EARTHQUAKE HAZARDS & SAFETY IN UTAH

Information supplied by the following:
Salt Lake County Planning Division
Utah Division of Comprehensive Emergency Management
Utah Geological & Mineral Survey
University of Utah Seismograph Stations

Each dot represents one earthquake located by University of Utah Seismograph Stations from July 1962 through March 1989 (10,732 earthquakes).

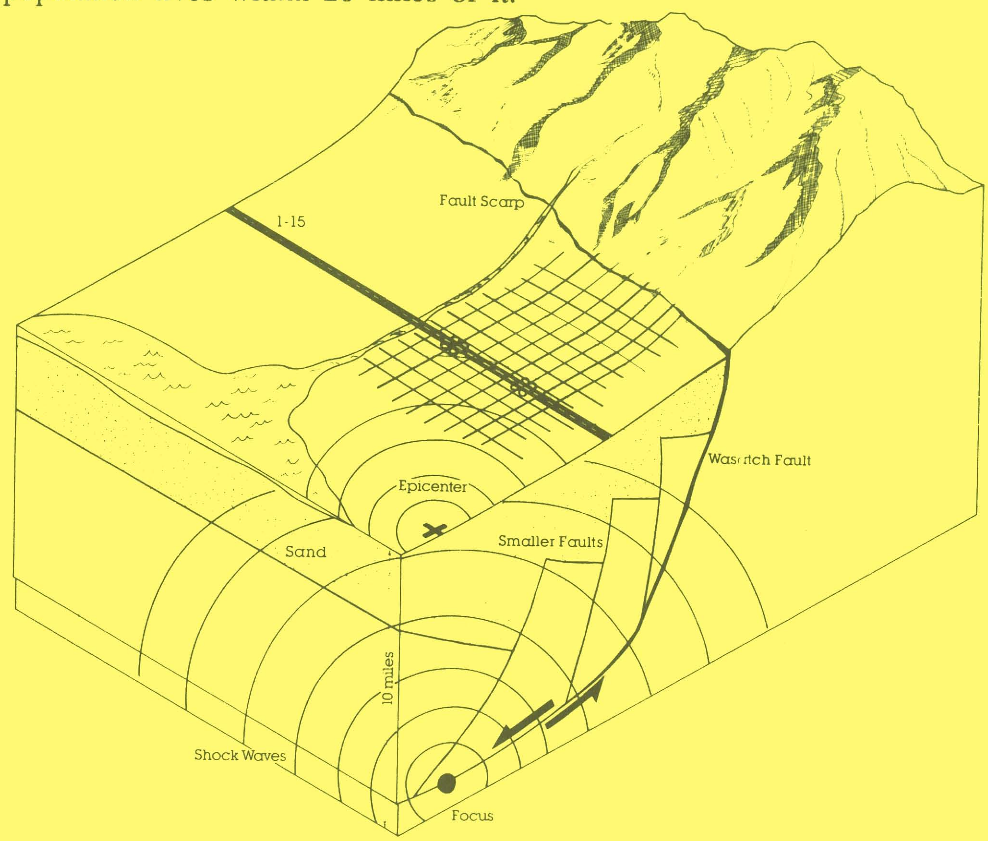
EARTHQUAKE HAZARDS

Earthquakes can and do occur over much of the state of Utah.

The RISK from earthquakes to people and property in any specific locality is determined by the following:

1) the **size or magnitude** of the earthquake
2) the **geology** of the particular area - type of rock, sediment; soil conditions; ground water; fault location
3) the **geologic hazards** it could produce - rockfalls, landslides, mudflows, floods, subsidence, liquefaction
4) the **location, design,** and **building materials** of man-made structures

Although numerous active faults exist, the WASATCH FAULT causes the greatest concern because 90% of Utah's population lives within 20 miles of it.



A major earthquake (up to magnitude 7.5) could occur along the Wasatch Fault at any time resulting in both <u>ground shaking</u> over a widespread area and <u>surface fault offset</u> of up to 20 feet in limited areas. The following could happen:

I. **GEOLOGIC CHANGES (HAZARDS)**
   A. Rockfalls, Landslides, Mudflows
   B. Liquefaction - The soil becomes a thick liquid incapable of supporting buildings. This may cause cracks in foundations or whole buildings to tilt.
   C. Flooding of low lying areas near the Great Salt Lake/Utah Lake due to tilting of valley floor

II. **PROPERTY DAMAGE**
   A. Damage to man-made structures such as buildings, overpasses, bridges, dams
   B. Breakage of gas, electric, water and sewer lines disrupting service and causing fire hazards
   C. Falling objects that cause injuries

No one knows when or where the next major earthquake will occur, but all scientists agree that we must be prepared.

EARTHQUAKE SAFETY

I. KNOW WHAT TO DO DURING

A. STAY CALM.

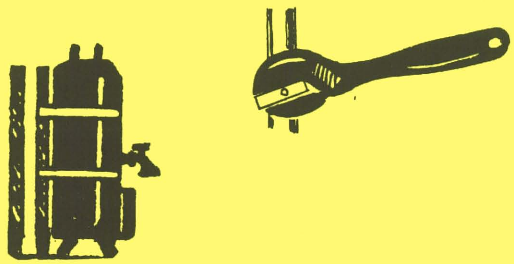
B. DUCK & COVER

1. IF INSIDE, STAY THERE!
Duck under table & hold onto its legs. or stand in interior door frame. If no protective cover is available, sit next to an interior wall & cover head/neck with arms.

2. IF OUTSIDE, STAY THERE!
Move into open away from buildings & electric wires. Park car away from bridges/overpasses. Stay in car until shaking stops.

II. PREPARE AHEAD OF TIME

A. PREPARE YOUR HOME



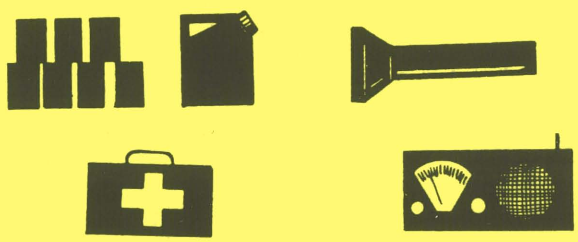
1. Identify possible hazards & reduce their risk.
   a. Remove heavy objects from high shelves.
   b. Anchor top-heavy furniture with brackets to wall or floor (refrigerators, bookshelves, etc.)
2. Reduce the risk of fire.
   a. Learn how to turn off utilities (gas electricity, water)
   b. Anchor water heater

B. DEVELOP FAMILY RESPONSE PLAN

1. Determine "safe" areas in each room.
2. Hold earthquake drills.
3. Decide on family meeting place.
4. Identify out-of-state contact.

