state agencies, and local governments about appropriate responses, defensive actions, and funding alternatives. The state should be prepared to compensate for adverse socioeconomic impacts of hazard notifications through existing disaster-relief programs.

ACKNOWLEDGMENTS

Much of the information used to prepare this report came from personal discussions with the individuals listed below[6], most of whom are closely involved with hazard-mitigation programs at the local, state, and federal levels. I thank them for sharing their personal knowledge, opinions, and suggestions.

J.L. Aho — CH2M Hill, Inc. (Anchorage, Alaska)
R.A. Andrews — Seismic Safety Commission, State of California

[6] Affiliations in 1982.

G.W. Carte	Alaska Tsunami Warning Center (National Oceanic and Atmospheric Administration) and Mayor of Palmer
J.N. Davies	Division of Geological and Geophysical Surveys, State of Alaska
C.L. Davis	State Fire Marshal's Office (Fairbanks), State of Alaska
J.F. Davis	Division of Mines and Geology, State of California
T.E. Gay, Jr.	Division of Mines and Geology, State of California
Ron Goldberg	Division of State Health Planning and Development, State of Alaska
S.B. Hardy	Division of Geological and Geophysical Surveys, State of Alaska, and Planning Commission, Fairbanks North Star Borough
Paul Jenke	Division of Land and Water Management, State of Alaska
W.R. Junge	Colorado Geological Survey
S.F. Mack	Division of Land and Water Management, State of Alaska
G.D. March	Division of Geological and Geophysical Surveys, State of Alaska
Jim McCalpin	Jefferson County, Colorado
J.F. Meehan	Office of the State Architect, State of California
Shirley Meudt	Division of Emergency Services, State of Alaska
C.L. Miller	Division of Municipal and Regional Assistance, State of Alaska
J.L. Mintier	Office of Planning and Research, State of California
Tim Mittendorf	Fairbanks North Star Borough
Paul Morrison	Department of Water Resources, State of California
R.A. Page	U.S. Geological Survey
W.W. Peak	Division of Safety of Dams, State of California
Vern Persson	Division of Safety of Dams, State of California
R.D. Reger	Division of Geological and Geophysical Surveys, State of Alaska
J.R. Riehle	U.S. Geological Survey
W.P. Rogers	Colorado Geological Survey
Phil Schmuck	Department of Local Affairs, State of Colorado
L.L. Selkregg	University of Alaska, Anchorage, and Anchorage Municipal Assembly
J.M. Soule	Colorado Geological Survey
D.W. Sprague	State Mining and Geology Board, State of California
P.A. Stromberg	Seismic Safety Commission, State of California
Dennis Thomason	Division of Emergency Services, State of Alaska
R.G. Updike	Division of Geological and Geophysical Surveys, State of Alaska, and Anchorage Geotechnical Advisory Commission
Ron Watts	Building Department, Municipality of Anchorage
Leila Wise	Department of Natural Resources, State of Alaska
T.M. Wootton	Office of Strong Motion Studies, California Division of Mines and Geology

I especially thank Gay and Junge for arranging and coordinating meetings and interviews in their respective states and Reger for initiating this project and providing many valuable references and suggestions. The report was reviewed by Reger, Updike, Selkregg, and Miller. Selected sections of the document were reviewed by Hardy, March, and Davies.

REFERENCES CITED

Alaska Council on Science and Technology, 1980a, Alaska natural hazards: Research priorities and recommendations: Juneau, 7 p.

_________ 1980b, Alaskan seismology: Research priorities and recommendations: Juneau, 6 p.

Alaska Department of Labor, 1983, Alaska population overview, 1982: Juneau, 116 p.

Alfors, J.T., Burnett, J.L., and Gay, T.E., Jr., 1973, Urban geology master plan for California: Sacramento, California Division of Mines and Geology Bulletin 198, 112 p.

Amimoto, P.Y., 1974, Review of new hospital sites for seismic safety: Sacramento, California Geology, v. 27, no. 5, p. 110-113.

Baker, E.J., and McPhee, J.G., 1975, Land use management and regulation in hazardous areas: A research assessment: Boulder, University of Colorado Institute of Behavioral Science, Program on Technology, Environment and Man Monograph NSF-RA-E-75-008, 124 p.

Burton, Ian, Kates, R.W., and White, G.F., 1978, The environment as hazard: New York, Oxford University Press, 240 p.

California Division of Mines and Geology, 1976, Second report on the Strong-Motion Instrumentation Program: Sacramento, Special Publication 48, 39 p.

_________ 1979, California surface mining and reclamation policies and procedures: Sacramento, Special Publication 51, 40 p.

California Office of Planning and Research, 1980, General plan guidelines: Sacramento, 327 p.

California Seismic Safety Commission, 1977a, A review of the seismic safety element requirement in California: Sacramento, Report SSC 77-01, 31 p.

_________ 1977b, Report on local government implementation of the Special Studies Zones Act: Sacramento, 50 p.

_________ 1981, Annual report to the Governor and the legislature for January 1980 - June 1981: Sacramento, 25 p.

Campbell, Ian, 1976, The influence of geologic hazards on legislation in California: Sacramento, California Geology, v. 30, no. 10, p. 219-223.

Carter, Winn, 1983, The Utah Seismic Safety Advisory Council, in Hays, W.W., ed., A workshop on the 1886 Charleston, South Carolina earthquake and its implications for today: U.S. Geological Survey Open-file Report 83-043, p. 356-359.

Colorado Land Use Commission, 1976, House bill 1041 - Model land use regulations: Denver, 345 p.

_________ 1981, Land use planning in Colorado: Denver, unpublished report, 10 p.

Combellick, R.A., 1984, Potential for earthquake-induced liquefaction in the Fairbanks-Nenana area, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 84-5, 10 p., scale 1:250,000, 1 sheet.

Council of State Governments, 1972, Example state disaster act of 1972; suggested state legislation: Lexington, Kentucky, v. 32, p. 104-128.

__________ 1979, The states and natural hazards: Lexington, Kentucky, 99 p.

Cox, D.C., and Pararas-Carayannis, George, 1976, Catalog of tsunamis in Alaska, revised by J.P. Calebaugh: Boulder, Colorado, World Data Center for Solid Earth Geophysics, National Oceanic and Atmospheric Administration Report SE-1, 43 p.

Davies, J.N., 1983, Seismic, volcanic, and tsunami mitigation in Alaska - An unmet need: Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-11, 13 p.

Decker, Robert, and Decker, Barbara, 1981, The eruptions of Mount St. Helens: Scientific American, v. 244, no. 3, p. 68-80.

EERI Committee on Seismic Risk, 1984, Glossary of terms for probabilistic seismic-risk and hazard analysis: Earthquake Spectra, v. 1, no. 1, p. 33-40.

Federal Emergency Management Agency, 1982, Federal disaster-relief funding for Alaska, January 1960 to January 1982: Seattle, Washington, unpublished data, 23 p.

Fredston, J.A., and Sweet, L.R., 1985, Seward Highway avalanche data base: Alaska Department of Transportation and Public Facilities Research Notes, v. 5, no. 3, 2 p.

Hamilton, R.M., 1978, Earthquake hazards reduction program - Fiscal year 1978, Studies supported by the U.S. Geological Survey: U.S. Geological Survey Circular 780, 36 p.

Hart, E.W., 1975, Guidelines for evaluating the hazard of surface fault rupture and suggested outline for geologic reports on faults: Sacramento, California Division of Mines and Geology Note 49, 2 p.

__________ 1980, Fault-rupture hazard zones in California: Alquist-Priolo Special Studies Zones Act of 1972 with index to special studies zones maps: Sacramento, California Division of Mines and Geology Special Publication 42, 25 p.

Hart, E.W., and Wagner, D.L., 1975, Investigations of surface faulting - A critique: Association of Engineering Geologists Abstracts, 18th Annual Meeting, p. 24.

Hays, W.W., 1979, Program and plans of the U.S. Geological Survey for producing information needed in national seismic hazards and risk assessment, fiscal years 1980-84: U.S. Geological Survey Circular 816, 40 p.

Hays, W.W., and Shearer, C.F., 1981, Suggestions for improving decisionmaking to face geologic and hydrologic hazards, in Hays, W.W., ed., 1981, Facing geologic and hydrologic hazards - Earth-science considerations: U.S. Geological Survey Professional Paper 1240-B, 108 p.

International Conference of Building Officials, 1980, Issues which affect the role of building departments in earthquake hazard mitigation: Whittier, California, p. 12-13.

__________ 1982, Uniform building code (revised ed.): Whittier, California, 780 p.

Ives, J.D., and Krebs, P.V., 1978, Natural hazards research and land-use planning responses in mountainous terrain: The town of Vail, Colorado, Rocky Mountains, U.S.A.: Arctic and Alpine Research, v. 10, no. 2, p. 213-222.

2454 20130

Johnson, J.B., 1982, An evaluation of the Alaska Avalanche and Fire Weather Forecast System: Fairbanks, University of Alaska Geophysical Institute unpublished report to the Alaska Division of Geological and Geophysical Surveys, 57 p..

Joint Federal-State Land-Use Commission, 1979, Summary of major land issues in Alaska: Anchorage, Published Report 39, 128 p.

Junge, W.R., and Shelton, D.C., 1978, The geological review process: Denver, Colorado Geological Survey, 4 p.

Leighton, F.B., 1982, Overcoming landslide hazards: Professional Surveyor, v. 2, no. 3, p. 16-26.

Mann, A.E., 1979, The Field Act and California schools: Sacramento, California Seismic Safety Commission Report SSC 79-02, 77 p.

March, G.D., and Robertson, L.G., 1982, Snow avalanche atlas, Seward Highway, south-central Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 81, 168 p., scale 1:63,360, 3 sheets.

Meyers, Herbert, 1976, A historical summary of earthquake epicenters in and near Alaska: National Oceanic and Atmospheric Administration Technical Memorandum EDS NGSDC-1, 57 p.

Miller, D.J., 1960, Giant waves in Lituya Bay, Alaska: U.S. Geological Survey Professional Paper 354-C, 86 p.

Miller, R.D., and Dobrovolny, Ernest, 1959, Surficial geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Bulletin 1093, 128 p., scale 1:63,360, 6 sheets.

Miller, T.P., 1976, Augustine Volcano: Alaska Geographic, v. 4, no. 1, p. 17-28.

Mintier, J.L., and Stromberg, P.A., 1982, Seismic safety at the local level: Does planning make a difference?: Sacramento, California Seismic Safety Commission, 26 p.

National Research Council, 1973, The great Alaska earthquake of 1964 - Summary and recommendations: Washington, National Academy of Sciences, 291 p.

Nichols, D.R., and Campbell, C.C., eds., 1971, Environmental planning and urban geology: Washington, U.S. Department of the Interior and U.S. Department of Housing and Urban Development, 204 p.

Office of Emergency Preparedness, 1972, Disaster preparedness: Report to Congress: Washington, D.C., v. 1, 184 p.

Olson, R.A., and Scott, Stanley, 1980, Preparing for earthquakes: Where does California stand?: Berkeley, University of California Institute of Governmental Studies California Data Brief, v. 4, no. 3, 6 p.

Péwé, T.L., 1982, Geologic hazards of the Fairbanks area, Alaska: Alaska Division of Geological and Geophysical Surveys Special Report 15, 109 p.

Reed, K.M., ed., 1981, The U.S. Geological Survey in Alaska, 1981 programs: U.S. Geological Survey Circular 843, 111 p.

Rogers, W.P., Ladwig, L.R., Hornbaker, A.L., Schwochow, S.D., Hart, S.S., Shelton, D.C., Scroggs, D.L., and Soule, J.M., 1974, Guidelines and criteria for identification and land-use controls of geologic hazard and mineral resource areas: Denver, Colorado Geological Survey Special Publication 6, 146 p.

Rold, J.W., 1978, The communication of information for geologic-hazard mitigation - The Colorado example: Public meeting, Denver, Colorado, unpublished report prepared for public meeting on May 15, 1978, 14 p.

Rollins, A.M., 1978, Census-Alaska: Number of inhabitants, 1792-1970: Anchorage, University of Alaska, 117 p.

 2458 20130

Schnell, M.L., and Herd, D.G., 1983, National Earthquake Hazards Reduction Program: Report to the U.S. Congress - Overview: U.S. Geological Survey Circular 918, 65 p.

Scott, Stanley, 1981, Independent review of critical facilities, with special emphasis on state-federal relationships and dam safety: Sacramento, California Seismic Safety Commission Report SSC-81-01, 55 p.

Seed, H.B., and Wilson, S.D., 1966, The Turnagain Heights landslide in Anchorage, Alaska: Berkeley, University of California Soil Mechanics and Bituminous Materials Research Laboratory, 37 p.

Selkregg, L.L., Crittenden, E.D., and Williams, Norman Jr., 1970, Urban planning in the reconstruction, in The Great Alaska Earthquake of 1964, Human Ecology Volume: Washington, National Research Council, National Academy of Sciences, p. 186-242.

Selkregg, L.L., Ender, R.L., Johnson, S.F., Kim, J.C.K., Gorski, S.E., Preuss, Jane, and Kelso, Duncan, 1984, Seismic hazard mitigation: Planning and policy implementation - The Alaska case: Anchorage, University of Alaska, 332 p.

Slosson, J.E., 1975, Legislation related to earthquakes: Sacramento, California Geology, v. 28, no. 2, p. 37.

Stewart, R.M., Hart, E.W., and Amimoto, P.Y., 1977, The review process and the adequacy of geologic reports: Sacramento, California Geology, v. 30, no. 10, p. 224-229.

Tarr, R.S., and Martin, Lawrence, 1912, The earthquakes at Yakutat Bay, Alaska, in September, 1899: U.S. Geological Survey Professional Paper 69, 234 p.

Troxel, B.W., 1982, Limit of the law (letter to the editor): Geotimes, v. 27, no. 3, p. 9-10.

Turner, R.H., Nigg, J.M., Heller Paz, Denise, and Shaw Young, Barbara, 1979, Earthquake threat: The human response in southern California: Los Angeles, University of California Institute for Social Science Research, p. 92.

__________ 1980, Community response to earthquake threat in southern California: Los Angeles, University of California Institute for Social Science Research, Part 5, p. 64-70.

Ulery, C.A., and Updike, R.G., 1983, Subsurface structure of the cohesive facies of the Bootlegger Cove Formation, southwest Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 84 (in cooperation with the U.S. Geological Survey Office of Earthquake studies), 5 p., scale 1:15,840, 3 sheets.

Updike, R.G., 1984, Liquefaction-susceptibility analysis for foundation soils, Knik River bridge, Glenn Highway, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 84-26 (in cooperation with the U.S. Geological Survey Office of Earthquake Studies), 33 p.

University of Alaska, 1983, Research annual report, 1981-82: Fairbanks, 121 p.

University of Alaska Geophysical Institute, 1982, Annual report, 1981-82: Fairbanks, 254 p.

U.S. Geological Survey, 1977, Warning and preparedness for geologic-related hazards: Federal Register, v. 42, no. 70, p. 19292-19296.

__________ 1981, Goals, strategies, priorities and tasks of a national landslide hazard-reduction program: U.S. Geological Survey Open-file Report 81-987, 91 p.

__________ 1984, Revision of terminology for Geologic Hazard Warnings: Federal Register, v. 49, no. 21, p. 3938-3939.

White, G.F., and Haas, J.E., 1975, Assessment of research on natural hazards: Cambridge, Massachusetts, The MIT Press, 487 p.

Woodward-Clyde Consultants, 1980a, Assessment of review processes for seismic safety in California: San Francisco, unpublished report prepared for the California Seismic Safety Commission, 44 p.

__________ 1980b, Assessment of public policy regarding lifelines and critical facilities in California: San Francisco, unpublished report prepared for the California Seismic Safety Commission, 2 v., 115 p.

APPENDIX A

Introduced: 5/6/85
Referred: State Affairs and Finance

THE SENATE

BY STURGULEWSKI, V. FISCHER, IN RODEY AND ZHAROFF

SENATE BILL NO. 310
IN THE LEGISLATURE OF THE STATE OF ALASKA
FOURTEENTH LEGISLATURE - FIRST SESSION

A BILL

For an Act entitled: "An Act establishing the Alaska Natural Hazards Safety Commission."

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF ALASKA:

Section 1. FINDINGS. The legislature finds that

(1) although the state has made significant improvements in disaster preparedness since the great earthquake of 1964, there has been little corresponding improvement in measures to reduce the disaster potential of natural hazards and, consequently, to reduce dependence on disaster relief;

(2) there is a pressing need to provide a consistent policy framework and a means for continuing coordination of hazard-related programs and public safety practices at all governmental levels and in the private sector; this need is not being addressed by any continuing state government organization;

(3) through concerted efforts coordinated by a Natural Hazards Safety Commission, the state can make long-term progress toward mitigating the effects of natural hazards on persons and property, thereby reducing the costs of responding to and recovering from natural hazards.

Sec. 2. AS 44.19 is amended by adding new sections to read:

ARTICLE 15. ALASKA NATURAL HAZARDS SAFETY COMMISSION.

Sec. 44.19.241. COMMISSION ESTABLISHED. The Alaska Natural Hazards Safety Commission is established in the Office of the Governor.

Sec. 44.19.242. MEMBERSHIP. (a) The commission is composed of 11 members appointed by the governor for terms of three years. A member holds office until a successor is appointed and confirmed. A vacancy is filled for the unexpired term. The governor shall appoint to the commission a representative from the University of Alaska, a representative from local government, a representative from the Department of Natural Resources, a representative from the Department of Military and Veterans' Affairs, a representative from an appropriate federal agency and shall appoint the remaining six members from members of the public who are knowledgeable in the

2455 20130

fields of geology, seismology, hydrology, geotechnical engineering, structural engineering, emergency services, or planning.

(b) The commission shall elect annually from its members a chairman and vice-chairman. A majority of the commission may vote to replace an officer of the commission.

(c) Eight members constitutes a quorum.

(d) Commission members receive no compensation but are entitled to travel and per diem authorized for boards and commissions under AS 39.20.180.

Sec. 44.19.243. POWERS AND DUTIES. (a) The commission shall

(1) recommend goals and priorities for hazard mitigation to the public and private sectors;

(2) recommend policies to the governor and the legislature, including needed research, mapping, and monitoring programs;

(3) offer advice on coordinating disaster preparedness and hazard-mitigation activities of government at all levels, review the practices for recovery and reconstruction after a natural disaster, and recommend improvements to mitigate losses from similar future events;

(4) gather, analyze, and disseminate information of general interest on hazard mitigation;

(5) establish and maintain necessary working relationships with other public and private agencies;

(6) review predictions and warnings issued by the federal government, research institutions, and other organizations and persons and suggest appropriate responses at the state and local level; and

(7) review proposed hazard notifications and supporting information from state agencies, evaluate possible socioeconomic consequences, recommend that the governor issue formal hazard notifications when appropriate, and advise state and local agencies of appropriate responses.

(b) The commission may

(1) advise the governor and the legislature on disaster preparedness and hazard mitigation and on budgets for those activities, and recommend legislation or policies to improve disaster preparedness or hazard mitigation;

(2) conduct public hearings;

(3) appoint committees from its membership and appoint external advisory committees of ex-officio members; and

(4) accept grants, contributions, and appropriations from public agencies, private foundations, and individuals.

Sec. 44.19.244 DEFINITIONS. In AS 44.19.241 - 44.19.244

(1) "commission" means the Alaska Natural Hazards Safety Commission;

(2) "disaster preparedness" means establishing plans and programs for responding to and distributing funds to alleviate losses from a disaster as defined in AS 26.23.230;

2456 20130

(3) "hazard mitigation" or "mitigation" mean activities that prevent or alleviate the harmful effects of natural hazards to persons and property, including identification and evaluation of the hazards, assessment of the risks, and implementation of measures to reduce potential losses before a damaging event occurs.

Sec. 3. AS 44.66.010(a) is amended by adding a new paragraph to read:

(13) Alaska Natural Hazards Safety Commission (AS 44.19.241) June 30, 1989.

Sec. 4. Notwithstanding AS 44.19.242 enacted by sec. 2 of this Act, four of the initial members of the Alaska Natural Hazards Safety Commission shall serve terms of two years and three initial members shall serve terms of four years.

