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A REPORT TO THE 44TH UTAH LEGISLATURE

EARTHQUAKE SAFETY IN UTAH
AND
RECOMMENDATIONS FOR RISK REDUCTION

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INTRODUCTION

This report to the 44th Legislature of the State of Utah provides an interim summary of findings and recommendations by the Seismic Safety Advisory Council regarding earthquake safety in Utah. The purpose of the report is to indicate the results of earthquake safety studies by the Advisory Council since 1977. It is not a final report on the four-year effort of the Advisory Council, though most of the results of study effort now are compiled and many conclusions have been reached.

The Seismic Safety Advisory Council was established by Legislative Act in 1977 (Section 63-34a, UCA, 1953) and charged to recommend a consistent public policy framework for earthquake hazards reduction in Utah. The Advisory Council will present its final report by June 30, 1981.

Inasmuch as this report to the Legislature is near the end date of the Advisory Council, most earthquake risk studies are completed and recommendations for risk reduction are formulated. The principal work remaining to be completed by June 30, 1981, is preparation of a final report. Consequently, in this interim report we are able to comment in a general way and in particular regarding earthquake safety conditions in the State. We also are able to indicate specific actions that we believe would remove deficiencies in current practices that cause unnecessary earthquake risk to life and property.

This interim report includes, first, an executive summary that highlights the most important findings on earthquake safety pertinent to Utah conditions. This is followed by more detailed discussion of particular issues. Section 1 provides a brief overview of the work plan for investigating and evaluating various elements of earthquake safety in Utah that has been followed since 1977. In annotated format, we indicate studies, reports, and other actions by the Advisory Council. Section 2 furnishes a brief account of seismicity in Utah and the implications of this hazard as a threat to life and property. In Section 3 significant earthquake risk conditions, drawn from detailed study reports are described. Ways for correcting deficiencies also are suggested. In the last section, Section 4, we suggest and recommend administrative and legislative actions leading to improved earthquake safety practices.

The information presented in this report is drawn from a number of detailed technical reports prepared by the Advisory Council staff. The need for succinctness herein precludes complete treatment of each topic, and so simplifications of complex conditions are made that sometimes may be inadequate for the reader to evaluate fully without additional information. Those readers interested in more information on any particular topic should contact the Seismic Safety Advisory Council office. At the end of this interim report we have included a listing of reports prepared by the Advisory Council that address topics in greater depth.

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*All Board members have served since their appointments in 1977 when the Advisory Council was established.

CONTENTS

LIST OF TABLES AND FIGURES

SUMMARY AND MAJOR RECOMMENDATIONS

PURPOSE OF THE REPORT

This report sets forth the principal elements of a comprehensive earthquake safety policy for the State of Utah. Although drafted as an interim report to the 44th Utah Legislature, it contains the essential findings and recommendations that will appear in the final report of the Seismic Safety Advisory Council scheduled for completion by June 30, 1981. It presents the Advisory Council's response to a legislative charge established in 1977 to provide recommendations for a consistent policy framework for seismic safety in Utah, to recommend programs to reduce earthquake hazards, and suggest goals and priorities for earthquake hazards reduction.

UTAH'S EARTHQUAKE ENVIRONMENT AND HAZARDS

Earthquakes in Utah are an historical fact. Since settlement of the State in the mid nineteenth century, a continuous history of earthquakes has been observed. The historical record supplemented with more recent geologic evidence are the basis of earthquake risk assessments and risk reduction recommendations that are made. These data reveal that severe and damaging earthquakes are expected in future years, although one can only estimate their locations and strengths. Utah's settlement pattern has an unusual correlation with the region of greatest earthquake activity, and more than 80 percent of the population and development lie within a zone that defines the region of highest hazard.

The damaging effects of earthquakes, and thus their threat to life and property, impact principally upon the built environment -- the works of man. The concerns of earthquake safety therefore are focused upon where we build and what we build. Utility systems, roads, and dams, as well as buildings, are among the facilities that could be detrimentally affected. These types of facilities are the subjects of studies and associated hazards reduction recommendations by the Seismic Safety Advisory Council.

EARTHQUAKE SAFETY DEFICIENCIES

Facilities in Utah of the types indicated above are expected to be damaged by future earthquakes. Property losses assuredly will result from these earthquakes; the extent of resulting life loss and injury will depend upon unpredictable factors of earthquake strength, location, and quality of construction of facilities.

Earthquake resistance traditionally has not been considered in facilities design and construction in Utah. Older facilities generally are vulnerable to earthquake forces, as are many facilities constructed as recently as the 1970's. Standards for construction that include earthquake safety provisions continue to be ignored or rejected, even today.

Deficiencies of two types are implied in the above comments. The first deficiency concerns the need for appropriate consideration of earthquake safety in new facilities so that the inventory of unsafe or marginally safe facilities is not enlarged as the State grows. The second deficiency is the degree and nature of earthquake hazards in existing buildings, utility systems, dams, etc.

The two types of deficiencies described above have different remedies. The first deficiency results from lack of standards, guidelines, and adequate procedures in the planning and review of new facilities. The second deficiency, a result of past decisions, can be remedied only within the facilities themselves through some sort of abatement effort.

COST CONSIDERATIONS

Earthquake hazards in Utah pose an unavoidable cost. Hazards mitigation entails a cost just as does a decision to do nothing about the problem. The cost of mitigation occurs in the construction of stronger facilities. The cost of doing nothing looms in the future when the inevitiable earthquakes occur and cause losses.

Both sorts of costs can be effectively managed, but neither can be eliminated. Management of the cost of mitigation requires that prudent but mandatory policies be promulgated involving standards and procedures in design and construction of buildings and other facilities. Management of the cost of earthquake damage to existing facilities entails carefully drafted policies of selective hazards abatement, dealing first with conditions of highest hazard.

Policies recommended by the Seismic Safety Advisory Council are developed using benefit/cost analyses from which the most cost-effective remedies are selected. Detailed risk assessments of existing facilities reveal that earthquake hazards abatement is cost-effective only for special situations in Utah. These situations require greater discussion than can be provided in this summary, and the reader is referred to the full report and the detailed studies for specific cases.

OVERALL RECOMMENDATIONS

As the foundations of a comprehensive and coordinated earthquake safety program for Utah, the Seismic Safety Advisory Council makes the following general recommendations. These general recommendation statements are supplemented in other reports which contain specific recommended actions. The recommendations briefly stated below are more completely described later in this report.

Recommendations:

1. Adopt legislation requiring compliance with earthquake safety provisions of the building code.

2. Amend planning statutes to provide explicit authority for local governments to plan for earthquake safety.

3. Accelerate the State seismic risk mapping program to achieve completed mapping of the major risk areas within five years.

4. Adopt legislation requiring that siting evaluations of geologic hazards be made for all public-use facilities.

5. Enforce earthquake safety code provisions in facilities under State jurisdiction.

6. Establish seismic standards and review procedures for dams and reservoirs.

7. Strengthen licensing laws for architects and engineers to improve professional accountability.

8. Assist local governments to strengthen building code enforcement practices.

9. Promulgate and enforce standards concerning the earthquake resistance of public utility systems.

10. Promulgate guidelines and procedures within the Department of Health to reduce the earthquake risk to water supply and waste disposal systems.

11. Utilize regulatory authorities now available to ensure that new schools and health-care facilities meet appropriate earthquake safety standards.

12. Undertake a program of selective retrofit or replacement of high-hazard critical or large-occupancy facilities.

13. Encourage local governments to safeguard fire equipment buildings from operational dysfunction due to earthquakes through assistance from the State Fire Marshall's office.

14. Develop and implement abatement programs leading to eventual elimination of high-hazard, high-occupancy or critical facilities.

15. Identify and remove conditions in water supply systems that are vulnerable to earthquake damage.

16. Establish a strong-motion instrumentation program to obtain needed information about earthquake-induced ground motions in Utah soils.

17. Establish an earthquake safety office for the purpose of providing overall coordination and direction for earthquake safety in Utah.

SECTION 1

AN APPROACH TO EARTHQUAKE SAFETY ASSESSMENT AND THE SSAC WORK PLAN

FACT AND PHILOSOPHY

The constructions of man -- buildings, highways, utilities, and other development -- are the principal source of risk from earthquake hazards. This risk is to life safety and to property, the latter being primarily in the form of economic loss.

In the most fundamental sense, then, earthquake safety is concerned with WHERE WE BUILD and HOW WE BUILD. Where development occurs relative to earthquake activity and the geologic effects of this earthquake activity are the principal determinants of the degree of risk. The ability of a building, a bridge, or a water system component to withstand the effects of an earthquake is another principal factor that determines the degree of risk. Each aspect must be considered in any earthquake safety assessment; either aspect or both can produce a living environment less safe than we might expect or prefer.

The built environment is a vast domain of separate, often interconnected elements comprising buildings and other structures, streets and highways, bridges, electric power and gas supply systems, water supply systems, sewage disposal and treatment systems, dams and reservoirs, and many other things. Buildings may be divided into further categories such as schools, hospitals, offices, retail stores, assembly facilities, warehouses, residences, apartments, etc. The other broad classes also have sub-elements. Because the domain of element types is so extensive, no meaningful single way to accomplish earthquake safety can be suggested. The broad scope of risk conditions requires an equally broad range of risk-reduction considerations, many of which must be uniquely tailored to the type of facility in the built environment.

As a consequence of the situation stated above, this report could not and does not present a mere handful of simple generalities that can be quickly implemented and thereby enhance Utah's earthquake safety posture. For example, earthquake effects upon buildings are different than earthquake effects upon utilities systems, and so are the means for hazards reduction. In a similar way, the procedures in Utah by which buildings get built are different from the procedures by which utilities systems get built. Regulatory authorities and procedures are different, as are industry practices. Yet, since all of these factors affect earthquake safety, individual consideration necessarily was given to each issue. This report therefore covers a wide range of issues and recommendations.

A further complication of the study issues for earthquake safety is found in the various incumbent roles and responsibilities, both in the private and government sectors. Historically, government has had management and regulatory responsibilities over some resources and activities in

Utah, but not in others. And, such authority sometimes is at the State level, sometimes at the local level, and sometimes at several levels. In the case of earthquake safety, applications of risk reduction concepts cannot be considered apart from concurrent consideration of appropriate government roles. The Seismic Safety Advisory Council has concluded that State and local governments have necessary and important roles in helping to preserve the safety and prosperity of Utah citizens and that in some situations effective earthquake hazards reduction cannot be achieved without such involvement of government.

Advocates of minimum government sometimes argue that earthquake safety is a matter of personal choice and individual discretionary actions, or that earthquakes are ordained events over which none of us have any control. Accordingly, governmental involvement is said to be unnecessary or an encroachment upon individual rights. There are good reasons for rejecting these arguments. It is a fact that the effects of earthquakes that pose dangers to life and property can be mitigated through wise planning and construction. Moreover, there are certain characteristics in the way most people conduct their lives and businesses that supersede the arguments concerning individual rights. One such characteristic is that most people buy, rent, or work in buildings constructed by others, and all of us use and are especially dependent upon public utilities. Through this normal social process we rarely have individual control over safety features of the building or facility that we use or in which we work. Thus, individual safety typically is decided by the decisions of others, and government involvement becomes the vehicle by which this safety is reasonably assured. When building construction is regulated, it is for the purpose of preserving the rights and safety of others.