C. PUT TOGETHER A 72 HOUR SURVIVAL KIT

1. WATER (1 gal/person/day)
2. Canned or dried foods
3. Flashlight
4. First-Aid Kit
5. Fire Extinguisher
6. Battery-operated Radio



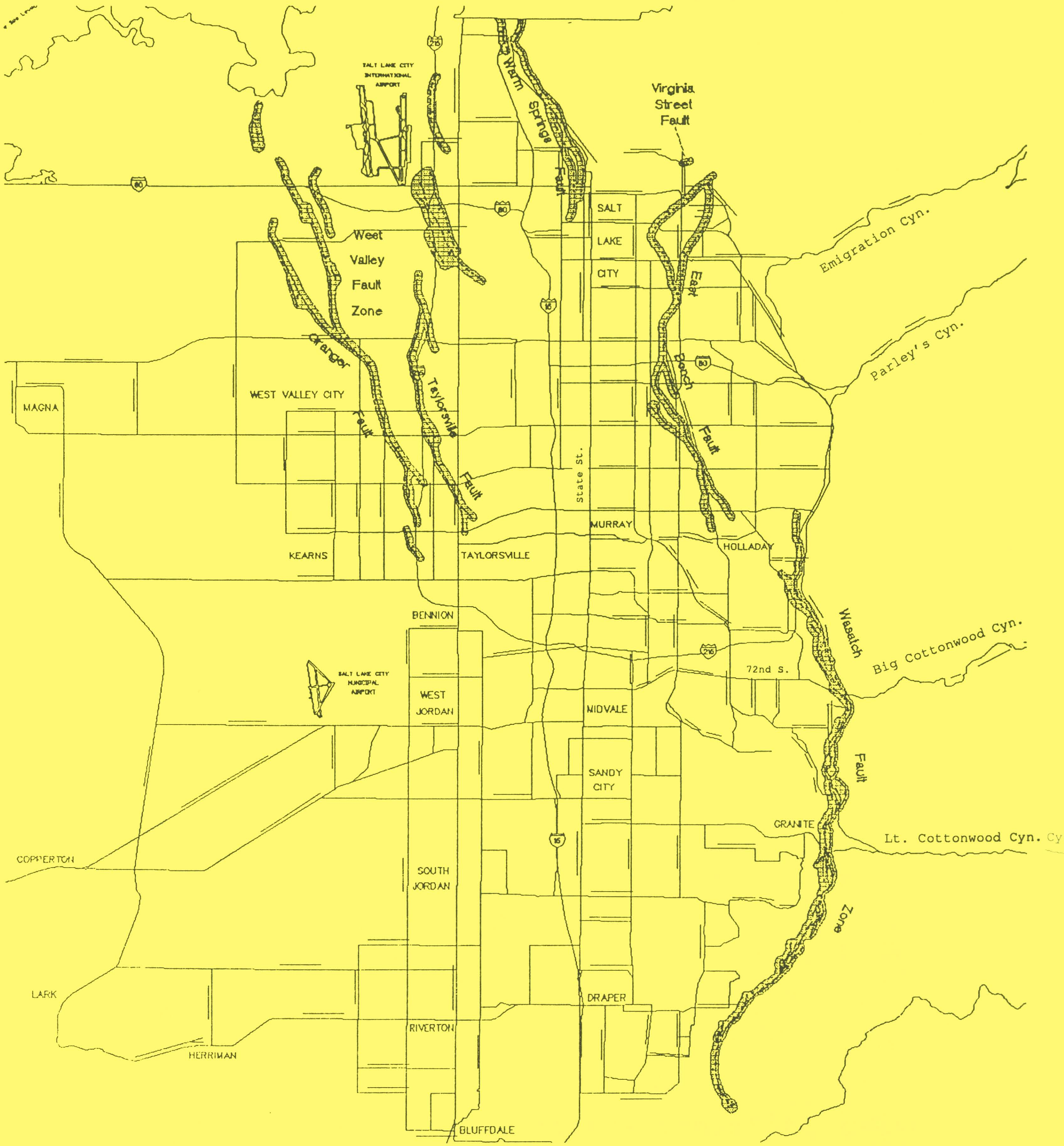
III. RESPOND AFTERWARD

A. ADMINISTER FIRST AID

B. CHECK FOR UTILITY DAMAGE & TURN OFF ONLY IF NECESSARY.

C. USE TELEPHONE ONLY FOR MEDICAL EMERGENCY.

D. BE AWARE THAT AFTERSHOCKS MAY CAUSE FURTHER DAMAGE.



Generalized Fault Map of Salt Lake County

For More Information Contact:
Salt Lake County Planning Division
468-2061

GEOLOGIC HAZARDS

ACTIVITIES: Consider role playing scenarios of conflict caused by the presence of geologic hazards. Discuss the pros and cons of mitigation of environmental dilemmas.

A. A seller which has a geologic hazard on his property and a buyer. Should the seller disclose the hazard?

B. A developer who has been told by county that he cannot build on his property. Should the county pay the developer a percentage of the land value to make-up for the profit the developer was expecting to make?

C. A property owner who suffers damage due to a geologic hazard and is suing the county because they issued a building permit. Would the owner understand if the permit was not issued?

D. How does a planner, who is concerned about extreme danger to his constituents, convince tax reformers or special-interest groups that tax monies should be spent on mitigation of a geologic hazard that has a recurrence interval of 500 years or a 1 in 5 chance of occurring in 50 years?

E. Should lending agencies require geologic hazard insurance and a geologic report of property before making loans?

F. Devise your own scenarios and discussions. Assign people to collect articles of geologic hazards from magazines and newspapers.

EARTHQUAKE HAZARDS

1) Causes of earthquakes: driving mechanisms
   a) legend: animals, gods, avenging angels, societal mores, more gods.
   b) man-made: pumping waste fluids, underground explosions, rock burst.
   c) plate boundaries: subduction, spreading, transform.
   d) other geologic sources: volcanic, geothermal.

2) Earthquake parameters: seismic waves, energy, damage scale.
   a) seismic waves and wave properties: P & S body waves, Surface waves.
   b) location of epicenter using seismic waves.
   c) energy released during earthquake: RICHTER MAGNITUDE.
   d) site specific damage due to shaking: MODIFIED MERCALLI INTENSITY VALUES.

   ACTIVITIES:
      i) locate epicenter of an earthquake
         Source: EPICENTRAL LOCATION EXERCISE
      ii) graphical depiction of magnitude scale. Source: GRAPHICAL REPRESENTATION OF RICHTER MAGNITUDE.
      iii) plot damaging Utah earthquakes equal to or greater than magnitude 5, associated intensities, and types of damage on Utah state map. Source: EARTHQUAKE TABLE.

3) Earthquake hazards: GROUND SHAKING
   a) seismic wave period
   b) soil amplification
   c) resonance of buildings
   d) building reactions: different construction types.

4) Earthquake hazards: SURFACE RUPTURE
   a) rupture length & displacement
   b) zone of deformation including tectonic subsidence
   c) easement in a fault zone

5) Earthquake hazards: LIQUEFACTION
   a) ground surface deformation
   b) loss of bearing strength
   c) lateral spread: slopes 0.5% ($1/3^\circ$) to 5% (3°)
   d) earthflow: slopes > 5% (3°)
   e) sand boils & sinkholes

6) Earthquake hazards: HYDROLOGIC CHANGES
   a) changes in springs: odor, taste, turbidity, flow
   b) changes in streams: direction, flow.

7) Earthquake hazards: LANDSLIDES other than flows
   a) rock falls
   b) Madison Canyon landslide & Quake Lake.

GRAPHICAL REPRESENTATION OF RICHTER MAGNITUDE

The magnitude of an earthquake is an estimate of the energy contained in the seismic waves. Magnitudes usually reported in press releases are more properly termed the Local, or Richter magnitude (M_L). The Richter magnitude is proportional to the ground movement indicated by the trace of the passage of seismic waves on a seismometer (Richter, 1935). Figure 1 shows a graphical procedure for determining the Richter Magnitude.

Divisions of the magnitude scale are in logarithmic increments, that is, for each one-magnitude unit change the amplitude of the seismic wave (equivalent to ground displacement) changes by a factor of 10 and the amount of energy released changes by a factor of $10^{1.5}$, i.e., each magnitude unit increase equals an energy increase of 31.6 (table 1).