Sec. 5. Nothing in this Act is intended to transfer to the commission the authorities and responsibilities of other state agencies, boards, councils, or commissions or of local governments.

APPENDIX B
Glossary[7]

acceptable risk - A level of risk that can be accommodated without undue hardship and represents a realistic goal for design requirements for engineered structures.

active fault - a fault that, based on historical, seismological, or geological evidence, has a high probability of producing an earthquake.

avalanche - see debris avalanche, slushflow avalanche, and snow avalanche.

building code - a document that specifies minimum design and construction requirements for structures.

calculated risk - the estimated total risk to a facility or the public that corresponds to a specific level of mitigation.

chronic hazard - a hazard that produces small, persistent or episodic changes in the earth's surface that may be minor over short periods of time, but may cause major damage to structures over long periods of time.

creep - slow, more or less continuous downslope movement of soil or rock under gravitational stresses.

critical facility - a structure that houses or serves many people or otherwise poses unusually high hazards to public health and safety if the structure is damaged or malfunctions.

debris avalanche - a very rapid sliding or flowage of initially coherent soil and rock; a very rapid debris flow.

debris flow - a moderately rapid downslope flowage of soil, rock, and water that is triggered almost invariably by unusually heavy rain.

design criteria, design standards - minimum standards for layout, materials, structural properties, and construction of a facility (for example, building codes, design requirements in flood plains, or contract specifications).

design event - intensity of a natural event that is used as the basis for a structure's design.

design forces, design loads, design motions - static forces or motions at a site (for example, loads, displacements, velocities, or accelerations) that are used as the basis for a structure's design.

disaster - an event that causes great harm to people or property over a short period of time.

---

[7] Most definitions modified from Bates and Jackson, 1980; EERI Committee on Seismic Risk, 1984; and Woodward-Clyde Consultants, 1980b.

disaster preparedness - plans, procedures, funds, facilities, and supplies established to respond to a natural disaster, distribute financial losses, and allow for an orderly recovery.

disaster recovery - the process of restoring services; relocating or rebuilding homes, businesses, and public facilities; and reestablishing normal social and economic activities.

disaster relief - provision of grants and loans to assist individuals, businesses, and state and local governments in recovering from a disaster.

disaster response - implementation of disaster-preparedness plans and other postdisaster activities (for example, search and rescue, debris removal, security, and provision of food, water, shelter, and medical aid) to restore public safety and facilitate recovery.

earthquake - a sudden motion or vibration in the earth caused by an abrupt release of energy.

fault - a fracture or fracture zone in the earth's crust along which there has been displacement of the sides relative to one another and parallel to the fracture.

frost heaving - the uneven lifting and deformation of the ground surface that results from freezing of ground water and growth of ground-ice masses.

gelifluction - solifluction in an area underlain by frozen ground.

geologic hazard - a natural or man-made geologic condition that potentially endangers life and property (for example, landslide, earthquake, flood, volcanic eruption, ground subsidence, erosion, or snow avalanche).

geotechnical - pertaining to the application of information about the earth's crust and surface materials to solve civil-engineering problems.

hazard - see natural hazard.

hazard evaluation - data collection and analysis to identify and describe a natural hazard and determine its potential severity, the area affected, and probability of occurrence.

hazard mitigation - policies and activities undertaken to prevent or minimize the likelihood of property damage and injuries from natural hazards (includes hazard evaluation, risk assessment, and hazard reduction).

hazard reduction - the application of technical information about hazards to develop policies and procedures for land use, facility design and construction, protection works, and warning systems to reduce the likelihood of property damage or injury.

heave - uneven uplift of the ground surface caused by expansion or displacement, such as from swelling clay, seepage pressure, or frost action.

intensity - a qualitative or quantitative measure of an event's severity at a specific site.

landslide - the perceptible, downward and outward sliding of soil, rock, and vegetation under gravitational influence.

magnitude (of an earthquake) - a measure of the strength or total energy released by an earthquake.

mappability - the relative ease of accurately locating or delineating a geologic hazard on a map at a scale appropriate for land-use planning (usually 1 in. = 1 mi or greater).

mass movement - the downslope displacement of a portion of the land surface as a unit, as in creep, landslide, flow, or avalanche.

maximum credible event - the most severe event of a given type (for example, flood, earthquake, or landslide) that can be expected at a site, considering the known natural processes or conditions in the area.

maximum probable event - the most severe event of a given type (for example, flood, earthquake, or landslide) that can reasonably be expected to occur within the design life of a facility; often defined as the event that occurs once every 100 yr.

mitigation - see hazard mitigation.

mudflow - a rapid downslope flow of predominantly fine-grained material generally combined with a large amount of water; usually flows along an active or abandoned stream course.

natural hazard - a natural condition that may endanger life and property (includes all geologic hazards plus nongeologic conditions like drought, tornados, hail, forest fires, and lightning).

nodal point - a location in a structure that vibrates very little relative to other locations at a given oscillation period during an earthquake.

nuée ardente - a rapidly flowing, turbulent, gaseous cloud (sometimes incandescent) that is erupted from a volcano; contains ash and other explosively ejected volcanic debris in its lower part.

performance criteria - minimum standards for the operational capabilities of a facility during and after an event of given intensity (for example, the services that a hospital must be capable of continuing after a major earthquake, or the volume of water that a dam must be capable of retaining during a 100-yr flood).

protection works - structural improvements made in hazardous areas to limit the adverse effects of natural events (examples include flood-control dams and levees, retaining walls, slope-drainage systems, refurbishing of old buildings against earthquake damage, and mobile-home anchoring systems).

pyroclastic flow - a rapidly moving, turbulent mixture of mostly fine-grained material and gas ejected explosively from a volcano.

residual risk - the difference between calculated risk and acceptable risk; represents the risk that can be reasonably reduced through mitigation.

risk - the probability of a given level of social or economic damage or loss resulting from one or more natural hazards based on the probability of the event occurring, its severity, location, and the probability that people or property will be adversely affected.

safety factor (engineering) - the ratio of a material's maximum strength (for example, soil, rock, concrete, or steel) to the probable maximum load to be applied to it.

seiche - oscillatory motion of a body of water in which the period of oscillation is determined by the dimensions of the containing basin. Onshore runup of the resulting waves has been known to exceed elevations of 1,000 ft.

seismic - pertaining to earthquakes or other natural or man-made vibrations in the earth.

siltation - accumulation of predominantly fine-grained sediment in a basin or behind a natural or man-made structure that obstructs the flow of sediment-laden water.

slushflow avalanche - a powerful flow of wet snow, soil, rock, and debris that occurs primarily in arctic and subarctic mountainous regions during rapid spring melting of the seasonal snow cover.

snow avalanche - the rapid falling or sliding of a large mass of snow that often incorporates considerable soil, rock, and debris.

solifluction - the slow, viscous, downslope flow of water-saturated soil.

subsidence - uneven sinking of the ground surface caused by regional tectonic lowering of the crust or, locally, by collapse of underground solution cavities, melting of massive ground ice, soil compaction, or shrinking of clay-rich soils on drying.

tsunami - a large gravitational sea wave produced by a volcanic eruption or submarine earthquake.

volcanic bomb - a mass of expelled lava that is rounded like a bombshell as it falls.

warning system - a means of notifying the public of an impending catastrophic event so that preparations can be made, the area can be evacuated, and disaster-response plans can be implemented.

APPENDIX C
Acronyms

AAFWFS - Alaska Avalanche and Fire Weather Forecast System
ACST - Alaska Council on Science and Technology
ADES - Alaska Division of Emergency Services
ASHA - Alaska State Housing Authority
BLM - Bureau of Land Management (U.S.)
CEQA - California Environmental Quality Act
CGS - Colorado Geological Survey
DEC - Department of Environmental Conservation (Alaska)
DES - Division of Emergency Services (Alaska)
DGGS - Division of Geological and Geophysical Surveys (Alaska)
DLWM - Division of Land and Water Management (Alaska)
DMG - Division of Mines and Geology (California)
DMRA - Division of Municipal and Regional Assistance (Alaska)
DNR - Department of Natural Resources (Alaska)
DOT/PF - Department of Transportation and Public Facilities (Alaska)
DSD - Division of Safety of Dams (California)
DWR - Department of Water Resources (California)
EHRP - Earthquake Hazards Reduction Program (U.S.)
FEMA - Federal Emergency Management Agency
FERC - Federal Energy Regulatory Commission
FNSB - Fairbanks North Star Borough
ICBO - International Conference of Building Officials
NOAA - National Oceanic and Atmospheric Administration (U.S.)
NSF - National Science Foundation
OMB - Office of Management and Budget (U.S.)
SCEPP - Southern California Earthquake Preparedness Program
SHAP - Seward Highway Avalanche Project (Alaska)
SHPD - Office of Statewide Health Planning and Development (California)
SMARA - Surface Mining and Reclamation Act (California)
SMGB - State Mining and Geology Board (California)
SMIP - Strong-motion Instrumentation Program (California)
SSC - Seismic Safety Commission (California)
UBC - Uniform Building Code
USFS - U.S. Forest Service
USGS - U.S. Geological Survey

REDUCING LOSSES FROM EARTHQUAKES THROUGH PERSONAL PREPAREDNESS

by

William J. Kockelman
U.S. Geological Survey
Menlo Park, California 94025

PREFACE

After estimating long-term probabilities for future great earthquakes in the Aleutians, Jacob (1984) concludes that "average recurrence periods for great Aleutian earthquakes measure approximately 80 years. In seismic gaps with no great earthquakes for the past 80 years or more, the conditional probabilities for great events in the next 20 years are significantly higher than in recently ruptured zones (99 to 30% versus 17 to 9%). The Shumagin, Yakataga, and perhaps the Unalaska seismic gaps appear to have the highest presently known probability rates for a great earthquake anywhere in the U.S."

INTRODUCTION

Actions to reduce earthquake hazards can be divided into five phases: two before the event, one during the event, and two after the event. These five phases are: (1) pre-event mitigation techniques which may take 1 to 20 years, (2) preparedness measures which may take 1 to 20 weeks, (3) response during the event, (4) recovery operations following the event which may take 1 to 20 weeks, and (5) post-event reconstruction activities which may take 1 to 20 years. These times vary depending upon the magnitude of the earthquake and the resources available to the community and metropolitan area.

Preparedness is one phase of hazard reduction; personal preparedness is just one aspect of that phase. For example, the Council of State Governments (1976) suggests an outline for a comprehensive state emergency preparedness plan and the Western States Seismic Policy Council (1984, Appendix A) reports on the status of the States' earthquake preparedness projects. The Southern California Earthquake Preparedness Project (1983), through "planning partner" arrangements with selected public jurisdictions and private entities, has developed planning guidelines for responding to, and recovering from, an earthquake. The Federal Emergency Management Agency recently funded the Central United States Earthquake Consortium -- the nation's first effort to develop and coordinate earthquake preparedness activities in a region composed of several states. Corporate, utility, and governmental preparedness (as well as mitigation, response, recovery, and reconstruction) can be very complex; discussion of these is beyond the scope of this paper.

A prerequisite to personal preparedness is familiarity with and concern about all five of the hazard-reduction phases. For example, strengthening the structure of the home, storing water, and showing family members how to shut off the electric-, gas-, and water-supply lines are only a part of one phase -- personal preparedness. Equally important are other phases which might include picking up children from an evacuated school, securing heavy objects at the work place as well as in the home, and retrofitting the commuter-highway overpasses needed to reunite a family. For purposes of this paper, we will introduce all five hazard-reduction phases.

MITIGATION TECHNIQUES

Many long-range techniques for reducing earthquake hazards before the event are available to planners, engineers, and decisionmakers. Some of these are well known to the planning profession, such as public acquisition of hazardous areas; or to the engineering profession, such as designing and constructing earthquake-resistant structures. Others are obvious, such as warning signs and regulations. Still others have been successfully used in solving landslide, flood, and soil problems, but have not heretofore been applied to earthquake hazards.

These and other techniques are in List 1 under the general headings of discouraging new development, removing or converting existing unsafe development, providing financial incentives or disincentives, regulating new development, protecting existing development, and ensuring the construction of earthquake-resistant structures.

These techniques may be used in a variety of combinations to help reduce both existing and potential earthquake hazards. Most of them are long range, taking from 1 to 20 years or more to prepare, adopt, and execute. Many of the techniques have been discussed and illustrated by William Spangle and Associates, and others (1980), Brown and Kockelman (1983), Kockelman (1983), Blair and Spangle (1979), Nichols and Buchanan-Banks (1974), and Jaffee and others (1981).

PREPAREDNESS MEASURES

Preparedness measures are necessary because long-range mitigation techniques can not completely reduce all damage and all threats to life safety. In addition, preparedness is applicable to home, school, and place of work and enhances disaster response. Important personal preparedness measures include:

- Storing emergency supplies for survival, sanitation, safety, and cooking.
- Knowing first-aid and water-purification procedures.
- Developing or being familiar with evacuation routes and deciding on a place for the reunion of the family.
- Learning how to shut off gas-, electric-, and water-supply service lines.
- Securing valuable and nonstructural objects to prevent damage or personal injury.
- Keeping portable extinguishers and garden hoses ready for fighting fires.

Preparedness measures can be taken anywhere from 1 to 20 weeks or more before an event. An excellent booklet by Lafferty (undated) on earthquake preparedness includes: suggested topics for family discussions, family-member assignment check list, community-awareness check list, list of food items for a 2-week emergency supply, suggested replacement periods for stored food, and

List 1. Some mitigation techniques for reducing earthquake hazards

Discouraging new development in hazardous areas by:

Adopting seismic-safety or alternate-land-use plans
Developing public-facility and utility service-area policies
Disclosing the hazards to potential buyers
Enacting Presidential and gubernatorial executive orders
Informing and educating the public
Posting warnings of potential hazards

Removing or converting existing unsafe development through:

Acquiring or exchanging hazardous properties
Clearing and redeveloping blighted areas before an earthquake
Discontinuing uses that do not conform with zoning regulations
Reconstructing damaged areas after an earthquake
Removing unsafe structures

Providing financial incentives or disincentives by:

Adopting lending policies that reflect risk of loss
Clarifying the legal liability of property owners
Conditioning Federal and state financial assistance
Making public capital improvements in safe areas
Providing tax credits or lower assessments to property owners
Requiring nonsubsidized insurance related to level of hazard

Regulating new development in hazardous areas by:

Creating special hazard-reduction zones and regulations
Enacting subdivision ordinances
Placing moratoriums on rebuilding
Regulating building setbacks from known hazardous areas
Requiring appropriate land-use zoning districts and regulations

Protecting existing development through:

Creating improvement districts that assess costs to beneficiaries
Operating monitoring, warning, and evacuating systems
Securing building contents and nonstructural components
Stabilizing potential earthquake-triggered landslides
Strengthening or retrofitting unreinforced masonry buildings

Ensuring the construction of earthquake-resistant structures by:

Adopting or enforcing modern building codes
Conducting appropriate engineering, geologic, and seismologic studies
Investigating and evaluating risk of a proposed site or structure
Repairing, strengthening, or reconstructing after an earthquake
Testing and strengthening or replacing critical facilities

sample menus for the first 72 hours after an earthquake. Another booklet, by the American Red Cross (1982), includes: extensive lists of home-emergency supplies, procedures for purifying water, first-aid instructions, and an earthquake-survival test. These preparedness measures provide not only for increased safety and reduced damage, but have the additional value of giving people confidence in their ability to cope with a disaster.

Many of us are overwhelmed by the broad range of techniques, measures, operations, and activities available for reducing earthquake hazards; this feeling is completely justified. However, we should make an effort to be personally prepared. There are several reasons **not** to be prepared for an earthquake; those reasons are restated (and refuted) in List 2.

Three personal preparedness measures are discussed here: inspecting and strengthening the home; organizing the neighborhood, school, church, or civic group; and securing heavy or valuable objects around the home, school, or workplace.

Inspecting and Strengthening the Home

The 1971 San Fernando earthquake provided lessons in the types of home structures most likely to fail. Potential weaknesses include numerous cracks that penetrate the entire foundation, unbolted sill plates, cripple walls, lack of solid sheeting or shear panels, unreinforced masonry chimneys, poorly attached masonry veneer, lack of diagonal bracing, large window openings, and untied terra cotta or slate roofing tiles.

A special report by Sunset Magazine (1982) on **Getting Ready for a Big Quake** provides general instructions on how to check your home for both structural and nonstructural safety, and how to make it more earthquake resistant. Additional reference material includes **The Home Builders Guide for Earthquake Design** by Shapiro, Okino, Hom, and Associates (1980), **An Earthquake Advisor's Handbook for Wood-Frame Houses** edited by Chusid (1980), and **Peace of Mind in Earthquake Country** by Yanev (1974).

List 2. -- **Seven Reasons Not to Get Ready for an Earthquake**

Reason #1 If a bad earthquake hits, we'll all be dead anyway.
Not true. There may be a lot of fatalities, but many more people will be alive -- and your loved ones may be among those who need your help. This is similar to the "why wear your seat belt" response: defeatist.

Reason #2 If I had food, I'd have to defend it with a gun against all the people who wouldn't have food.
Deciding to store emergency supplies is a personal decision. Some people store much more than they will need, in order to be able to give to others. Other people are organizing their entire block or neighborhood so they aren't the only ones with food. Cooperation is a key to survival. Naturally, you will have to make up your own mind. But ask yourself honestly: how would you react if faced with a life or death situation? Would you steal or kill for your family members? Why not prepare, and spare yourself that predicament.

Reason #3 The rest of the country will come to our aid. Helicopters will be here in no time to drop food and water.
Take a second to think about recent disasters in this country. First of all, none have been on the scale of a good-sized earthquake -- the kind we already know can happen in the Bay Area. Federal or state aid takes days to organize and mobilize; meanwhile, you are on your own. Transportation of emergency supplies will be hampered by destroyed highways, overpasses, train tracks, etc.

Reason #4 I have enough food in my house to last quite a while.
Take another look. In many homes, much of that food is perishable (in your refrigerator or freezer, which may no longer work) or unsuitable (requires cooking or is nutritionally forgettable --marshmallows, chocolate chips, etc.). Water is even more important. You can live for awhile without food, but it is curtains if you don't have water. If you have a pool in your back yard and a water filter in your emergency kit, you are in A-1 shape. Don't depend on a water heater tank; pipes may rupture and the water may leak out.

Reason #5 I don't have any room to store emergency goods.
Some kits are quite compact and can fit in a linen closet or under a bed. In a small apartment, emergency food and equipment may mean making some changes. But what is more important? 15 pairs of shoes on the closet floor, or food and water that could save your life???

Reason #6 Storing food in your house is useless, because the house will fall down on it. It could be inedible, or impossible to get to.
Possible. If you have a garden shed or a free-standing garage, that might be a safer storage area. But again, wouldn't you rather be trying to figure out how to get to the food after your house falls down, than trying to figure out where to buy, beg, or steal water and food?! If this is a big concern to you, you could have your house inspected to see how likely it is to withstand an earthquake, and what structural changes could improve those chances.

Reason #7 It will never happen to me.
Talk to someone from Coalinga.

Source: Mele Kent (1983) from an interview with Randy Shadoe; reprinted by permission.

Organizing the Neighborhhod

State and Federal assistance usually takes days to organize and mobilize; see List 2, reason nos. 2 and 3. However, immediate help is usually available from your neighbors and friends. According to Popkin, a study by Haas and others (1977, p. xxix) suggests that "families in the United States rely on institutional support for post-disaster assistance, with help from relatives and friends or self-help playing only a small part in their recovery." Neighborhood groups can very often bridge this gap and can influence government decisionmakers in order to expedite recovery operations and reconstruction activities. Sunset Magazine (1982) gives an outline for organizing a neighborhood preparedness group and provides a sample registration form. The Southern California Earthquake Preparedness Project (1983) has developed a neighborhood self-help planning guide which tells how to set up a community program.

Securing Nonstructural Objects

People have been hurt by falling light fixtures, flying glass, overturning shelves, and spilled chemicals. The Federal Emergency Management Agency (1981, Table 2) estimates that one-third of the property lost in future earthquakes in California will be attributed to building contents. Such contents are only one part of the nonstructural portion of a building.