It is in the context described above that the Seismic Safety Advisory Council has delineated and recommended a governmental role in earthquake safety. Such recommendations that are made have evolved from careful consideration of degree of earthquake risk, feasibility of applying hazards reduction concepts, and cost.

A CONCERN ABOUT COST

The cost of earthquake safety received special attention throughout the four-year study period of the Advisory Council. When alternative courses of action have been available, recommendations have been shaped almost completely by cost feasibility studies.

Cost is, itself, somewhat unique in an earthquake safety context. There is, for instance, a cost for doing nothing to enhance earthquake safety. That cost is in terms of life and property losses that earthquakes in Utah certainly will cause in future years. There also is a cost for mitigating earthquake hazards. That cost is largely in construction and planning practices. The cost of mitigation also varies in accordance with the degree of risk reduction that one may seek and with the unique risk situation for each facility.

Two factors have received primary emphasis in the benefit/cost analyses made during development of the recommendations contained in this report. The first is life safety; the second is the importance of the facility.

Although other factors, such as property loss, might have received equal emphasis, the consequent risk conditions and resulting recommendations would be proportionately more extensive than the subjects treated in this report. Stated another way, the Seismic Safety Advisory Council has set forth a recommended earthquake safety program for Utah that is derived principally from risk to life and potential disruption of essential services.

The Seismic Safety Advisory Council has sought to suggest an earthquake safety program that Utah can afford, that it can accept, and that provides reasonable safety. Higher goals, which may be desired by some persons, are possible; they may not be economically feasible nor policaly acceptable. Any lesser goal than recommended likely would fail to enhance Utah's earthquake safety posture.

ADVISORY COUNCIL WORK PLAN -- 1977-1981

Legitimate concerns that State government might have for earthquake safety potentially encompass a broad range of programs and activities. A comprehensive evaluation of earthquake risk requires that each program area and activity be considered. To ensure that all pertinent elements would be considered within the time frame allowed for preparation of its recommendations, the Advisory Council initially established a four-year work plan consisting of separately identified study elements and time scheduling for study of each element. The work plan is shown in Figure 1. The study effort has adhered to the work schedule.

Individual reports on the earthquake safety aspects of most elements of the work plan have been developed. These reports contain risk assessments and recommendations that are believed to represent feasible and reasonable actions to correct observed earthquake safety deficiencies. Table 1 provides a summary of the individual studies, reports, and other activities by the Advisory Council as it has carried out those responsibilities delegated by the Utah Legislature. In the table, work plan elements are listed in the same sequence as they appear in Figure 1.

Figure 2 aggregates elements of the work plan in generic categories according to the subjects of consequent recommendations. Both listings show clearly that there are many agencies of State and local governments and many activities in which earthquake safety issues are pertinent. The presence of State government is found in all of the categories of Figure 2, either directly through authorized programs or indirectly by statutory authority granted to other levels of government. Studies and recommendations for earthquake safety by the Advisory Council touch upon all of these subjects. Recommendations typically deal with specific problems among the individual work plan elements.

All recommendations set forth herein should be viewed as parts of a comprehensive plan for earthquake safety policy for the State of Utah. There are important interrelationships among some study elements so that certain of the earthquake safety recommendations should be considered inseparable. Partial or selective adoption of the recommendations could, in effect, weaken the goal set by the Legislature to "provide a consistent public policy framework for earthquake hazards reduction."

TABLE 1

SUMMARY OF STUDY SUBJECTS AND PRODUCTS

Seismic Safety Advisory Council -- July, 1977 to December, 1980

LIABILITIES ANALYSIS	Report by committee incomplete.
STRONG-MOTION INSTRUMENTATION	Final report completed with recommendations.
BUILDING CODES AND ENFORCEMENT	Contract report on earthquake safety cost completed in 1978. Workshop presented in 1978. Legislation recommended in 1979 and 1980. Seismic zone map prepared for Utah.
SEISMIC RISK MAPPING	Contract report on mapping guidelines completed in 1978. Program expansion recommended in 1979. Map of Utah faults distributed in 1980.
SEISMIC SAFETY PLANNING ELEMENTS	Recommendations completed in 1979. Planning guidelines prepared and distributed in 1980. Seminar presented in 1980. Legislation recommended in 1980.
PROFESSIONAL EDUCATION AND LICENSING	Curriculum suggestions sent to universities in 1978. Licensing recommendations made in 1980. Procedures of State Department of Registration being studied regarding monitoring of licensed professionals.
SCHOOL FACILITIES	Final report completed with recommendations. Legislation recommended in 1980.
DAM SAFETY AND SITING	Final report completed with recommendations.
PUBLIC UTILITIES FACILITIES	Draft report on water supply systems completed. Draft report on electric power systems completed. Draft report manuscript on oil and gas systems completed. Draft report manuscript on communications systems completed. Recommendations for all are drafted. Seminar on water supply systems presented in 1979.
HAZARDOUS BUILDINGS	Contract report on program options completed in 1979. Report and recommendations to be circulated.
HOSPITAL FACILITIES	Final report completed with recommendations.
STATE FACILITIES	Final report completed with recommendations.
PRIORITY-USE FACILITIES	Final report completed with recommendations.
TRANSPORTATION FACILITIES	Contract report completed in 1980. Draft manuscript with recommendations completed.
FEDERAL FACILITIES	Procedures reviewed, no recommendations.
PUBLIC EDUCATION	Descriptive brochure about SSAC printed and distributed. Attorney General's opinion on planning authority of cities and counties obtained in 1978. Newspaper and TV interviews. Presentations to school administrators, State agencies, professional engineers. Technical papers and presentations to professional committees -- national and State.
STATE AGENCY PREPAREDNESS PLANNING	Agency reports assembled and reviewed. Draft report with recommendations completed.
LOCAL PREPAREDNESS PLANNING	Draft report completed.
HAZARDS ALERTS AND PREDICTION	Federal initiatives and procedures reviewed, no recommendations.
EMERGENCY MEDICAL SERVICES PLANNING	Draft report with recommendations completed.
EQUIPMENT MOBILIZATION	Draft report with recommendations completed.
LAW AND ORDER PLANNING	Draft report with recommendations completed.

Figure 1

SEISMIC SAFETY ISSUES AND FOUR-YEAR WORK SCHEDULE

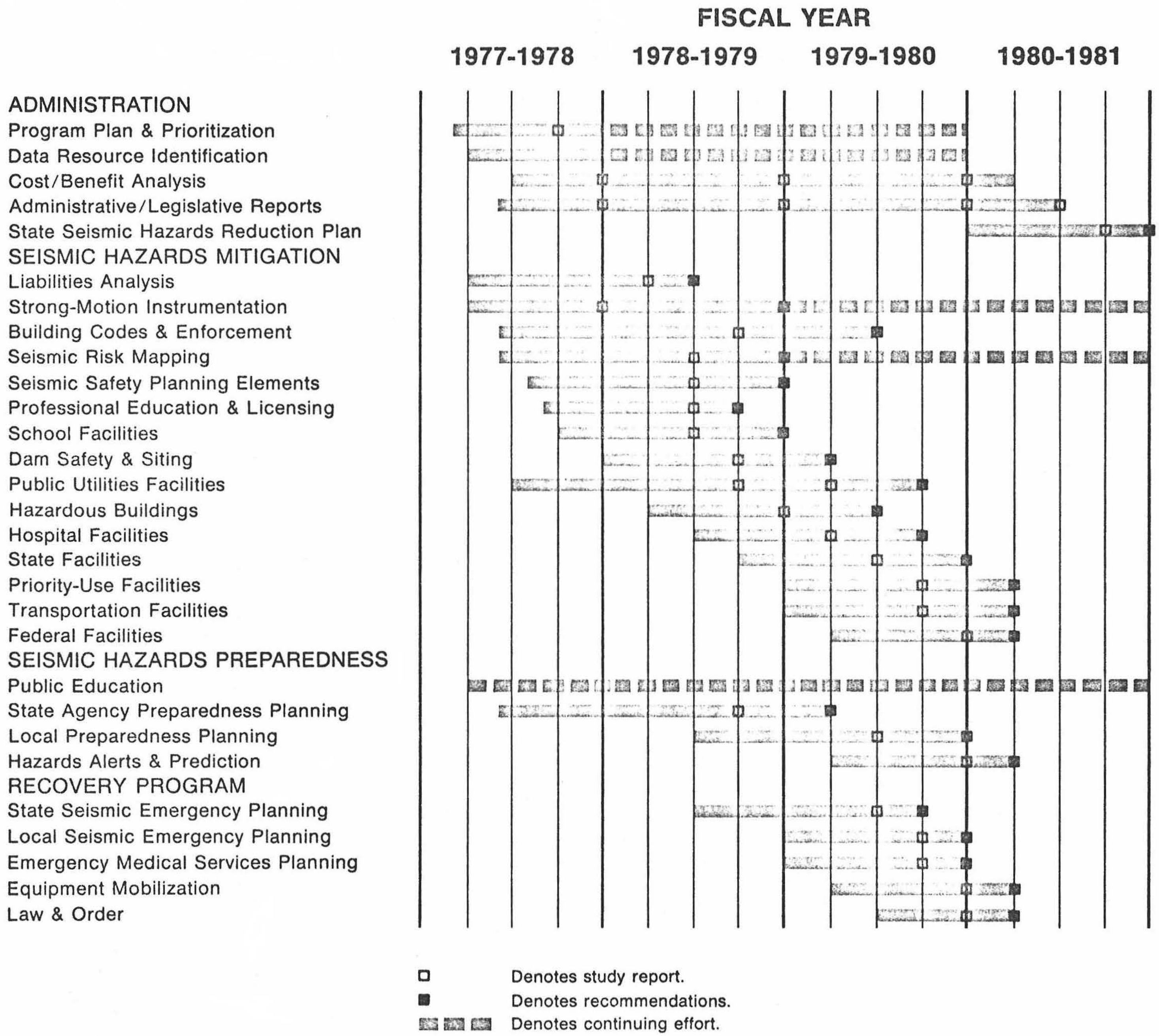
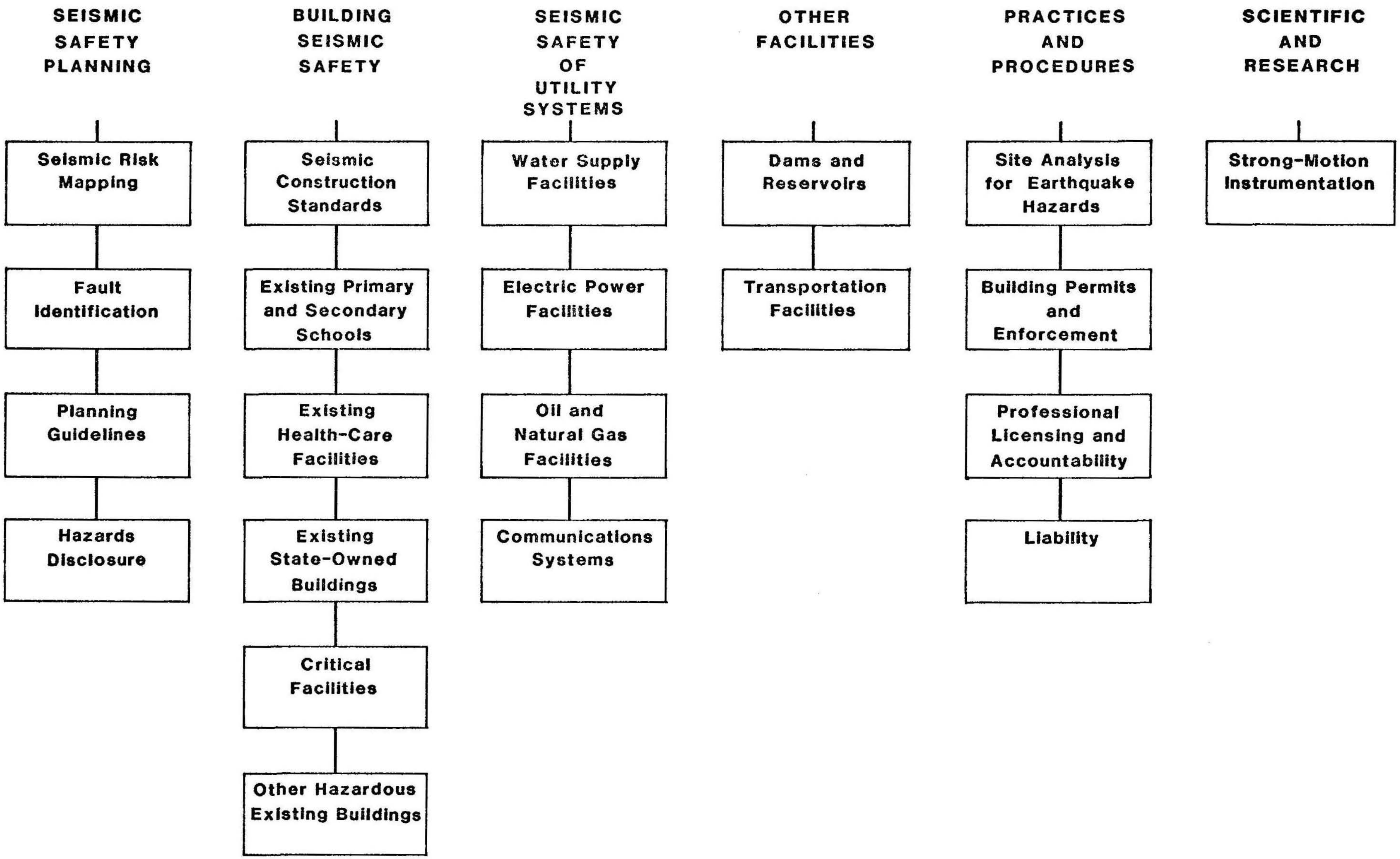