Table 1: Equivalent energy by TNT mass for Richter magnitudes (Earth Science Curriculum Project, 1967; Smith, 1979)

Richter Magnitude	Approximate energy (TNT equivalent)	Energy use equivalent
-1	20 g, 3/4 oz	rifle bullet (approximate)
0	600 g, 1.3 lbs	enough to blast a tree stump
1	20 kg, 45 lbs	small construction blast
2	600 kg, 2/3 ton	average quarry blast
3	20 tonne, 20 ton	large quarry blast
4	600 tonne, 600 ton	small atom bomb
5	20 ktonne, 20 kton	standard atom bomb
6	600 ktonne,600 kton	small hydrogen bomb
7	20 mtonne, 20 mton	energy enough to heat New York City for one year (1967 energy consumptive rate)
8	600 mtonne,600 mton	energy enough to heat New York City for 30 years (1967 estimate)
9	20,000 mtonne 20,000 mton	energy equal to world's coal & oil production for 5 years (1967 estimate).

The magnitude scale can be better understood if presented graphically. The 10- or $10^{1.5}$-fold change of magnitude units or energy increment can be represented by using the areas or volumes of geometric forms. Table 2 gives area, volumes, and diameters for circles and spheres proportional to Richter magnitudes. Energy (Ergs) proportional to volumes of spheres is shown in table 3.

Table 2: Areas, volumes, and diameters for circles and spheres proportional to Richter magnitude units (Clarke, 1988).

Circles			Spheres		
M	Area (in2)	Diameter (in)	M	Volume (in3)	Diameter (in)
0	0.0001327	0.013	0	0.00000115	0.013
1	0.001327	0.041	1	0.0000115	0.028
2	0.01327	0.130	2	0.000115	0.060
3	0.1327	0.411	3	0.00115	0.130
4	1.327	1.300	4	0.0115	0.280
5	13.273	4.111	5	0.115	0.603
6	132.73	13.000	6	1.150	1.300
7	1327.3	41.109	7	11.503	2.801
8	13273.0	129.998	8	115.030	6.034
9	132730.0	411.019	9	1153.000	13.000

Note: the area of the circle or sphere changes by a factor of $10^{1.0}$ with each unit of magnitude change.

Table 3: Volumes and diameters for proportional spheres representing seismic energy (Clarke, 1988).

M	Energy (Ergs)	Volume (in3)	Diameter (in)
0	6.3×10^{11}	0.00000115	0.013
1	2.0×10^{13}	0.00003638	0.041
2	6.3×10^{14}	0.0011503	0.130
3	2.0×10^{16}	0.036375	0.411
4	6.3×10^{17}	1.1503	1.300
5	2.0×10^{19}	36.375	4.111
6	6.3×10^{20}	1,150.3	13.000
7	2.0×10^{22}	36,373	41.109
8	6.3×10^{23}	1,150,300	129.998
9	2.0×10^{25}	36,375,000	411.091

Note: the area of the sphere changes by a factor of $10^{1.5}$ with each unit of magnitude change.

Note: $6.3 \times 10^{11} = 6.3 \times 100,000,000,000 = 630,000,000,000$

ACTIVITIES

1. Draw a representation of changes in magnitude units. Use your imagination, e.g. orbits with magnitude-proportional radii around a dot; distances to world/universe localities; diameter of atom up to universe; etc.

2. Prepare visual representations of energy change with magnitude change by comparing energy change using familiar objects for example, a) volume of a pea, golf ball, hardball, softball, beachball, hot-air balloon, Goodyear blimp; b) payload of "matchbook" trucks, Tonka trucks, small pickups, large pickups (1/2, 3/4, 1 ton), dump trucks, cement trucks, ore-hauling trucks (real-life Tonka trucks); c) buildings; d) organisms, ranging from fly to dinosaur; e) volume of water in a thimble up to the world ocean; f) optical (microscopic to telescopic images); g) personal (smallest object on human body -dandruff?- compared to the largest part, or entire body, or Guinness Book of Records largest body); h) construct geometric forms e.g. a cube showing magnitude units as volume or size; i) number of pennys -1 cent to 109 cents ($10 million); j) whatever you can think of.

3. Consider other sensory means to illustrate magnitude or energy such as sound (decibels are measured on a logarithmic scale), heat, touch (while blindfolded, feel objects of various sizes), etc.

EARTHQUAKE TABLE

Date, location, MM intensity, and Richter magnitude of the LARGEST EARTHQUAKES IN THE UTAH REGION[1], 1850-June, 1987 (modified from Arabasz and others, 1987)

Date	Location (Lat D M, Long D M)	Maximum MMI	Magnitude[2] M_L	Reference
Nov 10,1884	Northeastern Utah (42 0, 111 16)	VIII	6-6.3	3
Dec 5,1887	Kanab (37 2.8, 112 31.3)	VII	5.5-5.7	4,5,6
Aug 1,1900	Eureka District (39 57.2, 112 6.8)	VII	5.5-5.7	3,4
Nov 13,1901	Beaver/Richfield (38 46.2, 112 5.0)	X	6.7-7.0	3,4,7
Nov 17,1902	Pine Valley (37 23.6, 113 31.2)	VIII	6.1-6.3	3,4,7
Oct 5,1909	Hansel Valley (41 46.0, 112 40.0)	IX	6.3-6.7	3,4 5,8
May 22,1910	Salt Lake City (40 44.9, 111 51)	VIII	5.5-5.7	3,4 5,7
May 13,1914	Ogden (41 13.5, 111 57.6)	VII	5.5-5.7	3,4 5,7,8
Oct 5,1915	Ibapah (40 6.0, 114 0)	VII	4.3-5.5	3,4 5,7
Sep 29/Oct 1 1921	Elsinore (38 41, 112 9)	VIII	6.1-6.3	3,4 7,8
Mar 12,1934	Kosmo, Hansel Valley (41 30.0, 112 30.0)	IX	6.6-7.0	3,4 5,9
Nov 18,1937	Lucin (42 6.0, 113 54.0)	VI	5.4	3,9
Jul 21,1959	UT-AZ border near Kanab (37 0, 112 30)	VI	5.5-5.8	4,5,6
Aug 30,1962	Richmond, Cache Valley (42 2.4, 111 44.4)	VII	5.7	4,5,6,8

Date	Location	Maximum MMI	Magnitude[2] M_L	Reference
Aug 16,1966	Nevada-SW Utah (37 27.6, 114 9)	VI	5.6	6,10
Mar 27,1975	Pocatello Valley, ID (42 6, 112 31.2)	VIII	6.0	6,10
Aug 14,1988	San Rafael Swell (39 7.3, 110 50.3)	VI	5.3	11,12
Jan 29,1989	Salina (38 49.5, 111 36.8)	VI[14]	5.4	13

Notes:

1 Earthquakes (aftershocks excluded) of Richter magnitude (M_L) 5.3 or greater and/or Modified Mercalli intensity (MMI) of VII or greater in the Utah region (Utah and areas slightly outside Utah's borders).