Nonstructural damage is caused by object inertia or building distortion. For example, if an office computer or file cabinet is shaken, only friction will restrain it from overturning or falling on its user. As the structure bends or distorts, windows, partitions, and other items set in the structure are stressed, causing them to shatter, crack, or spring out of place. Numerous protective countermeasures are available, including:

- o Bolting down sharp or heavy office machines, equipment, and fixtures.
- o Tying artwork to the walls.
- o Connecting filing cabinets together at the top and tying them to the wall.

- Zigzagging free-standing, movable partitions.
- Using smaller, operable, and wood-frame windows to accommodate structural drift.
- Installing locks on cupboards.
- Boxing large containers that contain hazardous chemicals.
- Strapping hot-water heaters to wall studs with plumber's tape.

An excellent book on reducing the risk of nonstructural earthquake damage was prepared for The Southern California Earthquake Preparedness Project by Reitherman (1983). It describes typical conditions found in office, retail, and government buildings. Measures are suggested for restraining over 20 nonstructural building components, such as office machines, electrical equipment, file cabinets, built-in partitions, suspended ceilings, exterior ornamentation, elevators, piping, stairways, and parapets. Each component is rated for existing and upgraded vulnerability for life-safety hazards, percent of replacement-value damaged, and post-earthquake outages for three levels of shaking intensity (Figure 1).

RESPONSE DURING THE EVENT

According to Blair and Spangle (1979) "individuals are virtually helpless during the course of an earthquake. They must 'ride it out' wherever they happen to be at the time the earthquake strikes..... Helplessness is confined to those seconds when the ground is shaking; man has the knowledge and ability to avert many of the damaging effects of earthquakes." An enlightened response can occur during and immediately following the event. It includes short-term emergency assistance, and should be geared to reduce secondary damage and speed recovery operations. During and immediately after an earthquake, appropriate responses could include:

- Ducking under a desk, table, or bed; or standing in a doorway.
- Remaining calm and reassuring children and pets.
- Avoiding window openings, high buildings, power poles, heavy tile roofs, and overhanging structures.
- Fighting fires, escaping, or evacuating.
- Drawing and conserving water.

- Shutting off gas-, water-, and electric-supply lines.
- Checking for injuries.
- Listening to radio and television for emergency bulletins.
- Checking for damage to building, sewers, and drains.
- Cleaning up broken glass and spilled toxins.
- Assisting in neighborhood or workplace search-and-rescue operations.

Brochures such as **When an Earthquake Strikes** by the Santa Clara County Girl Scout Council (undated), **Safety Tips for Washington Earthquakes** by the Washington State Department of Emergency Services (undated), and **Earthquakes -- How to Protect Your Life and Property** by Gere and Shah (1980) contain excellent advice.

Lafferty (undated) provides a check list of responses for when an earthquake strikes, safety rules to be followed during an earthquake, and a form for authorizing medical treatment of minors. The American Red Cross (1982) also provides advice on coping with childrens' reactions to earthquakes and instructions for turning off gas-, electric-, and water-supply lines.

RECOVERY OPERATIONS

Recovery operations take from 1 to 20 weeks and may continue until all public facilities, institutions, and utilities return to normal. Repair of critical facilities* may have first priority in a community or metropolitan area.

---

*The term "critical facilities" is used here to include:

(a) Lifelines such as major communication, utility, and transportation facilities, and their connection to emergency facilities;
(b) Unique or large structures whose failure might be catastrophic, such as dams or buildings where explosive, toxic, and radioactive materials are stored or handled;
(c) High-occupancy buildings, such as schools, churches, hotels, offices, auditoriums, and stadiums; and
(d) Emergency facilities such as police and fire stations, hospitals, communications centers, and disaster-response centers.

2555 20130

Personal-recovery activities include:

- Ensuring safe passage to or from the home and its rooms.
- Repairing power and telephone lines.
- Repairing water-, gas-, and sewer-service lines.
- Inspecting structures and posting warning signs if they are found unsafe for habitation.
- Assisting neighborhood or community groups that are assigned burial, temporary-shelter, vaccination, and transport tasks.

Personal recovery is difficult to separate from the recovery of the community or metropolitan area. For example, Rubin (1978) has written a helpful booklet on **Natural Disaster Recovery Planning for Local Public Officials** which includes: a discussion of the impact of a disaster on a community, warning signs that indicate insufficient community preparedness, and examples of successful community recovery. The Pan-American Health Organization (1981) has provided easy-to-read comprehensive procedures for emergency relief including: management of mass casualties; disease control; management of relief supplies; and the planning, layout, and management of temporary settlements and refugee camps. Examples of continuing response and recovery activities for a volcanic eruption were given in a series of **Technical Information Network** bulletins released by the Federal Coordinating Office (1980).

RECONSTRUCTION ACTIVITIES

The reconstruction phase usually involves strengthening weakened or damaged structures, razing irreparable or obsolete buildings, or commencing a neighborhood or community redevelopment program. This phase, taking from 1 to 20 years or more, provides a unique opportunity to reduce future damage and loss of life from similar events by:

- Relocating structures to less hazardous areas; for example, out of a fault-rupture zone or landslide area.
- Constructing earthquake-resistant structures, particularly critical facilities.

- Lowering population densities in hazardous areas.
- Realigning infrastructures -- pipelines, power lines, and transportation routes -- to minimize the transversing of hazardous areas.
- Introducing redundancy into critical facilities; for example, alternate transportation and pipeline routes across fault-rupture zones.

The post-event reconstruction phase can also be considered a mitigation technique (see List 1). Other techniques which may be used in conjunction with this one are moratoriums on rebuilding, regulations concerning land-use, location of capital improvements, and financial incentives and disincentives. William Spangle and Associates, and others (1980) describe reconstruction plans and actions taken after the following earthquake disasters: 1971 San Fernando Valley, California; 1964 Alaska; 1969 Santa Rosa, California; 1963 Skopje, Yugoslavia; and 1972 Managua, Nicaragua. In addition, their discussion of the San Fernando and Alaska earthquakes includes issues, options, and opportunities seized or missed. Popkin in **Reconstruction Following A Disaster** (Haas and others, editors, 1979, p. xxix) notes:

> Most policy issues involving reconstruction arise because some element of the community wants to avoid a similar future disaster. This usually happens shortly after the disaster and may cause conflict with the widely-held desire to return to normal as quickly as possible. The strongest pressure of all for prompt return to normalcy comes from the existence of displaced families and businesses. Such pressures do not necessarily make for orderly, well-planned reconstruction processes.

CONCLUSION

Many ways to reduce earthquake hazards are available, including: long-term mitigation techniques, preparedness measures, responses, recovery operations, and reconstruction activities. However, a prerequisite to their effective use is public awareness. Turner and others (1980) make the following recommendations for improving public awareness:

- Carefully prepared and selected advice concerning earthquake preparedness for individuals and households should be given widespread and repeated public distribution through the media as well as other channels.

- This preparedness advice should come from some authoritative government agency and should be endorsed by well-known local government officials and public personages.

- Each recommended preparedness measure should be presented in conjunction with a brief but credible explanation justifying that recommendation and suggesting how it can be implemented.

- Some responsible state agency should develop a program to promote earthquake safety in the household making use of local government, private agencies, and citizen groups. An especially useful program of this type would be one that conducted household safety inspections.

Successful programs promoting public awareness include SEISMOS '83, a City of Los Angeles simulated seismic event and metropolitan response (Manning, 1983); the 12th Annual Japanese National Earthquake Preparedness Week and Drill (Bernson, 1983); the 1983 National Seismic Policy Conference (Western States Seismic Policy Council, 1984); the South Carolina Seismic Safety Consortium conferences (Bagwell, 1983); and the Governor's Conference on Geologic Hazards (Utah Geological and Mineral Survey, 1983).

ACKNOWLEDGEMENTS

Joyce Bagwell, Baptist College at Charleston, Pamela Johnston, U.S. Virgin Islands Disaster Programs Office, Cheryl Tateishi, The Southern California Earthquake Preparedness Project, and Jane Bullock, Federal Emergency Management Agency, kindly reviewed this paper and provided valuable suggestions. Special thanks are owed Catherine Campbell for editing and Cynthia Ramseyer for word processing.

REFERENCES

American Red Cross, 1982, Safety and survival in an earthquake: Southern California Division, Los Angeles Chapter, American Red Cross, Los Angeles, Calif., 44 p.

Bagwell, J.B., 1983, The current state of earthquake hazard awareness in the Southeastern United States in Hays, W.W. and Gori, P.L., eds., 1983, A workshop on "The 1886 Charleston, South Carolina, earthquake and its implications for today": U.S. Geological Survey Open-file Report 83-843, Reston, Va., p. 315-322.

Bernson, Hal, 1983, Report to the Los Angeles City Council on earthquake preparedness week and drill -- Japan 1983: Los Angeles, 8 p.

Blair, M.L., and Spangle, W.E., 1979, Seismic safety and land-use planning -- selected examples from California: U.S. Geological Survey Professional Paper 941-B, 82 p.

Brown, R.D., Jr., and Kockelman, W.J., 1983, Geologic principles for prudent land use -- a decisionmaker's guide for the San Francisco Bay region: U.S. Geological Survey Professional Paper 946, 97 p.

Chusid, J.M., editor, 1982, An earthquake advisor's handbook for wood frame houses: University of California Center for Planning and Development Research, Berkeley, Calif., 90 p.

Council of State Governments, 1976, Comprehensive emergency preparedness planning in state government: The Council of State Governments, Lexington, Ky., 47 p.

Federal Coordinating Office, 1980, Mount St. Helens Technical Information Network: Federal Emergency Management Agency, Vancouver, Wash., series of 33 bulletins.

Federal Emergency Management Agency, 1981, An assessment of the consequences and preparations for a catastrophic California earthquake--findings and actions taken: Federal Emergency Management Agency, Washington, D.C., 59 p.

Gere, J.M., and Shah, H.C., 1980, Earthquakes -- how to protect your life and property: John A. Blume Earthquake Engineering Center, Stanford University, Calif., 16 p.

Haas, J.E., Kates, R.W., and Bowden, M.J., eds., 1977, Reconstruction following disaster: MIT Press, Cambridge, Mass., 331 p.

Jacob, K.H., 1984, Estimates of long-term probabilities for future great earthquakes in the Aleutians: Geophysical Research Letters, vol. 11, no. 4, p. 295-298.

Jaffe, Martin, Butler, JoAnn, and Thurow, Charles, 1981, Reducing earthquake risks -- a planner's guide: American Planning Association, Planning Advisory Service Report 364, 82 p.

2557 20130

Kent, Mele, 1983, Seven reasons not to get ready for an earthquake: Palo Alto Co-op News, vol. XLIX, no. 22, p. 1.

Kockelman, W.J., 1983, Examples of the use of geologic and seismologic information for earthquake-hazard reduction in Southern California: U.S. Geological Survey Open-file Report 83-82, 58 p.

Lafferty, Libby, undated, Earthquake preparedness -- A guide and handbook for your home, family, and community: Creative Home Economics Services of California, La Canada, Calif., 32 p.

Manning, D.O., 1983, City of Los Angeles, "Seismos '83" -- a simulated seismic event and metropolitan response: City of Los Angeles Fire Department, Los Angeles, Calif., 21 p.

Nichols, D.M. and Buchanan-Banks, J.M., 1974, Seismic hazards and land-use planning: U.S. Geological Survey Circular 690, Reston, Va., 33 p.

Pan American Health Organization, 1981, A guide to emergency health management after natural disaster: Pan American Health Organization Scientific Publication 407, World Health Organization, Washington, D.C., 67 p.

Reitherman, Robert, 1983, Reducing the risks of nonstructural earthquake damage -- a practical guide: California Seismic Safety Commission, Sacramento, Calif., 87 p.

Rubin, C.B., 1979, Natural disaster recovery planning for local public officials: Academy for Contemporary Problems, Columbus, Oh., 20 p.

Santa Clara County Girl Scout Council, undated, When an earthquake strikes -- be prepared: San Jose, Calif., brochure.

Shapiro, Okino, Hom and Associates, 1980, The home builder's guide for earthquake design -- guideline 6: U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Washington, D.C., 57 p.

Southern California Earthquake Preparedness Project, 1983, Comprehensive earthquake preparedness planning guidelines: Van Nuys, Calif., 9 parts.

Sunset Magazine, 1982, Getting ready for a big quake: Menlo Park, Calif., March 1982, p. 104-113.

Turner, R.H., and others, 1980, Community response to earthquake threat in Southern California: University of California Institute for Social Science Research, Los Angeles, Calif., 10 parts.

Utah Geological and Mineral Survey, 1983, Governor's conference on geologic hazards: Utah State Department of Natural Resources Circular 74, 99 p.

Washington State Department of Emergency Services and Federal Emergency Management Agency, undated, Earthquake -- safety tips for Washington earthquakes: Olympia, Wash., brochure.

Western States Seismic Policy Council, 1984, Proceedings of the 1983 National Seismic Policy Conference: Washington State Department of Emergency Services, Olympia, Wash., 158 p., 4 appendices.

William Spangle and Associates, and others, 1980, Land-use planning after earthquakes: William Spangle and Associates, Portola Valley, Calif., 158 p.

Yanev, P.I., 1974, Peace of mind in earthquake country -- how to save your home and life: Chronicle Books, San Francisco, 304 p.

APPENDIX A

List of Participants

Workshop on "Evaluation of Regional and Urban Earthquake Hazards and Risk in Alaska"

Dr. S. Ted Algermissen
U.S. Geological Survey
Box 25046, MS 966
Denver Federal Center
Denver, Colorado 80225

Mr. Bud Alto
Civil Engineer
Alyeska Pipeline Service Company
1835 S. Bragan
Anchorage, Alaska 99512

Ms. Laura Beck
Municipality of Anchorage
Community Planning Department
Pouch 6-650
Anchorage, Alaska 99502

Ms. Elizabeth C. Behrendt
Public Information Specialist
U.S. Geological Survey
Public Inquires Office
4230 University Drive, Room 101
Anchorage, Alaska 99508-4664

Dr. Niren Biswas
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

Mr. Donald Bruggers
Harding Lawson
601 East 57 Place
Anchorage, Alaska 99503

Mr. Richard Buck
Federal Emergency Management Agency
Region X
Federal Regional Center
Bothell, Washington 98021

Mr. George W. Carte'
Alaskan Tsunami Warning Center
NOAA, National Weather Service
P.O. Box Y
Palmer, Alaska 99645

Dr. Mehmet Celebi
U.S. Geological Survey
345 Middlefield Road, MS 977
Menlo Park, California 94025

Mr. Jack Cervantes
Director, Office of Emergency Management
Municipality of Anchorage Fire Department
1301 E. 80th Avenue
Anchorage, Alaska 99504-4998

Mr. Lloyd Cluff
33 Mountain Spring
San Francisco, California 94114

Mr. David Cole
Dowl Engineering
4040 B Street
Anchorage, Alaska 99501

Mr. Rodney A. Combellick
Geologist
Alaska Division of Geological and
Geophysical Surveys
794 University Avenue, BSMT
Fairbanks, Alaska 99708

Mr. C. B. Crouse
Earthquake Technology
3777 Long Beach Boulevard
Long Beach, California 90807

Dr. John N. Davies
State Seismologist
Natural Hazards Building
Diggs Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

Dr. Allan F. Divis
Engineering Geologist
Terratch Ltd.
1016 Hardell Lane
Vista, California 92083

2586 20130

Dr. W. F. Downs
Sr. Scientist
INEL
P.O. Box 1625
Idaho Falls, Idaho 83415

Mr. Alvaro Espinosa
U.S. Geological Survey
Box 25046, MS 966
Denver Federal Center
Denver, Colorado 80225

Sen. Vic Fischer
Alaska Legislature
600 Barrow #603
Anchorage, Alaska 99501

Mr. Stephen Foo
Mobile Oil Company
Dallas, Texas

Mr. Nelson M. Franklin, P.E.
Principal
Franklin & Allen, Inc.
Consulting Engineers
1813 E. First Avenue, #207
Anchorage, Alaska 99501

Ms. Paula L. Gori
U.S. Geological Survey
905 National Center
Reston, Virginia 22092

Mr. Joe L. Hayes
Civil Engineer
P.O. Box 101821
Anchorage, Alaska 99510

Dr. Walter Hays
U.S. Geological Survey
905 National Center
Reston, Virginia 22092

Mr. Mark Holum
Manager
Alaska Soil Testing & Engineering
6100 A Street
Anchorage, Alaska 99502

Dr. I. M. Idriss
Woodward Clyde Consultants
203 North Golden Circle Drive
Santa Ana, California 92705

Dr. Klaus Jacobs
Lamont-Doherty Geological
Observatory at Columbia University
Palisades, New York 10964

Professor Paul C. Jennings
Civil Engineering & Allied Mechanics
MC 104-44
California Institute of Technology
Pasadena, California 91125

Mr. Gary Johnson
Federal Emergency Management Agency
500 C Street S.W.
Washington D.C. 20472

Dr. C. S. Kaliappan
Engineering Coordinator
Alaska Pipeline Service Co.
1835 S. Bragan Street
Anchorage, Alaska 99512

Mr. Roger W. Klepinger
Deputy Regional Supervisor, Resource
Evaluation
Mineral Management Service
P.O. Box 10-1159
Anchorage, Alaska 99504

Mr. William J. Kockelman
U.S. Geological Survey
345 Middlefield Road, MS 922
Menlo Park, California 94025

Dr. John C. Lahr
U.S. Geological Survey
345 Middlefield Road, MS 977
Menlo Park, California 94025

Ms. Sara McCoulough
Executive Director, American Red Cross
South Central Alaska Chapter
P.O. Box 10-1139
325 E 3rd Street
Anchorage, Alaska 99510

Mr. Duane L. Miller
Consulting Engineer
Duane Miller & Associates
9720 Hillside Drive
Anchorage, Alaska 99516

2552 2080

Dr. Thomas P. Miller
Geologist
U.S. Geological Survey
4200 University Drive
Anchorage, Alaska 99508

Mr. Frank Miller
Geologist
Minerals Management Service
U.S. Department of the Interior
2900 Boniface Parkway #429
Anchorage, Alaska 99508

Mr. Stuart P. Nishenko
U.S. Geological Survey
P.O. Box 25046, MS 967
Denver Federal Center
Denver, Colorado 80225

Dr. Harold W. Olsen
U.S. Geological Survey
P.O. Box 25046, MS 966
Denver Federal Center
Denver, Colorado 80225

Dr. Robert A. Page
U.S. Geological Survey
345 Middlefield Road, MS 977
Menlo Park, California 94025

Mr. Robert J. Peters
Sr. Structural Engineer
URS Corporation
825 8th Avenue
Anchorage, Alaska 99501

Dr. Arvid Phukan
Professor of Civil Engineers
University of Alaska
Anchorage, Alaska 99503

Dr. George Plafker
U.S. Geological Survey
Branch of Alaskan Geology
345 Middlefield Road, MS 904
Menlo Park, California 90425

Ms. Jane Preuss
Urban Regional Research
616 1st Avenue
Suite 200
Seattle, Washington 98104

Mr. Bill Pyle
Manager-Earth Sciences
Woodward-Clyde Consultants
701 Sesame Street
Anchorage, Alaska 99503

Ms. John W. Reeder
Geologist
State of Alaska
Director of Geology and Geophy. Survey
Pouch 7-028
Anchorage, Alaska 99510

Mr. Henry R. Schmoll
U.S. Geological Survey
P.O. Box 25046, MS 972
Denver Federal Center
Denver, Colorado 80225

Dr. Lidia Selkregg
School of Business & Public Affairs
University of Alaska
3210 Providence Drive
Anchorage, Alaska 99508

Mr. Jim Sey
Alaska Division of Emergency Services
P.O. Box 2267
Palmer, Alaska 99645

Ms. Barbara J. Sheinberg
Municipality of Anchorage
Community Planning Department
Pouch 6-650
Anchorage, Alaska 99502

Dr. Jogeshwar P. Singh
Harding Lawson Associates
7655 Redwood Boulevard
Novato, California 94948

Mr. Alexander Sisson
Union Oil Company of California
2413 Lord Baranof Drive
Anchorage, Alaska 99503

Mr. Jerome J. Smith, MPH
Director, Disaster Services
American Red Cross
South Central Alaska Chapter
325 E 3rd Avenue, 3908 Apollo Drive
Anchorage, Alaska 99504

2651 20130

Mr. Karl V. Steinbrugge
6851 Cutting Boulevard
El Cerrito, California 94530

Dr. John Taber
Lamont-Doherty Geological Observatory
at Columbia University
Palisades, New York 10964

Mr. Howard P. Thomas
Vice President
Woodward-Clyde Consultants
701 Sesame Street
Anchorage, Alaska 99503

Mr. Ted Trueblood
Alaska Railroad
Pouch 7-2111
Anchorage, Alaska 99501

Ms. Susan K. Tubbesing
Natural Hazards Research & Applications
Information Center
University of Colorado
Campus Box 482
Boulder, Colorado 80309

Mr. Lloyd Turner
Alaska Division of Emergency Services
P.O. Box 2267
Palmer, Alaska 99645

Mr. Frank Tyler
Planner
Alaska Department of Natural Resources
Anchorage, Alaska 99502

Ms. Catherine Ulery
Alaska Geological Survey
P.O. Box 772116
Eagle River, Alaska 99577

Mr. Randall G. Updike
Chief, Engineering Geologist Section
Department of Natural Resources
Division of Geological and
Geophysical Surveys
P.O. Box 772116
Eagle River, Alaska 99577

Dr. Yogesh Vyas
Exxon Production Research Company
P.O. Box 2189
Houston, Texas 77252-2189

Ms. Katherine West
Director's Office
U.S. Geological Survey
4200 University Drive
Anchorage, Alaska 99508

Mr. John Whitney
62011 Rochhill Circle
Anchorage, Alaska 99516

Dr. John H. Wiggins
Senior Scientist
NTS/JH Wiggins Company
1650 S. Pacific Coast Highway
Redondo Beach, California 90277

2685 20130

APPENDIX B

GLOSSARY OF TERMS USED IN EARTHQUAKE HAZARDS ASSESSMENTS

Accelerogram. The record from an accelerometer showing acceleration as a function of time. The peak acceleration is the largest value of acceleration on the accelerogram.