Figure 2

A TOPICAL LISTING OF SEISMIC SAFETY STUDIES AND RECOMMENDATIONS



SECTION 2

EARTHQUAKES AND EARTHQUAKE HAZARDS

SEISMICITY IN UTAH

Earthquakes are common throughout the State of Utah. The most severe and frequent earthquakes historically have occurred along a central region extending from the north central border to the southwest border. This seismic region is a part of an area that has become known as the Intermountain Seismic Belt. Figure 3 indicates on a map of Utah the locations and relative strengths of larger earthquakes having the potential to cause damage and to pose life safety risks. The earthquakes shown cover a period from 1850 to 1978, or 128 years of Utah history. Earthquakes in the 6+ Richter magnitude range have occurred during this period which, in geologic time frame, is very short.

Geologic evidence and observations in other seismically active regions suggest that major and potentially disastrous earthquakes in Utah in the future most likely will occur within that area designated as part of the Intermountain Seismic Belt. The Wasatch Fault, extending north-south through the center of the State is believed to pose the greatest earthquake threat. The Wasatch Fault is said to be capable of producing earthquakes in the 7+ Richter magnitude range, and there is evidence that earthquakes of at least such magnitude have occurred in the past few thousand years, although prior to settlement of the State. An earthquake of such strength in a populated area would be most serious for the State given its present development and past construction practices.

Figure 4 shows a seismic zone map for Utah prepared by the Seismic Safety Advisory Council. Developed from the last current information, this map indicates the relative degrees of earthquake risk in the State. Its purpose is to serve as a guide for the construction of buildings and other facilities so that they may be sufficiently strong to withstand earthquakes of strengths that reasonably can be expected. Although the seismic zones in the new map are somewhat different from other similar maps used in prior years, the changes essentially are refinements of boundaries rather than increases in expected earthquake strengths.

EARTHQUAKE EFFECTS UPON BUILDINGS AND OTHER FACILITIES

Earthquake damage to buildings and other facilities is influenced primarily by four factors: (1) earthquake strength, (2) earthquake location relative to the building, (3) degree of ground shaking, and (4) construction characteristics of the building. Damage may occur in ordinary buildings (those not designed with earthquake resistance) at a lower strength threshold level of 4.5 to 5 Richter magnitude. As the earthquake magnitude increases, so do the degree and extent of damage. Earthquakes in the 6+ Richter magnitude range can cause severe damage and create severe hazards to life safety. Building collapse at such strengths normally is limited to structures of poor materials or poorly assembled. Earthquakes in the 7+ Richter

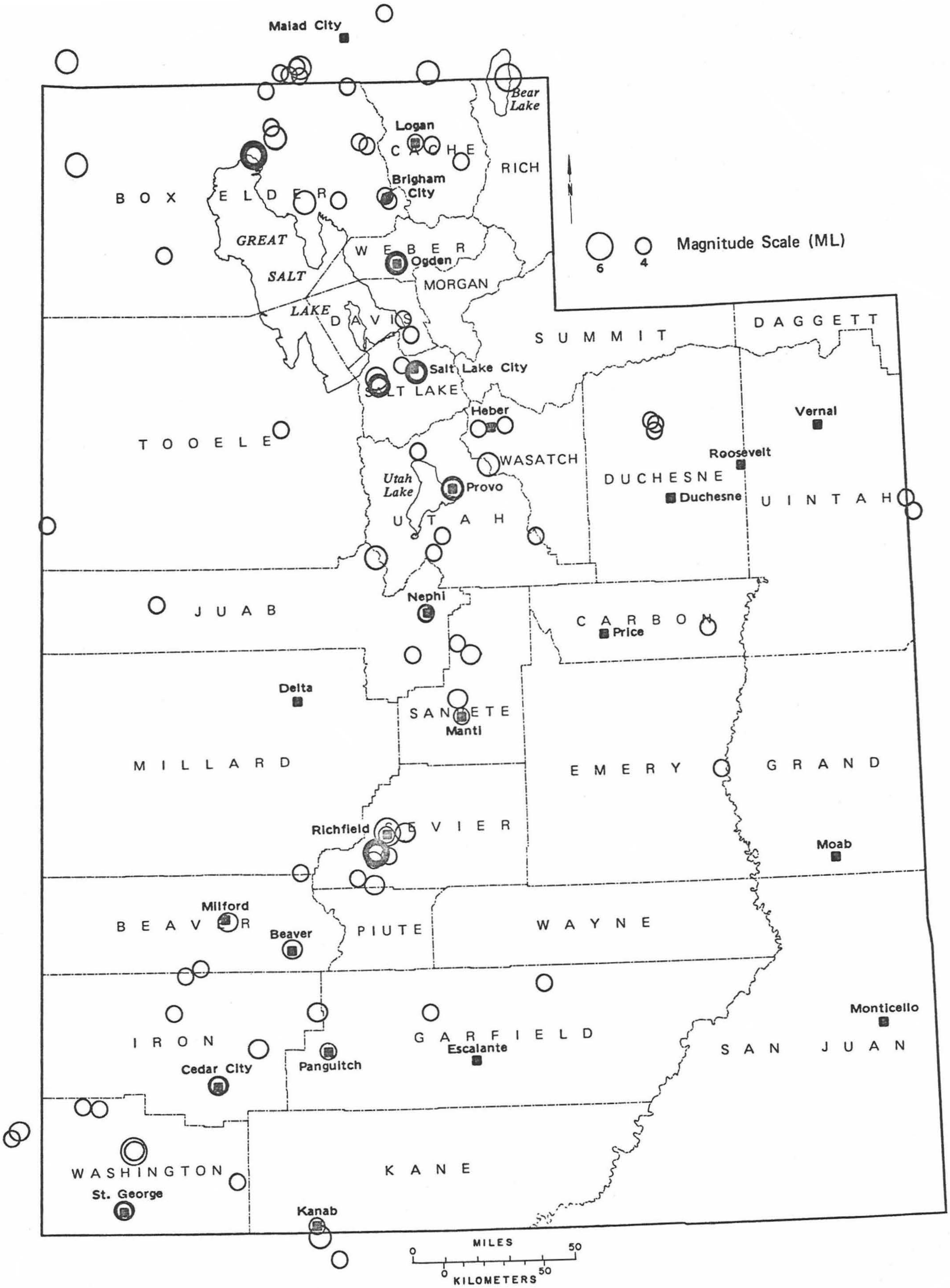


Figure 3

HISTORICAL SEISMICITY IN UTAH -- 1850 - JUNE 1978

MAGNITUDE 4.0 (INTENSITY V) OR GREATER

(Reference: *Earthquake Studies In Utah,* W.J. Arabasz, R.B. Smith, and W.D. Richins)