2 Earthquake magnitudes from 1884-1921 were calculated from maximum MMI intensity due to lack of instrumental data.

3 Williams and Tapper, 1953

4 Cook and Smith, 1967

5 Coffman and von Hake, 1973

6 U.S. Dept Commerce

7 Townley and Allen, 1939

8 Hays and others, 1974

9 Jones, 1975

10 Arabasz and McKee, 1979

11 Case, 1988

12 Nava and others, 1988

13 University of Utah Seismograph Stations, 1989.

14 Preliminary MMI value (John Mimsch, National Earthquake Information Center, personal communication, 3 May, 1989).

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Modified MERCALLI EARTHQUAKE INTENSITY SCALE
(AGI data sheet 47a)

Because the performance of masonry is such an important criterion for evaluating intensity, this version specifies four qualities of masonry, brick or otherwise, as follows:

<u>Masonry A</u>: Good workmanship, mortar, and design; reinforced, especially laterally, and bound together using steel, concrete, etc.; designed to resist lateral forces.

<u>Masonry B</u>: Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.

<u>Masonry C</u>: Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.

<u>Masonry D</u>: Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

INTENSITY

I Not felt. Marginal and long-period effects of large earthquakes.

II Felt by persons at rest, on upper floors, or favorably places.

III Felt indoors. Hanging object swings. Vibration like passing of light truck. Duration estimated. May not be recognized as an earthquake.

IV Hanging objects swing. Vibration like passing of heavy trucks, or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.

V Felt outdoors, direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI Felt by all. Many frightened and run outdoors. People walk unsteadily. Windows, dishes, glassware broken. Knicknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken visible, or heard to rustle.

Mercalli Intensity Scale (cont.)

VII Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, unbraced parapets and architectural ornaments. Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving-in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B, none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed pining broken off. Branches broken from trees. Changes in flow or temperature of springs and well. Cracks in wet ground and on steep slopes.

IX General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frame cracked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.

X Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent sightly.

XI Rails bent greatly. Underground pipelines completely out of service.

XII Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into air.

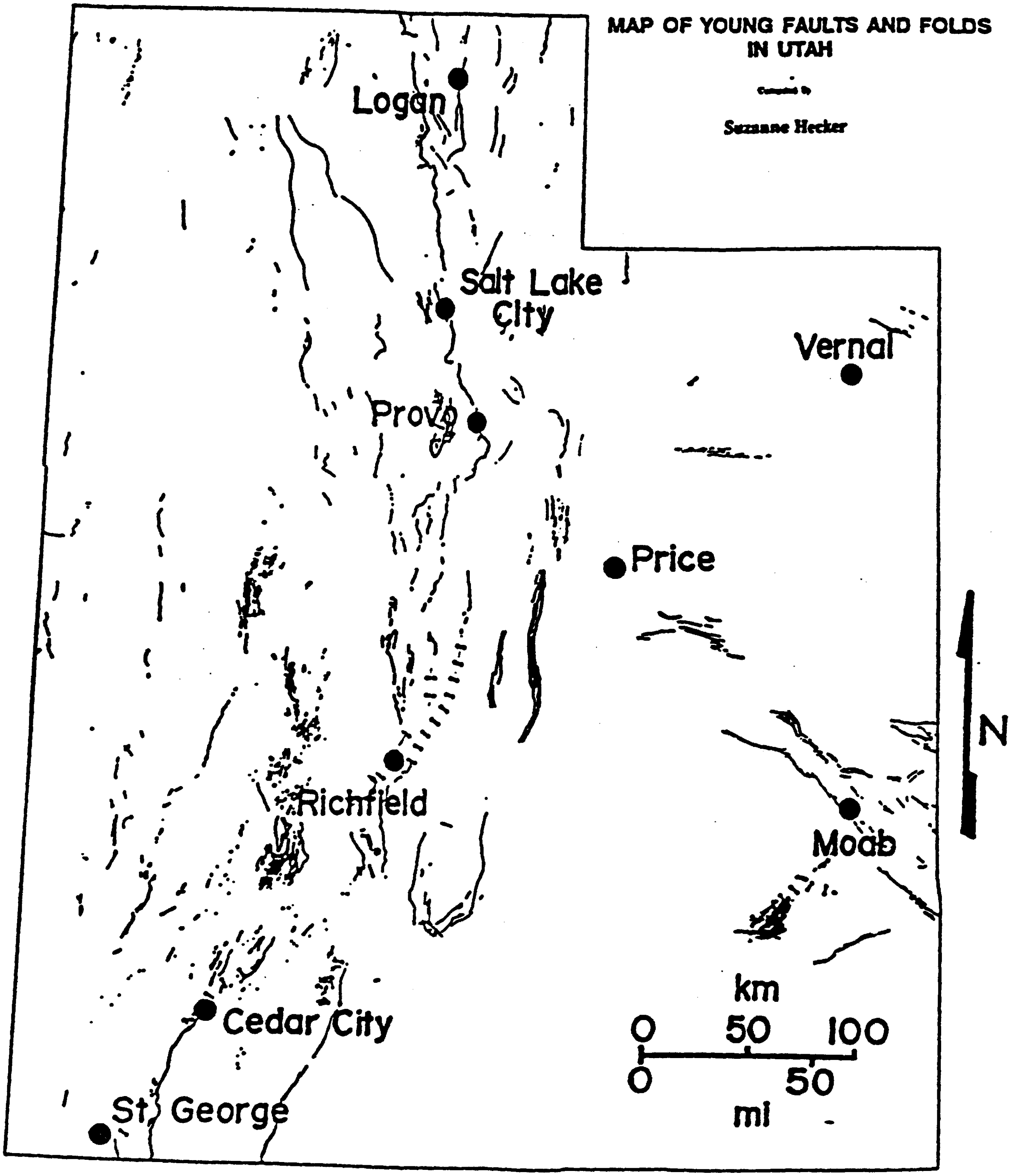
PRELIMINARY
SUBJECT TO REVIEW

UTAH NATURAL RESOURCES
Utah Geological and Mineral Survey
606 Black Hawk Way
Salt Lake City, UT 84108-1280