Acceptable Risk. A probability of occurrences of social or economic consequences due to earthquakes that is sufficiently low (for example in comparison to other natural or manmade risks) as to be judged by appropriate authorities to represent a realistic basis for determining design requirements for engineered structures, or for taking certain social or economic actions.

Active fault. A fault is active if, because of its present tectonic setting, it can undergo movement from time to time in the immediate geologic future. This active state exists independently of the geologists' ability to recognize it. Geologists have used a number of characteristics to identify active faults, such as historic seismicity or surface faulting, geologically recent displacement inferred from topography or stratigraphy, or physical connection with an active fault. However, not enough is known of the behavior of faults to assure identification of all active faults by such characteristics. Selection of the criteria used to identify active faults for a particular purpose must be influenced by the consequences of fault movement on the engineering structures involved.

Asthenosphere. The worldwide layer below the lithosphere which is marked by low seismic wave velocities. It is a soft layer, probably partially molten.

Attenuation law. A description of the average behavior of one or more characteristics of earthquake ground motion as a function of distance from the source of energy.

Attenuation. A decrease in seismic signal strength with distance which depends not only on geometrical spreading, but also may be related to the physical characteristics of the transmitting medium that cause absorption and scattering.

b-value. A parameter indicating the relative frequency of earthquakes of different sizes derived from historical seismicity data.

Capable fault. A fault along which future surface displacement is possible, especially during the lifetime of the engineering project under consideration.

Convection. A mechanism of heat transfer through a liquid in which hot material from the bottom rises because of its lesser density, while cool surface materials sinks.

Convergence Zone. A band along which moving plates collide and area is lost either by shortening and crustal thickening or subduction and destruction of crust. The site of volcanism, earthquakes, trenches, and mountain building.

Design earthquake. A specification of the ground motion at a site based on integrated studies of historic seismicity and structural geology used for the earthquake-resistant design of a structure.

Design spectra. Spectra used in earthquake-resistant design which correlate with design earthquake ground motion values. Design spectra typically are smooth curves that take into account features peculiar to a geographic region and a particular site.

Design time history. One of a family of time histories used in earthquake-resistant design which produces a response spectrum enveloping the smooth design spectrum, for a selected value of damping.

Duration. A qualitative or quantitative description of the length of time during which ground motion at a site exhibits certain characteristics such as being equal to or exceeding a specified level of acceleration such as 0.05g.

Earthquake hazards. The probability that natural events accompanying an earthquake such as ground shaking, ground failure, surface faulting, tectonic deformation, and inundation, which may cause damage and loss of life, will occur at a site during a specified exposure time. See earthquake risk.

Earthquake risk. The probability that social or economic consequences of earthquakes, expressed in dollars or casualties, will equal or exceed specified values at a site during a specified exposure time.

Earthquake waves. Elastic waves (P, S, Love, Rayleigh) propagating in the Earth, set in motion by faulting of a portion of the Earth.

Effective peak acceleration. The peak ground acceleration after the ground-motion record has been filtered to remove the very high frequencies that have little or no influence upon structural response.

Elastic rebound theory. A theory of fault movement and earthquake generation that holds that faults remain lock while strain energy accumulates in the rock, and then suddenly slip and release this energy.

Epicenter. The point on the Earth's surface vertically above the point where the first fault rupture and the first earthquake motion occur.

Exceedance probability. The probability (for example, 10 percent) over some period of time that an event will generate a level of ground shaking greater than some specified level.

Exposure time. The period of time (for example, 50 years) that a structure is exposed to the earthquake threat. The exposure time is sometimes related to the design lifetime of the structure and is used in seismic risk calculations.

Fault. A fracture or fracture zone in the Earth along which displacement of the two sides relative to one another has occurred parallel to the fracture. See Active and Capable faults.

Focal depth. The vertical distance between the hypocenter and the Earth's surface in an earthquake.

Ground motion. A general term including all aspects of motion; for example, particle acceleration, velocity, or displacement; stress and strain; duration; and spectral content generated by a nuclear explosion, an earthquake, or another energy source.

Intensity. A numerical index describing the effects of an earthquake on the Earth's surface, on man, and on structures built by him. The scale in common use in the United States today is the Modified Mercalli scale of 1931 with intensity values indicated by Roman numerals from I to XII. The narrative descriptions of each intensity value are summarized below.

I. Not felt--or, except rarely under especially favorable circumstances. Under certain conditions, at and outside the boundary of the area in which a great shock is felt: sometimes birds and animals reported uneasy or disturbed; sometimes dizziness or nausea experienced; sometimes trees, structures, liquids, bodies of water, may sway--doors may swing, very slowly.

II. Felt indoors by few, especially on upper floors, or by sensitive, or nervous persons. Also, as in grade I, but often more noticeably: sometimes hanging objects may swing, especially when delicately suspended; sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly; sometimes birds and animals reported uneasy or disturbed; sometimes dizziness or nausea experienced.

III. Felt indoors by several, motion usually rapid vibration. Sometimes not recognized to be an earthquake at first. Duration estimated in some cases. Vibration like that due to passing of light, or lightly loaded trucks, or heavy trucks some distance away. Hanging objects may swing slightly. Movements may be appreciable on upper levels of tall structures. Rocked standing motor cars slightly.

IV. Felt indoors by many, outdoors by few. Awakened few, especially light sleepers. Frightened no one, unless apprehensive from previous experience. Vibration like that due to passing of heavy or heavily loaded trucks. Sensation like heavy body of striking building or falling of heavy objects inside. Rattling of dishes, windows, doors; glassware and crockery clink or clash. Creaking of walls, frame, especially in the upper range of this grade. Hanging objects swung, in numerous instances. Disturbed liquids in open vessels slightly. Rocked standing motor cars noticeably.

V. Felt indoors by practially all, outdoors by many or most; outdoors direction estimated. Awakened many or most. Frightened few--slight excitement, a few ran outdoors. Buildings trembled throughout. Broke dishes and glassware to some extent. Cracked windows--in some cases, but not generally. Overturned vases, small or unstable objects, in many instances, with occasional fall. Hanging objects, doors, swing generally or considerably. Knocked pictures against

 2658 20130

walls, or swung them out of place. Opened, or closed, doors and shutters abruptly. Pendulum clocks stopped, started or ran fast, or slow. Move small objects, furnishings, the latter to slight extent. Spilled liquids in small amounts from well-filled open containers. Trees and bushes shaken slightly.

VI. Felt by all, indoors and outdoors. Frightened many, excitement general, some alarm, many ran outdoors. Awakened all. Persons made to move unsteadily. Trees and bushes shaken slightly to moderately. Liquid set in strong motion. Small bells rang--church, chapel, school, etc. Damage slight in poorly built buildings. Fall of plaster in small amount. Cracked plaster somewhat, especially fine cracks chimneys in some instances. Broke dishes, glassware, in considerable quantity, also some windows. Fall of knickknacks, books, pictures. Overturned furniture in many instances. Move furnishings of moderately heavy kind.

VII. Frightened all--general alarm, all ran outdoors. Some, or many, found it difficult to stand. Noticed by persons driving motor cars. Trees and bushes shaken moderately to strongly. Waves on ponds, lakes, and running water. Water turbid from mud stirred up. Incaving to some extent of sand or gravel stream banks. Rang large church bells, etc. Suspended objects made to quiver. Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc. Cracked chimneys to considerable extent, walls to some extent. Fall of plaster in considerable to large amount, also some stucco. Broke numerous windows and furniture to some extent. Shook down loosened brickwork and tiles. Broke weak chimneys at the roof-line (sometimes damaging roofs). Fall of cornices from towers and high buildings. Dislodged bricks and stones. Overturned heavy furniture, with damage from breaking. Damage considerable to concrete irrigation ditches.

VIII. Fright general--alarm approaches panic. Disturbed persons driving motor cars. Trees shaken strongly--branches and trunks broken off, especially palm trees. Ejected sand and mud in small amounts. Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters. Damage slight in structures (brick) built especially to withstand earthquakes. Considerable in ordinary substantial buildings, partial collapse, racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling. Fall of walls, cracked, broke, solid stone walls seriously. Wet ground to some extent, also ground on steep slopes. Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers. Moved conspicuously, overturned, very heavy furniture.

IX. Panic general. Cracked ground conspicuously. Damage considerable in (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames; serious to reservoirs; underground pipes sometimes broken.

X. Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks. Landslides considerable from river banks and steep coasts. Shifted sand and mud horizontally on beaches and flat land. Changes level of water in wells. Threw water on banks of canals, lakes, rivers, etc. Damage serious to dams, dikes, embankments. Severe to well-built wooden structures and bridges, some destroyed. Developed dangerous cracks in excellent brick walls. Destroyed most masonry and frame structures, also their foundations. Bent railroad rails slightly. Tore apart, or crushed endwise, pipelines buried in earth. Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.

XI. Disturbances in ground many and widespread, varying with ground material. Broad fissures, earth slumps, and land slips in soft, wet ground. Ejected water in large amounts charged with sand and mud. Caused sea-waves ("tidal" waves) of significant magnitude. Damage severe to wood-frame structures, especially near shock centers. Great to dams, dikes, embankments often for long distances. Few, if any (masonry) structures, remained standing. Destroyed large well-built bridges by the wrecking of supporting piers or pillars. Affected yielding wooden bridges less. Bent railroad rails greatly, and thrust them endwise. Put pipelines buried in each completely out of service.

XII. Damage total--practically all works of construction damaged greatly or destroyed. Disturbances in ground great and varied, numerous shearing cracks. Landslides, falls of rock of significant character, slumping of river banks, etc., numerous and extensive. Wrenched loose, tore off, large rock masses. Fault slips in firm rock, with notable horizontal and vertical offset displacements. Water channels, surface and underground, disturbed and modified greatly. Dammed lakes, produced waterfalls, deflected rivers, etc. Waves seen on ground surfaces (actually seen, probably, in some cases). Distorted lines of sight and level. Threw objects upward into the air.

Liquefaction. Temporary transformation of unconsolidated materials into a fluid mass.

Lithosophere. The outer, rigid shell of the earth, situated above the asthenosphere containing the crust, continents, and plates.

Magnitude. A quantity characteristic of the total energy released by an earthquake, as contrasted to intensity that describes its effects at a particular place. Professor C. F. Richter devised the logarithmic scale for local magnitude (M_L) in 1935. Magnitude is expressed in terms of the motion that would be measured by a standard type of seismograph located 100 km from the epicenter of an earthquake. Several other magnitude scales in addition to M_L are in use; for example, body-wave magnitude (m_b) and surface-wave magnitude (M_s), which utilize body waves and surface waves, and local magnitude (M_L). The scale is open ended, but the largest known earthquake have had M_s magnitudes near 8.9.

Mantle. The main bulk of earth between the crust and core, ranging from depths of about 40 to 2900 kilometers.

Mid-oceanridge. Characteristic type of plate boundary occurring in a divergence zone, a site where two plates are being pulled apart and new oceanic lithosphere is being created.

Plate tectonics. The theory and study of plate formation, movement, interaction, and destruction.

Plate. One of the dozen or more segments of the lithosphere that are internally rigid and move independently over the interior, meeting in convergence zones and separating in divergence zones.

Region. A geographical area, surrounding and including the construction site, which is sufficiently large to contain all the geologic features related to the evaluation of earthquake hazards at the site.

Response spectrum. The peak response of a series of simple harmonic oscillators having different natural periods when subjected mathematically to a particular earthquake ground motion. The response spectrum may be plotted as a curve on tripartite logarithmic graph paper showing the variations of the peak spectral acceleration, displacement, and velocity of the oscillators as a function of vibration period and damping.

Return period. For ground shaking, return period denotes the average period of time or recurrence interval between events causing ground shaking that exceeds a particular level at a site; the reciprocal of annual probability of exceedance. A return period of 475 years means that, on the average, a particular level of ground motion will be exceeded once in 475 years.

Risk. See earthquake risk.

Rock. Any solid rock either at the surface or underlying soil having a shear-wave velocity 2,500 ft/sec (765 m/s) at small (0.0001 percent) strains.

Sea-floor spreading. The mechanism by which new sea floor crust is created at ridges in divergence zones and adjacent plates are moved apart to make room.

Seismic Microzoning. The division of a region into geographic areas having a similar relative response to a particular earthquake hazard (for example, ground shaking, surface fault rupture, etc.). Microzoning requires an integrated study of: 1) the frequency of earthquake occurrence in the region, 2) the source parameters and mechanics of faulting for historical and recent earthquakes affecting the region, 3) the filtering characteristics of the crust and mantle constituting the regional paths along which the seismic waves travel, and 4) the filtering characteristics of the near-surface column of rock and soil.

Seismic zone. A generally large area within which seismic design requirements for structures are uniform.

Seismotectonic province. A geographic area characterized by similarity of geological structure and earthquake characteristics. The tectonic processes causing earthquakes have been identified in a seismotectonic province.

Source. The source of energy release causing an earthquake. The source is characterized by one or more variables, for example, magnitude stress drop, seismic moment. Regions can be divided into areas having spatially homogeneous source characteristics.

Strain. A quantity describing the exact deformation of each point in a body. Roughly the change in a dimension or volume divided by the original dimension or volume.

Stress. A quantity describing the forces acting on each part of a body in units of force per unit area.

Strong motion. Ground motion of sufficient amplitude to be of engineering interest in the evaluation of damage due to earthquakes or in earthquake-resistant design of structures.

Subduction zone. A dipping planar zone descending away from a trench and defined by high seismicity, interpreted as the shear zone between a sinking oceanic plate and an overriding plate.

Transform fault. A strike-slip fault connecting the ends of an offset in a mid-ocean ridge. Some pairs of plates slide past each other along transform faults.

Trench. A long and narrow deep trough in the sea floor; interpreted as marking the line along which a plate bends down into a subduction zone.

Triple junction. A point that is common to three plates and which must be the meeting place of three boundary features, such as convergence zones, divergence zones, or transform faults.

2656 20130

new odd pg)

APPENDIX C: DIRECTORY OF RESEARCHERS WORKING ON ALASKAN EARTHQUAKE PROBLEMS

Introduction

Every research study generates basic data which must be organized. A large but unorganized amount of data relating to the earthquake hazards in the Anchorage area already exist in published maps, reports, and computerized data sets. When organized, the resultant data base is an extremely valuable resource for a wide variety of user groups, including other researchers. In addition, the data base is expected to grow as research studies mature and as post earthquake investigations are conducted.

The objectives of this directory are: 1) to make quality data more readily available to researchers and policymakers, 2) to create a system that assures that new data will be available in the form most useful for meeting program objectives, and 3) to foster the creation of a system whereby potential users will have easy access to data in media, scales, and formats that are most useful to them. Accomplishing these objectives will ultimately require: 1) inventorying existing data sets, 2) developing data standards for critical data sets, 3) identifying user groups and determining their needs, 4) developing strategies for data management and data dissemination, and 5) assuring that important hazards data are available to the user community.

The following material describes an initial effort to produce a preliminary information system of researchers working on Alaskan earthquake problems. It provides a means whereby potential users can contact the producers of specific data sets for additional information. The material is organized as follows:

2683 2080

INVESTIGATOR	TYPES OF INFORMATION
GEOLOGIC	
1. George Plafker	Faults, terraces, deformation, and stress trajectories, maps.
2. Robert Page and others	Coordinated geologic and geophysical studies, abstracts, maps, cross sections.
SEISMOLOGICAL	
3. John N. Davies	Extend historical data base; provide conventional source of earthquake info for Alaskans; maintain statewide seismic monitoring; install and maintain some strong-motion accelerographs.
4. John G. Sindorf	Magnitude determination.
5. Klaus Jacob and John Tabor	Seismicity and tectonic data.
6. John Lahr, Christopher Stephens, and Robert Page	Seismicity data.
DEFORMATION	
7. Jim Savage and Mike Lisowski	Strain data.
8. Carl Mortensen	Tiltmeter data.
9. Allan F. Divis	Tectonic deformation data.
GROUND SHAKING HAZARD	
10. Henry Schmoll	Interpretative geologic data for use in earthquake hazards evaluations and land-use planning.
11. Alvaro Espinosa	Geologic and geophysical data needed for evaluation of the earthquake ground shaking hazard.
12. Yogesh Vyas	Literature on the ground motion hazard.
13. C. B. Crouse and Yogesh	Data on the seismic wave attenuation characteristics.
GROUND FAILURE HAZARD	
14. Randall Updike	Geotechnical characterization of engineering soils, mapping of engineering geology, surficial and bedrock mapping.
15. I. M. Idriss and Y. Moriwaki	Probabilistic evaluation of earthquake ground motions.
TSUNAMI HAZARD	
16. Jane Preuss	Develop a refined planning approach for communities susceptible to tsunamis.
17. T. F. Sokolowski	Enhance reactive and predictive parts of the Tsunami Warning System.
18. S. P. Nishenko, W. Spence, G. Choy	Provide updated estimates of seismic tsunami hazards.
George W. Carte	Evaluation of tsunami hazards.
DECISIONMAKING	
19. John H. Wiggins, Craig Taylor	Assist decision makers in selecting one of four basic alternatives for expanding the courthouse facilities.
ENGINEERING SEISMOLOGY	
20. Mehmet Celebi	Ambient vibration tests of buildings.

 2657 20130

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Alaska Geologic Earthquake Hazards

Funding source: U.S. Geological Survey

Date research began: 1973

Principal investigator(s): George Plafker

Address: U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

Phone number:

Main goal(s) of research:

To study and evaluate risk in Alaska from tectonic displacements, seismic shaking and secondary geologic effects.

Main accomplishments relevent to goals what remains to be completed:

Field investigations of surface characteristics of all known and suspected active faults in Alaska and regions of vertical tectonic displacements relative to sea level in Gulf of Alaska completed.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

Numerous reports on specific faults, terrace sequences, and earthquakes published or to be published.

A data file on active faults in Alaska has been compiled and is in review stage prior to publication.

A neotectonic map of Alaska showing state of activity of faults, areas of vertical detonation with average rates, and stress trajectories is compiled and will be published as an MF.