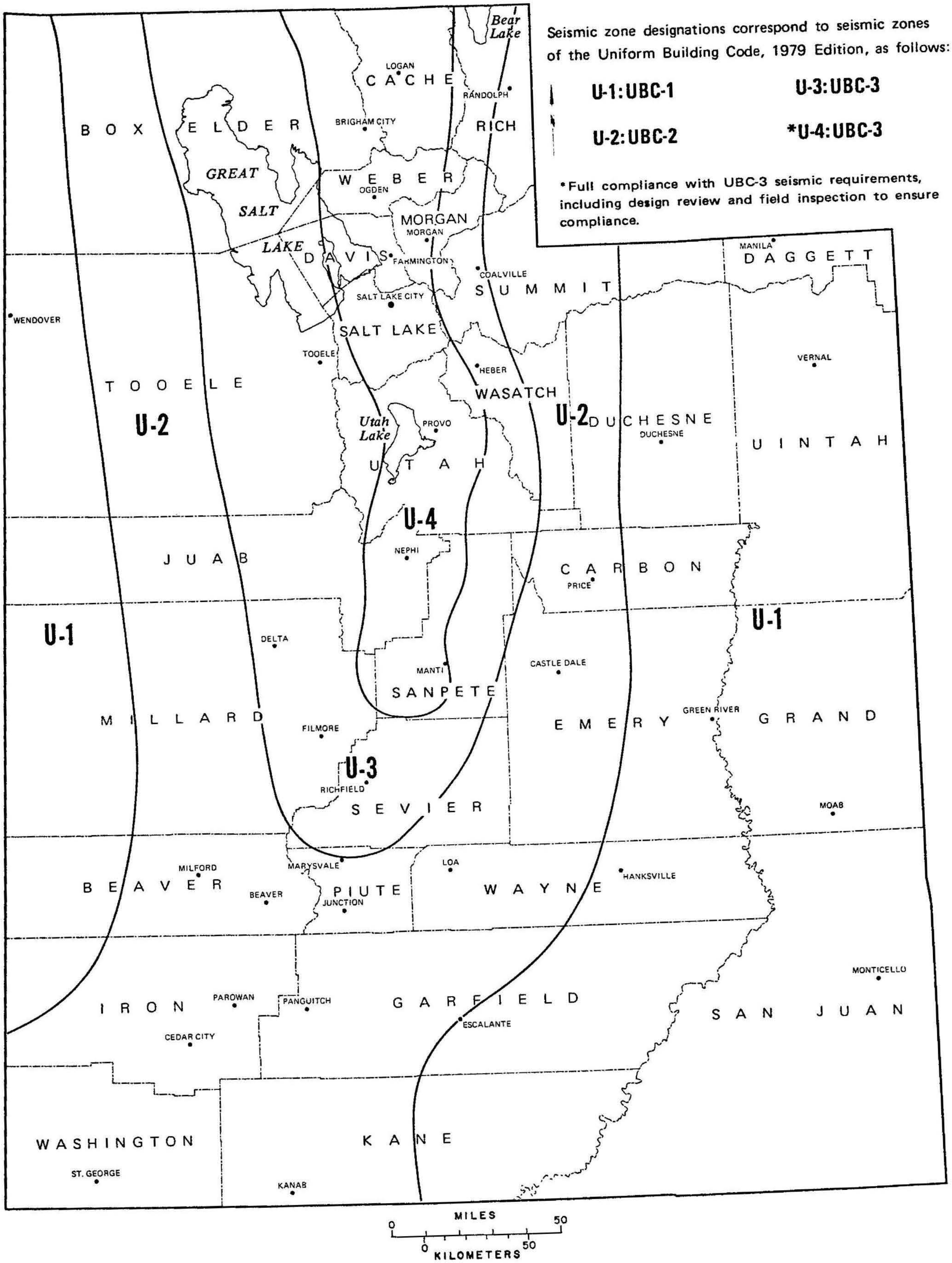


Figure 4
SEISMIC ZONES
January 1980
(Recommended by the Utah Seismic Safety Advisory Council)

magnitude range assuredly will cause collapse of many non-earthquake-resistant buildings and could even cause severe damage to some that are seismically designed. As we have noted above, Utah's seismic environment has the potential to produce earthquakes of the higher magnitudes and relatively frequently has produced earthquakes in the middle range.

Utah's settlement pattern has an unusual correlation with the region of highest earthquake activity. More than 80 percent of the State's population and development lie within the region roughly affected by the Wasatch Fault zone. Thus, the greatest number of people, buildings, and other facilities are coincident with the region of highest earthquake hazard and so have the greatest risk exposure. The extent to which people and facilities are exposed to earthquake risk will continue to increase in future years simply because of State growth. So, even though the earthquake hazard may not change in the future, the exposure of people and property to earthquake loss will grow larger. One consequence of this is that future earthquake losses in Utah are expected to be larger than in the past even without a severe earthquake. This prospect can be avoided if earthquake-resistant construction practices are adopted and widely followed.

The vulnerability of buildings and other types of facilities to earthquakes is most closely related to their construction systems. Although the methods of vulnerability analysis are highly complex, and although individual variations occur in almost every facility, techniques are available for estimating earthquake effects. Such techniques provide a basis for the design of new facilities and for evaluating the ability of existing facilities to resist earthquakes. Additional information obtained from inspections of earthquake damage has made it possible to make rough estimates of vulnerability.

Data obtained from earthquakes in other places show that unreinforced masonry buildings are especially vulnerable to earthquakes, even relatively moderate ones. Multistory structures of unreinforced masonry construction are even more hazardous. These data also show that other facilities, such as utility systems and transporation systems, often fail when earthquake strengths are in the range of strengths possible in Utah. Failures of electric power systems, water supply lines, and sewage disposal systems can be especially harmful to the economic viability of any social system, even when life safety may not be threatened.

MITIGATION OF EARTHQUAKE EFFECTS

Earthquake hazards reduction in Utah are considered in two parts -- those actions applicable to new facilities and those actions applicable to existing facilities. The two situations are considered separately because different problems, solutions, and socio-economic conditions are present that require different treatment.

The design and construction of new facilities that are earthquake-resistant is the easier and least costly to solve of the two problem situations. The standard building code adopted throughout Utah includes adequate provisions for earthquake resistance in buildings -- if only there were full compliance with it. Similar standards are available for improving the earthquake resistance of utility, transportation, and communications systems, but they are infrequently utilized. Earthquake resistance is rather easily included if done at the right time during construction of any facility. The cost for doing so rarely exceeds just 1 or 2 percent of the total cost of construction. Such a small amount for earthquake safety often is less than the bid spread when construction is contracted. Given these facts, one may fairly ask if the public interest is served when new facilities for public use are allowed to be built without incorporating earthquake-resistant concepts.

Earthquake hazards reduction for existing facilities has no simple answers. Social, business, and economic dislocations are found to occur for almost every kind of mitigation action that one might suggest. Sometimes the cost of a remedy is clearly greater than the earthquake risk; in other cases the trade-off between cost and risk is less obvious. In such cases and after all facts are disclosed for each side of the issue, political wisdom must be called upon for the correct decision. The Seismic Safety Advisory Council has attempted to compile factual information on earthquake vulnerability for several types of existing facilities and has concluded generally that long-term incremental hazards abatement offers the only economically feasible direction. Utah cannot correct 130 years of earthquake safety neglect in just a few years; yet neither can the State continue onward as if the risk to life and property were not present.

SECTION 3

EARTHQUAKE RISK ASSESSMENTS

In this section of the report, assessments of earthquake risk are summarized for selected situations that have been studied by the Seismic Safety Advisory Council. In presenting selected findings, no attempt is made to fully discuss them. Readers seeking more detail are referred to study reports of the Advisory Council. In like manner, selected recommendations derived from study findings are presented herein. The complete list of recommendations appears in Section 4. Detailed discussion of them is reserved for the Advisory Council's final report.

SEISMIC SAFETY PLANNING

Through the normal planning processes followed by local governments, much can be done to reduce inadvertent exposure of development to earthquakes. Within existing statutory authority, planning departments may exercise control over building and other development in the interests of public health, safety, and welfare. The Attorney General's Office has given an opinion that planning for earthquake safety is within the intent of planning statutes (Cf. Formal Opinion No. 78-008), although the language contained in the statutes is not explicit in this regard. A planning subcommittee of the Seismic Safety Advisory Council has concluded that the absence of explicit statutory authority relating to earthquake safety planning impedes broad application of planning practices beneficial to reducing earthquake exposure. Such planning practices include, but are not limited to, land-use controls in active fault zones. Amendments to existing planning legislation have been recommended that would explicitly authorize local governments to undertake earthquake safety planning. The language of the recommended amendments is permissive, not obligatory.

The same earthquake safety planning sub-committee has identified certain types of base information needed by planning agencies when they elect to incorporate earthquake safety planning practices. Much of the needed information can be compiled most efficiently and effectively by State government. Moreover, most of it likely will not be compiled without State participation. State involvement is favored primarily because of the highly technical nature of the work. Staffs of most local planning agencies are not technically qualified to do the type of seismic mapping that is needed. The State earthquake risk mapping program, administered by the Utah Geological and Mineral Survey, is intended to meet this need, but it is not yet doing so. After four years, the risk mapping effort has succeeded in mapping only partially just one county. Since planning staffs of local governments have advised that base risk map information must be available before planning procedures may be implemented, it has become apparent that an accelerated risk mapping effort must be undertaken before earthquake safety can become a routine part of the planning processes in Utah. A five-year expanded program has been recommended to meet this near-term need. A further recommendation is that the risk mapping effort should be contracted to the private sector if, after one more year, the Utah Geological and Mineral Survey has not demonstrated meaningful forward movement of the mapping program.

Studies prepared by the Seismic Safety Advisory Council have highlighted three important roles for the State that would assist planning departments of local government in earthquake safety planning. One role is providing training to planning personnel in order to overcome background deficiencies among planners who traditionally have no experience in earthquake safety planning. A second role is providing scientific, engineering, and engineering geology assistance to local planning agencies. A third role is providing guidelines, planning criteria, and models for earthquake safety planning practices.

In accord with these roles, the Seismic Safety Advisory Council presented a one-day seismic safety planning seminar for local planners in 1980, prepared and distributed written guidelines on earthquake safety planning, and developed the seismic zone map for Utah described earlier (Figure 4). In addition, a consolidated fault map of Utah prepared by Fugro, Inc., was printed and distributed throughout the State. The Utah Geological and Mineral Survey has assisted this effort through technical assistance on the siting of publicly-owned facilities. It is the judgement of the Seismic Safety Advisory Council that similar efforts will be needed for several years more as local planning departments build their expertise and capability to deal with earthquake safety in the planning process. Thus, continuing State assistance is needed in the near term. This assistance is administrative rather than legislative in nature.

BUILDING EARTHQUAKE SAFETY

Of all the elements of our built environment which can be damaged by earthquakes, buildings are the most obvious and the most studied. Perhaps this is because we conduct our affairs and our lives in buildings; perhaps it is because any life or property loss, from whatever cause, is widely visible. It also may be because the greatest life losses and property losses historically due to earthquakes have been caused by building failures. For all of these reasons and possibly others, building safety from earthquake effects is a primary concern.

Like fire safety for buildings, earthquake safety provisions appear in codes and standards that are adopted by governments to regulate construction so that life safety is protected. However, unlike fire safety, earthquake safety provisions often seem redundant and sometimes are incorrectly applied. Too often they are deemed unimportant; they sometimes are incorrectly applied or not enforced when they are required; and most importantly, their absence may not be missed for many years between infrequent earthquakes. When these deficiencies are weighed against the life safety risk in earthquake-prone regions, a strong case is made that earthquake safety is a proper governmental function in order to protect the public welfare.

The Seismic Safety Advisory Council has studied building earthquake safety in Utah from several perspectives for the purpose of evaluating the degree of risk to which the public may be exposed and for the purpose of evaluating the adequacy of construction practices in safeguarding against earthquake losses. The studies have focused upon: (1) the kind, degree, and associated cost of standards appropriate to Utah's earthquake environment, (2) the extent to which such standards may be applied today in new construction, and (3) the vulnerability of older existing buildings which likely were built without earthquake resistance. The findings from these studies are summarized below by subject.