MAP OF YOUNG FAULTS AND FOLDS IN UTAH

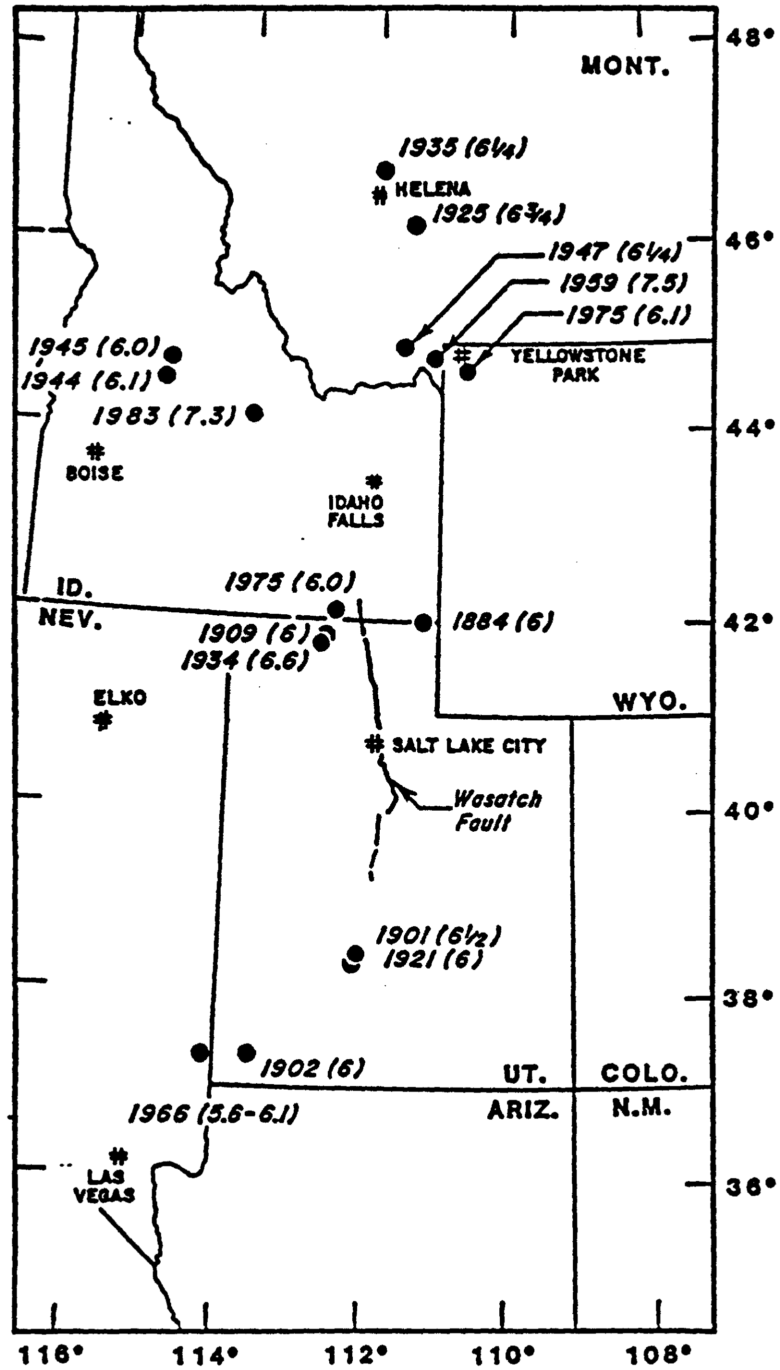
Compiled by

Suzanne Hecker



Solid lines represent faults and dotted lines represent folds that are known or suspected of being active during the Quaternary period (the past 1.6 million years). Arrows indicate fold types. Double outward-facing arrows indicate anticlines, double inward-facing arrows indicate synclines, and single-direction arrows indicate monoclines.

Earthquakes in the Intermountain Seismic Belt



Historical earthquakes of magnitude 6.0 and larger (large dots). Adapted from *Observational seismology and the evaluation of earthquake hazards and risk in the Wasatch Front area, Utah*, by Arabasz and others, 1989, U.S. Geological Survey Professional Paper, in press.

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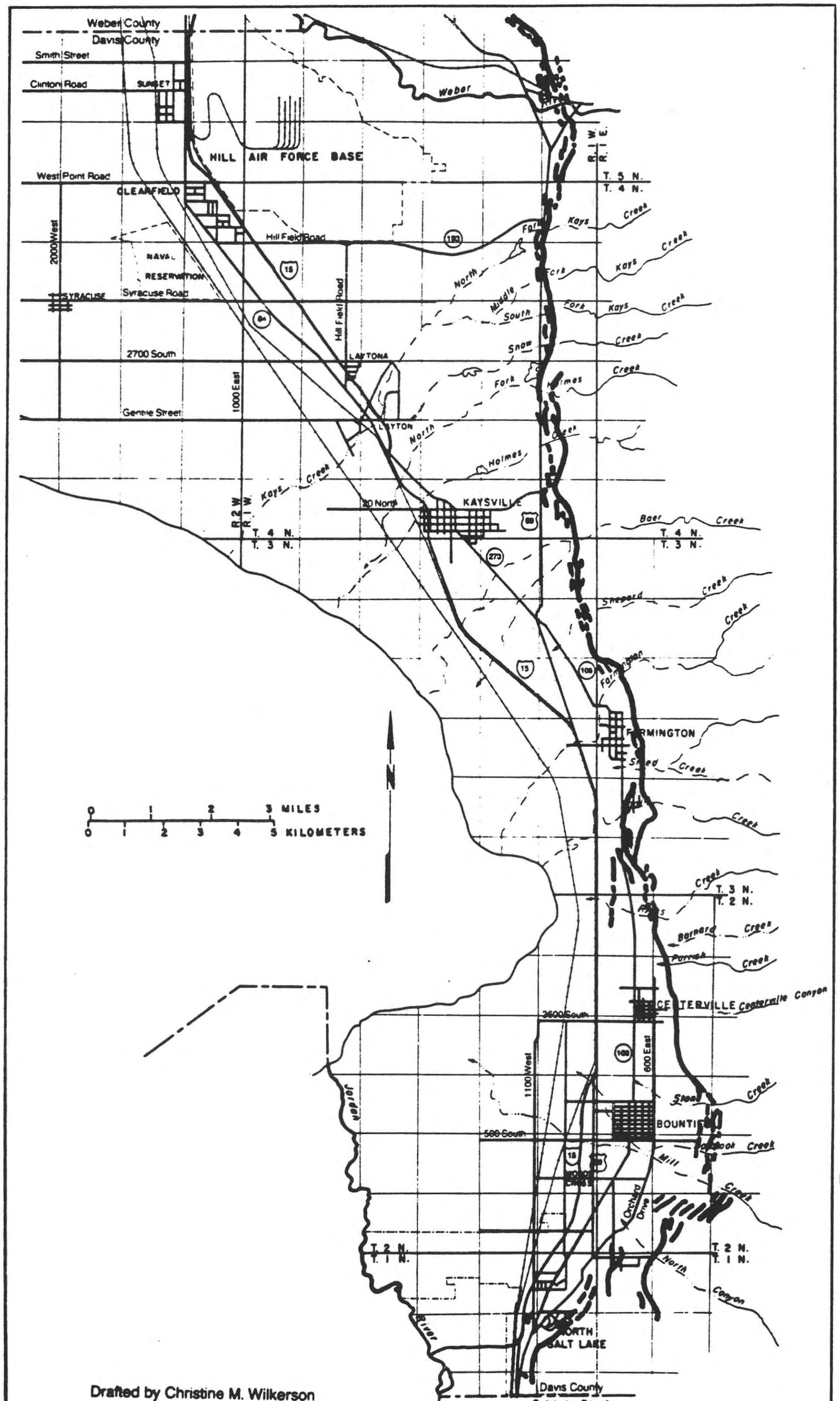
EARTHQUAKE FAULT MAP OF A PORTION OF DAVIS COUNTY, UTAH

UGMS Public Information Series 2



Known trace of fault with evidence of Holocene (about 10,000 years ago to present) movement.

(Dashed where existence is uncertain or inferred.)

This map is for general reference only. Detailed maps are available at the Davis County Planning Office.

Location of faults compiled from preliminary drafts of surficial geologic mapping by A.R. Nelson and S.F. Personius, U.S. Geological Survey, 1989.