2653 2013D

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Trans-Alaska Crustal Transect

Funding source: U.S. Geological Survey

Date research began: 1984

Principal investigator(s): Robert A. Page (coordinator), George Plafker, Warren J. Nokleberg, Gary S. Fuis, David L. Campbell, Michael A. Fisher

Address: (R. A. Page) Office of Earthquakes, Volcanoes and Engineering, U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, CA 94025

Phone number: 415-323-8111, ext. 2576 (FTS 467-2567)

Main goal(s) of research:

To investigate through coordinated geological and geophysical studies the structure, composition and evolution of the Alaskan crust along the Trans-Alaska oil pipeline corridor and across the Pacific and Arctic continental margins. This research will improve understanding of the earthquake potential along an important transportation/development corridor by delineating the geologic and tectonic framework.

Main accomplishments relevent to goals what remains to be completed:

Geologic, seismic refraction, gravity and magnetic studies have been completed from Prince William Sound to the Denali fault in the Alaska Range. The transect studies will continue through the 1980's with the area of study generally shifting progressively northward and with the scope of studies expanding to include deep seismic reflection profiling, magnetotelluric sounding, marine geophysical profiling, 3-D seismic imaging of the lithosphere, and heat flow studies.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

To date, only abstracts have been published (see attached list). Future products will include geologic and geophysical maps and cross sections, data reports, and technical articles in USGS publications and professional journals. Products will be written for earth scientists.

2687 20130

TACT Bibliography

1984

Page, R. A., Fuis, G. S., Mooney, W. D., Nokleberg, W. J., Plafker, G., and Campbell, D. L., 1984, Crustal transect of accreted tectonostratigraphic terranes in the Chugach Mountains and Copper River Basin, Alaska: Initial results of TACT [abs.]: EOS (Am. Geophys. Union Trans.), v. 65, no. 45, p. 985.

1985

Ambos, E. L., Fuis, G. S., Mooney, W. D., Page, R. A., Plafker, G., Nokleberg, W. J., Campell, D. L., and Daley, M. A., 1985, Lithospheric structure in southern Alaska from 1984 TACT seismic refraction data [abs.]: EOS (Am. Geophys. Union Trans.), v. 66, no. 18, p. 301.

*Coleman, R. G., and Burns, L. E., 1985, The Tonsina high-pressure mafic-ultramafic cumulate sequence, Chugach Mountains, Alaska [abs.]: Geol. Soc. Am. Abstracts with Programs, v. 17, no. 6, p. 348.

Fuis, G. S., Ambos, E. L., Mooney, W. D., Page, R. A., and Campbell, D. L., 1985, Crustal structure of southern Alaska--preliminary results of the TACT 1984 seismic refraction experiment [abs.]: Earthquake Notes, Seismol. Soc. Am. Eastern Section, v. 55, no. 1, p. 23.

Nokleberg, W. J., Plafker, G., Winkler, G. R., Pessel, G. M., and Wallace, W. K., 1985, Accretionary tectonics along the northern Chugach Mountains and southern Copper River Basin, Alaska [abs.]: Geol. Soc. Am. Abstracts with Programs, v. 17, no. 6, p. 397.

Plafker, G., Nokleberg, W. J., Fuis, G. S., Mooney, W. D., Page, R. A., Ambos, E. L., and Campbell, D. L., 1985, 1984 results of the Trans-Alaska Crustal Transect in the Chugach Mountains and Copper River Basin, Alaska [abs.]: Geol. Soc. Am. Abstracts with Programs, v. 17, no. 6, p. 400-401.

*Sisson, V. B., and Hollister, L. S., 1985, Relation of magma intrusion to deformation and uplift of eastern Chugach Mountains, Alaska [abs.]: Geol. Soc. Am. Abstracts with Programs, v. 17, no. 6, p. 408.

*Wallace, W. L., 1985, Tectonic evolution of the Haley Creek terrane, a rootless thrust sheet in the Chugach Mountains, Alaska [abs.]: Geol. Soc. Am. Abstracts with Programs, v. 17, no. 6, p. 416.

*Work partially supported by TACT field projects.

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Mitigations of Seismic Hazards in Alaska

Funding source: State of Alaska

Date research began: May 1981

Principal investigator(s): Dr. John N. Davies
Alaska Division Geology and Geophysical Surveys
794 University Ave.
Fairbanks, AK 99709
(907) 474-6166

Main goal(s) of research:

(1) Extend historical data base.
(2) Provide convenient source of earthquake info for Alaskans.
(3) Maintain statewide seismic monitoring.
(4) Install and maintain some strong-motion accelerographs.

Main accomplishments relevent to goals and what remains to be completed:

(1) Have done research on time of Russian occupation--need to publish.
(2) Have collected many files of earthquake info--need to sort and describe it.
(3) Have kept some stations operational--need to install more.
(4) Have begun process with USGS to select buildings--need to complete, purchase and install instruments.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

Call for more information.

2652 20130

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Earthquake magnitudes

Funding source: In House (NOAA)

Date research began: 1967 - ongoing

Principal investigator(s): John G. Sindorf
Alaska Tsunami Warning Center
Box Y
Palmer, AK 99645
(907) 745-4212

Main goal(s) of research:
Rapid determination of magnitudes of local to teleseismic earthquakes, and for events from between magnitude 3 to the largest ones. Have investigated using acceleration, Ms at closer distances, coda duration, etc. Some different methods have proven to be very useful. An example is LPMB which holds up when measuring events between MS 7 and 8.

Main accomplishments relevent to goals and what remains to be completed:
It is the goal of the ATWC to calculate several magnitude values for each of two or more methods or devices quickly and automatically.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
In Earthquake Notes (SSA Eastern Section Bulletin):
"Determining Magnitude Values from SP Vertical Seismometers", V. XLIII, 1972.
"Acceleration and Magnitude", V. XLV, No. 4, 1974.
"Mantle Waves and the Use of a Mantle Wave Magnitude Scale", V. 51, No. 2, 1980.

2751 20130

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Seismicity Tectonics, Earthquake Hazards and Prediction Studies in the Eastern Aleutian ore Alaska

Funding source: DOE, USGS, (and in the past NSF, NOAA-OCSEAP, Industry)

Date research began: 1973

Principal investigator(s): Klaus H. Jacob, John Taber

Address: Lamont-Doherty Geological Observatory
Palisades, New York 10964

Phone number: 914-359-2900 ext. 660

Main goal(s) of research:

To collect and analyze seismic and tectonic data for fundamental research into the processes that control seismicity, and deduce inferences from it for earthquake hazards investigation and equ-prediction along the Alaska-Aleutian subduction zone and associated ore systems.

Main accomplishments relevent to goals what remains to be completed:

Identification of major seismic gaps and calculation of their probabilities to rupture in great equ. during the next 20 years.

Monitoring of seismicity and volcanicity and crusted deformation in the Shumagin seismic gap.

Process all important Alaska-Aleutian strong motion records in a uniform digital format for distribution to users.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

 27BS 20130

Project Output. Pre-October 1980! Publications marked by an asterisk were not directly supported under these projects but strongly benefited either by logistic field support or close scientific cooperation with the present project. Only published journal articles are listed here. For oral presentations, abstracts and technical reports see Annual Project Reports.

Bilham, R., 1977. A sea-level recorder for tectonic studies, Geophys. J. R. Astr. Soc., 48, 307-314.

Bilham, R., and Beavan, J., 1979. Satellite telemetry of sea-level data to monitor crustal motions in the Shumagin Islands Region of the Aleutian Arc, in Terrestrial and Space Techniques in Earthquake Prediction Research; E.S.C.-E.G.S. Special, edited by A. Vogel, 269-283, Conference Proceedings, F. Vieweg and Sons, Braunschweig/Wiesbaden.

Cormier, V., 1975. Tectonics near the junction of the Aleutian and Kuril-Kamchatka arcs, and a mechanism for middle Tertiary magmatism in the Kamchatka Basin, Geol. Soc. Amer. Bull., 86, 443-453, 1975.

Davies, J. N., and House, L., 1979. Aleutian subduction zone seismicity, volcano-trench separation, and their relation to great thrust-type earthquakes, J. Geophys. Res., 84, 4583-4591.

House, L., and Boatwright, J., 1979. Investigation of two high stress-drop earthquakes in the Shumagin seismic gap, Alaska, in Geophys. Res., 85, 7151-7165.

*Jacob, H. K., 1970. Three-dimensional seismic ray tracing in a laterally heterogeneous spherical earth, J. Geophys. Res., 75, 6675-6689.

Jacob, K. H., 1972. Global tectonic implications of anomalous seismic P travel times from the nuclear explosion Longshot, J. Geophys. Res., 77, 2556-2573.

Jacob, K. H., and Hamada, K., 1972. The upper mantle beneath the Aleutian Island arc from pure-path Rayleigh-wave dispersion data, Bull. Seism. Soc. Amer., 62(6), 1439.

Jacob, K. H., Nakamura, K., and Davies, J. N., 1977. Trench-volcano gap along the Alaskan-Aleutian arc: Facts and speculations on the role of terrigenous sediments for subduction, in Island Arcs, Deep Sea Trenches and Back Arc Basins, edited by M. Talwani and W. C. Pitman, 243-258, AGU, Washington, D.C.

*Kelleher, J. A., 1970. Space-time seismicity of the Alaska-Aleutian seismic zone, J. Geophys. Res., 75, 5745-5756.

*Kelleher, J., Savino, J., Rowlett, H., and McCann, W., 1974. Why and where great thrust earthquakes occur along island arcs, J. Geophys. Res., 79, 4889-4899.

McCann, W. R., Nishenko, S. P., Sykes, L. R., and Krause, J., 1980. Seismic gaps and plate tectonics: seismic potential for major plate boundaries, Pure Appl. Geophys., 117, 1082-1147.

 2788 20130

McCann, W. R., Perez, O. J., and Sykes, L. R., 1980. Yakataga seismic gap, southern Alaska: Seismic history and earthquake potential, Science, 207, 1309-1314.

*Nakamura, K., 1977. Volcanoes as possible indicators of tectonic stress orientation--principal and proposal, J. Volc. Geotherm. Res., 2, 1-16.

Nakamura, K., Jacob, K. H., and Davies, J. N., 1977. Volcanoes as possible indicators of tectonic stress orientation--Aleutians and Alaska, in Stress in the Earth, edited by M. Wyss, PAGEOPH, 115, 87-112.

*Perfit, M. R., 1977. The petrochemistry of igneous rocks from the Cayman Trench and the Captains Bay pluton, Unalaska Island: Their relation to tectonic processes at plate margins, Ph.D. thesis, Columbia University, New York.

Sykes, L. R., 1971. Aftershock zones of great earthquakes, seismicity gaps, earthquake prediction for Alaska and the Aleutians, J. Geophys. Res., 76(36), 8021-8041.

*Sykes, L. R., 1977. Research on earthquake prediction and related areas at Columbia University, J. Phys. Earth, 25, Suppl., S13-S29.

Papers Published Since October 1980

Davies, J., Sykes, L., House, L., and Jacob, K., 1981. Shumagin seismic gap, Alaska Peninsula: History of great earthquakes, tectonic setting, and evidence for high seismic potential, J. Geophys. Res., 86(B5), 3821-3856.

House, L., and Boatwright J., 1980. Investigation of two high stress-drop earthquakes in the Shumagin seismic gap, Alaska, J. Geophys. Res., 85, 7151-7165.

House, L., Sykes, L. R., Davies, J. N., and Jacob, K. H., 1981. Identification of a possible seismic gap near Unalaska Island, Eastern Aleutians, Alaska, in Earthquake Prediction, An International Review, Maurice Ewing Series 4, edited by D. W. Simpson and P. G. Richards, 81-92, AGU, Washington, D.C.

McCann, W. R., Nishenko, S. P., Sykes, L. R., and Krause, J., 1980. Seismic gaps and plate tectonics: Seismic potential for major plate boundaries, Pure Appl. Geophys., 117, 1082-1147.

Nakamura, K., Plafker, G., Jacob, K. H., and Davies, J. N., 1980. A tectonic stress trajectory map of Alaska using information from volcanoes and faults, Bull. Earthquake Res. Inst., 55, Part 1, 89-100, Univ. of Tokyo.

Perez, O. J., and Jacob, K. H., 1980. St. Elias, Alaska, earthquake of February 28, 1979: Tectonic setting, and precursory seismic pattern, Bull. Seismol. Soc. Amer., 70, 1595-1606.

Perez, O. J., and Jacob, K. H., 1980. Tectonic model and seismic potential of the eastern Gulf of Alaska and Yakataga seismic gap, J. Geophys. Res., 85, 7132-7150.

2754 20130

Sykes, L. R., Kisslinger, J. B., House, L., Davies, J., and Jacob, K. H., 1980. Rupture zones of great earthquakes, Alaska-Aleutian arc, 1784-1980, Science, 210, 1343-1345.

Sykes, L. R., Kisslinger, J. B., House, L., Davies, J., and Jacob, K. H., 1981. Rupture zones and repeat times of great earthquakes along the Alaska-Aleutian arc, 1784-1980, in Earthquake Prediction, An International Review, Maurice Ewing Series 4, edited by D. W. Simpson and P. G. Richards, 73-80, AGU, Washington, D.C.

Sykes, L. R., and Quittmeyer, R. C., 1981. Repeat times of great earthquakes along simple plate boundaries, in Earthquake Prediction, An International Review, Maurice Ewing Series 4, edited by D. W. Simpson and P. G. Richards, 217-247, AGU, Washington, D.C.

Papers Published Since October 1981

House, L., and Jacob, K. H. (1982). Thermal stresses in subducting lithosphere: Consequences for double seismic zones, Nature, 295, 587-589.

McNutt, S. R., and Beavan, R. J., (1981). Volcanic earthquakes at Pavlof Volcano correlated with the solid earth tide, Nature, 294, no. 5842, 615-618.

McNutt, S. (1982). Seismic monitoring of volcanoes in the Aleutians, Volcano News, no. 11, page 7.

Reyners, M., and Coles, K. (1982). Fine structure of the dipping seismic zone and subduction mechanics in the Shumagin Islands, Alaska, J. Geophys. Res., 87, 356-366.

Papers Published Since October 1982

Beavan, J., Hauksson, E., McNutt, S. R., Bilham, R., and Jacob, K. H., 1983. Tilt and seismicity changes in the Shumagin seismic gap, Science, 222, 322-325.

Beavan, J., and Jacob, K. H., Processed Strong-Motion Data from Subduction Zones: Alaska, Report No. 1 in the series "Lamont-Processed Strong-Motion Data", 252 pp., Lamont-Doherty Geol. Obs., N.Y., 1984.

Hauksson, E., Armbruster, J., and Dobbs, S., Seismicity Patterns (1963-1983) as Stress Indicators in the Shumagin Seismic Gap, Alaska, Bull. Seismol. Soc. Am., 74, 2541-2558, 1984.

Hauksson, E., Structure of the Benioff Zone Beneath the Shumagin Islands, Alaska: Relocations of Local Earthquakes using 3-D Ray Tracing, J. Geophys. Res., 90, 635-649, 1985.

House, L., and Jacob, K. H., 1982. Thermal stresses in subducting lithosphere: Consequences for double seismic zones, Nature, 295, 587-589.

House, L. S., and Jacob, K. H., 1983. Earthquakes, plate subduction, and stress reversals in the eastern Aleutian arc, J. Geophys. Res., 88, 9347-9373.

 2758 20130

Jacob, K., and Hauksson, E., 1983. A seismotectonic analysis of the seismic and volcanic hazards in the Pribilof Islands - Eastern Aleutian Islands region of the Bering Sea, L-DGO Final Report to NOAA/OCSEAP, R.U. 16, 3/1/75-9/30/82, 224 p.

Jacob, K. H., Estimates of Long-Term Probabilities for Future Great Earthquakes in the Aleutians, J. Geophys. Res., 11, 295-298, 1984.

Jacob, K. H. and Mori, J., Strong Motions in Alaska-Type Subduction Zone Environments in Proceedings of the 8th World Conference on Earthquake Engineering, Vol. 2, 311-317, 1984.

McNutt, S. R., and Beavan, R. J., 1983. Correlation of the solid earth tide with volcanic earthquakes at Pavlof Volcano, Alaska, in Proc. Ninth International Symposium on Earth Tides, edited by J. T. Kuo, pp. 703-713, E. Schweizerbart'sche Verlagsbuchhandlung, D-7000, Stuttgart, Germany.

Mori, J., 1983. Dynamic stress drops of moderate earthquakes of the eastern Aleutians and their relation to a great earthquake, Bull. Seism. Soc. Am., 73, 1077-1097.

Mori, J., Short- and long-period subevents of the 4 February 1965 Rat Islands earthquake, Bull. Seismol. Soc. Am., 74, 1331-1347, 1984.

Papers in Preparation

Boyd, T. M. and Jacob, K. H., Seismicity of the Unalaska Region, Alaska.

Jacob, U. H., Seismicity, tectonics, and geohazards in the Gulf of Alaska regions. Chapter 6 in D. Hood (Editor): Gulf of Alaska; Physical Environment and Biological Resources.

McNutt, S. R., Eruption characteristics and cycles, and earthquake activity in the vicinity of Pavlof Volcano, Eastern Aleutians.

McNutt, S. R., Observations and analysis of B-type earthquakes, explosions, and volcanic tremor at Pavlof Volcano, Alaska.

McNutt, S. R. and Beavan, R. J., Periodic eruptions at Pavlof Volcano: The effects of sea level and an aseismic slip event, subm. J. Geophys. Res.

McNutt, S. R. and Jacob, K. H., Determination of large-scale velocity structure of the crust and upper mantle in the vicinity of Pavlof Volcano, Alaska, subm. J. Geophys. Res.

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Alaska Seismic Studies

Funding source: U.S. Geological Survey

Date research began: 1971

Principal investigator(s): John C. Lahr, Christopher D. Stephens, and Robert A. Page

Address: U.S.G.S., MS 977, 345 Middlefield Rd., Menlo Park, CA 94025

Phone number: (415) 323-8111 x2510

Main goal(s) of research: Perform long-term seismicity measurements in southern Alaska to:

1. Evaluate the seismic hazards in populated areas and areas of prepared future development.
2. Develop an improved understanding of the tectonic processes that are generating earthquakes.
3. Document premonitory earthquake phenomena which may prove useful for earthquake prediction.

Main accomplishments relevent to goals what remains to be completed:
See attached.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
See attached.

27B1 20130

Main Accomplishments and What Remains

A data base for earthquakes which occurred in southern coastal Alaska between Yakutat and Cook Inlet since 1971 has been compiled from regional seismic monitoring. These data have been used in delineating seismic source zones, in resolving large-scale first-order features of the seismotectonic framework, and in evaluating earthquake potential for hazard assessment studies. Many problems remain, including identifying additional source areas for potentially damaging earthquakes, understanding the origin of large historical earthquakes in light of the seismotectonic framework and current seismicity, refining the regional seismotectonic model, and searching for temporal variations in seismicity before and between large earthquakes.

Eight quarterly catalogs of earthquakes in southern Alaska are available from the USGS Open-File Services Section. Some copies may be obtained from John Lahr.

Hasegawa, H. S., Lahr, J. C., and Stephens, C. D., 1980. Fault parameters of the St. Elias, Alaska, earthquake of February 28, 1979, Bulletin of the Seismological Society of America, v. 70,no. 5, p. 1651-1660.

Lahr, J. C., 1975. Detailed seismic investigations of Pacific-North American plate interaction in southern Alaska, Ph.D. dissertation, Columbia University, 141 p.

Lahr, J. C., and Kachadoorian, Ruben, 1975. Preliminary geologic and seismic evaluation of the proposed Devil Canyon and Watana reservoir areas, Susitna River, Alaska. Prepared for the Alaska District Corps of Engineers, 24 p.

Lahr, J. C., and Page, R. A., 1975. Investigations of earthquakes below the Cook Inlet region of Alaska, in U.S. Geological Survey Alaska Program, 1975: U.S. Geological Survey Circular 722, p. 47-48.

Lahr, J. C., and Blackford, Michael, 1976. Gulf of Alaska seismicity, in the U.S. Geological Survey in Alaska: Accomplishments during 1975, U.S. Geololgical Survey Circular 733, p. 55.