Earthquake Construction Standards

One of the most important actions that can be taken to reduce the vulnerability of the State's citizens and their property to earthquakes is to require that new building construction comply with current earthquake safety standards. It makes no sense to add to the State's inventory of seismically unsafe buildings. Expert opinion is that full compliance with the earthquake safety standards of the *Uniform Building Code*, which is the code adopted by nearly all communities in Utah, would be adequate for Utah's earthquake environment. Accordingly, the Seismic Safety Advisory Council has recommended that new construction for buildings open to the public be required to comply with seismic safety provisions of the code currently adopted by the State Building Board (which is the 1979 Edition of the *Uniform Building Code*). Legislation to accomplish the purpose of this recommendation will be submitted to the 1981 Legislature.

Design, construction, and inspection practices are inseparable aspects of adequate earthquake safety standards. Improper design can void good construction and full inspection practices, and vice versa. Potential problems also are created by changing practices in construction inspection, or the lack of it, which in some instances have shifted responsibility for building safety from professionals to quasi-professional employees of the building owners. Design, construction, and inspection practices that are essential elements in the process of creating earthquake-safe buildings in accordance with recommended standards are discussed in a later section of this report.

Earthquake Risk in Existing Buildings

Earthquake hazards reduction for existing buildings presents complex and costly problems for which there are no easy answers and no single solution. Although most buildings in the State were constructed before earthquake-resistant standards were in force, it also is the case that many newer buildings were built without consideration of available seismic standards. The number of potentially hazardous existing buildings in Utah is therefore large. This large inventory of buildings cannot, as a whole, be either abandoned or fully retrofitted to meet current earthquake standards. The cost to do so prohibits such action.

Accordingly, the Advisory Council has undertaken detailed studies of several classes of existing buildings to estimate the risk to life safety and property damage posed by Utah's earthquake environment. From these studies, higher risk levels for certain classes and types of buildings have been identified, and program recommendations have been formulated to deal selectively with worst-case conditions. Detailed risk assessments have been prepared for existing primary and secondary schools, existing health-care facilities (hospitals and nursing homes), existing State-owned buildings, and other critical facilities such as fire stations, police stations, and local government emergency operations centers. Abatement of earthquake hazards for the vast number of other commerical, industrial, institutional, and residential buildings presents complex social and economic hardships that require considerably more study before feasible recommendations can be made.

The Seismic Safety Advisory Council has concluded generally that retrofit of existing buildings to improve their earthquake resistance can be justified, in life safety and economic terms, only for carefully selected instances. This does not mean that all other existing structures are risk-free but, instead, means that economic and social dislocations caused by widescale retrofit efforts would be greater than the life safety risks posed by Utah's earthquake environment. Recognizing this critical trade-off factor, the Advisory Council has suggested long-term remedial efforts that rely largely upon the normal cycle of building modernization or replacement to obtain the needed earthquake protection. This less disruptive alternative does have a major pitfall, however, that must be recognized and avoided. In particular, the long-term alternative easily could result in non-action through lack of attention and low program visibility.

More specific information, drawn from study reports by the Seismic Safety Advisory Council, helps to confirm the difficult earthquake safety problems of existing buildings. A few pertinent items from separate reports on existing school buildings, health-care facilities, and State-owned buildings are discussed below.

Existing Primary and Secondary Schools -- According to the study report prepared on this subject, of 580 school facilities in Utah consisting of over 700 separate buildings that in 1978 housed 315,000 pupils, more than 60 percent are of unreinforced masonry construction, and more than 140 buildings are 50 or more years old. Since these are two indicators of generally poor earthquake resistance in buildings, one may readily conclude that the exposure of school populations to earthquake risk is not small in Utah. The situation is not improved when one also observes that almost one-half of the unreinforced masonry school buildings are within Utah's worst earthquake zone.

The 580 school facilities have an estimated present value of $1.18 billion (1978 dollars). Average 100-year earthquake losses to these facilities are estimated at $70.6 million. The average number of fatalities caused by earthquake induced failures during any 100-year period are estimated at 58, with 943 corresponding hospitalized injuries. These estimates result from several large earthquakes rather than just one severe event and also from damage to more than one school building. Although the types of buildings most likely to collapse can be identified, one cannot predict with certainty where each earthquake will occur nor which buildings will be most affected. We therefore cannot state which buildings would collapse but can state the types most vulnerable.

The above death and injury estimates are derived from probability analysis techniques using the best available seismicity estimates. These estimates require brief explanation. Average losses are somewhat misleading for earthquake events that may occur in intervals of many tens of years. However, it is equally misleading to cite loss statistics based upon worst-case earthquake events that are expected to occur several centuries apart, except to indicate the upper boundary of loss. If a major earthquake were to occur in the next few years and if its epicenter were located near a large population concentration, then the death and injury estimates we have cited would be low. On the other hand, if no large earthquakes were to occur near populated areas during the next century or more; then the estimates would be high. That is why we have chosen to state the estimates in 100-year averages. Over many centuries, and assuming that the number of existing hazardous school facilities situation remains constant, the 100-year estimates are believed to represent the present risk exposure of Utah schools.

Risk reduction, either by incremental replacement or by retrofit of hazardous facilities, could lower the 100-year estimates to $14 million (1978 dollars) in property losses, 14 deaths, and 234 serious injuries, thus preventing about $56 million of property loss, 44 deaths, and 700+ injuries in a century. However, the cost for such an effort would approach $500 million (1978 dollars). Viewed in another way, the cost of preventing one earthquake-caused death is estimated at about $12 million. Whatever may be the value of life, that is an enormous cost for the State's public education system. Recognizing that the benefit-cost relationship is not favorable, the Seismic Safety Advisory Council has recommended, in lieu of a complete Statewide mitigation program, selective retrofit of facilities having the worst earthquake risk characteristics and located in the most severe earthquake zone. Even this more modest program will not be free of cost, however. Moreover, the program will require diligence by school administrators if it is to succeed. The Advisory Council has furnished specific recommendations aimed at ensuring continuing diligence for such a long-term mitigation effort.

Health-Care Facilities -- In an earthquake risk analysis of 45 hospitals and 84 nursing homes (all that could be located in Utah at the time of the study), 25 hospitals (containing 85 percent of the State's total bed capacity) and 69 nursing homes (containing 88 percent of the State's total bed capacity) were found to be located within Utah's worst earthquake zone. Hospitals with high seismic risk indicators, as obtained from construction characteristics, contain more than 66 percent of the total bed capacity; the percentage of nursing home bed capacity of similar circumstances is about the same. The 145 hospitals have an estimated present value of $526 million (1978 dollars); the 84 nursing homes have an estimated value of $85.5 million.

Average 100-year earthquake losses to Utah hospitals are estimated at $27.3 million; similar losses to nursing homes are estimated at $4.7 million. Average 100-year fatalities and injuries to hospitals and nursing homes, respectively, are estimated as follows.

	Deaths/100 years	Hospitalized Injuries/100 years
Hospitals	19	149
Nursing Homes	11	289

Risk reduction measures by replacement or retorift lead to the following comparable estimates.

	Property Losses Per 100 years	Deaths Per 100 years	Hospitalized Injuries Per 100 years
Hospitals	$6.6 million	6	93
Nursing Homes	$1.1 million	3	25

As was found for existing school facilities, the cost for reducing earthquake risk in Utah's health-care facilities also is extremely large in comparsion with the degree of life safety risk. This finding again led the Seismic Safety Advisory Council to recommend a long-term selective mitigation program in which worst-case health-care facilities are the first to receive attention. In this regard, the Utah State Mental Hospital and State Training School are identified as facilities having especially high earthquake risk and in need of early attention.

State-Owned Buildings -- An analysis of State-owned buildings in Utah shows results that are similar to studies of existing school and health-care facilities regarding their earthquake safety. State-owned buildings include offices, detention and confinement facilities, assembly and exposition structures, garages and storage warehouses, residences, and other facilities for special functions. Because State-owned buildings have widely ranging sizes and uses, several subclasses of facilities were separately evaluated so that significant risk situations could be identified more precisely. These differences in use plus wide variations in size, height, and construction systems create vastly different earthquake risk situations that cannot be aggregated and summarized. We therefore comment here on only a few findings drawn from the study report on State-owned buildings.

Several subclasses of State-owned buildings have especially high earthquake risk indicators and have uses that expose large numbers of people to unnecessary hazards. Confinement facilities, in particular the Utah State Training School and State Mental Hospital, are among these buildings having the highest risk. Facilities at the Utah State Fairgrounds also are among the most hazardous, especially the coliseum building.

In a legal as well as a social sense, the State appears to have special obligations regarding the safety of confined people. The finding that several confinement facilities are among the more earthquake-vulnerable of State-owned buildings should cause some concern among State leaders and should receive priority attention.

Buildings owned and used by the State of Utah number just under 300, excluding university buildings. Of the 293 buildings that could be identified, 267 were surveyed for the report. Of the total, 151, or 56 percent, are located within Utah's zone of greatest seismicity. Over 90 percent of the gross floor area of State-owned buildings lies within the worst seismic zone. Estimates of 100-year losses are that $8.9 million property damage, 8.6 deaths, and 139 serious injuries could be expected. Property loss data may be compared with the estimated present value (1979 dollars) of State-owned buildings of $150 million. The Seismic Safety Advisory Council has recommended actions by the State that would lower these risk statistics.

These recommendations are similar to others for school and health-care facilities in that selective long-term replacement or retrofit apears to be more reasonable and feasible than short-term, high-cost remedies.

In Summary -- Utah's earthquake environment, although more severe than most other states, is not severe enough to justify near-term high-cost hazards reduction programs; yet neither are severe earthquakes a remote possibility that justifies neglect. Geologic evidence shows that Utah will likely experience large earthquakes in the future -- perhaps next year, possibly not for a century or more. A severe earthquake in the next few years could be devastating to areas of the State given our current extent of mitigation efforts in building construction. The fundamental options available to the State are few in this regard: (1) The problem can be ignored and the risk taken; (2) short-term, high-cost remedial actions can be taken; or (3) long-term, low-cost remedial actions can be started which will systematically lower the risk in due time (with the added hope that the severe earthquake comes later rather than sooner). The Seismic Safety Advisory Council's recommendations for State earthquake safety policy have followed the third option.

SEISMIC SAFETY OF UTILITY SYSTEMS

Studies of earthquake risk to utility lifelines systems in Utah comprise another part of a comprehensive evaluation of earthquake safety. We define "lifelines" as those systems that if disrupted could cause immediate hardship as well as economic loss to a community. Electric power, communications systems, water supply, and sewage treatment systems clearly are included as lifelines. Post-earthquake relief and recovery efforts require transportation systems, energy, and in the winter, heat, so we also consider highway systems and oil and natural gas systems as lifelines. Railway and air transportation systems, though susceptible to disruption from earthquake events, do not appear to have the same degree of short-term criticality for Utah communities, and so less emphasis is placed upon them in our risk assessments. In this summary, dicsussions are limited to electric power, telephone, and oil and natural gas systems. Highway systems are discussed separately.

