SEISMIC RISK ASSESSMENT OF PRINCIPAL COMMUNICATIONS SYSTEMS IN UTAH AND RECOMMENDATIONS FOR RISK REDUCTION

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FOREWORD

The Utah Seismic Safety Advisory Council, established in 1977, is charged to prepare assessments of earthquake hazards and associated risks to life and property in the State of Utah, and to make recommendations for mitigating hazards that may be found.

This report presents an assessment of earthquake risk for principal communications systems in Utah. The report includes recommendations for reducing risks that are deemed reasonably manageable within available resources. The recommendations are set forth as judgements of the Seismic Safety Advisory Council in terms of effectiveness of the suggested action for reducing risk to life, health, and property.

This report is divided into a summary of findings, a discussion of earthquake effects upon communications systems in general and telephone systems in particular, an assessment of earthquake risks to Utah communications systems, and recommendations for earthquake risk reduction that deal primarily with policies and procedures rather than technical solutions.

The report presents an overview of earthquake risk to selected types of communications systems and treats particular elements of telephone and emergency radio broadcast systems primarily to highlight important systematic relationships that affect public service. The vulnerabilities of particular types of components to earthquake effects are discussed, and guidance is provided by which system operators may undertake more detailed evaluations of their particular systems, but no major weaknesses of facilities to earthquake damage were identified that warranted more rigorous study. Communications as an emergency response tool is stressed in the report, and special attention is given to evaluation of the vulnerability of systems serving this role in the State.

This report, like several others of similar nature dealing with various types of utilities, reveals the complexity of large systems serving entire communities, counties, and even larger regions. Such systems are made up of innumerable small and not so small components that must work together for effective and reliable distribution of the utility product. To achieve area-wide service, some components and some lines in the system are more important than others in the sense that more of the service population can be affected by unplanned failures. The perspective sought from the reader, then, is of a system which is reliant upon individual components. Such a perspective helps significantly to understand how earthquakes can cause inconvenience and economic loss to populations and businesses remote from the epicenters of the events. Such a perspective also helps one to realize that communication during times of emergencies is an essential element of effective response and that operational capability of communications systems is, indeed, a matter in which the general public has a direct and proper interest.

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SECTION 1

INTRODUCTION

The earthquake vulnerability of communications systems located in Utah has been the subject of separate study by the Seismic Safety Advisory Council primarily because of the importance of communications capability in a post-earthquake situation. Communications over significant distances may be needed to summon emergency aid, to coordinate rescue and medical efforts, to coordinate governmental response activities, and to collect damage data as well as to inform the concerned public about the event, to dispell rumors, and to give instructions when necessary. These activities are indispensible in an effective earthquake response effort. Tangentially, life safety may be at risk if information and instructions cannot be given to the public or if the need for aid or assistance cannot be made known.

In general, since telephone and radio are the principal means for communicating and since these systems extend over wide areas and even regions, the relatively localized distruptions that might be caused by earthquakes are likely to have significant consequences only for a local area. This examination of earthquake effects upon communication systems therefore focuses largely upon the localized impacts of earthquakes.

In this study, we have examined the types of communications systems typically available within a localized region and then have sought to evaluate the expected performance of these systems in earthquake conditions. In Section 3 a general overview of the seismic response of several types of communications systems is provided. In Section 4, the general information is utilized to evaluate earthquake risks to communication systems available in Utah. As a consequence of these findings, we provide in Section 5, recommendations for reducing earthquake risk to communication systems where particular concerns or deficiencies are observed. The recommendations contained here generally are of a policy type rather than technically specific. Indeed, we found no especially vulnerable conditions among the various types of communications systems which suggest a need for any actions more extensive than refinement of existing procedures in a few instances.

SECTION 2

SUMMARY OF FINDINGS

Principal findings resulting from the seimsmic risk assessment of communications systems in Utah reported herein are presented in this section without elaboration or extensive discussion. More detail is presented in Sections 3 and 4 regarding the expected effects of earthquakes upon facilities and equipment of typical communications systems. These effects are related more to general types of damage to communications systems that earthquakes might cause than they are to variations in effects based upon variations in earthquake strengths. Suitable information was not found that would allow more extensive evaluations to be made based upon earthquake strength.

In the evaluations of the earthquake vulnerabilities of communication systems presented in this report, distinction necessarily is made between broadcast communications by airwave and communications dependent upon wired connection between transmitter and receiver. In the case of airwave transmission, vulnerability assessment is limited to the ability of the transmitting station and tower, including both the facility and equipment, to withstand earthquake effects. In the case of wire-connected communications, consideration is given both to the vulnerability of the electronic equipment and to the facilities within which the equipment is housed as well as to the vulnerability of the wire connections between transmitter and receiver.

Principal findings of this study are listed and discussed below. Importance of the topic was not a basis for the list sequence, and readers will note that the findings are listed more or less in order of their appearance in the subsequent sections of the report.

Radio Communications

Radio broadcast facilities in the more seismically active regions of Utah are found to be located away from fault zones though within regions expected to be affected by ground vibrations. The vulnerability of buildings housing broadcast facilities therefore subjected to earthquake forces can be expected to be about the same as for any other types of structures. However, no effort was made for this study to assess the individual characteristics of the separate buildings housing radio broadcast facilities.

Some radio stations have broadcast capability from mobile units, and so the capability for broadcasting general public information has an added level of reliability. In addition, radio transmission can occur over many miles, and there is a sufficient number of radio stations spread throughout the State to reasonably insure that commercial radio communications can occur even though one or more stations in a local area may be rendered disfunctional by an earthquake.

Most radio broadcast transmission facilities are located to the west side of the Wasatch Mountains, away from fault zones and possibly even remote from areas expected to be affected by ground vibrations. In addition, the design of transmission towers typically is controlled by wind forces (another source of lateral force) which renders them less susceptible to earthquake damage. The conclusion to be drawn is that transmission facilities do not appear to be significantly jeopardized under earthquake conditions.

Statewide communications are possible through several independent systems, including privately owned radio and television stations and State networks, such as the State Microwave System. Although individual facilities of these systems lie within the most active seismic zones along the Wasatch Front, it is unlikely that any earthquake event would render the complete system dysfunctional, although, again, localized dysfunction is possible.

Telephone Communications Systems

Telephone communications in Utah, primarily though not entirely operated by Mountain Bell Telephone Company, combine microwave transmission with hardwire transmission. Typically, local areas or neighborhoods are served by wired connections feeding from homes and businesses to a central facility housing various types of electronic equipment and, from that point, by microwave transmission to other central facilities serving other neighborhoods. Although these switching stations could be extremely vulnerable to earthquake damage, this problem generally has been recognized, and special care has been taken in the design and anchorage of equipment in the central facilities to safeguard against damage that might be caused by earthquake forces. So, although there exists the possibility that telephone communications might be rendered dysfunctional for one or more neighborhoods feeding to a microwave facility, there is no reason to believe that such local failures would lead to systemwide dysfunction.

One aspect of communications systems, not considered in this study, is that of integration and coordination of multiple modes of communications. As this study indicates, there are several means of communications that can be mobilized for emergency use--including citizen band radios, commercial radio and television stations, and microwave and telephone systems. Concerns often are heard in post-disaster evaluations about a need for better integration and coordination of communications among these various systems. Although improved integration and coordination may be desirable, this is left as the subject of a study treating other aspects of communications systems besides earthquake vulnerability.

SECTION 3

A GENERAL OVERVIEW OF THE SEISMIC RESPONSE OF COMMUNICATIONS SYSTEMS

THE FUNCTION OF COMMUNICATIONS SYSTEMS AFTER EARTHQUAKES

The adequate functioning of communications systems after an earthquake is as important as the functioning of any other system called a "lifeline," a term also applied to water supply, electrical power, natural gas and oil, and transportation systems.

Telecommunications (communications over a significant distance) obviously are needed to summon emergency aid. Telecommunications also are needed to coordinate rescue and medical efforts, to collect damage data on utilities systems and other facilities, to aid speedy and safe reconstruction efforts, to arrest numerous rumors, and to evacuate areas if needed ([6], p. 200).

Long-distance requests for carpenters, electricians, architects, engineers, cranes, bulldozers, water-purification equipment, blood, and many other special needs that may be caused by an earthquake also require functioning communications systems. In the San Fernando Valley earthquake of 1971, for instance, communications was rated as the disaster activity causing most problems for hospitals ([11], p. 79). During the Alaska earthquake of 1964, for another instance, the Emergency Operating Center became the hub of disaster operations. Official "controlled" pronouncements were essential to prevent panic and misinformation ([12]).

An examination of such communications functions in post-disaster relief programs thus leads to the conclusion that some communication system or other must be reliable in the event of an earthquake. The need for communications is so essential, in fact, that alternative and redundant systems typically are provided for the most critical operations and activities, such as fire control, medical assistance, law enforcement, and governmental coordination.

Several sorts of communications systems are available for emergency response activities, and most of them are utilized in various combinations. Among the more common and more important, at least in terms of earthquake disasters, are telephones, radios (both commercial and private and of many frequencies), television, and local intercoms. As the reader may observe, some of these communications systems depend upon wired connection between the parties communicating, whereas the others depend upon transmission by airwave. Hence, each type has a somewhat different use or purpose, and also a different vulnerability to earthquake effects.

Telephone communications have become a way of life in most of the world. Daily dependency upon the telephone has carried over into emergency response planning, and the telephone is the communication means of first resort for these activities, even though there are extensive case histories where the telephone systems have malfunctioned, or have not been useable, during times of emergency. No doubt this dependency has come about because telephone communications are convenient, prompt, and usually effective. Widespread use of the telephone as a primary means of communication therefore must be recognized and accepted in emergencies, and exceptional effort is justified to insure continued functioning of the telephone system during and after earthquake emergencies.

In this report, we have given special attention to telephone communication systems earthquake response. Less attention is given to other types of communications systems, though consideration has been given to commercial radio transmission facilities and to several other radio and microwave systems installed in Utah that have bearing upon overall communications capability.

PAST SEISMIC DAMAGE AND ANALYSIS OF POSSIBLE FAILURES TO TELEPHONE SYSTEMS

Telephones can be needed after earthquakes to report a variety of matters that, in some cases, may be difficult to report in a timely fashion in other ways. For instance, telephones can be of use in reporting fires, famine, epidemics, injuries, and deaths, as well as various forms of damage. According to C.M. Duke and D.F. Moran, the reliability level of the telephone system should be at the highest level of all lifeline systems except for those involving nuclear power generation ([1]), p. 373). In other words, those authors regard the telephone system as being at least as important as the water supply and electric power transmission systems.