Lahr, J. C., Plafker, George, Stephens, C. D., Fogleman, K. A., and Blackford, M. E., 1979. Interim report on the St. Elias, Alaska, earthquake of 28 February 1979, U.S. Geological Survey Open-File Report 79-670, 35 p. Also in Earthquake Engineering Research Institute Newsletter, v. 13, no. 4, p. 54-76.

Lahr, J. C., and Plafker, George, 1980. Holocene Pacific-North American plate interaction in southern Alaska: Implications for the Yakataga seismic gap, Geology, v. 8, p. 483-486.

Lahr, J. C., Stephens, C. D., Hasegawa, Henry, and Boatwright, John, 1980. Alaska seismic gap only partially filled by 28 February 1979 earthquake, Science, v. 207, p. 1351-1353.

 2755 20130

McNutt, S. R., and Beavan, R. J., 1983. Correlation of the solid earth tide with volcanic earthquakes at Pavlof Volcano, Alaska, in Proc. Ninth International Symposium on Earth Tides, edited by J. T. Kuo, pp. 703-713, E. Schweizerbart'sche Verlagsbuchhandlung, D-7000, Stuttgart, Germany.

Mori, J., 1983. Dynamic stress drops of moderate earthquakes of the eastern Aleutians and their relation to a great earthquake, Bull. Seism. Soc. Am., 73, 1077-1097.

Mori, J., Short- and long-period subevents of the 4 February 1965 Rat Islands earthquake, Bull. Seismol. Soc. Am., 74, 1331-1347, 1984.

Papers in Preparation

Boyd, T. M. and Jacob, K. H., Seismicity of the Unalaska Region, Alaska.

Jacob, U. H., Seismicity, tectonics, and geohazards in the Gulf of Alaska regions. Chapter 6 in D. Hood (Editor): Gulf of Alaska; Physical Environment and Biological Resources.

McNutt, S. R., Eruption characteristics and cycles, and earthquake activity in the vicinity of Pavlof Volcano, Eastern Aleutians.

McNutt, S. R., Observations and analysis of B-type earthquakes, explosions, and volcanic tremor at Pavlof Volcano, Alaska.

McNutt, S. R. and Beavan, R. J., Periodic eruptions at Pavlof Volcano: The effects of sea level and an aseismic slip event, subm. J. Geophys. Res.

McNutt, S. R. and Jacob, K. H., Determination of large-scale velocity structure of the crust and upper mantle in the vicinity of Pavlof Volcano, Alaska, subm. J. Geophys. Res.

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Crustal Strain

Funding source: U.S. Geological Survey internal (SIR)

Date research began: 1975

Principal investigator(s): J. C. Savage and M. Lisowski

Address: U.S. Geological Survey
345 Middlefield Road
Menlo Park, California 94025

Phone number: 415 323-8111

Main goal(s) of research:

Measure strain accumulation along major faults in southern Alaska (Fairweather fault near Yakutat, Pacific subduction thrust near Yakataga and Shumagin Isl., Denali fault near Cantwell and Paxson, Todschunda fault near the White River).

Main accomplishments relevent to goals what remains to be completed:

Preliminary measurements of strain accumulation available at Yakutat, Yakataga, Shumagin Is., Cantwell, and Paxson. Continued monitoring of strain accumulation for a period of several decades is objective. The goal is to determine whether fluctuations in strain rate occur.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

Savage, J. C., M. Lisowski, W. H. Prescott, Strain accumulation across the Denali Fault in the Delta River Canyon, Alaska, J. Geophys. Res., 86, 1005-1014, 1981.

2782 20130

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Tiltmeter measurements in the Cape Yakataga area

Funding source: Not currently funded

Date research began: September 1976

Principal investigator(s): Carl E. Mortensen

Address: U.S. Geological Survey
345 Middlefield Road, MS 977
Menlo Park, California 94025

Phone number: 415 323-8111 ext. 2583

Main goal(s) of research:

To monitor crustal deformation, using borehole tiltmeters, in the Yakataga seismic gap.

Main accomplishments relevent to goals what remains to be completed:

Records of ground tilt between September 1976 to December 1984 (with some gaps).

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

Myren, G. D., C. E. Mortensen, T. L. Murray, and E. Y. Iwatsubo, 1980, Tiltmeter observations at Cape Yakataga, Alaska, preceding the St. Elias earthquake, M=7.8, of February 28, 1979, Bull. Seismol. Soc. of Amer., v. 70, no. 5, pp. 1661-1665.

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: (1) General geotechnical hazard evaluations for areas and structures.
(2) Historic uplift and offset based on NOAA C&GS Survey data
(3) Hazard evaluation of arctic marine deltas

Funding source: (1) Municipalities & Corporate
(2) Internal
(3) Internal

Date research began: (1) 1983 (2) 1985 (3) 1983

Principal investigator(s): Allan F. Divis

Address: Terratech Ltd.
1016 Hardell Lane
Vista, CA 92083

Phone number: (619) 727-1324 or 941-7730

Main goal(s) of research:
(1) Geotechnical support of construction and development.
(2) Utilization of NOAA vertical and horizontal data to quantify recent fault offset.
(3) Literature analysis & data summary.

Main accomplishments relevent to goals and what remains to be completed:
(1) Seismic and geological hazard evaluation of Seward, Resurrection Bay Area-completed.
(2) Acquisition of some historic data to evaluate feasibility of study--very preliminary.
(3) Paper in preparation.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
(1) a. Seismicity map/survey of Resurrection Bay
b. Geotechnical study--slope stability analysis
c. Marine geophysical study--data & analysis

(2) a. Preliminary data analysis

(3) a. As in coal above

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Engineering Geology/Environmental Geology, Anchorage

Funding source: Seismic Hazards Reduction Program

Date research began: 1965

Principal investigator(s): Henry R. Schmoll

Address: U.S. Geological Survey, MS 972, Box 25046
Denver, Colorado 80225

Phone number: FTS 776-7744

Main goal(s) of research:

Compilation of geologic data, mainly quaternary, for use in land-use planning and seismic hazards investigations.

Main accomplishments relevent to goals what remains to be completed:

Publication of generalized geologic and interpretive maps of Anchorage low land. Publication of preliminary maps of other part of municipality of Anchorage. Publication of glacial geology synthesis. Final publication of quaternary maps of entire municipality. Publication of subsurface data, Anchorage lowland.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

See attached bibliography of Engineering Geology, Anchorage Projects Publications, 1950-present.

USGS/Engineering Geology
Anchorage Projects Publications List, 1950-1985

Bartsch-Winkler, Susan, and Schmoll, H. R., 1983. Convoluted beds in late Holocene intertidal sediment at the mouth of Knik Arm, upper Cook Inlet, Alaska: U.S. Geological Survey Circular 868, p. 330-338.

______1984. Guide to Late Pleistocene and Holocene deposits of Turnagain Arm, Alaska: Anchorage, Alaska Geological Society, 70 p.

______1984. Bedding types in upper Holocene distributary tidal channel sequences, Knik Arm, upper Cook Inlet, Alaska: Journal of Sedimentary Petrology, v. 54, no. 4, p. 1237-1248.

Bennett, R. H., Lambert, D. N., Hulbert, M. H., Schmoll, H. R., and Bohlke, B. M., 1980. Clay fabric of sediments from various depositional environments [abs.]: Clay Mineral Society Annual Meeting Program.

Dobrovolny, Ernest, and Miller, R. D., 1950. Descriptive geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Open-File Report, 11 p., 2 maps.

Dobrovolny, Ernest, Miller, R. D., and Hansen, W. R., 1964. Engineering-geologic effects of the March 27, 1964, earthquake at Anchorage, Alaska, in Abstracts for 1964: Geological Society of America Special Paper 82, p. 46-47.

Dobrovolny, Ernest, and Schmoll, H. R., 1968, Geology as applied to development planning in the Greater Anchorage Area Borough, Alaska, in International Geological Congress, 23d, Prague, 1968, Abstracts, p. 300.

______1968. Geology as applied to urban planning: an example from the Greater Anchorage Area Borough, Alaska: International Geological Congress, 23d, Prague, 1968, Proceedings, Section 12, Engineering geology in country planning, p. 39-56. Reprinted, 1975, in Betz, Frederick, Jr., ed., Environmental geology: Benchmark Papers in Geology, v. 25, p. 49-66. Reprinted, 1976, in Tank, R. W., ed., Focus on environmental geology: New York, Oxford University Press, p. 11-26.

*______1974. Slope stability map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-E, scale 1:24,000.

Hansen, W. R., 1965. Effects of the earthquake of March 27, 1964, at Anchorage, Alaska: U.S. Geological Survey Professional Paper 542-A, 68 p.

Miller, R. D., 1957. Origin of the Pt. Campbell-Pt. Woronzof area as related to the "blue clay" that underlies Anchorage, Alaska: Geological Society of America Bulletin, v. 68, no. 12, pt. 2, p. 1907.

Miller, R. D., and Dobrovolny, Ernest, 1957. Pleistocene history of the Anchorage area, Alaska: Geological Society of America Bulletin, v. 68, no. 12, pt. 2, p. 1908.

 2787 2013O

_____1957. Surficial geology of Anchorage and vicnity, Alaska: U.S. Geological Survey Administrative Report, 267 p., 1 pl.

_____1959. Surficial geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Bulletin 1093, 128 p.

Schmoll, H. R., and Barnwell, W. W., 1984. East-west geologic cross section along the DeBarr line, Anchorage, Alaska: U.S. Geological Survey Open-File Report 84-791, 11 p., 1 pl.

*Schmoll, H. R., and Dobrovolny, Ernest, 1971. Generalized slope map of the Eagle River-Birchwood area, Greater Anchorage Area Borough, Alaska: U.S. Geological Survey Open-File Report, 1 map, scale 1:63,360.

*Schmoll, H. R., and Dobrovolny, Ernest, 1972. Generalized geologic map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-A, scale 1:24,000.

*_____, 1972. Slope map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-B, scale 1:24,000.

*_____1973. Construction materials map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-C, scale 1:24,000.

*_____1974. Foundation and excavation conditions map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-D, scale 1:24,000.

Schmoll, H. R., Dobrovolny, Ernest, and Gardner, C. A., 1980. Preliminary geologic map of the middle part of the Eagle River valley, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 80-890, 11 p., 1 pl., scale 1:25,000.

_____1981. Preliminary geologic map of Fire Island, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 81-552, 4 p.

*Schmoll, H. R., Dobrovolny, Ernest, and Zenone, Chester, 1971. Generalized geologic map of the Birchwood-Eagle River area, Greater Anchorage Area Borough, Alaska: U.S. Geological Survey Open-File Report, 1 map scale 1:63,360.

*Schmoll, H. R., and Emanuel, R. P., 1981. Generalized geologic map and hydrologic properties of the Potter Creek area, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 81-1168, 1 pl., scale 1:25,000.

*_____1983. Geologic materials and hydrogeologic characteristics in the Fire Lakes-Eklutna area, Anchorage, Alaska: U.S. Geological Survey Open-File Report 83-479, 1 pl., scale 1:25,000.

Schmoll, H. R., and Gardner, C. A., 1982, Diamicton of subglacial or subaqueous origin, Fire Island, Anchorage, Alaska: International Union for Quaternary Research (INQUA), XI Congress, Moscow, U.S.S.R., Abstracts, v. 1, p. 282.

Schmoll, H. R., Odum, J. K., and Espinosa, A. F., 1985. Seismotechnistratigraphic cells: an approach to the analysis of subsurface geology at Anchorage, Alaska, for seismic zonation studies: Geological Society of America Abstracts with Programs, v. 17, no. 7 (in press).

Schmoll, H. R., Szabo, B. J., Rubin, Meyer, and Dobrovolny, Ernest, 1972. Radiometric dating of marine shells from the Bootlegger Cove Clay, Anchorage, Alaska: Geological Society of America Bulletin, v. 83, p. 1107-1114.

Schmoll, H. R., and Yehle, L. A., 1983. Glaciation in the upper Cook Inlet basin: a preliminary reexamination based on geologic mapping in progress, in Thorson, R. M., and Hamilton, T. D., eds., Glaciation in Alaska--Extended abstracts from a workshop: Alaska Quaternary Center, University of Alaska Museum Occasional Paper no. 2, p. 75-81.

Schmoll, H. R., Yehle, L. A., Gardner, C. A., and Odum, J. K., 1984. Guide to surficial geology and stratigraphy within the upper Cook Inlet basin [prepared for the 80th annual meeting of the Cordilleran Section, Geological Society of America]: Anchorage, Alaska Geological Society, 89 p.

Updike, R. G., and Schmoll, H. R., 1984. A brief resume of the geology of Anchorage and vicinity: Geological Society of America Abstracts with Programs., v. 16, no. 5, p. 306.

*Zenone, Chester, Schmoll, H. R., and Dobrovolny, Ernest, 1974. Geology and ground water for land-use planning in the Eagle River-Chugiak area, Alaska: U.S. Geological Survey Open-File Report 74-57, 25 p., 1 pl.

Approved by Branch

Updike, R. G., Olsen, H. W., Schmoll, H. R., Kharaka, Y. K., and Stokoe, K. H.. Recent subsurface geologic and geotechnical studies adjacent to the Turnagain Heights landslide in Lynn Ary Park, Anchorage, Alaska: U.S. Geological Survey Bulletin, 73 ms p.

Submitted to Branch

Schmoll, H. R., and Yehle, L. A., Glaciation of the upper Cook Inlet region, Alaska, in Hamilton, T. D., Thorson, R. M., and Reed, K. M., eds., Glaciation in Alaska: Anchorage, Alaska Geological Society, 79 ms p.

*Publications intended for a broad, mainly non-geological audience.

DIRECTORY OF EARTHQUAKE HAZARDS RESEARCH and OTHER RELATED ACTIVITIES IN ALASKA

Inventory Form

Title of research:

Seismic Hazard studies, Anchorage, Alaska

Funding source:

U.S. Geological Survey

Date research began:

FY 84

Principal investigator(s):

A. F. Espinosa

Address: U.S. Geological Survey
Box 25046, Denver Federal Center, MS 966
Denver, CO 80225

Phone number: (303)-236-1597
FTS 776-1597

Main goal(s) of research:

To study and evaluate the seismic hazards in the Anchorage and vicinity in Alaska. The hazard evaluation is performed at (1) the global scale, (2) the regional scale, (3) the local scale, and (4) at the engineering scale. Field geological and seismological investigations are carried out in conjunction with this multidisciplinary effort.

Main accomplishments relevant to goals and what remains to be completed:

Geologic field maps of surficial geologic material and of stratigraphic subsurface materials have been released. Seismological stong-motion field stations have been deployed in Anchorage. A seismological field study consisting of 12 portable self-contained systems have been deployed in Anchorage and vicinity. Analysis of borehole information and geotechnical classification of the lithological units is being completed. A large intensity data-base catalog has been edited. Seismicity maps at (a) global and (b) regional scales have been released. A seismicity catalog from 1900 to 1984 has been completed. Several quadrangle maps at 1:25,000 and at 1:63,360 scales are being drawn. A close working relationship with the Department of Natural Resources of Alaska has been developed in order to bypass possible duplication of efforts in geological field mapping. Attenuation functions in a subductive area are being developed.

2851 20130

Other studies (such as those of G. Plafker) will be used to delineate the seismic source zones in southern Alaska. These source zones will be used to evaluate deterministically and probabilistically the seismic risk in an urban area. A damage study from the 1964 Alaskan earthquake is being used in conjunction with several geological cross sections in Anchorage in order to ascertain if there is any correlation between the local surficial geologic material and the overall trend of damage sustained by manmade structures. A shallow-reflection profile through Anchorage proper will assist in identifying the major discontinuities in the region.

A shallow-reflection profile to the northeast of Anchorage is of utmost importance. This profile has the objective of identifying a suspect Quaternary fault in that region. Also, it is of utmost importance to carry on another shallow-reflection profile across a fault gap (discontinuity region) of the Castle Mountain fault. This fault is located about 20 km away from Anchorage and it presents a seismic potential hazard to the urban area. A vertical lithological control study should be performed in Anchorage by means of a careful drill-hole study. This task will allow us to verify the geological cross section maps of the region and also will allow us to identify the geotechnical distribution of parameters with depth. The outcome of this phase of our project work is to elucidate a physical-parameter distribution for the Anchorage Bowl and to be able to compute theoretically the expected ground motion in the region. All the tasks identified above are of an applied multidisciplinary research effort which will allow the community to develop a more realistic "land use and an urban development plan" for the region.

What products (data ,maps, reports, etc.) are available (provide bibliographic citations whre appropriate) and intended audience or user:

A data base on earthquake intensities (Modified Mercalli Intensity ratings) from 1900 through 1981 has been compiled and is in the process of being prepared for publication.

A seismicity map for Alaska and the Aleutian Islands at 1:12,500,000 scale has been released.

A new projection "Modified stereographic conformal projection" for Alaska has been coded for the computer, including the geographical display of the State of Alaska. This map has a low cartographic distortion (the Alaska Map E has a very high distortion).

A seismicity catalog has been compiled from 1900 to 1984 and is being prepared for publication.

A geologic cross section map in Anchorage has been released. Several quadrangle surficial geologic maps are being prepared for publication.

Several reports and oral presentations have been published or are to be published (see attached references).

Bartsch-Winkler, Susan, and Schmoll, H. R., 1984, Convoluted beds in late Holocene intertidal sediment at the mouth of Knik Arm, upper Cook Inlet, Alaska: U.S. Geological Survey Circular 868, p. 105-108.

______1984, Guide to Late Pleistocene and Holocene deposits of Turnagain Arm, Alaska: Anchorage, Alaska Geological Society, 70 p.

______1984, Bedding types in upper Holocene distributary tidal channel sequences, Knik Arm, upper Cook Inlet, Alaska: Journal of Sedimentary Petrology, v. 54, no. 4, p. 1237-1248.

Bennett, R. H., Lambert, D. N., Hulbert, M. H., Schmoll, H. R., and Bohlke, B. M., 1980, Clay fabric of sediments from various depositional environments [abs.]: Clay Mineral Society Annual Meeting Program.

Dobrovolny, Ernest, and Miller, R. D., 1950, Descriptive geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Open-File Report, 11 p., 2 maps.

Dobrovolny, Ernest, Miller, R. D., and Hansen, W. R., 1964, Engineering-geologic effects of the March 27, 1964, earthquake at Anchorage, Alaska, in Abstracts for 1964: Geological Society of America Special Paper 82, p. 46-47.

Dobrovolny, Ernest, and Schmoll, H. R., 1968, Geology as applied to development planning in the Greater Anchorage Area Borough, Alaska, in International Geological Congress, 23d, Prague, 1968, Abstracts, p. 300.

______1968, Geology as applied to urban planning: an example from the Greater Anchorage Area Borough, Alaska: International Geological Congress, 23d, Prague, 1968, Proceedings, Section 12, Engineering geology in country planning, p. 39-56. Reprinted, 1975, in Betz, Frederick, Jr., ed., Environmental geology: Benchmark Papers in Geology, v. 25, p. 49-66. Reprinted, 1976, in Tank, R. W., ed., Focus on environmental geology: New York, Oxford University Press, p. 11-26.

______1974, Slope stability map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-E, scale 1:24,000.

Espinosa, A. F., 1984, Seismicity of Alaska and the Aleutian Islands, 1960-1983: U.S. Geological Survey Map 84-855.

Espinosa, A. F., and Michael, J. A., 1984, Seismicity of the Arctic and adjoining regions, 1960-1983: U.S. Geological Survey Map 84-376.

Espinosa, A. F., Schmoll, H. R., Brockman, S. R., Yehle, L. A., Odum, J. K., Michael, J. A., and Rukstales, K. S., 1985, Seismic hazard studies, Anchorage, Alaska, in Hays, W. W., and Gori, Paula, eds., Evaluation of regional and urban earthquake hazards and risk in Alaska: U.S. Geological Survey Open-file Report 85-   , 17 p.

Espinosa, A. F., 1985, "Mapping a Subduction Plate", cover picture and caption of a 3-D display of the mean-surface of the Lithospheric Pacific Plate mapping procedure applied to seismological data in the Alaskan-Aleutian Island region. Geophysical Research Letters, American Geophysical Union, Vol. 12, No. 8.