Richter magnitude is a familiar way to describe the strength of an earthquake. The term is a measure of the energy released and is the value usually reported by earthquake monitoring stations. Earthquakes also are often described in terms of their damaging effects. The Modified Mercalli Intensity (MMI) scale, ranging in value from I to XII, with XII representing the most severe damage, is the most commonly used measure in this regard. Use of the MMI scale allows one to estimate expected damage caused by earthquakes of different strengths. In our studies of utilities lifelines and buildings, we have used the MMI intensity scale so that loss estimates may be made.

There is a limited correlation between the magnitude and intensity scales. An area affected by an earthquake of MMI XII, an intensity reached only in the most catastrophic earthquake, would be in complete destruction. Such an area would correspond roughly to an earthquake of Richter magnitude 8.3 or greater. Intensities generally decrease as the distance from the earthquake epicenter increases, due to the attenuating effect of distance.

The following table outlines maximum expected earthquake strengths in each of the Utah macrozones both in Richter magnitude and MMI scales. These strengths are referenced in subsequent discussions about the vulnerability of lifelines systems.

Seismic Zone	Modified Mercalli Intensity MMI (Max. expected)	Approximate Equivalent Richter Magnitude
U-1	VI	4.9
U-2	VII	5.5
U-3	IX	6.7
U-4	X	7.3

Expected earthquake intensities provide considerable information about the vulnerability of utility lifelines in Utah, although users of such information must recognize that these estimates are derived from observed effects in actual earthquakes elsewhere and so provide only approximations. If, for instance, tanks (water or petroleum storage) buckle only at MMI VII and above, then tanks generally are safe in Utah's seismic Zone U-1, and are vulnerable with increasing degree in zones U-2, U-3, and U-4. If, for another instance, oil pipelines tend to rupture only at MMI IX or above, then such pipelines are vulnerable only in zones U-3 and U-4. In the main, only unreinforced masonry structures face hazardous seismic problems in Zones U-1 and U-2, and their risk is so much less than the risk of similar structures in Zones U-3 and especially U-4 that concern for the seismic response of lifelines systems is justfiably concentrated upon Zones U-3 and U-4.

In order to estimate the comparative vulnerability of lifelines systems, we have attempted to extend the notion of intensity damage thresholds to the major components of each type of utility system and after that have sought to evaluate the criticality of these various components to the overall operation of each system. Data so derived are the basis for our conclusions regarding the vulnerability of utility lifelines in Utah. Pertinent data are furnished herein that give some idea of how earthquakes affect utility systems.

MMI VII DAMAGE. At MMI VII, and possibly as low as MMI VI, some poorly constructured buildings such as unreinforced masonry or adobe structures, can suffer damage. Radio and TV stations often are of such construction and are not seismically designed. Some microwave equipment buildings, pump stations in water systems, and small hydroelectric stations that have little seismic resistance will be affected at MMI VII. At such lower intensities, unanchored or poorly anchored equipment can be damaged, including telephone building equipment and distribution transformers. Poorly sited aboveground tanks can buckle, and underground pipes in poor condition can rupture.

In Utah, apart from radio and TV station buildings and some underground water pipes in poor condition, only the electric power distribution system appears to be vulnerable at low MMI VII intensities. Distribution substations also exist at telephone equipment buildings and at refineries.

Rupture of underground water pipes could cause problems to other underground systems such as telephone systems wherein, say, some older splice cases are made or lead and may rupture. Telephone equipment in equipment buildings, however, appears to be braced to resist seismic forces.

MMI VIII DAMAGE. At MMI VIII, water, electric power, and possibly telephone and refinery systems are subject to damage. Cast-iron or asbestos cement water pipes can suffer as much as one break or more per kilometer. Water leakage can affect other systems. Transmission substations designed in accordance with standards for Zone 3 of the Uniform Building Code may suffer severe damage, and even substations designed more substantially can suffer porcelain failures. Utah Power and Light Company has designed its substations by more rigorous seismic standards since 1971, but two important stations, the Camp Williams and the Ben Lomond stations, were both constructed before 1971. Unanchored or poorly anchored massive equipment, including standby generators and booster pumps, can move or become misaligned at MMI VIII. The Lark booster station in the Mountain Fuel Supply Company system and standby generators in the Mountain Bell system are possible examples of such vulnerabilities.

In response to suggestion by the Advisory Council staff, Utah Power and Light Company examined what would happen if the Camp Williams substation were disabled by an earthquake event. Although an extensive power outage is expected following an earthquake that disables the Camp Williams transmission substation, the study indicated that 90 percent of the power could be restored for the transmission system within 2 to 4 hours -- provided that full generation capability is available in the system and that power can be purchased from other utility systems. Implicit in the assumptions of such a study was the recognition that a short-term power outage is inevitable. Backup power is thus needed for all lifeline systems that may be dependent upon continuous electric power.

Since unanchored aboveground tanks and also inflexible inlet and outlet connections at tanks can suffer damage at MMI VIII, refineries also may suffer problems. Even though dikes and recovery systems are required for Utah refineries, and even though recent design practices appear to be very good, older tanks may buckle at MMI VIII and existing inflexible inlet and outlet connections often may rupture.

MMI IX DAMAGE. At MMI VIII and IX, some ruptures can occur to pipe that is more earthquake-resistant, such as welded steel, ductile iron, pvc, and polyethylene pipes. Pipes of such material, however, are much safer in earthquakes than cast-iron or asbestos-cement pipes. Mountain Fuel Supply Company, which uses such pipes of greater earthquake resistance, has at least implicitly designed its system to resist earthquake damage until very high intensities are reached. Oil pipelines appear to be even more seismically resistant, and ruptures have been observed only when there is ground displacement at MMI IX and above.

At MMI IX, penstocks can rupture leading to failures in some hydroelectric generating facilities. Other types of generating facilities generally are designed to meet high earthquake safety standards, although older facilities such as the Gadsby Plant were designed prior to many earthquake engineering advances. Hydroelectric generating facilities appear to be more vulnerable than other types of generating facilities. Hydroelectric plants presently furnish a negligble portion of the electric power in high-risk earthquake zones in Utah. Pipes or conduits crossing the Wasatch fault, or other areas of possible ground displacement, are vulnerable to rupture at MMI IX. All utility lifelines systems have lines crossing faults in the major service areas along Utah's Wasatch Front. Only in a few cases have pipelines been valved so that fault displacements minimize spills or losses.

MMI X DAMAGE. Anchored tanks and buried reservoirs typically seem to be damaged only at or above MMI X. However, inflexible inlet and outlet connections can be ruptured at MMI VIII or IX.

Based upon the above information, one may conclude that any earthquakes in the 6+ Richter magnitude range along Utah's Wasatch Front will cause failures of certain components in nearly all utility systems. For earthquakes in the lower Richter 6 magnitude range, the failures likely will be localized and probably will cause only brief discontinuance of services. At higher magnitudes, service losses are expected to be widespread and possibly for an extended time period.

Earthquake Safety Standards For Utilities Systems

In general, utility lifelines of all types in Utah are not regulated with respect to construction practices and siting decisions that may involve earthquake safety. This applies to public, private, and quasi-public utilities regardless of who owns and operates them and regardless of any other type of regulation that may occur.

Regulatory authority over utilities systems is divested among several levels of government and among several agencies within each level. There is some uncertainty as to whether or not existing authority to regulate utilities includes oversight of construction and siting practices. Since such regulation has not been attempted, the practice has not been widely tested, although at least one basic type of utility recently has come under closer regulatory scrutiny that includes review of siting and construction decisions. The recently established Safe Drinking Water Committee of the State Department of Health appears to have sufficient authority to promulgate some pertinent earthquake safety regulations for water supply systems.

The extent to which earthquake safety practices may be applied deliberately by utility companies appears to be decided largely by the industries or local agencies acting at their own discretion and with their own judgement. While it is true that some utility industries (mostly outside Utah) have prepared standards to guide the construction of more seismically resistant systems, it also is the case that utility companies in Utah have complete discretion on whether or not to follow any particular standard and even which from among the standards to choose. Hence, we find, for example, that two different electric utility companies in Utah serving essentially contiguous areas in the Wasatch fault region follow two completely different standards with respect to earthquake resistance even though the seismic risk levels for both utilities systems are essentially the same.

A consequence of the conditions noted above is that earthquake safety may or may not be considered by particular utilities. Seismic standards that are applied may be different, and the degree of compliance with any standard said to be used is not monitored or verified by an independent party.

Even though there is a lack of guidelines governing utility systems construction for earthquake safety, some commendable actions have been taken by several Utah utilities companies to mitigate the effects of moderate to strong earthquakes. Utah Power and Light Company states that its new bulk substations are designed in accordance with recent higher standards derived in part from damage other utilities experienced during the 1971 San Fernando earthquake. Mountain Bell braces its equipment in accordance with recommenations developed by Bell Laboratories. Oil pipelines of Chevron Oil Company are valved at fault crossings, and some refineries design their storage tanks in accordance with seismic standards to resist translation and buckling failures. It also must be pointed out, though, that these selected migigation practices do not deal with the variety of other earthquake vulnerabilities of the systems.

Numerous mitigation techniques are available to improve the seismic performance of utility lifelines, and most, if not all, are applicable in Utah. Many of these are low-cost techniques dealing with detailing practices. Others may involve careful site selection processes. All require awareness of the technical factors and deliberate commitment by those doing the designs and construction of the systems.

For purposes of discussion, we distinguish two approaches to earthquake hazards mitigation for utility systems, of which both should be applied -- siting to avoid conditions that may be hazardous during an earthquake, and construction to resist the seismic effects when hazardous site conditions cannot be avoided.

Siting considerations involve such things as identifying and avoiding fault zones for critical components, avoiding soils that may be unstable when subjected to seismic forces, and locating facilities that may cause secondary hazards, such as flooding from ruptured water tanks or fires from ruptured fuel tanks, away from populations and other development.

Construction practices that improve earthquake resistance should be followed in every situation in Utah's seismic environment. Clearly, good site selection will make such construction easier and less costly in most cases. When siting choice is not possible, then the degree of earthquake risk must be considered in the design and construction, and the strength of the design decided accordingly. Choices of component materials, anchorage, bracing, and configuration are among the ways to achieve the needed seismic resistance. These safeguarding actions can be taken only by the utilities industries themselves.

Several resources are available to the utility companies in applying these earthquake mitigation techniques. For example, the Utah Geologic and Mineral Survey provides siting assistance upon request. Technical publications also are available that suggest low-cost mitigation measures for utility systems.

Evaluations of most lifelines utilities industries in Utah by the Seismic Safety Advisory Council reveal possible deficiencies in regulatory controls, procedures, and practices through which oversight of the industries is maintained in the public interest. These dificiencies result in utility systems which are more vulnerable to earthquakes than they need to be. The vulnerabilities could result in loss of services, thereby affecting the public users in economic terms as well as convenience. There is reason then, for review of the deficiencies in order to improve utility system reliability and possibly to reduce losses that ultimately are borne by the ratepayers.

Among the observed deficiencies are the following.