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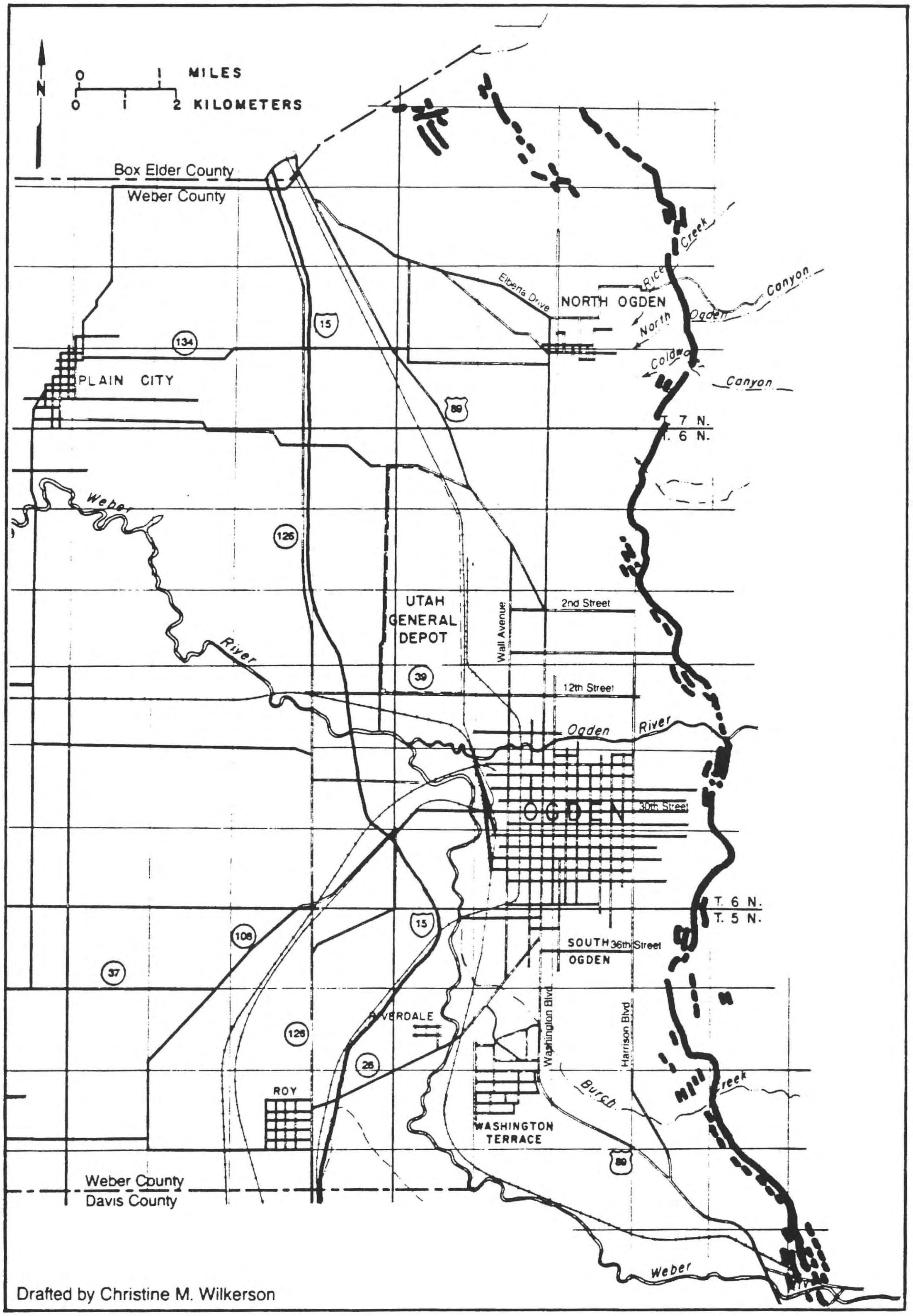
The Utah Geological and Mineral Survey is a division within the Department of Natural Resources, Dee Hansen, Executive Director.

EARTHQUAKE FAULT MAP OF A PORTION OF WEBER COUNTY, UTAH

UGMS Public Information Series 1



Known trace of fault with evidence of Holocene (about 10,000 years ago to present) movement.

(Dashed where existence is uncertain or inferred.)

This map for general reference only. Detailed maps are available at the Weber County Planning Office.

Location of faults compiled from preliminary drafts of surficial geologic mapping by A.R. Nelson and S.F. Personius, U.S. Geological Survey, 1989, and S.F. Personius, U.S. Geological Survey Map MF-2402, 1988.

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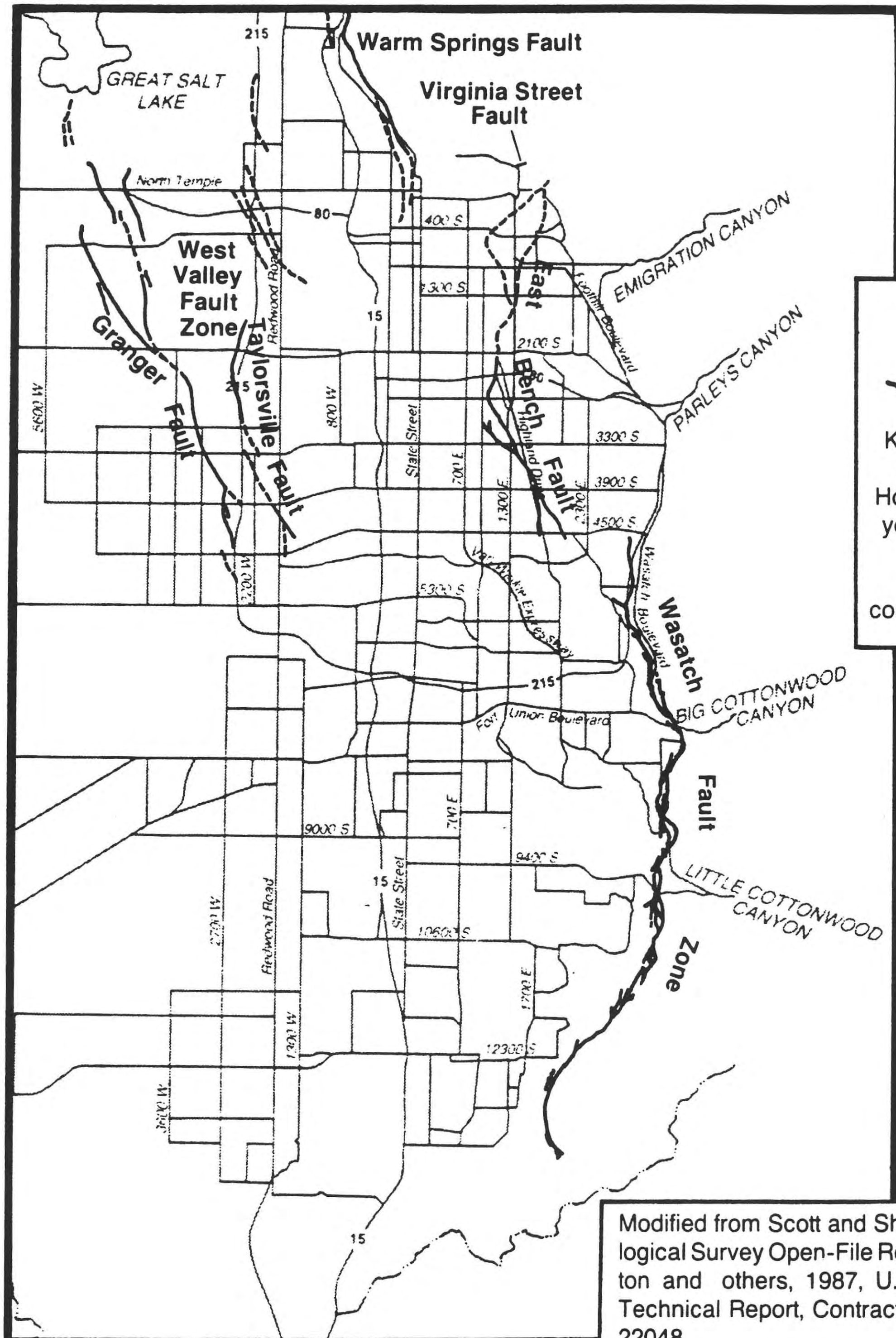
EARTHQUAKE FAULT MAP OF A PORTION OF SALT LAKE COUNTY, UTAH

UGMS Public Information Series 3

This map is for general reference only.