Hansen, W. R., 1965, Effects of the earthquake of March 27, 1964, at Anchorage, Alaska: U.S. Geological Survey Professional Paper 542-A, 68 p.

Miller, R. D., 1957, Origin of the Pt. Campbell-Pt. Woronzof area as related to the "blue clay" that underlies Anchorage, Alaska: Geological Society of America Bulletin, v. 68 no. 12, pt. 2, p. 1907.

2888 20130

Miller, R. D., and Dobrovolny, Ernest, 1957, Pleistocene history of the Anchorage area, Alaska: Geological Society of America Bulletin, v. 68, no. 12, pt. 2, p. 1908.

______1957, Surficial geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Administrative Report, 267 p., 1 pl.

______1959, Surficial geology of Anchorage and vicinity, Alaska: U.S. Geological Survey Bulletin 1093, 128 p.

Nichols, D. R., and Yehle, L. A., 1985, Volcanic debris flows, Copper River basin, Alaska, in Committee for International Exchange of Landslide Technique, eds., Proceedings of IVth International Conference and Field Workshop on Landslides: The Japan Landslide Society, Tokyo, p. 365-372.

______1985, Volcanic debris flows, Copper River basin, Alaska: Japan Landslide Institute Bulletin, 8 p.

Odum, J. K., 1985, Difficulties in characterizing weak Tertiary rocks using field and laboratory geotechnical tests--the Tyonek Formation, Cook Inlet region, Alaska, as an example [abs.]: Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 680.

Odum, J. K., Gardner, C. A., Yehle, L. A., and Schmoll, H. R., 1985, Strength and durability properties of Tyonek Formation core, Cook Inlet region, Alaska: American Association of Petroleum Geologists Bulletin, v. 69, no. 4, p. 674.

Schmoll, H. R., 1985, USGS engineering geology products in the Anchorage area, Alaska: A review, in Hays, W. W., and Gori, Paula, eds., Evaluation of regional and urban earthquake hazards and risk in Alaska: U.S. Geological Survey Open-File Report 85- , 18 p.

Schmoll, H. R., and Barnwell, W. W., 1984, East-west geologic cross section along the DeBarr line, Anchorage, Alaska: U.S. Geological Survey Open-File Report 84-791, 11 p., 1 pl.

Schmoll, H. R., and Dobrovolny, Ernest, 1971, Generalized slope map of the Eagle River-Birchwood area, Greater Anchorage Area Borough, Alaska: U.S. Geological Survey Open-File Report, 1 map, scale 1:63,360.

______1972, Generalized geologic map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-A, scale 1:24,000.

______1972, Slope map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-B, scale 1:24,000.

______1973, Construction materials map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-C, scale 1:24,000.

______1974, Foundation and excavation conditions map of Anchorage and vicinity, Alaska: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-787-D, scale 1:24,000.

Schmoll, H. R., Dobrovolny, Ernest, and Gardner, C. A., 1980, Preliminary geologic map of the middle part of the Eagle River valley, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 80-890, 11 p., 1 pl., scale 1:25,000.

______1981, Preliminary geologic map of Fire Island, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 81-552, 4 p.

Schmoll, H. R., Dobrovolny, Ernest, and Zenone, Chester, 1971, Generalized geologic map of the Birchwood-Eagle River area, Greater Anchorage Area Borough, Alaska: U.S. Geological Survey Open-File Report, 1 map, scale 1:63,360.

2854 20130

Schmoll, H. R., and Emanuel, R. P., 1981, Generalized geologic map and hydrologic properties of the Potter Creek area, Municipality of Anchorage, Alaska: U.S. Geological Survey Open-File Report 81-1168, 1 pl., scale 1:25,000.

______1983, Geologic materials and hydrogeologic characteristics in the Fire Lakes-Eklutna area, Anchorage, Alaska: U.S. Geological Survey Open-File Report 83-479, 1 pl., scale 1:25,000.

Schmoll, H. R., Espinosa, A. F., and Odum, J. K., 1985, Subsurface mapping at Anchorage, Alaska: a tool for the delineation of seismotechnistratigraphic (STS) cells: International Association of Engineering Geologists, Fifth International Congress.

Schmoll, H. R., and Gardner, C. A., 1982, Diamicton of subglacial or subaqueous origin, Fire Island, Anchorage, Alaska: International Union for Quaternary Research (INQUA), XI Congress, Moscow, U.S.S.R., Abstracts, v. 1, p. 282.

Schmoll, H. R., Odum, J. K., and Espinosa, A. F., 1985, Seismotechnistratigraphic cells: an approach to the analysis of subsurface geology at Anchorage, Alaska, for seismic zonation studies [abs.]: Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 710.

Schmoll, H. R., Szabo, B. J., Rubin, Meyer, and Dobrovolny, Ernest, 1972, Radiometric dating of marine shells from the Bootlegger Cove Clay, Anchorage, Alaska: Geological Society of America Bulletin, V. 83, p. 1107-1114.

Schmoll, H. R., and Yehle, L. A., 1983, Glaciation in the upper Cook Inlet basin: a preliminary reexamination based on geologic mapping in progress, in Thorson, R. M., and Hamilton, T. D., eds., Glaciation in Alaska--Extended abstracts from a workshop: Alaska Quaternary Center, University of Alaska Museum Occasional Paper no. 2, p. 75-81.

______1985, Glaciation of the upper Cook Inlet region, Alaska, in Hamilton, T. D., Thorson, R. M., and Reed, K. M., eds., Glaciation in Alaska: Anchorage, Alaska Geological Society, 79 ms p.

Schmoll, H. R., Yehle, L. A., Gardner, C. A., and Odum, J. K., 1984, Guide to surficial geology and stratigraphy within the upper Cook Inlet basin [prepared for the 80th annual meeting of the Cordilleran Section, Geological Society of America]: Anchorage, Alaska Geological Society, 89 p.

Updike, R. G., Olsen, H. W., Schmoll, H. R., Kharaka, Y. K., and Stokoe, K. H., 1985, Recent subsurface geologic and geotechnical studies adjacent to the Turnagain Heights landslide in Lynn Ary Park, Anchorage, Alaska: U.S. Geological Survey Bulletin, 73 ms p.

Updike, R. G., and Schmoll, H. R., 1984, A brief resume of the geology of Anchorage and vicinity: Geological Society of America Abstracts with Programs, v. 16, no. 5, p. 306.

Yehle, L. A., Odum, J. K., Schmoll, H. R., and Dearborn, L. L., 1985, Overview of the geology and geophysics of the Tikishla Park drill hole, USGS A-84-1, Anchorage, Alaska: U.S. Geological Survey Open-File Report.

Yehle, L. A., Odum, J. K., and Reneau, David, 1985, Generalized interpretation of geologic materials from shot holes drilled for the Trans-Alaska Crustal Transect project, Copper River basin and adjacent regions, Alaska, May-June 1984: U.S. Geological Survey Open-File Report 85-582, 33 p.

Zenone, Chester, Schmoll, H. R., and Dobrovolny, Ernest, 1974, Geology and ground water for land-use planning in the Eagle River-Chugiak area, Alaska: U.S. Geological Survey Open-File Report 74-57, 25 p., 1 pl.

2858 20130

Seismic Hazard Studies, Anchorage, Alaska

9950-03643

A. F. Espinosa
Branch of Engineering Geology and Tectonics
U.S. Geological Survey
Box 25046, MS 966, Denver Federal Center
Denver, CO 80225
(303) 236-1597

Investigations

1. A "completeness" of the seismicity catalogue is being investigated in order to use lower magnitude thresholds in (a) spatial and magnitude-temporal distribution of shallow ($h \leq 33$ km) and intermediate ($33 < h \leq 100$ km) seismicity ($M_S \geq 5.5$) occurring within a specified area in the period of time which uses (a) historical and (b) instrumentally recorded earthquakes. This effort is part of the seismicity study being carried out in this project for the Anchorage and vicinity region in Alaska.

2. A damage evaluation for the City of Anchorage, sustained from the 1964 Alaskan earthquake, is in preparation with damage data that have not been published previously. This information and local surficial geological data is planned to be used in order to evaluate transfer-function amplification curves in Anchorage and to ascertain any existing correlation between damage and soil conditions in the area.

3. A suite of seismicity maps and depth cross sections for the Anchorage and vicinity region in Alaska are being prepared. A technique has been developed to map the subducting plate on a three-dimensional finite-difference display for Anchorage and vicinity. ISC, USGS, and Menlo Park's local seismicity data files are used to perform the geometrical mapping of the lithosphere in this region.

4. The intensity catalogue covering the period 1900 through 1981 for the State of Alaska has undergone a very careful editing process during last year and a half. A total of 14 isoseismal maps have been compiled and drawn for Alaska, and attenuation laws are being derived from the above data set.

5. A report describing geologic materials from shot holes drilled in 1984 for the Trans-Alaska Crustal Transect project has been finished. The most significant finding of this work is that deposits in the central part of the Copper River basin are dominantly lacustrine silt and clay with thinner intervening units of alluvial gravel and sand. No diamicton or other evidence of glacial deposits was found in the central basin. These findings support the controversial concept that during each of several glaciations the center of the basin was not occupied by glacier ice but instead was the site of glacial Lake Atna and its predecessors throughout the glaciation. These observations further bring into question the direct glacial origin of any diamictons exposed along river bluffs in the central part of the basin.

2884 20130

6. A model which incorporates the concept of seismotechnistratigraphic cells as a method for delineation of subsurface geology beneath Anchorage, Alaska, and its application to seismic hazards studies is under study.

7. A report is being prepared that describes the difficulties encountered in testing relatively weak, nonhomogeneous rocks, in contrast to standard techniques that have been developed for either high modulus, homogeneous rocks or low modulus soils. Most of the problems encountered are discussed and derived from drill core samples from the west side of Cook Inlet but are equally applicable to similar rocks of the same formation that underlie the Anchorage area.

8. A study has been performed which describes volcanic debris flows of the Copper River basin, based on work undertaken several years ago. At least five flows are now recognized, and interpretated to have accompanied lengthy periods of active volcanism in the western Wrangell Mountains that occurred within Pleistocene time; two of the flows may have resulted from lateral-blast eruptions similar to the one that occurred at Mount Saint Helens, Washington, in 1980.

9. Two papers were presented at the workshop, "Evaluation of Regional and Urban Earthquake Hazards and Risk in Alaska", convened in Anchorage, Alaska, on September 1985. One of the papers described the accomplishments and aims of the present project, and the other reviewed the history of engineering geology research in the Anchorage area from 1948 to the present, displaying selected products of those efforts.

10. The geologic map of the northwestern quarter of the Tyonek A-4 quadrangle at 1:31,680 scale has been revised and completed. Also, the geologic map of the Tyonek B-4 quadrangle has been reviewed. These two maps will be released shortly.

11. A report describing the geology and geophysics of the Tikishla Park hole, drilled in Anchorage in 1984, has been completed.

12. A draft of an invited paper describing Tertiary to Holocene glaciation of Cook Inlet region has been completed. The paper discusses new ideas that have evolved during studies undertaken over the past several years and embodies the concept of glacioestuarine associations as a means of classifying both stratigraphically and geomorphically evidenced depositional units.

13. An open-file report describing cuttings from shot holes drilled for the Trans-Alaska Crustal Transect Project in the Copper River basin in 1985 has been completed.

14. The first draft of a USGS Professional Paper interpreting results from geotechnical testing of cores from four drill holes in the Tyonek Formation has been completed.

15. Contributions consisting of surficial geology input to the geologic map of the Gulkana B-1 quadrangle, covering about half of the map (which is being prepared as an adjunct to the Trans-Alaska Crustal Transect Project), have been nearly completed.

16. The northeastern sheet of the three-sheet geologic materials map of the Municipality of Anchorage has been checked following drafting of line work and is in the process of undergoing minor cartographic revision.

17. An abstract was prepared for a paper to be presented at the Fifth Congress of the International Association of Engineering Geologists to be held in 1986. This paper discusses the development of the technique of preparing a map that portrays the subsurface geology in the Anchorage metropolitan area based on the concept of seismotechnistratigraphic cells.

Reports

Espinosa, A. F., Schmoll, H. R., Brockman, S. R., Yehle, L. A., Odum, J. K., Michael, J. A., and Rukstales, K. S., 1985, Seismic hazard studies, Anchorage, Alaska, in Hays, W. W., and Gori, Paula, eds., Evaluation of regional and urban earthquake hazards and risk in Alaska: U.S. Geological Survey Open-File Report 85- , 17 p.

Nichols, D. R., and Yehle, L. A., 1985, Volcanic debris flows, Copper River basin, Alaska, in Committee for International Exchange of Landslide Technique (eds.), Proceedings of IVth International Conference and Field Workshop on Landslides: The Japan Landslide Society, Tokyo, p. 365-372.

Odum, J. K., 1985, Difficulties in characterizing weak Tertiary rocks using field and laboratory geotechnical tests--the Tyonek Formation, Cook Inlet region, Alaska, as an example: Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 680.

Schmoll, H. R., 1985, USGS engineering geology products in the Anchorage area, Alaska: A review, in Hays, W. W., and Gori, Paula, eds., Evaluation of regional and urban earthquake hazards and risk in Alaska: U.S. Geological Survey Open-File Report 85- , 18 p.

Schmoll, H. R., Odum, J. K., and Espinosa, A. F., 1985, Seismotechnistratigraphic cells: an approach to the analysis of subsurface geology at Anchorage, Alaska, for use in seismic zonation studies: Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 710.

Yehle, L. A., Odum, J. K., and Reneau, David, 1985, Generalized interpretation of geologic materials from shot holes drilled for the Trans-Alaska Crustal Transect project, Copper River basin and adjacent regions, Alaska, May-June 1984: U.S. Geological Survey Open-File Report 85-582, 33 p.

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Ground Motion for the Alaskan Subduction Zone Earthquakes.

Funding source: Exxon Affiliates

Date research began: 1976

Principal investigator(s): Exxon Production Research Co. (Y. K. Vyas)

Address: P.O. Box 2189, Houston, TX 77252-2189

Phone number: (713) 940-3723

Main goal(s) of research:
Establish procedures and practice to develop map accurate estimates of future earthquake design ground motions.

Main accomplishments relevent to goals and what remains to be completed:

- o Developed a semi-empirical method to simulate strong ground-motions for giant earthquakes.
- o Improve regional attenuation relationships needed for seismic hazard analysis.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

- o Public-domain literature (SSA Abstracts, Seminar notes and World Conference papers).

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Seismic Hazard Study of North Aluetian Shelf

Funding source: Exxon Production Research Co. (EPR)

Date research began: January, 1984, January 1985

Principal investigator(s): C. B. Crouse and Yogesh Vyas (EPR)

Address: Earth Technology
3777 Long Beach Blvd.
Long Beach, CA 90807

Phone number: (213) 595-6611

Main goal(s) of research:

- To produce PSV attenuation equations for subduction earthquakes in Alaska.
- To produce improved seismic hazard maps for North Aleutian Shelf region.
- Study effect of St. George basin geology on PSV.

Main accomplishments relevent to goals and what remains to be completed:

1. Completed
2. To be completed by 12/85
3. To be completed by 12/85

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
None are available at this time.

2882 20130

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Earthquake Hazards Studies, Upper Cook Inlet, Alaska

Funding source: USGS Earthquake Hazards Reduction Program
State of Alaska Department of Natural Resources

Date research began: 1978

Principal investigator(s): Dr. Randall G. Updike
Chief, Engineering Geology Section

Address: State of Alaska Division of Geological & Geophysical Surveys
P.O. Box 772116
Eagle River, Alaska 99577

Phone number: (907) 688-3555

Main goal(s) of research:
(1) Geotechnical characterization of engineering soils, Anchorage
(2) Three dimensional mapping of the engineering geology of Anchorage
(3) Surficial and bedrock mapping of geology along the Border Ranges Fault zone, west front Chugach Mountains, in the vicinity of Anchorage

Main accomplishments relevent to goals and what remains to be completed:

1. Parametric characterization of Anchorage area soils using (a) electric cone penetration testing, (b) resonant column testing, (c) cyclic triaxial testing, (d) scanning electron microscopy, (e) static testing of engineering geologic facies;
2. Completion of geologic maps, structure contour maps, isopach maps, and cross-sections of north Anchorage and south Anchorage.
3. Completion of geologic maps of 5 quadrangles along fault zone.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
See attached sheet.

 2883 20130

Lade, P. V., Updike, R. G., and Cole, D. A., 1985. Cyclic triaxial tests of the Bootlegger Cove Formation, Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 85- , in press.

Reger, R. D., and Updike, R. G., 1983. A working model for Late Pleistocene glaciation of the Anchorage lowland, Upper Cook Inlet, Alaska: Alaskan Quaternary Center, University of Alaska Museum Occasional Paper 2, p. 71.

Reger, R. D., and Updike, R. G., 1983. Upper Cook Inlet Region and the Matanuska Valley, Guidebook to permafrost and Quaternary geology: International Conference on Permafrost Guidebook 1: Alaska Division of Geological and Geophysical Surveys, p. 185-263.

Ulery, C. A., and Updike, R. G., 1984. Subsurface structure of the cohesive facies of the Bootlegger Cove Formation in southwest Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 84.

Updike, R. G., Geotechnical mapping and testing programs, Upper Cook Inlet, Alaska: U.S. Geological Survey Summaries of Technical Reports, N.E.H.R.P., Open-file Report 83-90, p. 64-65.

Updike, R. G., 1982. Cooperative earthquake hazards project, geotechnical soils investigations, Upper Cook Inlet, Alaska: U.S. Geological Survey Summaries of Technical Reports, N.E.H.R.P., Open-file Report 82-65, p. 67-68.

Updike, R. G., Cole, D. A., and Ulery, C. A., 1982. Shear moduli and damping ratios for the Bootlegger Cove Formation as determined by resonant column testing: Alaska Division of Geological and Geophysical Surveys Geologic Report 73, p. 7-12.

Updike, R. C., 1983. Inclinometer strain analyses of Anchorage landslides, 1965-80: Alaska Division of Geological and Geophysical Surveys Professional Report 80, 141 p.

Updike, R. G., and Ulery, C. A., 1983. Preliminary geologic map of the Anchorage B-6NW (Eklutna Lake) Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 83-8.

Updike, R. G., 1984. Liquefaction susceptibility analysis for foundation soils, Knik River Bridge, Glenn Highway, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigations 84-26, 33 p.

Updike, R. G., 1984. The Turnagain Heights landslide--an assessment using the electric cone penetration test: Alaska Division of Geological and Geophysical Surveys Report of Investigation-F, 84-13, 55 p.

Updike, R. G., Dearborn, L. D., Ulery, C. A., and Weir, J. L., 1984. A guide to the geology of Anchorage: Alaska Geological Society Guidebook for Geological Society of America Cordilleran Section field trip, 75 p.

2857 20130

Updike, R. G., Yamamoto, Nagisa, and Glaesman, P. W., 1984. Moisture density and textural analyses of modern tidal flat sediments, upper Knik Arm, Cook Inlet, Alaska: Alaska Division of Geological and Geophysical Surveys Report of Investigation, 84-20.

Updike, R. G., 1985. Current geological evaluations of earthquake hazards in the Anchorage area, Alaska: The Northern Engineer, v. 17, in press.

Updike, R. G., 1985. Engineering geologic maps, Government Hill area, Anchorage, Alaska: U.S. Geological Survey I-series maa, I-1610.

Updike, R. G., and Carpenter, B. A., 1985. Engineering geology of the Government Hill area, Anchorage, Alaska: U.S. Geological Survey Bulletin, 92 p. in press.

Updike, R. G., Olsen, H. W., Schmoll, H. R., Stokoe, K. H., 11, and Kharaka, Y. F., 1985. Geologic and geotechnical conditions adjacent to the Turnagain Heights landslide, Anchorage, Alaska: U.S. Geological Survey Bulletin, in press.

Updike, R. G., and Oscarson, R. C., 1985. An atlas of facies microfabrics of the Bootlegger Cove Formation using the scanning electron microscope: U.S. Geological Survey Bulletin, 46 p., in press.

Updike, R. G., and Ulery, C. A., 1985. A geotechnical cross-section in downtown Anchorage utilizing the electric cone penetration test: Alaska Division of Geological and Geophysical Report of Investigations, 85- , in press.