- No known procedures exist that require independent review of earthquake safety features in the design of electric power substations, telephone equipment facilities (other than local building controls), natural gas supply facilities, refineries, or a number of other details important to earthquake safety. Consequently, no one but the industries truly understands the earthquake risk to these systems, and the industries themselves often do not know.

- Evidence exists that some hazards mitigation measures dealing with safe siting and avoidance of fault zones for critical components are disregarded or never evaluated in the building of some utility lifelines. It appears that at least one telephone equipment building, for instance, recently was constructed in a fault zone.

- All utility industries seem to have given only minimal consider-sation to developing comprehensive seismic safety standards that treat the entire system and components, though we can point to examples of specific guidelines for particular components. As previously noted, there also is inconsistency among standards utilized by utilities of the same industry even though seismic hazards in a region or area may be much the same.

- Public user groups, or their representatives in governmental agencies, have been excluded from decisions regarding degree of earthquake performance capability that utility lifelines should have, and there are no known instances in Utah where public dialogue in such matters has even taken place.

The Seismic Safety Advisory Council recommends as a matter of State policy that each of these deficiencies be corrected.

OTHER CRITICAL FACILITIES

There are two other elements of the built environment which have earthquake safety implications but do not fall within the major study topics heretofore discussed. These are water impoundment facilities (dams and reservoirs) and transportation systems (primarily highway structures). Each is the subject of a separate study by the Seismic Safety Advisory Council.

Seismic Safety of Dams and Reservoirs

The State of Utah has a direct regulatory role in the construction and maintenance of water impoundment facilities and also has a dam safety office (within the Division of Water Rights). Earthquake safety studies of the

Seismic Safety Advisory Council have focused upon the operation of these state programs rather than upon earthquake risk studies of specific dam facilities. The purpose of such studies was to evaluate how adequately earthquake risk has been and is being considered in these programs. The studies were limited in scope primarily because earthquake risk analysis of specific dams and reservoirs requires technical competency and in-depth analysis not possible within the available resources or study time period.

As with the earthquake risk studies of buildings, both existing dam safety procedures and new dam construction standards and procedures were evaluated by the Seismic Safety Advisory Council. As a consequency of the evaluations, recommendations were made to the State Engineer regarding pre-construction geotechnical site investigations and report procedures. The State Engineer has accepted in principle the recommendations pertaining to new dam construction. Adoption of these recommendations should lead to improvements in review procedures involving earthquake considerations, and resulting guidelines for dam design prepared by the State Engineer should lead to improved services from design consultants.

The Seismic Safety Advisory Council also observed weaknesses in the federally funded dam safety program administered by the State of Utah. Suggestions were made to significantly strengthen the seismic evaluation phase of that program. However, changes in that program, if any, will be constrained by federal guidelines that govern the work.

Highway Structures

Recent California earthquakes have demonstrated that highway structures (elevated roadways, bridges, and overpasses) can be severely damaged even by moderate earthquakes. In such occurrences, life safety is at risk and transporation disruption occurs. As well, highway structures are extremely costly installations, and so are the repairs of failed structures.

A study of Utah highway structures prepared by an engineering consultant for the Seismic Safety Advisory Council indicates that many bridges and overpasses are vulnerable to earthquake damage of the same sort experienced by California's highway structures. The consultant's report, titled "Preliminary Seismic Hazards Evaluation of Highway Structures in Utah," identifies several specific points of vulnerability -- among them the length of support at hinges and girder bearings, reinforcement in pile caps, and soil liquefaction.

Although there appears to be an awareness of earthquake-resistant concepts among Utah highway structures design personnel, no general policy is in effect which requires application of these concepts. While this situation is not as bleak as it might appear, neither is as much being done as might be expected in the State to provide for better earthquake performance of highway structures. To some extent Utah highway structures designers have kept abreast of the advancing state of knowledge regarding earthquake considerations, and it is fortunate that a large number of standard highway structures designed in the State are not among the types most vulnerable to earthquake forces. Still, these are circumstantial conditions rather than a result of deliberate planning, and as the engineering report states, "All existing bridges in Utah designed by the Utah State Department of Highways, Structures Division, or their consultants were designed in compliance with the AASHTO (American Association of State Highway and Transporation Officials) or AASHO code current at the time, except for the seismic provisions of the code."

The same report mentioned above includes other information suggesting how particularly vulnerable conditions of existing highway structures might be modified to improve their earthquake resistance. Based upon experiences gained in California where bridge structures currently are being retrofit for reason of increasing their earthquake resistance, the cost is quite modest in comparison with the cost of the structure itself. Highway structures typically are extremely costly facilities. The dollar loss from just two or three bridge failures would more than cover the cost of the more important retrofit elements for the most vulnerable structures. Thus, the benefit/cost ratio is favorable, and so economic arguments for taking retrofit action appear to be justified in selected cases.

The Seismic Safety Advisory Council has not yet set forth recommendations which address the earthquake safety of highway structures, but such information as cited above suggests that some sort of State policy on this risk condition should be established.

PRACTICES AND PROCEDURES

The full process by which all sorts of buildings and other facilities are conceived, designed, and built is rather complex and normally involves many parties. Such things as site selection, design, review of plans, construction, and inspection are among the process elements. Each step in the process usually involves a separate organization, professional, or other party. Each process element includes decisions or practices that are rather critical to the ultimate earthquake performance of the facility. In this regard, we would observe that seismically correct design is of little value if the construction fails to comply with all essential details. The reverse also holds. Practices by building departments also play an important part in ensuring the safety of future occupants of buildings. Review and approval of plans must be accompanied by competent inspection of construction as it takes place.

Due to their importance to earthquake safety, then, practices and procedures in the building industry have received special attention by the Seismic Safety Advisory Council. Aspects examined include the availability and suitability of earthquake design standards and codes, their adoption and use, application of the standards by design professionals, and enforcement of adopted standards by agencies of government that may have jurisdictional authority. The Advisory Council also has examined the ability and aggressiveness of the various building professionals, organizations, and other parties to upgrade practices that affect earthquake safety. The overall and general conclusion is that the process, i.e., the practices and procedures, by which buildings get built is not effective either in avoiding or correcting earthquake safety problems.

There are understandable reasons that practices and procedures are not ideal as we might prefer. Just a few are cited. Utah's traditions of local autonomy and minimum governmental intervention tend to run counter to the goal of protecting the public health, safety and general welfare. Even when regulations have been established to control many elements of the building process, a general tendency within the State of Utah is toward a low enforcement profile. Practices and procedures that should be halted often are not. Self-policing of practices by organizations involved in the building process does not occur as often as it should. Utah agencies of government have more authority than they choose to exercise, and they have more ordinances and regulations on their books than they choose to follow. The consequence insofar as concerns earthquake safety is that the citizens of the State, believing that what is written is being followed, are in effect being misled.

Recommendations by the Seismic Safety Advisory Council address these problems in specific ways. Site evaluations of geologic hazards and stricter enforcement of existing regulations have been suggested. Suggestions have been made for improving the application of present regulations governing plan review, approval of plans, and inspection during construction. These suggestions do not establish new regulations but, instead, seek to strengthen those already followed. Suggestions similarly are formulated concerning improved practices and procedures in the siting, design, and construction of utilities systems. In this case, the suggestions call for an expanded oversight role of regulatory agencies to include consideration of the quality of utility facilities as well as costs of services to ratepayers.

All of the above and other recommendations have a common characteristic -- namely, greater State involvement in the various elements of the building process. Although this commom characteristic runs counter to State traditions, the Seismic Safety Advisory Council sees no evidence that the permissive practices of the past have resulted in meaningful improvements that serve to ensure the safety of citizens from earthquakes. Yet, upon casual review of present regulations, standards, and statements of responsibility, most people would conclude that the process seems adequate, even if not ideal. Policy recommendations that are made seek to bring substance to these existing practices.

SCIENTIFIC AND RESEARCH POSTURE

Earthquake phenomenology and earthquake risk assessments involve highly technical problems that are not yet fully understood. Thus, scientific and research work must continue even as an adequate public policy is shaped. For the most part, the scientific and research efforts are being conducted within the nation's universities and by the federal government. These sources have contributed most to Utah's earthquake knowledge.

Utah's earthquake data base has been markedly improved in recent years, although there still are some deficiencies. Nonetheless, the data base is sufficient for deriving an appropriate earthquake safety policy. With State and federal support, the University of Utah Seismograph Stations have contributed significant new information on Utah seismicity. Other information has resulted from recent contract studies funded by the U.S. Geological Survey.

Continued and unfaltering State support of earthquake research in Utah's institutions of higher education is essential for achieving a broadened knowledge of the Utah earthquake environment, especially in view of the incomplete state of this knowledge. The University of Utah Seismograph Stations earthquake monitoring provides an important public service to the State which is additional to the research work. Both activities are important components of a comprehensive earthquake safety program that must continue to be funded. Because the earthquake monitoring program contributes directly to fulfilling a need of the State, the interests of all citizens are served through funding support. The State must be prepared to replace funds for earthquake research lost as one-time or limited federal contract support expires. There remain important problems to be addressed, such as earthquake prediction, identification of source areas, and communication of current earthquake hazards information to user citizens.

One particular deficiency in Utah's earthquake data base of special concern is the near total absence of strong ground motion measurements in soil and rock structures unique to the State. Strong ground motions are the cause of nearly all significant earthquake damage. Information about the motion and effects of ground attenuation therefore is required to establish design parameters and to evaluate earthquake damage potential. In the absence of specific Utah data, it has been necessary in the preparation of risk assessments to use similar data obtained for other regions. However, certain technical problems arise from doing so. One problem pertains to the motion amplification effects caused by the deep alluvial deposits along the western slopes of the Wasatch Mountain Range. Until this sort of data is obtained for Utah soils, or until some other scientific means is developed that can substitute, the accuracy of some earthquake safety assessments in Utah will be limited. Moreover, seismic risk mapping of the State will be constrained without such data.

A strong-motion instrumentation array has been recommended by the Seismic Safety Advisory Council to overcome this deficiency. The recommendation is that the instruments be operated by the University of Utah Seismograph Stations as a complement to the short-period seismographs presently used to locate earthquakes. A further recommendation is that attempts be made to obtain the strong-motion instruments through a federal grant funds which, by precedence, have been available for similar installations elsewhere, and that the State assume responsibility for the long-term operation and maintenance of the instruments through funding to the University of Utah. The recommended arrangement would be advantageous to the State in several ways. The instruments would be under the care of knowledgeable personnel; the University's research opportunities would be broadened; and strong-motion data would become available for use in State earthquake safety policy development.

SECTION 4

RECOMMENDED ADMINISTRATIVE AND LEGISLATIVE ACTIONS FOR IMPROVED EARTHQUAKE SAFETY

MEETING THE NEEDS IN TWO WAYS

Many different agencies and levels of government have significant responsibilities in matters that affect earthquake safety. These responsibilities derive in part from statutory obligations, in part from local ordinances, and in part from an implicit general obligation to safeguard public life, safety, and welfare.

Enhancement of the State's earthquake safety posture will result from collective actions among these many agencies and levels of government. Both administrative and legislative participation are required to accomplish all of the needed actions.