Data are scarce on the past response of telephone systems to earthquakes (telephone conversation with John Foss, Bell Laboratories, 3-11-80). Data come from at least three earthquakes: from Niigata (Japan) in 1964, from Alaska in 1964, and from San Fernando Valley (California) in 1971. Discussions of actual or possible earthquake damage may be divided into six categories for various components or aspects of telephone systems.

1. Buildings, and microwave towers
2. Equipment in buildings
3. Underground cable (including connections to buildings)
4. Aerial cable
5. Overloading of circuits
6. Systematic aspects--multiple routing and dependence upon electric power.

Buildings And Microwave Towers

In general, telephone system buildings have been well constructed, and so have suffered little earthquake damage in the past ([2], p. 151).

Of seventeen telephone buildings surveyed after the San Fernando Valley earthquake, only three suffered some structural damage in spite of the fact that all surveyed buildings were affected at Intensity VI or above and five were affected at Intensity X. Owing to high intensities, several structures suffered minor ceiling or plaster damage, but the major damage was to equipment rather than to structures ([3], pp. 39-58).

During the 1978 Tokachi-Oki (Japan) earthquake, a microwave antenna was displaced at a relay station and communication between two main islands was interrupted for almost a day ([4], p. 178).

Equipment In Buildings

To date, the most expensive and significant damage to telephone systems has occurred to equipment in main buildings. The most spectacular instance was the demolition of $4.5 million, or one hundred tons, of equipment in the Sylmar Central Office as a result of the San Fernando Valley earthquake. In that earthquake, equipment damage occurred in ten of the twelve or so main buildings that contained important equipment ([3], pp. 34-58).

In the 1964 Alaska earthquake, one of the four Anchorage exchanges suffered equipment damage as relay racks and panels were tipped over by the vibration ([5], p. 1,051).

Most of the equipment damage caused by these earthquakes, it appears, could have been avoided through better techniques for securing, anchoring, or mounting equipment. Some special damage, though, could occur to air-supported disc memories used in data processing systems that is not related directly to equipment anchorage ([6], p. 208). In one report, it is recommended that mechanical locking is preferable to magnetic catches on data processing equipment units ([7], p. 3,312).

Underground Cable

Damage to underground telephone cables was reported in both the Alaska and Niigata earthquakes

In the Alaska earthquake, a 600-pair cable traversed ground that suffered from several landslides. Another 200-pair cable stretched tight at a manhole splice in an area of slides and ground rupture and also suffered two broken splices ([5], p. 1,052). Inspected duct systems, of asbestos cement, suffered 520 cracks in 7.19 kilometers. The cracks were concentrated near a slide and also near slopes of stream valleys and local drainage channels. Soil and water entered the ducts and water entered even some hairline cracks ([5], p. 1,059). Underground systems remained 80-percent operational except in totally destroyed portions ([5], pp. 1,060-1,061).

In the Niigata (Japan) earthquake, underground conduits broke and manholes were damaged. Rates of conduit damage were very high in some areas. In the exchange offices most severly affected, a total of 59.5 km. out of 106.1 km. of conduit was damaged, and 113 of 407 manholes were damaged ([8], pp. 525, 526).

In California today, major intercity cables use ductile iron pipes for conduits at active fault crossings, and excess slack is provided in the cables which are laid in sand beds ([1], p. 369).

According to John Foss of Bell Laboratories, axial elongations of cable pose the greatest threat to its ability to carry signals. Special measures are available to protect cables at fault crossings, although axial elongations can also occur as a result of seismic compression waves along the cable length. At building attachments, moreover, cables should be protected against shearing ([6], pp. 205, 206). According to another study, failure of cables occurs routinely as a result of construction activities, water penetration, and other matters, so that telephone companies have developed techniques for speedy location of failure points and rapid repair ([9], p. 215).

Aerial Cable

According to one source, the most common "seismic damage to telephone communication systems is breakage of service and overhead wires, and the partial or complete uprooting of the structures which support them" ([4], p. 178).

In the 1964 Alaskan earthquake, the overhead system had cracked insulators, pulled splices in conductors, broken or partly failed pole-line transformer mounting brackets, and several broken ground wires ([5], p. 1,053). Overhead systems were 75-percent operational in Anchorage after the earthquake and 90-percent operational after light repairs ([5], pp. 1,053, 1,059-1,061).

In the 1971 San Fernando Valley earthquake, 676 repairs were made of broken service wires from cable or pole to customer and another 96 repairs were made of other assorted problems in the distribution system ([3], p. 57).

According to John Foss, aerial cable suffers the same potential problems as buried cable and also may suffer further problems resulting from the whipping of the cable-pole system. Slack cable with heavy mass attached may become suddenly taut, and pole-mounted equipment, such as amplifier equipment, may be subjected to severe oscillations ([6], p. 206).

Overloading

Extensive post-disaster use of a telephone system can lead to overloading of circuits and possible malfunction from blown fuses ([2], p. 45). To overcome such problems, control procedures have been developed to minimize breakdowns resulting from overloading ([1], p. 369). In the San Fernando earthquake, the "bulk of nonemergency calls were selectively blocked" ([6], p. 200). However, control procedures that do not allow calls to be made can further vex distressed parties who may seek assistance.

Systematic Aspects--Multiple Routing And Dependence Upon Electric Power

Failure at various points in a telephone system need not entail user loss if alternative routing exists for calls. Likewise, certain sorts of failures, such as electrical power failure, need not impede a system in which standby generators exist to compensate for lost power. In Anchorage, for instance, all four telephone exchanges lost electrical power and switched to emergency batteries for continued operation ([5], p. 1,051).

THE SEISMIC RESPONSE OF OTHER COMMUNICATIONS SYSTEMS

Data on the seismic response of other communcations systems are even more scarce than data on the seismic response of telephone systems. The analysis of such other communications systems must be made based upon their building structures, their non-building structures, and their network characteristics, including the availability and distribution of equipment, and their network performance given particular types of malfunctions. For one instance of such network characteristics, many radio stations in Alaska were off the air as a result of a general power outage ([9], p. 212). Networks that do not rely upon power, or that do not rely exclusively upon power, are hence better able to perform after an earthquake, since power outages are routine in larger earthquakes.

In addition to radio and TV stations, a variety of other means may be used for communication. Microwave systems, amateur or ham radio, citizens-band radio, radio-equipped taxis and public cars, and even human messengers are vehicles of communication. In such cases, the availability of relevant equipment and operators becomes important in such means of communication ([6], p. 46). According to Eugene Haas, noted authority on societal response to disasters, persons engaged in search-and-rescue missions need to be well-coordinated and also to have the fastest and most reliable modes of communication so that they can convey reports to hospitals and ambulance services ([2], p. 45). Prior coordination of those engaged in rescue and reconstruction efforts can thus also save valuable time in such efforts. Treatment of this aspect of communications is beyond the scope of this study.

Damage to radio and TV facilities has been subdivided into damage to studio buildings and their equipment, to lines from the studios to towers, and to tower structures themselves ([10], p. 149). Since damage to studio buildings can be estimated in terms of building characteristics, and damage to lines in terms of their configuration characteristics, including how they are attached to buildings, only considerations pertaining to towers will be mentioned here.

TV towers are usually on mountain tops in Utah where environmental conditions normally are severe. Consequently, these towers generally have well designed foundations. Towers located on Utah's salt flats can have corrosion problems that can result in strength deterioration over the years, and so these towers may be more susceptible to earthquake-induced ground motions than is realized. Standby power at towers needs to be braced. Towers that require ceramic insulators may be vulnerable to damage, in the same manner as are electric power systems. Since immediate life-safety hazards may not be perceived by designers, towers may not have special lateral load features ([10], p. 149, [11], p. 225).

Towers may be freestanding cantilevers on the ground, guyed to the ground, or freestanding and/or guyed on top of other stuctures, such as buildings. Those towers on other buildings may suffer resonance effects from building motions producing both vertical and horizontal amplification in the tower motion. Separation of guy anchors may lead to unequal tension on guy cables during lateral motions, with resulting failure of the tower. Antennas, lead-horns, waveguides, and couplers should be rigidly attached to prevent resonance, but flexibility in waveguide runs between towers is needed to prevent displacement damage to the waveguide. Metal plate protectors also may be needed to prevent possible overhead damage to waveguides ([6], pp. 206, 207).

The 1949 Puget Sound earthquake resulted in the buckling of a free-standing radio tower in Seattle. In the 1971 San Fernando Valley earthquake, electric power failures to receivers led to communication outages in the heavily damaged area ([11], p. 226).

In summary, little is known about the seismic response of communications networks outside of the vast amount of information about nodes of the system, such as buildings. Such matters concerning seismic response can be reasonably speculated upon given practices of securing equipment and designing structures to resist lateral loads, and also given information about the seismic resistance of various materials that may be used in conduits, or at building connections.

SECTION 4

EARTHQUAKE RISKS TO COMMUNICATIONS SYSTEMS IN UTAH

In this section, general characteristics of communications systems serving Utah will be discussed along with the general seismicity in the State. On the basis of findings in Section 3, some preliminary results are derived concerning possible future effects of earthquakes upon communications systems.

SEISMICITY IN UTAH

Locations in Utah vary considerably in terms of expected seismicity. The zonation map of Utah contained in the recent Uniform Building Code indicates, for instance, that a large portion of the State lies in an area of high seismic activity, a Zone 3 region, whereas other portions of Utah lie in zones of lesser activity (See Figure 1). More recent research has indicated that a slightly different group of macrozones is warranted, and that, in locations close to the Wasatch fault, even more seismic activity is expected in the future than has been recorded in the limited historical past. The new zones are outlined in Figure 2.

In Figure 2, the zone of highest expected seismicity is Zone U-4, followed by Zone U-3, Zone U-2, and then Zone U-1. Large portions of eastern Utah lie in no macrozone owing to the negligible seismicity expected in such locations.

The most appropriate measurement of seismicity for a given site might seem to be the return interval at a given acceleration (g) value. However, not only is such a measurement difficult to develop from other data, but some evidence has been reported that peak g-values may not accurately indicate dyanamic structural response. Here, in place of g-values, we shall employ intensity values as an indicator of expected seismicity. The Modified Mercalli Intensity scale serves as the basis of measurement.

Intensity values, given in Roman numerals, are indicators of earthquake effects upon human works. At Intensity VI, some buildings have failed. As intensities increase, damage to various structures also increases. Intensity VIII corresponds roughly to an acceleration of 0.15 g, and 0.5 g is exceeded at Intensity IX or X.[1]

In Zone U-1, the maximum expected earthquake, based upon the historical record, is estimated at a near-field Intensity VI ([15], p. 17). Such an earthquake could damage some communications equipment but most system structures and equipment, should be undamaged. Hence, not much direct seismic damage to communications systems is expected in Zone U-1.