Detailed maps are available at the Salt Lake County Planning Department.



Explanation

Known trace of fault with evidence of Holocene (about 10,000 years ago to present) movement. (Dashed where concealed or inferred)

Scale

0 1 2 MILES

0 1 2 3 KILOMETERS

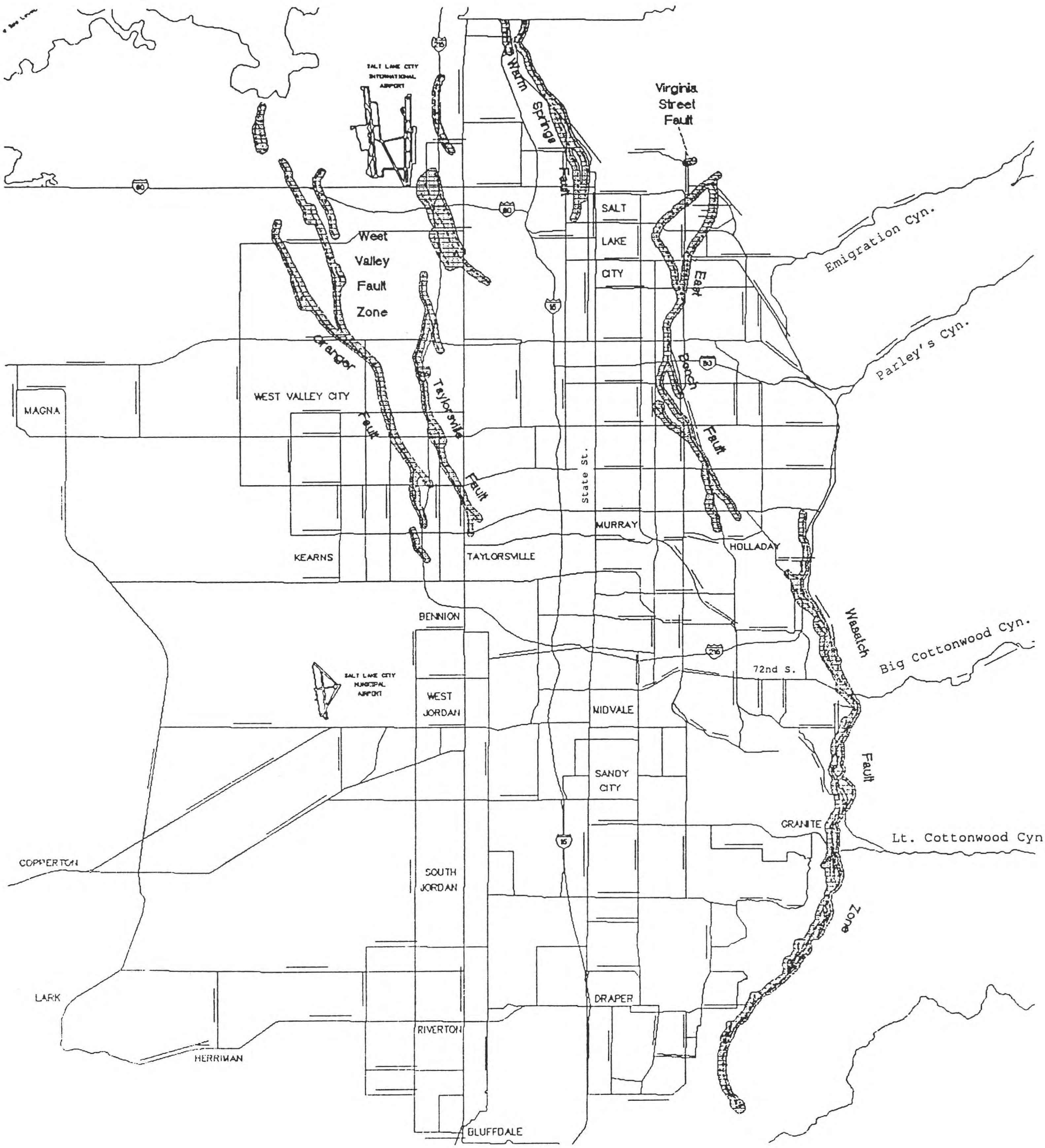
N

Modified from Scott and Shroba, 1985, U.S. Geological Survey Open-File Report 85-448; and Keaton and others, 1987, U.S. Geological Survey Technical Report, Contract number 14-08-0001-22048.

Drafted by Bill D. Black from digitized map provided by Craig V. Nelson, Salt Lake County Planning Department.

UTAH GEOLOGICAL AND MINERAL SURVEY
M. Lee Allison, Director
606 Black Hawk Way
Salt Lake City, Utah 84108-1280

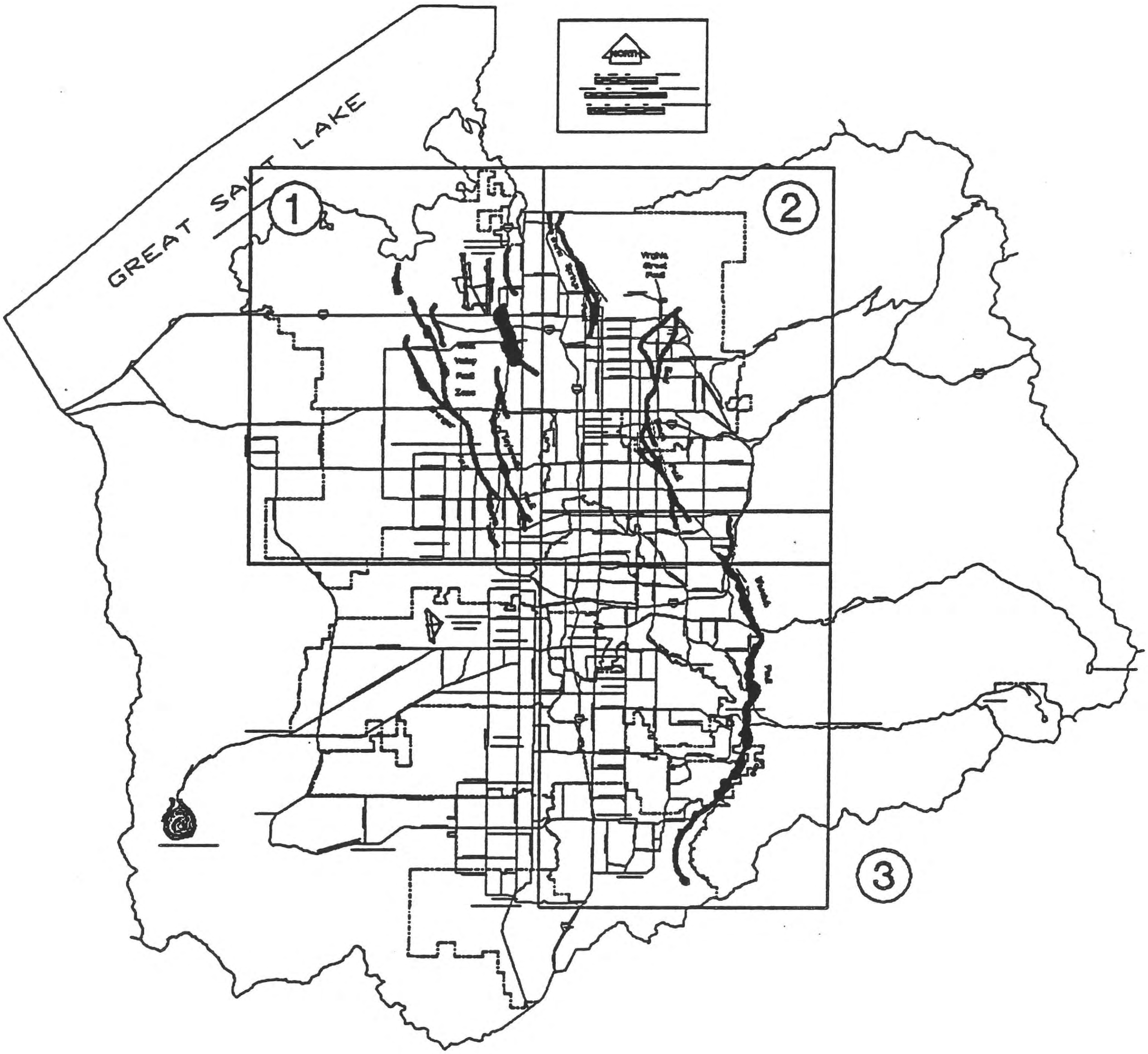
The Utah Geological and Mineral Survey is a division within the Department of Natural Resources, Dee Hansen, Executive Director.