Many earthquake safety needs may be met through actions or authority granted under existing Utah statutes, but some new legislation also is needed. Study findings are that significant forward strides in earthquake safety are possible simply by utilizing fully those existing statutory authorities. Such actions we have called administrative actions.

Success in utilizing administrative remedies to improve the State's earthquake safety situation is largely dependent upon the degree of commitment and effectiveness of administration. In this regard, we believe that administrative committment and effectiveness can be raised to higher levels in Utah. We also believe that many earthquake safety goals can be reached through programs of information dissemination and assistance rather than through legislature mandates.

Legislation for earthquake safety has been viewed by the Seismic Safety Advisory Council as a remedy of last resort. Legislation therefore has been recommended only where existing statutory authority may be missing or where administrative actions have been demonstrated to be ineffective. The amount of needed legislation therefore is not large.

Perhaps the most needed earthquake safety action in Utah is endorsement of a goal to seek an appropriate and affordable level of earthquake protection. There are indications that a visible State committment to such a goal would produce significant forward movement in earthquake safety among local governments and the private sector. The mere presence of the Seismic Safety Advisory Council during the past several years has demonstrated that there is broad-based concern for earthquake safety which needs only to be nutured. This is a role that only the State can fulfill, and so the Advisory Council strongly recommends that an earthquake safety office be established in order to provide continuing State coordination, information, and presence.

FOUNDATIONS FOR AN EARTHQUAKE SAFETY PROGRAM

The foundations of a comprehensive and coordinated earthquake safety program for Utah are contained in 17 general recommendations dealing with five principal issues. These issues are stated next along with the associated recommendations. In this report, the recommendations are stated in general terms in order that the principal thrust of each may be set forth in policy terms. More specific recommendations dealing with specific problems or observed earthquake safety deficiencies are found in the study reports prepared by the Advisory Council.

The point is again emphasized that earthquake safety is a broad subject that reaches many agencies and levels of government and that requires equally wide ranging treatment. Accordingly, recommended policies are neither simple to state nor, even when properly described, simple to grasp. The Advisory Council therefore urges careful reading of the abbreviated statements and recommendations that follow, so that initial perceptions by the reader do not obscure fundamental points.

Issue No. 1

A general policy for designing and constructing new buildings, utilities systems, and other facilities to resist earthquake forces likely in Utah is, by far, the most needed, most effective risk reduction measure, and the most cost-effective action that can be taken in Utah. This recommended action is really a test of State will to face the earthquake safety issue; since the needed standards and practices already are known and their effectiveness has been adequately documented.

RECOMMENDATION 1. The State should adopt legislation requiring that all buildings and other facilities open to use by the public be designed and constructed in full compliance with earthquake safety standards adopted by the State.

Issue No. 2

Planning decisions involving the use of land have significant long-term implications for earthquake safety. Such decisions can be made intelligently only when the earthquake hazards, such as fault zones, unstable soils, and liquefiable soils, are known, mapped, and the data are used in reviews of planning proposals made by developers. Since planning is a power granted by the State to local governments, the State should make every possible effort to ensure that the planning authority so granted allows and encourages local application of earthquake safety practices. Further, the State should provide assistance to planning agencies of local governments in instances when the level of technical expertise may not be otherwise available to them.

RECOMMENDATION 2. Existing statutes in the Utah Code pertaining to the planning authority of cities and towns and counties should be amended to include explicit reference to earthquake safety as a permitted activity under the enabling statement.

RECOMMENDATION 3. The State seismic risk mapping program, presently administered by the Utah Geological and Mineral Survey, *should be accelerated so that needed earthquake hazards information is made available to local governments within the next five-year period.*

RECOMMENDATION 4. As a means of avoiding unnecessary and costly risk to life and property, the State should adopt legislation requiring that siting evaluations of geologic hazards be prepared in advance of the construction of facilities used by the public.

Issue No. 3

Procedures by which earthquake safety policies may be administered are equally as important as the policies themselves. Some procedures that are followed in the design, review, and construction of facilities are ineffective in ensuring that earthquake safty is adequately considered, even when statutes and adopted rules or ordinances imply otherwise. A serious consequence is that public users of facilities incorrectly believe that earthquake safety is routinely included. The State has a responsibility to provide leadership to ensure that authorized administrative procedures are fully and competently carried out.

The following recommendations address specific program areas where administrative control should be strengthened as a means to enhance the State's earthquake safety posture.

RECOMMENDATION 5. The State should insist upon full enforcement of earthquake safety code provisions in facilities under State jurisdiction, including schools, State-owned buildings, and health-care facilities.

RECOMMENDATION 6. Seismic standards and review procedures for dam and reservoir construction should be promulgated.

RECOMMENDATION 7. Established procedures for administering licensing laws for architects and engineers should be modified to strengthen those portions dealing with professional accountability.

RECOMMENDATION 8. Guidelines should be established and assistance should be made available to local governments for strengthening enforcement of regulations and codes governing construction, including compliance with State laws regarding licensed professional services. (Strengthened enforcement here means more thorough, more competent enforcement of reasonable standards that have been accepted.)

RECOMMENDATION 9. The Public Service Commission should promulgate and enforce standards of earthquake safety performance for utility systems it regulates in the public interest.

RECOMMENDATION 10. Guidelines and procedures should be established by the Department of Health pertaining to earthquake risk reduction for water supply and waste disposal systems, and assistance should be provided to local governments in applying the guidelines.

Issue No. 4

Special attention to earthquake safety is needed for facilities whose continued operation is critical immediately after an earthquake or whose failure could cause significant numbers of injuries and possibly deaths. Hospitals, fire stations, and communications systems are the more important among critical facilities. Schools, high-rise buildings, and large assembly buildings are examples of high-exposure facilities. These types of facilities merit thorough consideration of earthquake safety and full compliance with earthquake safety standards. Existing and new facilities are of equal importance, and both should be addressed.

RECOMMENDATION 11. Regulatory authorities now granted to State agencies concerning oversight of school buildings and health-care facilities should be fully utilized to ensure that new buildings are planned and built in accordance with appropriate earthquake safety standards.

RECOMMENDATION 12. Programs should be established leading to retrofit or replacement of high-hazard critical and large-occupancy facilities. (Specific recommendations call for selective retrofit or replacement, as determined from high earthquake risk indicators, and phased over several years. This strategy is the most cost-effective.)

RECOMMENDATION 13. The State Fire Marshall's Office should assist local governments to safeguard fire equipment buildings from earthquake damage in order to ensure that fire fighting capability remains functional after an earthquake.

RECOMMENDATION 14. Local governments should develop and implement abatement programs leading to eventual elimination of conditions in high-occupancy facilities that may be vulnerable to earthquake damage affecting life safety.

RECOMMENDATION 15. Operators of public water supply systems should undertake comprehensive review of their systems for the purpose of identifying and then eliminating conditions that are vulnerable to earthquake damage and that might disrupt service.

Issue No. 5

Neither the state of knowledge of seismicity nor effective utilization of present earthquake knowledge are at a state of completion in Utah. Only through concerted and continuing attention can long-term progress be made toward higher levels of earthquake safety. Continuing efforts are needed both in research that advances applications technology and in coordination of programs that utilize present knowledge. The State has a responsibility to identify and support further scientific exploration when the interests of its citizens are directly served. It has an even greater responsibility to provide the framework within which earthquake safety policies may be recommended and coordinated. In conjunction with these goals, the following recommendations are made.

RECOMMENDATION 16. A strong-motion instrumentation program should be established for the purpose of obtaining needed scientific information about earthquake-induced ground motions in soil structures unique to Utah.

RECOMMENDATION 17. An earthquake safety office should be established in the Office of the State Planning Coordinator for the purpose of coordinating established earthquake safety policies, setting earthquake safety goals and priorities, monitoring progress of earthquake safety programs, and gathering and disseminating earthquake safety information to the public and to other governmental units.

REPORTS AND PUBLICATIONS BY THE SEISMIC SAFETY ADVISORY COUNCIL

USSAC-01	Purposes and Activities of the Utah Seismic Safety Advisory Council; Undated pamphlet.
USSAC-02	Activities Report for the Period July 1977-June 1978; 1978.
USSAC-03	Seismic Zones For Construction in Utah; September, 1979.
USSAC-04	Seismic Zone Map of Utah; January, 1980.
USSAC-05	Seismic Risk Assessment of Utah Primary and Secondary Schools and Recommendations for Risk Reduction; December 1979.
USSAC-06	Seismic Risk Assessment of Utah Health-Care Facilities and Recommendations for Risk Reduction; December, 1979.
USSAC-07	Seismic Hazards and Geologic Hazards Related to Comprehensive Planning in Utah: Guidelines for Preparation of a Seismic Safety Element of the Comprehensive Plan; April, 1980.
USSAC-08	Seismic Safety Considerations for Dams and Reservoirs in Utah; April, 1980.
USSAC-09	Briefing Material on the Seismic Risk of Utility Lifelines in Utah; June, 1980.
USSAC-10	Seismic Strong-Motion Instrumentation for Utah: Current Status, Needs, and Recommendations; August, 1980.
USSAC-11	Seismic Risk Assessment of State-Owned Buildings in Utah and Recommendations for Risk Reduction; December, 1980.
USSAC-12	Seismic Risk Assessment of Fire Stations, Police Facilities, and Other Critical Municipal Facilities in Utah and Recommendations for Risk Reduction; (Expected completion January, 1981).
USSAC-13	A Report to the 44th Utah Legislature: Earthquake Safety in Utah and Recommendations for Risk Reduction; January, 1981.
USSAC-14	Seismic Risk Assessment of Public Culinary Water Supply Systems in Utah and Recommendations for Risk Reduction; (Expected completion February, 1981).
USSAC-15	Seismic Risk Assessment of Electric Power Systems in Utah and Recommendations for Risk Reduction; (Expected completion March, 1981).

USSAC-16	Seismic Risk Assessment of Oil and Natural Gas Systems in Utah and Recommendations for Risk Reduction; (Expected completion March, 1981).
USSAC-17	An Evaluation of Utah's Emergency Management Planning and Capability for Earthquake Disasters; (Expected completion March, 1981).
USSAC-18	Seismic Risk Assessment of Utah Highway Systems and Recommendations for Risk Reduction; (Expected completion, April, 1981).

OTHER REPORTS -- PREPARED FOR THE SEISMIC SAFETY ADVISORY COUNCIL

(Copies are not available for distribution)

- A Methodology For Seismic Safety Cost/Benefit Analysis, Bureau of Community Development, University of Utah; May, 1978.

- Cost Analysis for Application of Seismic Safety Provisions of the Uniform Building Code to Commerical Buildings of Intermediate Scale, Lee C. Knell and Associates, Architects and Planners; September, 1978.

- Development of Criteria for Seismic Risk Mapping in Utah, Dames and Moore; July, 1978.

- Considerations and Alternatives for Abatement of Seismically Hazardous Existing Buildings in Utah, J.H. Wiggins Company; July, 1979.

- Preliminary Seismic Hazards Evaluation of Highway Structures in Utah, Agbabian Associates; December, 1980.