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[1] For a more complete account of the Modified Mercalli Scale, see Appendix A and also [16], pp. 202-205. For attempts to correlate intenisty and maximum effective peak acceleration values, see [17].

So, the only zones where much expected direct damage should occur to communication systems are Zones U-2, U-3, and U-4.

In Zone U-4, the maximum expected earthquake, based upon geological evidence, is an estimated epicentral Intensity X. Such an earthquake could cause considerable damage to communications systems.

In Zone U-3, the maximum expected earthquake is an Intensity IX, as based upon historical records. Here, again, such an earthquake could damage communications systems and their associated structures.

In Zone U-2, the historical record indicates that an estimated Intensity VII earthquake is the maximum likely ([15], p. 17). Such an earthquake could damage unanchored equipment banks and even some older more vulnerable structures.

Another way to compare the main seismic zones is to examine recurrence intervals for expected earthquakes. However, estimated recurrence intervals for the different zones may be misleading unless one takes into account the diverse sizes of the zones. Zone U-1 is about 261,000 sq. km, Zone U-4 is only about 14,000 sq. km., Zone U-3 is about 29,200 sq. km., and Zone U-2 is about 76,400 sq. km.

Table 1 indicates the expected recurrence intervals of epicentral intensities equalling or exceeding the given intensity somewhere within the zone. If one recognizes that recurrence intervals for given intensities being located in the zone are a result of either having epicentral intensities in the zone or attenuation from earthquakes lying outside the zone, then one can bear in mind that the intervals in Table 1 do not take into account attenuation from outside the zone.

Not all earthquake epicenters are expected to lie close to some communication system facilities or structures. But, Table 1 indicates that large earthquakes are expected that could damage vulnerable facilties.

Given the wide differences in area among the various zones, a more direct measure of the vulnerability of a given facility or piece of equipment comes from estimates of recurrence intervals for intensities equalled or exceeded at sites randomly chosen within a given zone.

Table 2 indicates clearly that sites in Zone U-4 are considerably more susceptible to levels of ground shaking that cause earthquake damage. At the same time, structures and equipment that are designed to resist the effects of lower intensities are much less likely to suffer damage.

In summary, not only does Utah have considerable seismicity, but certain portions of the State have much more expected seismicity than others. When recent geological evidence is added to historical records, only California clearly has a higher expected seismicity among the contiguous United States than the seismicity in Zone U-4, a macrozone that compares in seismicity even to portions of Nevada and other high risk portions of the United States (Cf. [15], pp. 17, 18, plus adjustments in the methodology).

EARTHQUAKE RISKS TO RADIO AND TELEVISION STATION FACILITIES

This report covers three topics in regard to the risk to radio and television stations posed by earthquakes. First, it is necessary to identify and to locate those facilities that can be used as part of an emergency broadcasting system. Second, on an aggregate level, the seismic vulnerability of such station buildings must be assessed. Third, the seismic vulnerability of transmitters, such as microwave towers and radio towers, must be addressed.

Figure 3 shows the spatial distribution of commercial radio stations throughout the State. The spatial distribution, plus information about areal coverage of radio stations in various counties, indicate that it is highly unlikely that public radio coverage would be completely unavailable after an earthquake. For, even if stations within a given locale are damaged, radio coverage is available from stations elsewhere.

Figure 4 indicates the distribution of commercial radio and TV stations within Salt Lake County. Once again, it is highly unlikely that all such facilities would be rendered non-functional by a single earthquake. Hence, given the distances among commercial radio stations in Utah, public radio coverage of any given area should be available in the event of an earthquake.

Figure 5 indicates the location of Emergency Broadcast System (EBS) stations throughout the State. All but two of these stations have emergency backup generators. Other stations also belong to the EBS network, and some can be relied upon for transmission in the event of an earthquake. Public information via commercial radio transmission therefore appears to be possible throughout Utah, even though one or more individual stations might have transmission disrupted during and after an earthquake.

A complete survey of the construction characteristics of radio and television stations is unavailable at the present time. However, a partial survey made available by Richard Hughes, engineer at H.C. Hughes Company, indicates that radio and television stations generally cannot be expected to be of earthquake-resistant construction. In the partial survey, twelve facility complexes were categorized, including five television stations and associated radio stations. All surveyed facility complexes were located in Weber County, Salt Lake County, or Utah County. Hence, all were located in seismic Zone U-4. Structures were classified from 1 to 7, where lower categories represent more earthquake-resistant construction. From estimates provided by Richard Hughes, and from estimates of seismicity for Zone U-4, the following 100-year estimates are derived for the seven categories for expected non-functionality, or 50-percent structural damage, in Zone U-4.

Category 1a	--	1.1%
Category 1b	--	2.1%
Category 2	--	3.4%
Category 3	--	6.2%
Category 4	--	11.0%
Category 5	--	17.8%
Category 6	--	23.3%
Category 7	--	28.9%

Such a list indicates that the seismic vulnerability of radio and TV facilities varies greatly from category to category. Within the framework of such categories and associated damage estimates, one finds that most surveyed radio and television facilities fall into the more vulnerable categories.

Category 1b	--	2 Facilities
Category 5	--	1 Facility
Category 6	--	9 Facilities

Since the time that the survey way made in 1975, one television station has moved, and one of the radio stations has been replaced in the same structure by another. The new TV station appears to be no worse than Category 2. Two EBC stations were included in the group--a specially designated county Emergency Broadcasting Station and a Statewide Emergency Broadcasting Station--and both are of Category 6 classification.

If such a sample indicates anything about other radio and TV facilties in the State, it is that one cannot expect, without direct site-examination, radio and television stations to have earthquake-resistant facilities.

Emergency programs therefore must rely upon the spatial distribution of radio stations, and upon the improbability that all will be rendered nonfunctional, rather than relying upon any single radio station to carry out the mission of public information broadcasts. The availability of mobile units also might be considered in emergency communications plans. Several of the stations surveyed had mobile units, which might prove to be useful following an earthquake.

EARTHQUAKE RISKS TO RADIO AND TELEVISION TOWERS

Figure 6 indicates the location of selected radio and television transmission towers in the greater Salt Lake County area. As Figure 6 indicates, radio and television towers, like their stations, are widely dispersed, although a cluster does exist atop the Oquirrh Mountains. In fact, the five principal television stations serving Utah have transmitting towers located on top of the Oquirrh Mountains.

In analyzing radio and telvision towers, Richard Hughes used the following estimates for percent of facilities rendered nonfunctional by earthquakes given Modified Mercalli intensities.

Intenisty VI	--	2%
Intensity VII	--	10%
Intensity VIII	--	20%
Intensity IX	--	30%

Such percents are the same as those provided for Category 3 facilities. In addition, those structures located on the Oquirrh Mountains are just outside Zone U-4, since they are more than 20 kilometers from the Wasatch fault. As a result, the expected long-term instances of non-functionality to such towers as a result of earthquakes are less than what they would be if the facilities were located closer to the Wasatch fault. Moreover, although guy wires are used on some of the towers, several towers are self-supporting. Hence, redundancy in the radio and TV transmission system and also spatial distribution suggest that some towers should remain functional after an earthquake.

Electric power outages can affect both transmitting towers and studios of radio and TV stations on a routine basis. In the USGS study of earthquake losses in the Salt Lake City, Utah area, 4 of 11 radio stations surveyed had backup power ([11], p. 221). Of the four Salt Lake television stations, standby power exists at all towers. Only KCPX does not have standby power at the studio. Therefore, were a general electric power outage to occur, those radio and television stations dependent upon electric power from the utility network alone may be forced to go off the air. But those stations with standby power can be expected to be operational, all other things being equal.

Several stations also indicated that they had mobile units. During the 1976 general power outage in northern Utah, as but one instance, although KTVX-4 and KCPX were forced off the air, KSL-5, KSL-AM & FM, KUTV-2, KUED/KUER, and KALL indicated that standby power was available. KALL, for instance, can transmit signals from mobile units that can be picked up both at the transmitter and at the studio. KSL indicated, moreover, that it has emergency power available at all tower sites in the State--either battery power at microwave sites or diesel power at AM sites.

This survey does not indicate any mounting or security problems with such back-up generators or their fuel supplies, although evidence exists that some generators are not adequately secured ([11], p. 225). Problems may also exist with the communication equipment that links the broadcast studio with its tower. Such equipment often is located on a tall building, and emergency back-up power is not always available ([11], p. 225).

EARTHQUAKE RISK TO THE STATE OF UTAH'S NATURAL DISASTER RESPONSE SYSTEM

In this subsection several important facilities within the State's natural disaster response system are surveyed in order to obtain a preliminary view of the physical vulnerability of the system to earthquakes. This report does not cover the overall capabilities of the telecommunications system in response to possible future earthquakes. Only a few main facilities are surveyed. An examination of the total Statewide earthquake response capability would require a more thorough investigation than is undertaken here.

Figure 7 and Figure 8 outline Multi-County Planning Districts and Department of Transportation (DOT) Districts, respectively. Figure 8 also indicates locations of DOT communications centers, which are centers of telecommunications activity within each District and which also are points of connection among Districts. The Salt Lake Center is the hub of all Statewide telecommunications flow and of flow to other states.

In a survey of all State buildings, the State Building Board has provided some information pertinent to the seismic resistance of DOT communications centers. All existing centers were constructed after 1960. Except for the Price facility, which is of wood-frame construction, all structures have masonry bearing walls. Only the Orem facility has as many as two stories. The largest is the Salt Lake structure, with 12,928 square feet of floor area. The Richfield structure has 6,852 square feet, and the Orem structure has 5,698 square feet. In general, those structures in the zone of highest seismicity (Zone U-4) have been constructed more recently and may have incorporated some earthquake resistance in the construction. An actual inspection of each structure would be needed in order to ascertain any significant seismic deficiencies. Such was not undertaken for this report.

Figure 9 provides a skeletal outline of the State Microwave System. The lines from Monroe to Teasdale and Teasdale to Bald Mesa, and also from Little Mountain to Logan, have not yet been completed. When such lines are complete, the system will become much more flexible in allowing response to disasters insofar as a loop system then will be formed. A loop system enables any node, or point of connection, to malfunction and for the remainder of the system to operate. If, for instance, the Lake Mountain facility were to malfunction, the loop system would enable communications from the State office to Levan to be routed through Bald Mesa and Frisco. Without the completion of the loop, a malfunction at Lake Mountain would arrest all south-directed communications from Salt Lake to Levan, Frisco, Richfield, Cedar City, and St. George, and vice versa. Thus, a loop system has significant advantages for earthquake response capability, especially since earthquakes are localized events not likely to damage nodes far enough apart to make the loop inoperative. Thus, the State Microwave System allows for regional communications, and such communications will be quite versatile upon completion of a loop for the system.