Updike, R. G., and Ulery, C. A., 1985. Engineering geologic map and cross sections, southwest Anchorage, Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 89.

Abstracts

Schaff, R. G., and Updike, R. G., 1984. Lessons learned--and not learned--from the 1964 Alaskan earthquake: Seismological Society of America Annual Meeting, Invited paper for Consuming Plate Boundaries Symposium, v. 55, no. 1, p. 18.

Updike, R. G., Engineering Geologic Facies of the Bootlegger Cove Formation, Anchorage, Alaska (abst.): Geological Society of America Annual Meeting, New Orleans, Abstracts with Programs, p. 636.

Updike, R. G., 1983. Seismic liquefaction potential in the Anchorage area, south-central Alaska (abst.): Symposium on liquefiable deposits in the western United States, Geological Society of America, Rocky Mountain/Cordilleran Sections Annual Meetings, Salt Lake City, Abstracts with Programs, p. 374.

Updike, R. G., 1984. Current geological evaluations of earthquake hazards, Anchorage, Alaska: American Association for the Advancement of Scientific Arctic Section Annual Meeting Abstracts.

2853 20130

Updike, R. G., and Oscarson, R. C., 1984. The dynamic behavior of sensitive clays as indicated by microfabric studies (abst.): Geological Society of America Cordilleran Section Meetings, Anchorage, Abstracts with Programs, v. 16, no. 5, p. 338.

2887 2030

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Evaluation of Ground Failure Susceptibility, Opportunity and Potential in the Anchorage, Alaska Urban Area

Funding source: U.S. Geological Survey

Date research began: May 1985

Principal investigator(s): I. M. Idriss and Y. Moriwaki

Address: Woodward-Clyde Consultants
203 N. Golden Circle Drive
Santa Ana, California 92705

Phone number: 714 835-6886

Main goal(s) of research:

Probabilistic evaluation of earthquake ground motions in Anchorage. Delineation of areas susceptible to ground failure (liquefaction in cohesionless soils and undrained failure in clay soils). Combination of the two to estimate potential for ground failure in Anchorage.

Main accomplishments relevent to goals what remains to be completed:

Project is just getting underway.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

Directory of Earthquake Hazards Reserach
and Other Related Activities in Alaska

Inventory Form

Title of research: Comprehensive Planning for Tsunami Hazard Areas

Funding source: National Science Foundation

Date research began: October 1984

Principal investigator(s): Jane Preuss, A.I.C.P.

Address: 616 First Avenue/Suite 200
Lowman and Hanford Building
Seattle, WA 98104

Phone number: (206) 624-1669

Main goal(s) of research: The project will develop a refined planning approach for communities which are susceptible to tsunamis by using the City of Kodiak as a case example. The methodology first gained a better understanding of the causes of damage through numerical simulation ofthe 1964 event at decreasing geographic scales, and increasing levels of specificity for 1964 conditions and for present conditions. The final product will be prototype urban planning concepts minimizing property damage and maximizing emergency preparedness while ensuring continued economic functioning.

Main accomplishments relevent to goals and what remains to be completed:
See attached sheet.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:

Intended Audience:
- o Architects and Urban Planners in coastal communities susceptible to tsunamis.
- o Emergency Preparedness Planners
- o Harbormasters in tsunami susceptible communities

Expected Product:
- o Paper to be published in Proceedings of International Union of Geodesy and Geophysics - International Tsunami Symposium, November 1985
- o Final Project Report. Expected publication June 1986
- o Project Summary. Expected publication June 1986

Directory of Earthquake Hazards Research and
Other Related Activities in Alaska

Inventory Form

Main accomplishments relevent to goals and what remains to be completed:
The regional analysis verified wave heights and patterns of the 1964 Alaska tsunami as the basis for evaluating regional land use trends. The project scale analyzed specific characteristics of damage patterns in downtown Kodiak in 1964. For subsequent planning purposes at the project scale two distinct districts have been created within the greater downtown area. The Damage Control District encompasses the projected run-up area. Sub-districts within the Damage Control District relate to uses which could easily become floating debris, e.g. water borne uses (boats), parking and log storage areas, flammable and toxic uses, and buildings with high occupancy uses. In addition, a Life Safety District is proposed which consists of an evacuation zone and a receiving zone for evacuees.

The project is presently developing a series of alternative scenarios for which development concepts will be prepared. They will assume: reoccurrance of subsidence, no subsidence; extensive erosion of fill material; no significant erosion. Subsequently, alternative development control techniques will be developed to mitigate damage for a series of administrative areas within the Damage Control and Life Safety Districts.

- o Fire Protection Sub-Zone
- o Building Control Zone--Foundation Type/Construction Recommendations
- o Water Safety District (Bearths and Moorages)
- o Use Restriction Zone
- o Life Safety Zone--Evacuation Route Design and Traffic Plan (pedestrian and vehicular)

2951 20130

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Automating the Pacific and Alaska Tsunami Warning Centers

Funding source: NOAA

Date research began: 1965

Principal investigator(s): T. F. Sokolowski

Address: Box Y, Palmer, AK 99645

Phone number: (907) 745-5474

Main goal(s) of research:
To enhance the reactive and predictive parts of the Tsunami Warning System.

Main accomplishments relevent to goals and what remains to be completed:
See attached abstracts.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
See attached references.

2985 20130

THE ALASKA TSUNAMI WARNING CENTER'S RESPONSIBILITIES AND OPERATIONS

National Oceanic and Atmospheric Administration
National Weather Service
Alaska Tsunami Warning Center, Palmer, Alaska, USA

Abstract

The Alaska Tsunami Warning Center was established in 1967 to provide timely tsunami watches and warnings to Alaska for Alaskan tsunamigenic events. Since the initial inception to the present time, many changes have occurred in areas, such as: responsibility, data networks, technique developments, operational procedures, and community preparedness. The watch and warning responsibilities have increased to include the west coasts of Canada and the United States. Seismic and tide data networks have been enlarged to enhance the accuracy of earthquake locations and sizing, and for confirming the existence of a tsunami. New procedures are continually being implemented at the ATWC, using advanced techniques and mini and micro computer systems, for processing data and disseminating information. In addition to advancing the ATWC's operational capabilities, community preparedness efforts continue to aid those individuals who may be caught in the immediate vicinity of a violent earthquake and its subsequent tsunami.

MINI AND MICRO COMPUTER APPLICATIONS AT THE ALASKA TSUNAMI WARNING CENTER

NOAA/NWS Alaska Tsunami Warning Center
Palmer, Alaska USA

The Alaska Tsunami Warning Center (ATWC) has been integrating computers into the Center's operational procedures to automate many of the manual functions in providing tsunami watch, warning, and other services. The present automated processes use a Data General S230 mini computer that performs basic interactive epicenter computations, teletypewriter message compositions, and an initial phase of processing earthquake data automatically. Recent advances in micro computer technology and capabilities now permit a direction towards implementation of micro computers at the ATWC to perform the present and additional levels of automation. Initial advantages of this system are decreased cost and size, maximizing aid for the staff, minimizing response times, and standardizing procedures. The micros will be networked to communicate with each other and be physically distributed so that interactive and real-time tasks can be performed concurrently by duty personnel. At the present time, a micro has been implemented as a basic interactive system to determine epicenters, generate teletypewriter messages, and to serve as an interactive backup for the present mini computer. Future development will address improving the interactive system, processing real-time seismic data for automatic epicenter determinations, and processing near real-time tide data from U.S. west coat sites and real-time tide data from Alaska sites.

 29B8 20B0

References

Sokolowski, T. J., and Miller, G. R., 1967. Automatic epicenter locations from a quadripartite array, Bull. Seismol. Soc. Amer., v. 57, p. 269-275.

Sokolowski, T. J., and Miller, G. R., 1970. Identification of source regions from a single seismic record, Proceedings, 1969 International Tsunami Symposium, Honolulu, Hawaii.

Sokolowski, T. J., May 1983. Automation highlights of the Pacific and Alaska Tsunami Warning Centers, ITIC Tsunami Newsletter, XVI, No. 1, p. 1-5.

Sokolowski, T. J., December 1983. Automation highlights of the Pacific and Alaska Tsunami Warning Centers, ITIC Tsunami Newsletter, XVI, No. 2, p. 1-9.

Sokolowski, T. J., and Fuller, G. R., Blackford, M. E., and Jorgensen, W. J., 1983. The Alaska Tsunami Warning Center's automatic earthquake processing system, Proceedings, International Tsunami Symposium, Hamburg, Germany, p. 131-148.

Sokolowski, T. J., 1985. The Alaska Tsunami Warning Center's responsibilities and operations, presented at the workshop for the International Coordination Group for the Tsunami Warning System in the Pacific, Sidney, Canada (in publication).

Sokolowski, T. J., 1985. Mini and micro computer applications at the Alaska Tsunami Warning Center, Presented at the International Tsunami Symposium, Victoria, Canada (in publication).

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Circum Pacific seismic and tsunami hazards evaluation

Funding source: AID

Date research began: 1/1/1984

Principal investigator(s): S. P. Nishenko, W. Spence, G. Choy

Address: USGS, MS 967, DFC, Denver, CO 80225

Phone number: (303) 236-1506 FTS 776-1506

Main goal(s) of research:
To provide updated estimates of seismic and tsunami hazards for major plate boundaries of the Circum-Pacific region.

Main accomplishments relevent to goals and what remains to be completed:
1) Initial seismic hazards assessment for Queen Charlotte-Alaska-Aleutian seismic zone.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
1) Nishenko, JGR 90, 3589-3615, 1985
2) Sykes and Nishenko, JGR, 89, 5905-5927, 1984

2958 20130

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Community preparedness for tsunami and earthquake

Funding source: Mostly in house (NOAA)

Date research began: 1975 - ongoing

Principal investigator(s): George W. Carte
Alaska Tsunami Warning Center
Box Y
Palmer, AK 99645
(907) 745-4212

Main goal(s) of research:
Evaluate state of preparedness of Alaskan communities for the purpose of improvement. Evaluate the degree of hazard for earthquakes and tsunamis for coastal Alaska.

Main accomplishments relevent to goals and what remains to be completed:
A somewhat subjective tsunami hazard evaluation was prepared for all Pacific coastal communities over 25 population in Alaska (with assistance of Robert Eppley). This needs further numerical refinement for distant soruce tsunamis, and subjective and objective refinement for local source tsunamis. A numerical tsunami preparedness assessment for Alaska was made for 46 Alaskan communities. The assessment rating factors could be further refined and more communities need to be evaluated.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
"Tsunami Hazard and Community Preparedness in Alaska", 1981, NOAA Technical memorandum NWS AR-29, National Weather Service, Regional Headquarters, Anchorage, Alaska, February 1981.
"A Tsunami Preparedness Assessment for Alaska", 1984, in Science of Tsunami Hazards, v. 2, no. 2, p. 119-124.
"Distant Source Tsunami Hazard in Alaska", 1982, unpublished handout listing 83 communities, with notes, Alaska Tsunami Warning Center, Palmer, Alaska.

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Earthquake Risk Analysis on the Alaska State Courthouse Expansion Alternatives.

Funding source: Alaska State Courthouse Authority

Date research began: July 1984

Principal investigator(s): John H. Wiggins
Craig Taylor

Address: 1650 S. Pacific Coast Highway
Redondo Beach, CA 90277

Phone number: (213) 316-2257

Main goal(s) of research:
Assist decision makers in selecting one of four basic alternatives for expanding the courthouse facilities considering the earthquake hazard and benefits of each alternative.

Main accomplishments relevent to goals and what remains to be completed:
Provided a rational basis for decision making in earthquake countries for an important facility. All affected parties were involved. Refinement of the procedures needs to be accomplished.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
Report is proprietary to the Alaska State Courthouse System. Please contact Mr. Arthur Snowden for a copy. Request, however, may be denied.

Directory of Earthquake Hazards Research
and Other Related Activities in Alaska

Inventory Form

Title of research: Study of performance of structures in Alaska through strong motion instrumentation

Funding source: USGS and possibly State of Alaska

Date research began: September 1984

Principal investigator(s): M. Celebi

Address: USGS, 345 Middlefield Road (MS 977)
Menlo Park, CA 94025

Phone number: (415) 323-8111 x2394

Main goal(s) of research:

- o To select & prioritize structures in Alaska for strong motion instrumentation.
- o To perform ambient vibration tests to obtain dynamic characteristics before strong motion events.
- o To study their performance after strong motion events.
- o To deduce conclusions for future code revisions and hazard reduction.

Main accomplishments relevent to goals and what remains to be completed:
Work is being carried out through a committee consisting of academicians, practicing engineers and scientists. An open file report with recommendations is being prepared. Implementation will be in accordance with the recommendations of the committee.

What products (data, maps, reports, etc.) are available (provide bibliographic citations where appropriate) and intended audience or user:
Open file report will be issued soon. Papers will be prepared as a result of data to be obtained from ambient vibration tests, analysis and from future strong motion events.

2955 20130

STRONG-MOTION ACCELEROGRAPH STATIONS LOCATED IN ALASKA
Maintained by U.S. Geological Survey (February 1986)

STATE/STATION	INSTRUMENT SERIAL NUMBER	COMMENTS	COORDINATES	OWNER
Alaska				
Anchorage				
Humana Hospital				
First Floor	SMA-2543	Minimal structural instrumentation	61.21 149.82	USGS *
4th Floor	SMA-2544			
7th Floor	SMA-2545			
Alaska Pacific University				
Ground	SMA-2340	Ground	61.19 149.80	USGS
New Federal Building 701 "C" Street				
Basement	SMA-296	Ground	61.22 149.88	USGS
Anchorage Westward Hilton 3rd & "E" Street				
Basement	SMA-311	Minimal structural instrumentation	61.22 149.89	USGS
22nd Floor	SMA-310			
U.S. Geological Survey - Golden				
Alaska Art Institute	SMA-5649	Ground	61.19 149.96	USGS
Anchorage Lutheran Church	SMA-5691	Ground	61.21 149.89	USGS
Arctic Ski Lodge	SMA-5693	Ground	61.25 148.53	USGS
Fire Station #6	SMA-5695	Ground	61.21 149.75	USGS
Russian Jack Springs	SMA-5692	Ground	61.21 149.78	USGS
Sullivan Arena	SMA-5696	Ground	61.21 149.87	USGS
Mun. of Anchorage				
Fire Station #2	SMA-5455	Ground	61.23 149.86	Municipality of Anchorage
Fire Station #3	SMA-5437	Ground	61.21 149.82	""
Fire Station #4	SMA-5438	Ground	61.18 149.85	""
Fire Station #5	SMA-5439	Ground	61.19 149.92	""
Fire Station #7	SMA-5454	Ground	61.15 149.95	""

2956 20130

Fire Station #8	SMA-5457	Ground	61.124 149.77	Municipality of Anchorage
Fire Station #10	SMA-5453	Ground	61.15 149.86	""
Airport Fire Station #1	SMA-5456	Ground	61.174 149.97	""
Central Police Station	SMA-5452	Ground	61.22 149.885	""
Bancas Point Ground Site	SMA-4054	Ground	59.95 139.64	USGS
Bradley Lake Ground Site	SMA-4225	Ground	59.76 150.86	USGS
Cantwell Highway Station Ground	SMA-2256	Ground	63.39 148.88	USGS
Cape Yakataga White Alice Station Ground	SMA-591	Ground	60.07 142.43	USGS
Cordova Earth Station Ground	SMA-2254	Ground		USGS
FAA Flight Service Center Ground	SMA-1928	Ground		USGS
Fairbanks University of Alaska Duckering Hall Ground	SMA-1926	Ground	64.85 147.82	USGS
Magnetic Observatory Seismic Vault Ground	SMA-1932	Ground	64.86 147.83	USGS
Guyot Hill Ground	SMA-3089	Ground	60.15 141.47	USGS
Homer Airport Services Building Fire Station	SMA-302	Ground	59.64 151.50	USGS
Icy Bay Gulf Timber Co. Ground	SMA-2248	Ground	59.97 141.64	USGS
Juneau Auke Bay Fisheries Lab Butler Building Basement	SMA-2255	Ground	58.38 134.64	USGS
Kodiak U.S. Coast Guard Base Central Supply Building Basement	SMA-214	Ground	57.75 152.50	USGS

2982 20130

Kayak Island Ridge / Ground	SMA-2436	Ground	59.86 144.49	USGS
Middleton Island / FAA Communications Building / Ground	SMA-594	Ground	59.44 146.33	USGS
Moose Creek Dam / Fairbanks area / Lower Gallery	SMA-4005	Minimal structural instrumentation	64.79 147.18	Corps of Engineers
Mt. Baldy / Ground	SMA-3567	Ground	61.04 152.34	USGS
Mt. Hamilton / Ground	SMA-3933	Ground	60.34 144.26	USGS
Seldovia / Seldovia School / Basement	SMA-2259	Ground	59.44 151.71	USGS
Seward / Fire Station / Basement	SMA-1935	Ground	60.11 149.44	USGS
Sherman Glacier / Ground	SMA-2437	Ground	60.53 145.21	USGS
Sitka / Sitka Harbor Bridge / Structure Array	CRA-147	Extensive structural instrumentatin	57.05 133.34	USGS *
Ground	SMA-1994	Ground	57.05 133.34	USGS
Slana / Highway Maintenance Station / Ground	SMA-2252	Ground	62.73 144.01	USGS
Suckling Hills / Ground	SMA-4053	Ground	60.06 143.79	USGS
Sunshine Point / Ground	SMA-3568	Ground	60.18 142.84	USGS
Talkeetna / FAA VOR Site / Ground	SMA-596	Ground	62.30 150.10	USGS
Trims Camp / State Highway Department / Ground	SMA-312	Ground	63.42 145.75	USGS
Tsina / Ground	SMA-3566	Ground	61.23 145.34	USGS

2983 20130

Valdcz				
City Hall	SMA-313	Ground	61.14 146.36	USGS
Valdez Dock Company Ground	SMA-2260	Ground	61.13 146.36	USGS
High School Ground	SMA-593	Ground	61.14 146.35	USGS
Whitticr				
Alaska Railroad Ground	SMA-	Ground	60.78 148.68	USGS
Waxcll Ridge Ground	SMA-3934	Ground	60.45 142.85	USGS
Yakutat				
FAA VORTAC Site Ground	SMA-326	Ground	59.51 139.67	USGS

* Original cooperative station. USGS assumed ownership through negotiations.

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY

STATION	CODE	LAT. (N)	LONG. (W)	LEVEL*	HT*
Big Koniuji Is.	BKJ	55.1607	159.5663	1	0
Chernabura Is.	CNB	54.8200	159.5883	1	0
Cold Bay FAA	CDB	55.2100	162.710	1	2
Deer Island	DRR	54.9235	162.2832	1	0
Dolgoi Is.	DLG	55.1410	161.8357	1	0
Dutch Harbor	DUT	53.8983	166.5367	1	1
Ivanof Bay	IVF	55.8958	159.5300	1	0
Nagai Is.	NGI	55.0393	160.0692	1	0
Pirate Shake	PRS	55.2312	159.8548	1	0
San Diego Bay	SGB	55.5458	160.4538	1	0
Sand Point	SAN	55.3400	160.4972	1	1
Simeonof Is.	SIM	54.920	159.258	1	0
Sanak Is.	SNK	54.4740	162.7753	1	0

UNIVERSITY OF ALASKA GEOPHYSICAL INSTITUTE

STATION	CODE	LAT. (N)	LONG. (W)	LEVEL*	HT*
Badger	BADG	64.8150	147.3885	1	
Freeman	FREE	64.8400	147.3338	1	
Lakloey	LAKL	64.8233	147.5008	1	
Bonnifield	BONN	64.8430	147.7267	1	
Steese	STES	64.9050	147.6047	1	
Farmers Loop	LOOP	64.8895	147.8083	1	
Goldstream	GOLD	64.9248	147.9360	1	
Institute Pier	GIA	64.8598	147.8475	0	8

*LEVEL convention is 0 = basement, 1 = ground floor, etc.
HT convention is 0 = no structure, 1 = 1 story, etc.

☆U.S. GOVERNMENT PRIN

2953 20130 IMP.