Information about the building facilities at the microwave sites was provided by Steven H. Proctor, Communications Manager, Utah Department of Transportation. Plans of eight of the structures also were available.

Five of the structures are concrete slab-on-grade buildings with plywood roofs. The structures appear to have moderate seismic resistance, but one cannot be sure of this without examining their reinforcement. One such structure, at Little Mountain, is both at the terminal of the eventual loop system and in the zone of highest seismicity. Hence, possible damage to such a structure could entail possible communications loss to the northern portion of the State. The only other such structure in a zone of relatively high seismicity is at Utah Hill near St. George.

Three other structures are wood-frame structures that appear to have inherent seismic resistance. However, other possibly vulnerable facilities exist at Delle, Ensign Peak, Monroe Peak, and Lake Mountain.

Much equipment is located within various DOT headquarters and other public safety buildings, and several transmission towers are located upon tops of buildings. No antennas or towers appear to be on buildings two stories or more, except for the State Office Building and the Hidden Peak structures. Nonetheless, possible ground motion amplification for such towers could occur.

In general, then, the DOT District Centers appear to be somewhat vulnerable to earthquakes, although information is limited about their specific construction. The eventual loop system also will entail less concern for the vulnerabilities of specific structures, except for those that are also part of linear or radial systems, as at Little Mountain. Several microwave facilities appear to have marginal seismic resistance, the most important being at Little Mountain. It is not known how those antennas placed upon buildings will respond under dynamic loadings.

Microwave towers themselves generally are designed for wind loadings. Based upon preliminary finding that adequate wind loadings generally entail adequacy for seismic loadings, they may perform acceptably under eathquake conditions. Such control by wind loadings is indicated by exemplary wind-seismic load comparisons made by Microflect Company, Salem, Oregon, and provided by J. Robert Callaway of its engineering department.

EARTHQUAKE RISK TO TELEPHONE SYSTEMS IN UTAH

Information about the expected seismic response of Utah's telephone systems is limited to findings in the 1976 USGS report [11], to a tour with Mr. Lynn Arnold, district manager for network, administration and maintenance, of Mountain Bell, and to discussions with Ray L. Christensen, district staff manager for the Mountain Bell network. Findings are presented in the same order outlined for telephone systems in Section 3 of this report.

Buildings And Microwave Towers

General information about telephone buildings is limited to an updating of the USGS report of buildings in four counties within Zone U-4. Table 3 summarizes the updated information. Those telephone buildings constructed before 1961 are presumed to be constructed according to lower standards than those constructed after 1961, owing to improvements in building codes over the past years. Multistory structures also may be more vulnerable to ground shaking than are one and two-story structures. However, more detailed information would be needed in order to determine more precisely how such facilities, possilby designed according to higher civil engineering standards, would respond in earthquakes.

It also is known that several telephone structures are very close to the Wasatch fault. One recent structure (3480 Danish Road in Salt Lake Valley) appears to be within the fault zone of deformation. One other structure is identified in the USGS report as being within the zone of deformation ([11], p. 232).

Thus, both dates of construction and proximity to the fault zone of deformation suggest but do not establish that some telephone buildings may be vulnerable to earthquake damage. If a telephone building were to be damaged, according to Mr. Christensen, then the localized area that the building serves would have an extremely difficult time with service. Portable units and other means may be available for rapid restoration of emergency services, but full restoration of service might take some time. Figure 10 indicates the distribution of new and older (pre-1961) structures in terms of a very rough outline of Mountain Bell telephone buildings and transmission cables in the four-county region studied in the 1976 USGS report. Localized areas that may be more vulnerable to loss of telephone service due to earthquakes can only be surmised from the apparent locations of seismically vulnerable facilities shown in Figure 10.

Less information is available about the Mountain Bell microwave system, since such information is guarded on the basis of military security and other grounds. Microwave towers generally are resistant to earthquake vibration, as indicated in the subsection on State natural disaster response systems. Also according to Ray Christensen, the Mountain Bell system is looped so that loss of any single microwave unit leaves telecommunication still possible between any other two. Microwave equipment buildings are purported to be all-metal structures, and so are presumably more earthquake-resistant than the microwave equipment facilities within the State system. Equipment in the buildings is braced, thus adding to its seismic resistance.

In general, several buildings in the Mountain Bell system may be vulnerable to earthquake damage, so that localized areas may be out of service. Such loss, of course, is dependent upon where the earthquake strikes. No problems were noted in Mountain Bell's microwave system of which only a little is known outside the industry.

Equipment In Buildings

According to Ray Christensen, Bell Laboratories standards have been used to anchor and brace telephone equipment in Utah since 1962 and have been applied for all major equipment. A tour of one telephone building confirmed the extensive attention paid to this primary means of mitigating earthquake losses. Unanswered questions remained only about the specifications actually employed and their variation, if any, concerning the vulnerability of extremely important standby generators and about the vulnerability of disc memories. In the main, though, Mountain Bell's attention to seismic bracing and anchoring appears to be laudatory (Cf. [11], p. 230).

Underground Cable

According to Mr. Christensen, older underground conduits are tile, whereas newer conduits are plastic encased in cement. Older splice cases are a lead-sheath type, whereas newer ones are plastic coated.

Both conduits and splice cases may be vulnerable to earthquake-induced damage in varying degrees according to flexibility and strength of materials. However, the conduit system is protected by the use of air compressors and back-up compressors which keep outside materials from entering and possibly damaging the lines even when the conduit may be breached by small cracks. Conduit and line rupture due to large ground offsets, of course, cannot be protected by such means.

Figure 10 also indicates that the historical development of the Mountain Bell system has led some transmission lines to criss-cross the Wasatch fault. Fault ruptures could cause elongations and other damage that might have been somewhat averted with more prescient planning. Eastern portions of Salt Lake County can be identified as being more likely to lose service if fault ruptures occur and damage conduits. Other portions of the Mountain Bell transmission system appear to have means of alternative routing should damage occur to underground cables.

According to Mr. Christensen, monitoring of the system through air pressure changes or electronic means implies that problems can be identified and located very rapidly. Expedient repair may be constrained, though, if the number of failures is large.

Aboveground Cable

Use of aboveground cable appears to be very limited in the Mountain Bell system, except in areas of small numbers of service connections. Localized areas where aboveground cable are used may be more vulnerable to loss of service as a result of earthquakes than are areas served by buried cables.

Overloading

According to Mr. Christensen, overloading is a problem faced routinely by Mountain Bell on such days as Mother's Day as well as during storms and disasters. In general, the system is designed only to handle 97 percent of all service on the most busy hour of the busiest day. One-hundred percent reliability would increase rates considerably for users. Disaster plans by the company thus take into account inevitable overloading. It is stated that only "essential" services are allowed in emergencies. Further information about the logistics of disaster response was unavailable for the preparation of this report.

Systematic Aspects--Multiple Routing And Dependence Upon Electric Power

Only those features of the Mountain Bell system already addressed give clues as to how well the system may respond to earthquakes in spite of damage to components. Figure 10 indicates that eastern portions of Salt Lake County may be more vulnerable to loss of service, since such areas are not served by multiple routes should fault ruptures occur. In addition, in spite of multiple routing of transmission lines, vulnerability of older buildings, which serve specific locales, implies that some locales (including all of Utah County, for example) are more vulnerable to service loss from earthquakes.

SECTION 5

RECOMMENDATIONS FOR REDUCING EARTHQUAKE RISK TO COMMUNICATIONS SYSTEMS IN UTAH

The following recommendations result from a study of the expected impact of earthquakes upon communications systems in Utah. The study, titled "Seismic Risk Assessment Of Principal Communication Systems In Utah," provides information upon the extent and nature of hazards posed by earthquakes to communications facilities. The recommendations that follow are based upon findings from this study.

Because communications systems are essential for effective, well coordinated post-disaster response and recovery activities, special attention has been given to their vulnerability and to their expected performance in an earthquake environment. The purpose of this analysis has been to assess their capability to remain functional even if subjected to earthquake loadings. Such factors as system capability, accessibility during normal and emergency periods, location of facilities relative to zones of seismic activity, and special vulnerabilities associated with particular equipment or components are among the more important which were assessed.

Earthquakes appear to pose problems for communications systems in at least three ways. First, the facilities housing the communications systems may be susceptible to damage which, in turn, might damage the communications equipment through collapse of building components. Second, there is the possibility that the communications equipment may be damaged directly by earthquake effects, such as collapse of transmission towers or toppling of electronic equipment mounted on walls or supported on shelves. Third, there is the possiblity of equipment malfunction during the use period after an emergency, such as by user overload, as apparently has happened frequently with telephone systems following earthquakes in other regions. Each of these types of potential systems malfunction requires somewhat different treatment.

From the point of view of public policy, general statements of purpose and intent appear to be more suitable than recommendations for specific mitigation actions. The recommendations which follow are of this type. In this study of earthquake vulnerability of communications systems, we have not discovered significant types of vulnerabilities, either in the locations of systems facilities or in the safeguards provided to protect the equipment from loss. Nonetheless, it must be noted that the analysis undertaken in the preparation of this report was limited principally to radio transmission systems and telephone systems, and none of these analyses extended to individual facilities. Hence, subsequent further assessments of particular communications systems that might be made in the future may lead to the conclusion that additional recommendations are needed to safeguard the systems from earthquake damage.

1. <u>It is recommended as a general policy that all State programs</u>

and agencies recognize and emphasize the importance of communications during emergency periods and that, as a minimum, the facilities housing essential communications equipment expected to be used during emergency periods by these agencies be housed in facilities and structures designed to resist the most severe earthquakes expected in the location or area of each facility.

Generally speaking, the importance of communications systems is widely recognized by those who install, operate, and use them. Also, there is no evidence to suggest that vulnerable facilities are intentionally or unintentionally constructed. However, even though existing facilities housing communications systems typically are more sturdy than ordinary buildings, there is no reliable methodology available for deriving general conclusions about the capability of the facilities to withstand earthquake forces except by separate analysis of each facility. Further, there is no hard evidence to confirm that earthquake forces were considered in the original designs of many of the facilities. Hence, this recommendation, dealing with the objective of securing the operational capability of communications systems, is intended, first, as a means to express a degree of public concern for the operational reliability of the systems and, second, to serve as an additional stimulus to provide maximum encouragement to owners and operators of the systems to consider earthquake effects.

2. It is recommended that telephone and radio broadcast and transmission systems equipment located within buildings be adequately braced or otherwise anchored to prevent displacement or movement as might be caused by earthquake ground shaking.

The findings of this study are that telephone systems of Mountain Bell Telephone Company routinely are braced to resist displacement due to earthquake or other lateral forces. Less is known about the bracing and anchorage of equipment for radio broadcast and transmission equipment. The purpose of this recommendation is simply to point out the importance of bracing and anchorage as a means to safeguard against damage and loss of operational capability.

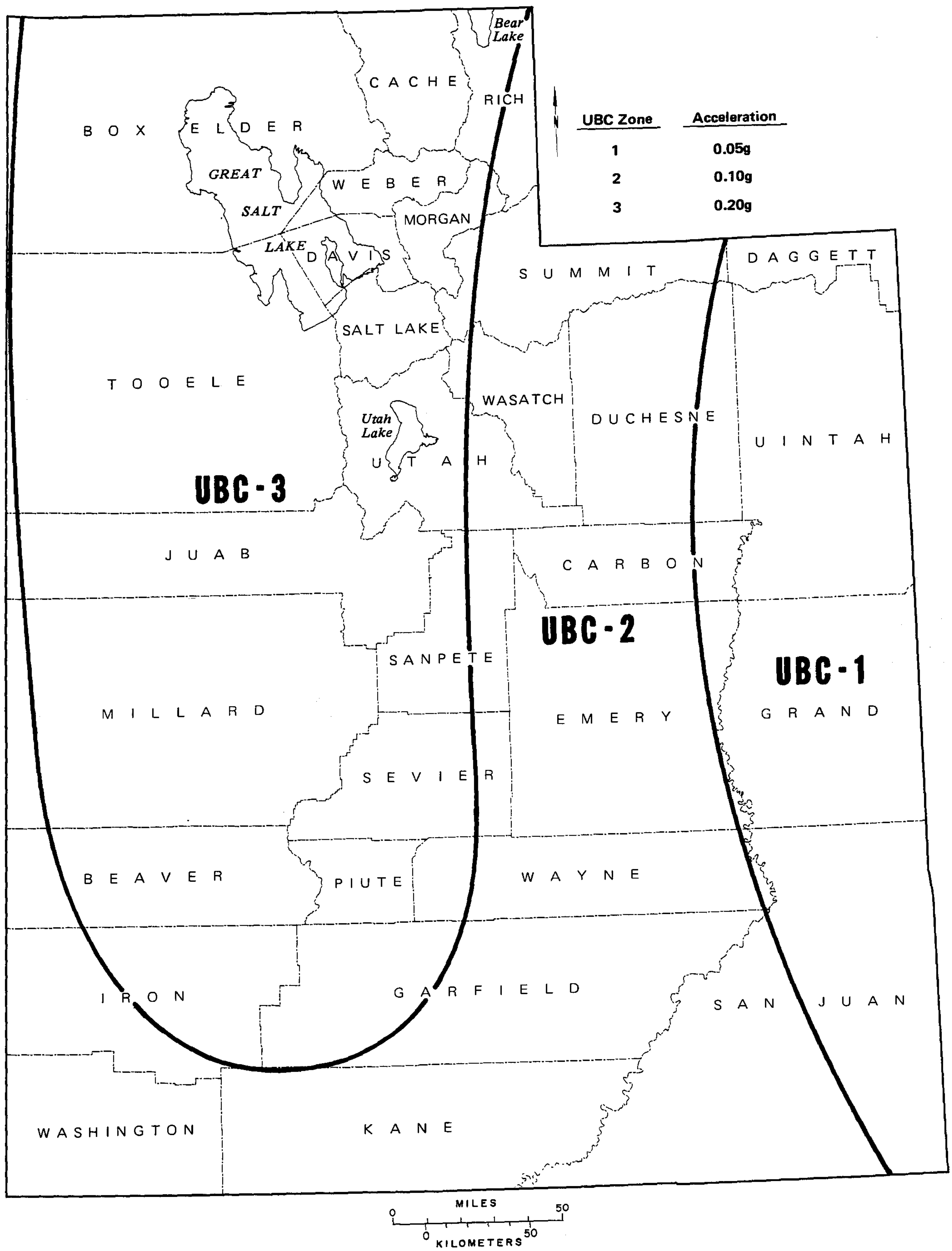

Figure 1
SEISMIC ZONES—1976 UNIFORM BUILDING CODE
STATE OF UTAH

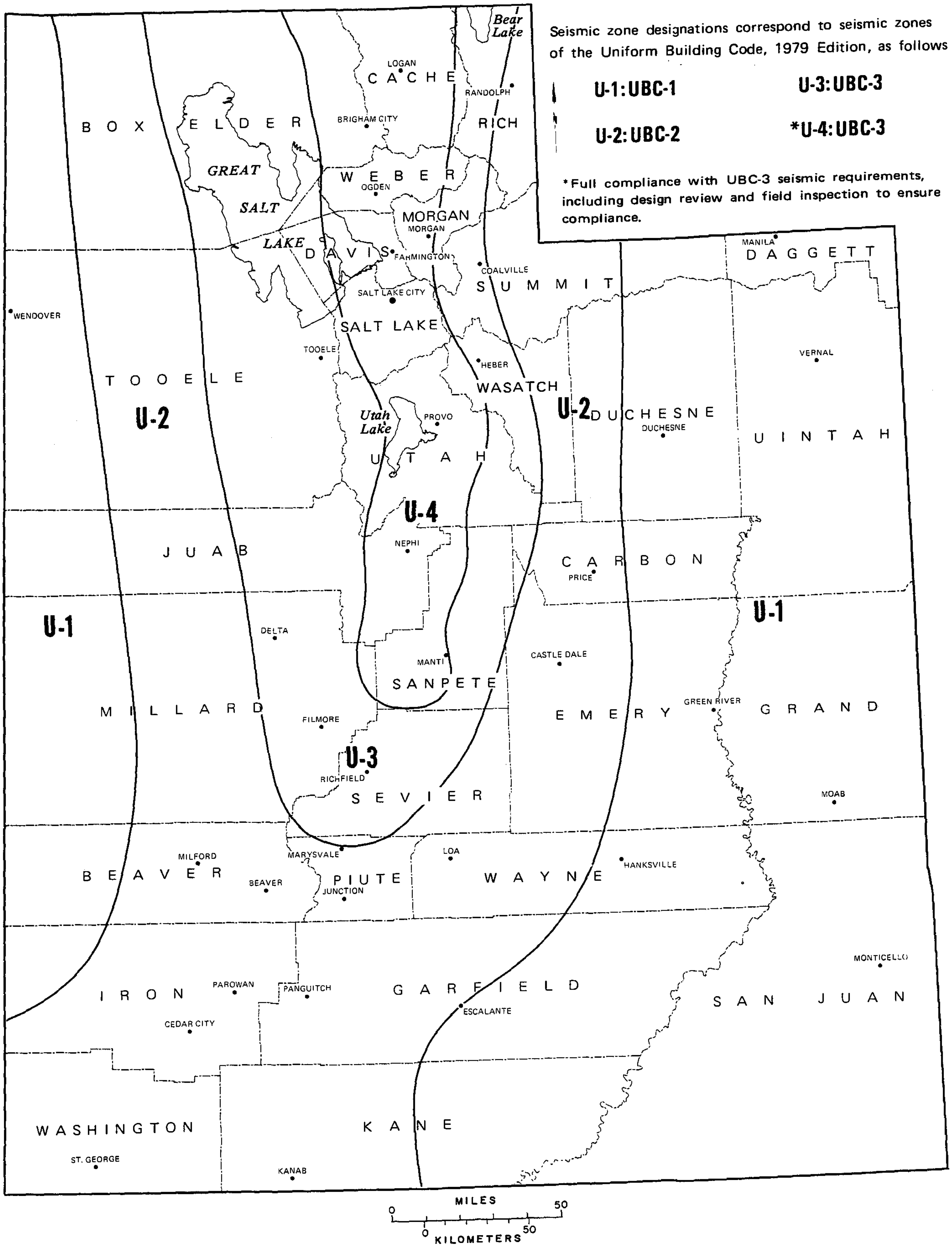

Figure 2
SEISMIC ZONES
January 1980
(Recommended by the Utah Seismic Safety Advisory Council)

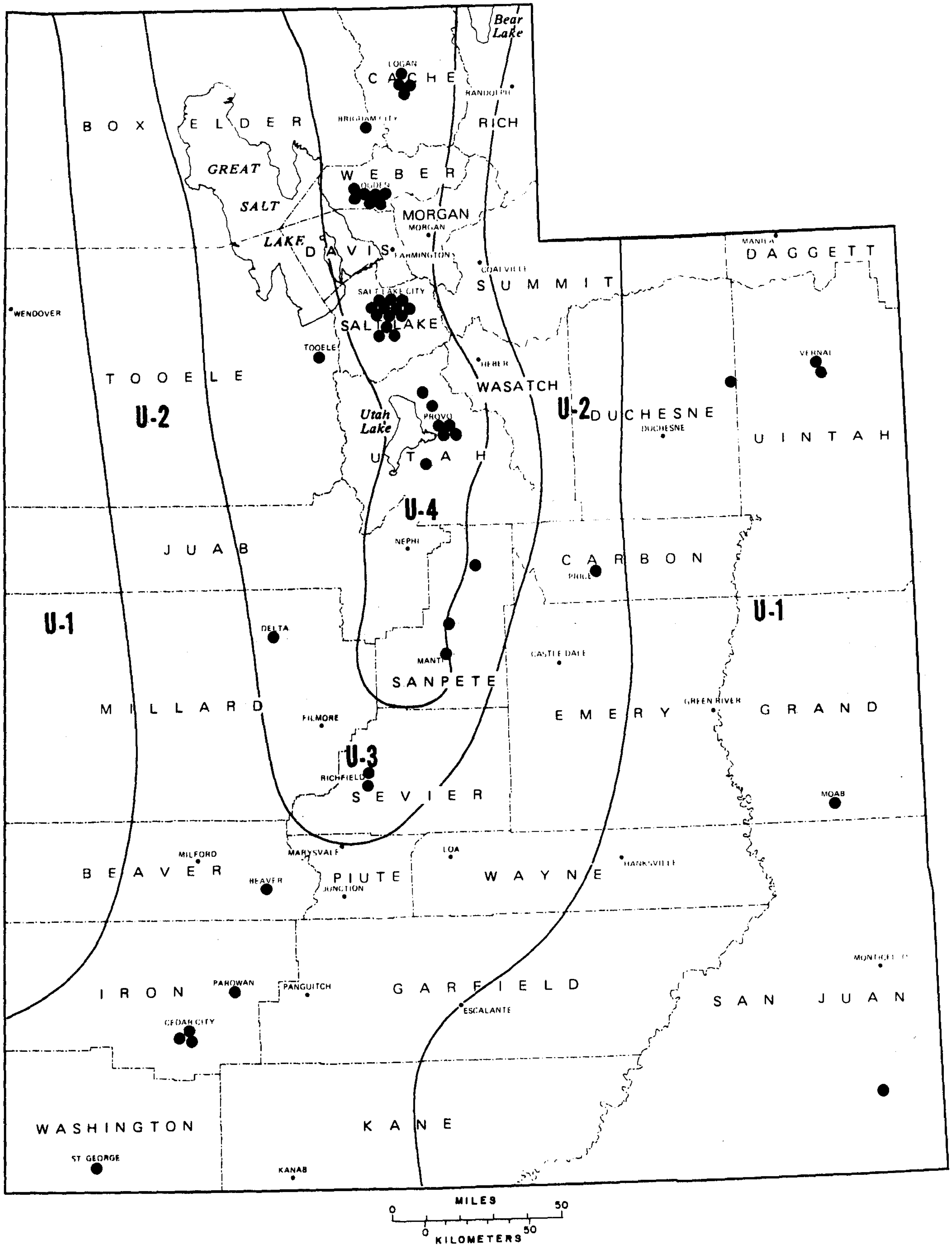

Figure 3

APPROXIMATE LOCATIONS OF RADIO STATIONS IN UTAH IN RELATION TO SEISMIC ZONES

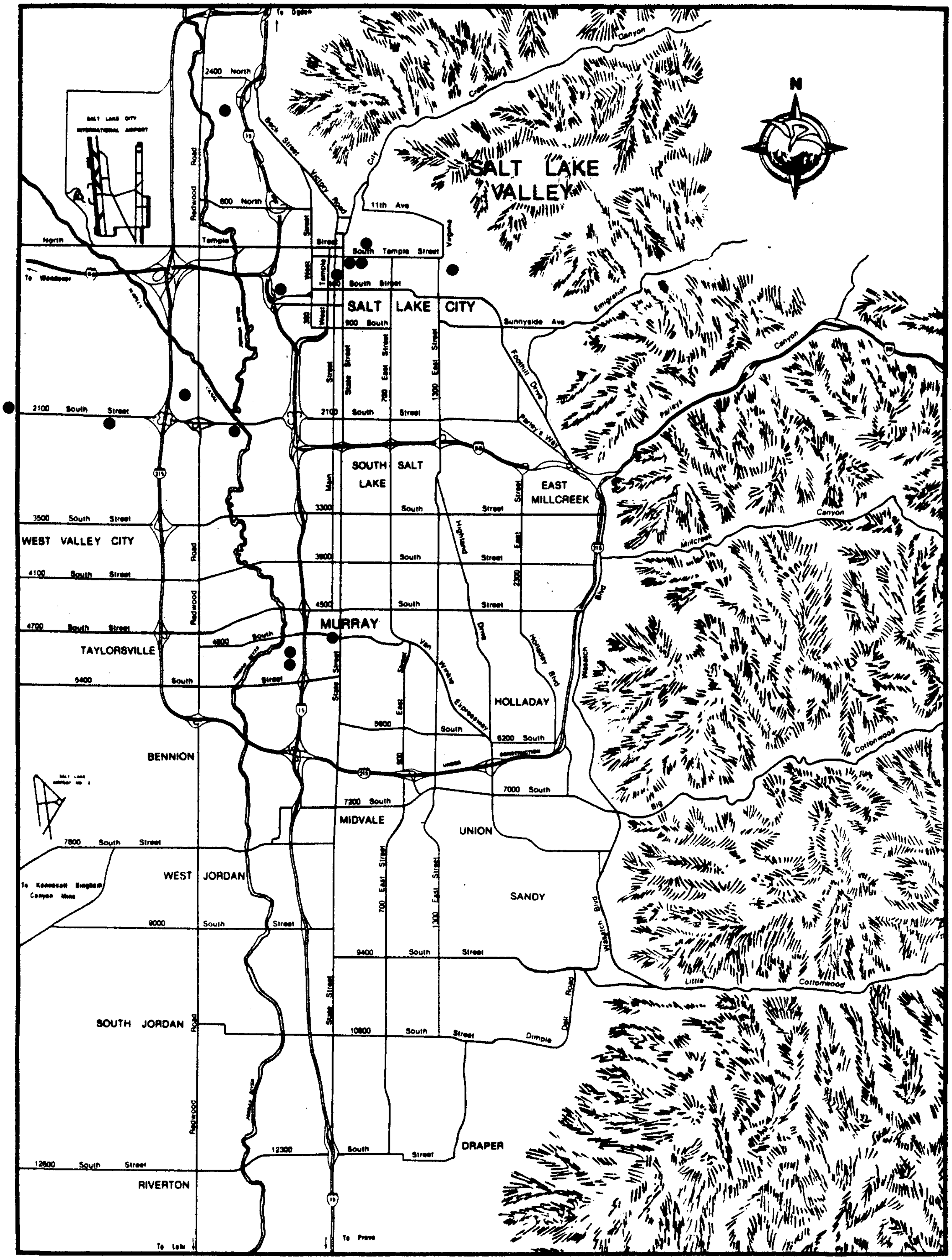

Figure 4

APPROXIMATE LOCATIONS OF RADIO AND TV STATIONS IN SALT LAKE COUNTY

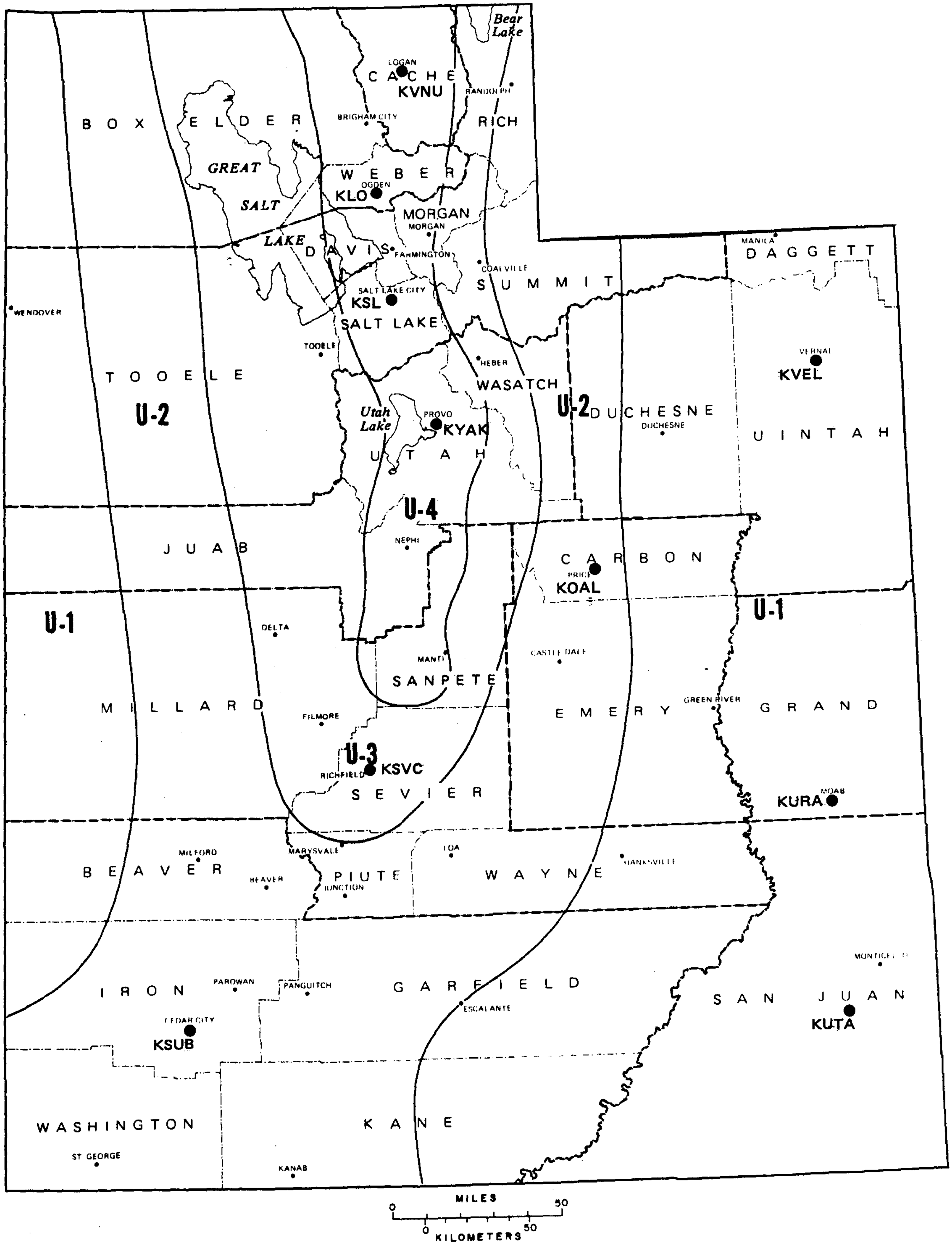

Figure 5

OPERATIONAL AREAS OF THE UTAH EMERGENCY BROADCAST SYSTEM
(CALL LETTERS ARE OF CPCS-1 STATIONS)

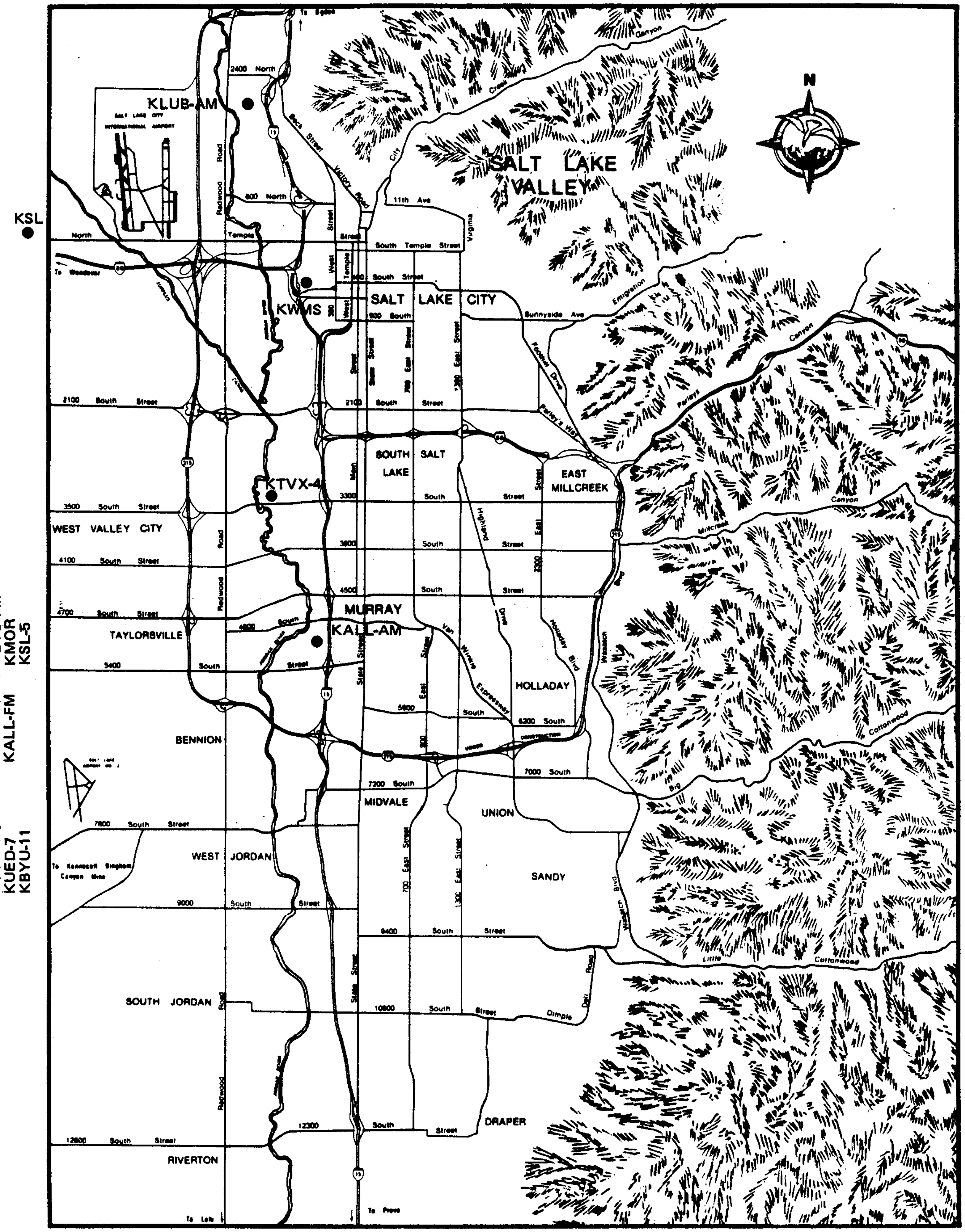

Figure 6

LOCATION OF SELECTED RADIO AND TELEVISION TRANSMISSION TOWERS IN SALT LAKE COUNTY

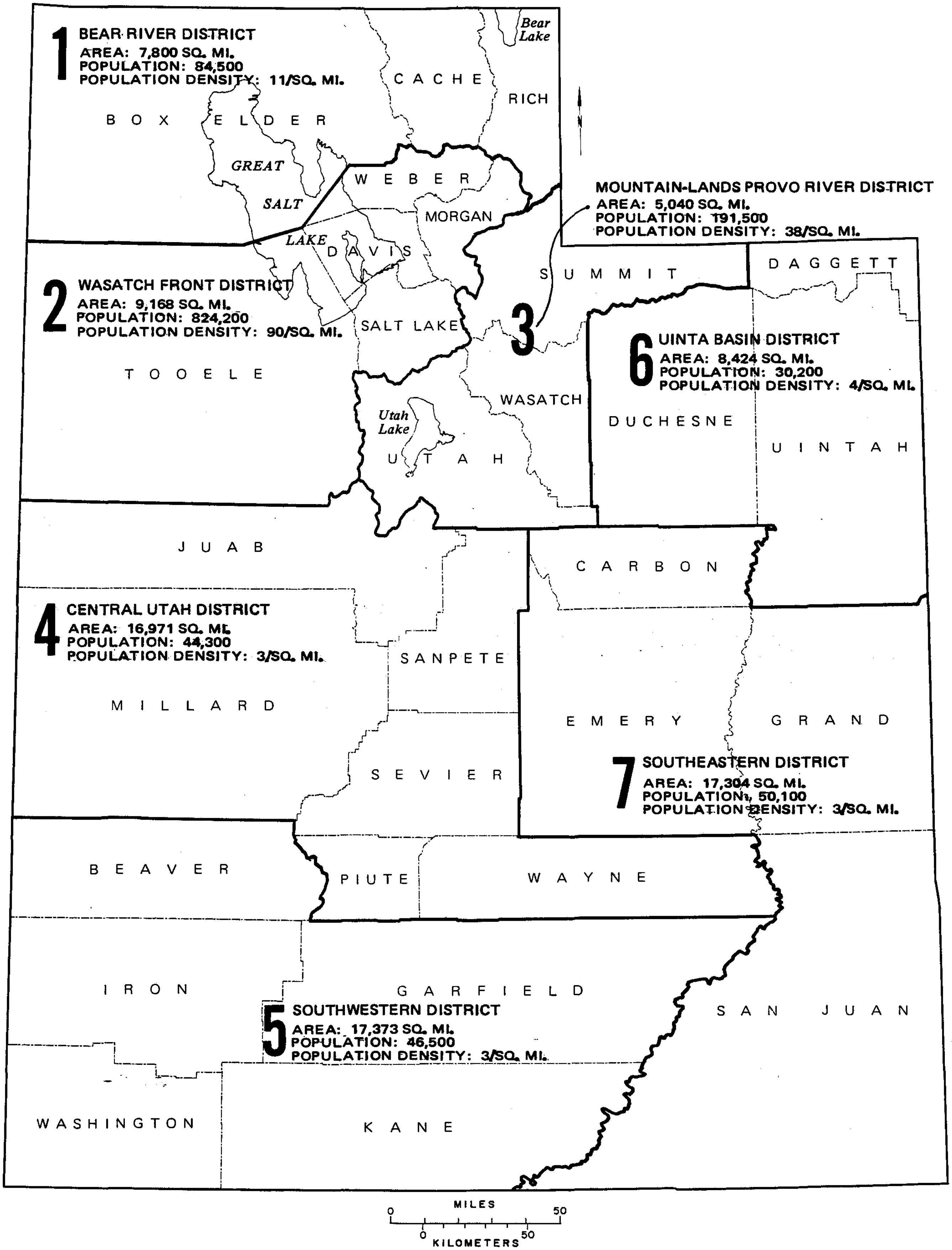

Figure 7

UTAH MULTI-COUNTY PLANNING DISTRICTS • POPULATION AND ECONOMIC SKETCH

Source: *Utah State Comprehensive Outdoor Recreation Plan Summary*, 1980.

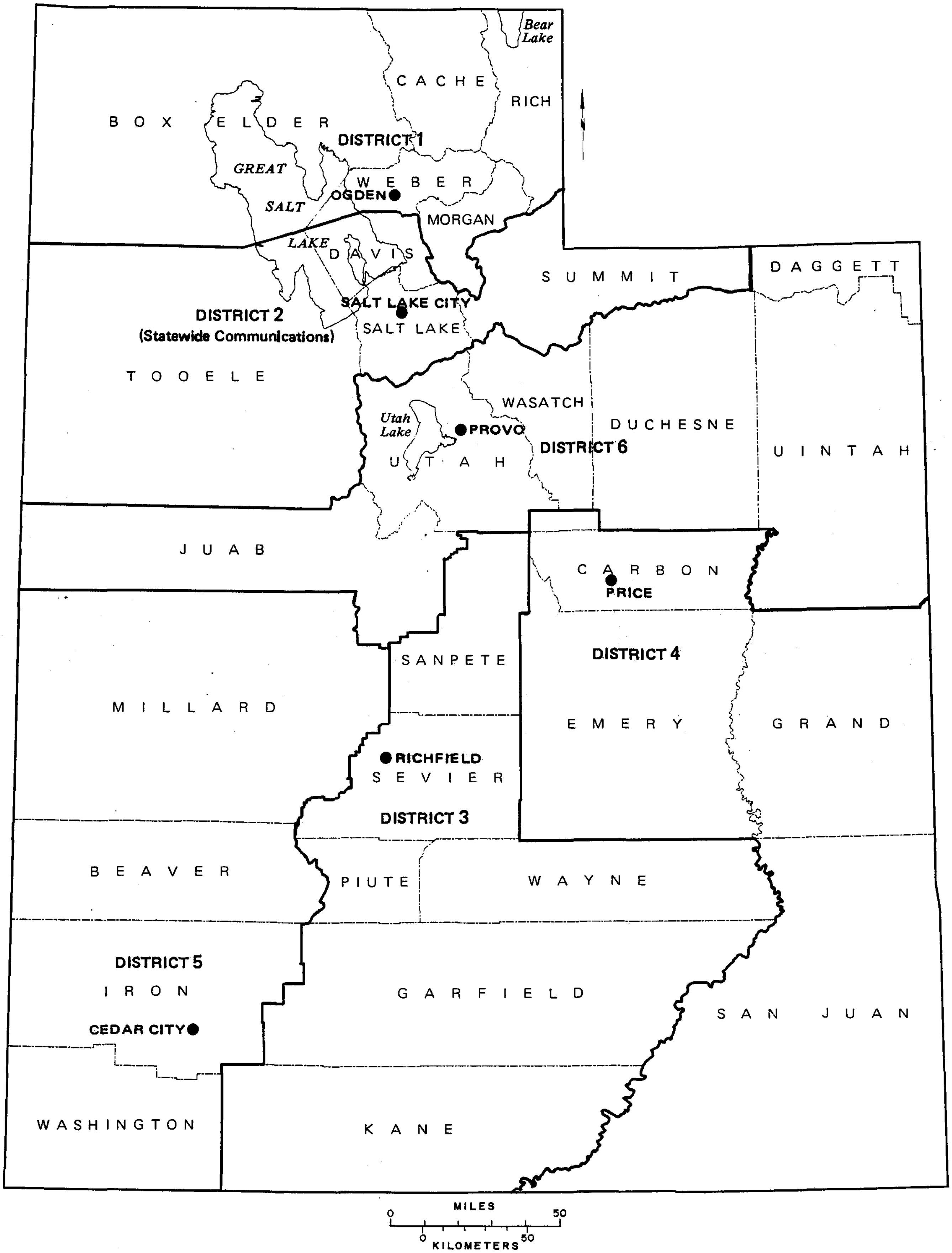

Figure 8

DEPARTMENT OF TRANSPORTATION DISTRICTS AND LOCATIONS OF DISTRICT COMMUNICATION CENTERS
STATE OF UTAH

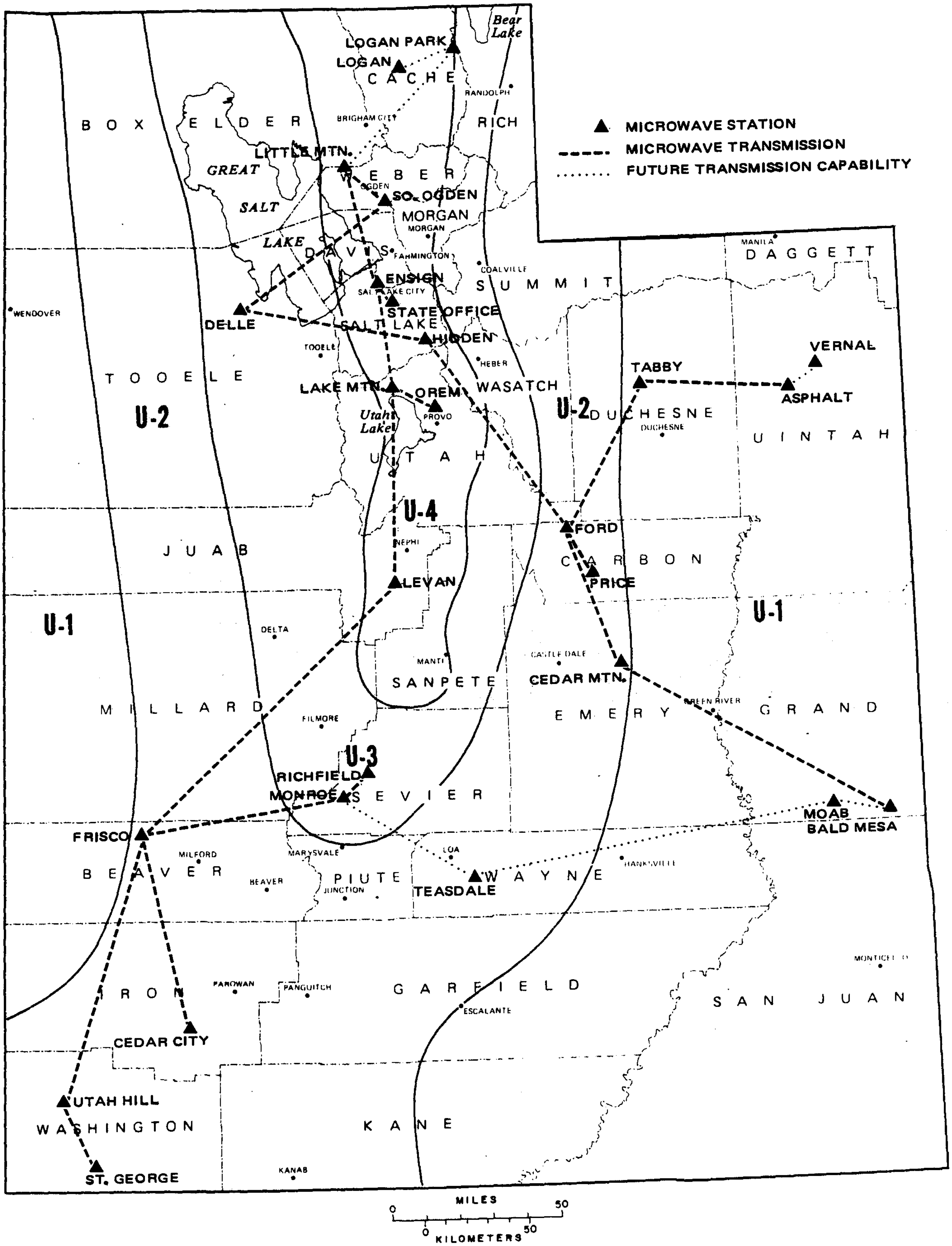

Figure 9

STATE MICROWAVE SYSTEM
STATE OF UTAH

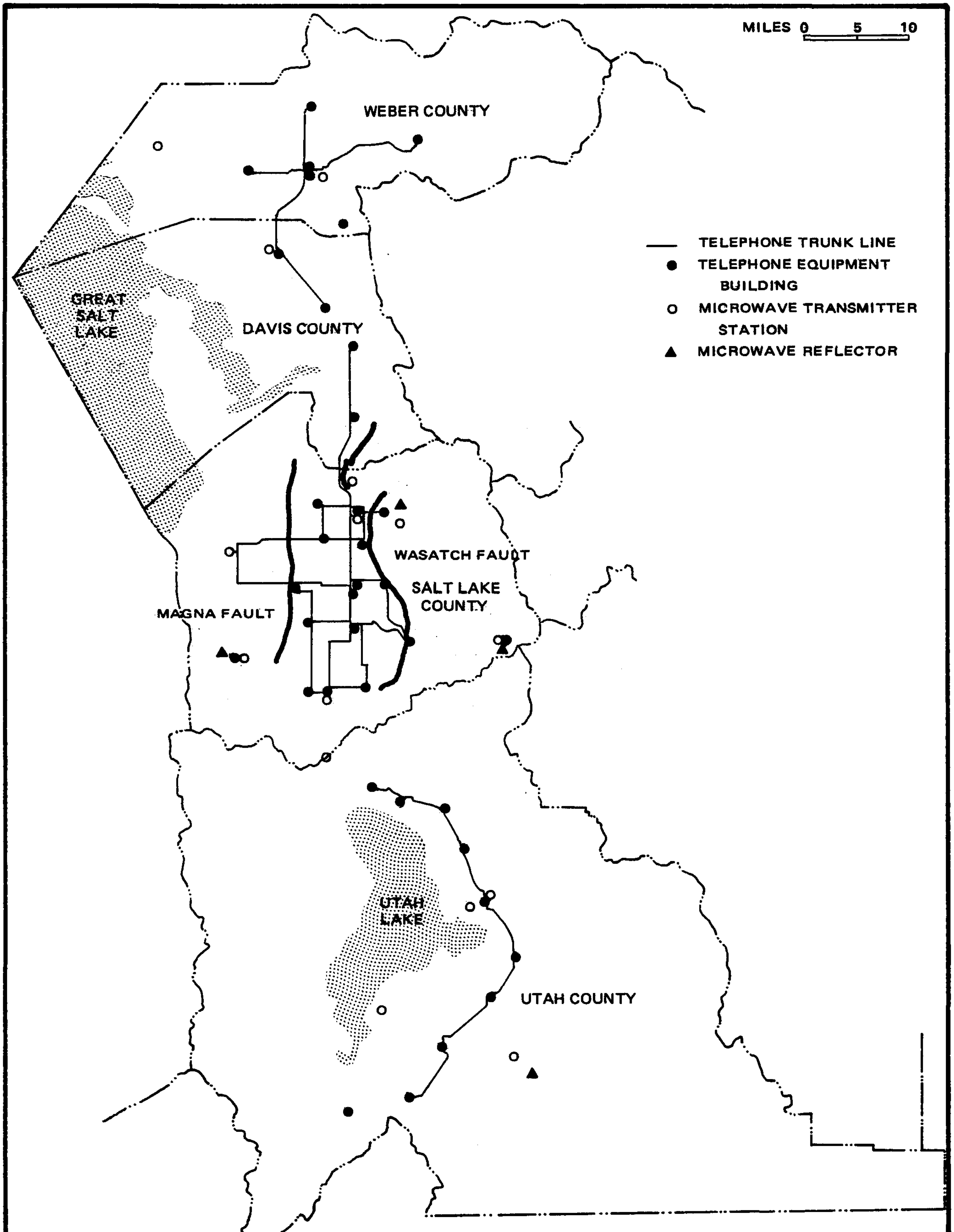

Figure 10

APPROXIMATE LOCATIONS OF TELEPHONE FACILITIES IN THE FOUR-COUNTY NORTH CENTRAL UTAH REGION
Source: Mountain Bell Telephone Company, [11], p. 224.

TABLE 1

EXPECTED RECURRENCE INTERVALS IN YEARS OF EARTHQUAKES WHOSE EPICENTER EQUALS OR EXCEEDS THE GIVEN INTENSITY SOMEWHERE IN THE GIVEN ZONE

Seismic Zone	Intensity Equalled or Exceeded				
	X+	IX+	VIII+	VII+	VI+
Zone U-1	3,300	770	200	56	16
Zone U-2	900	190	50	14	4
Zone U-3	1,250	260	65	11	4
Zone U-4	450	133	39	12	4
Cumulative For All Four Zones	223	56	15	4	1

TABLE 2

RECURRENCE INTERVALS IN YEARS FOR INTENSITIES EQUALLED OR EXCEEDED AT SITES RANDOMLY CHOSEN WITHIN GIVEN SEISMIC ZONES

Seismic Zone	Intensities Equalled Or Exceeded				
	X+	IX+	VIII+	VII+	VI+
Zone U-1	--	--	1.7×10^5	29×10^3	6,300
Zone U-2	10^6	$.67 \times 10^3$	10×10^3	2,000	450
Zone U-3	5×10^5	90×10^3	8,200	1,300	221
Zone U-4	15×10^3	2,400	620	180	54

TABLE 3

TELEPHONE BUILDING CONSTRUCTION DATA--STATE OF UTAH
(Source: Mountain Bell Telephone Company ([11], p. 231))

County	Constructed before 1961			Constructed after 1961		
	1 and 2 stories	3 and more stories	Total	1 and 2 stories	3 and more stories	Total
Weber ------	2	1	3	3	0	3
Davis ------	3	0	3	1	0	1
Salt Lake --	8	2	10	9	1	10
Utah -------	10	0	10	0	0	0
Totals -----	23	3	26	13	1	14

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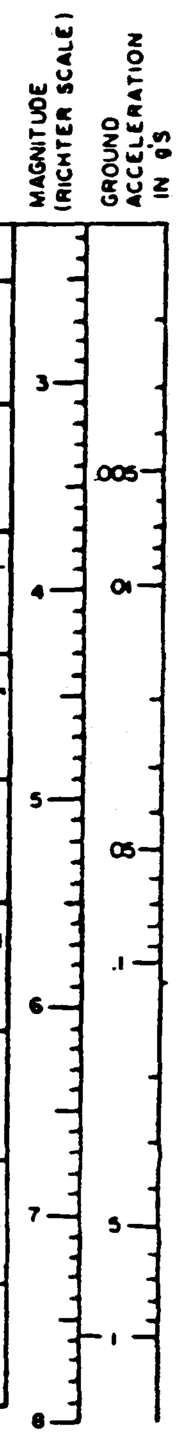
APPENDIX A

MODIFIED MERCALLI INTENSITY SCALE APPROXIMATE RELATIONSHIP WITH MAGNITUDE AND GROUND ACCELERATION

ABRIDGED MODIFIED MERCALLI INTENSITY SCALE

I	Not felt except by a very few under especially favourable circumstances.
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
IV	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.
VI	Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.
IX	Damage considerable in specially designed structures, well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations, ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.



Modified Mercalli Intensity Scale after Wood and Neumann, 1931. (Intensities XI and XII not included).

Magnitude and acceleration values taken from Nuclear Reactors and Earthquakes, TID-7024, United States Atomic Energy Commission.