Generalized Fault Map of Salt Lake County

For More Information Contact:
Salt Lake County Planning Division
468-2061

SURFACE FAULT RUPTURE SPECIAL STUDY AREAS



SALT LAKE COUNTY PUBLIC WORKS, PLANNING DIVISION - JUNE 1988

SALT LAKE COUNTY
PLANNING DIVISION

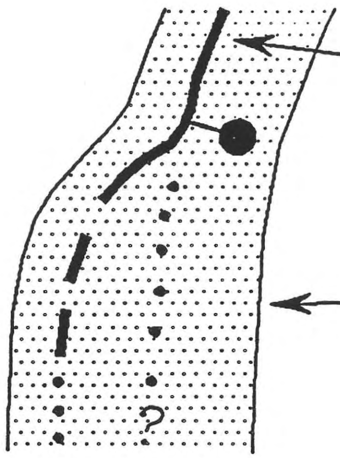
CRAIG V NELSON
County Geologist

2001 S State St #N3700
Salt Lake City, Utah 84190-4200

(801) 468-2061

SURFACE FAULT RUPTURE SPECIAL STUDY AREAS

EXPLANATION

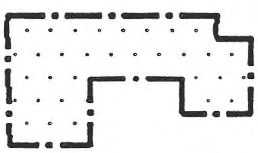


FAULTS

Faults are mapped as solid lines where their location is known from scarps or trenching; dashed lines indicate approximate or inferred fault locations; dotted lines represent areas where faults are concealed. The bar and ball symbols indicate the direction of fault dip and downthrown side.

SPECIAL STUDY AREA

The shaded area indicates locations where site specific engineering geology studies should be performed to determine the nature of fault deformation at the site, and then make recommendations prior to development.



INCORPORATED CITY BOUNDARIES

SPECIAL STUDY AREA GUIDELINES

Should a Site Specific Engineering Geology Study be Performed Prior to Building Permit Approval?

Land Use (Type of Facility)	Within Special Study Area
Essential Facilities (UBC 2312(k)) and High Occupancy Buildings (UBC A–1, A–2, A–2.1)	YES
Industrial & Commercial Buildings (>2 stories or >5,000 square feet)	YES
Multi–Family Residential (4 or more units/acre) Other Industrial & Commercial	YES
Residential Subdivisions	YES
Residential Single Lots & Muti–Family Developments (less than 4 units/acre)	NO*

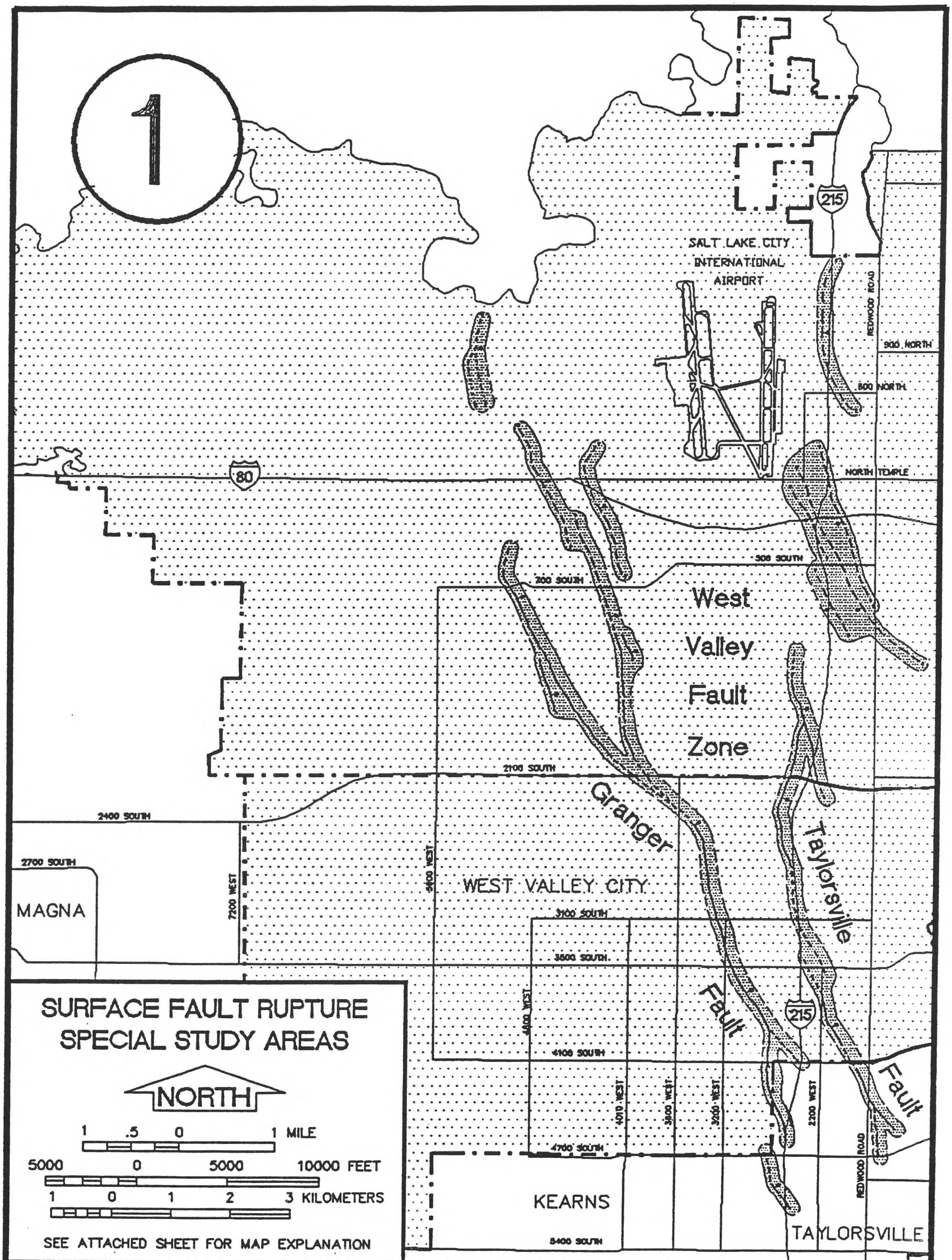
* But Disclosure of Potential Hazard to Buyers/Residents is Recommended.

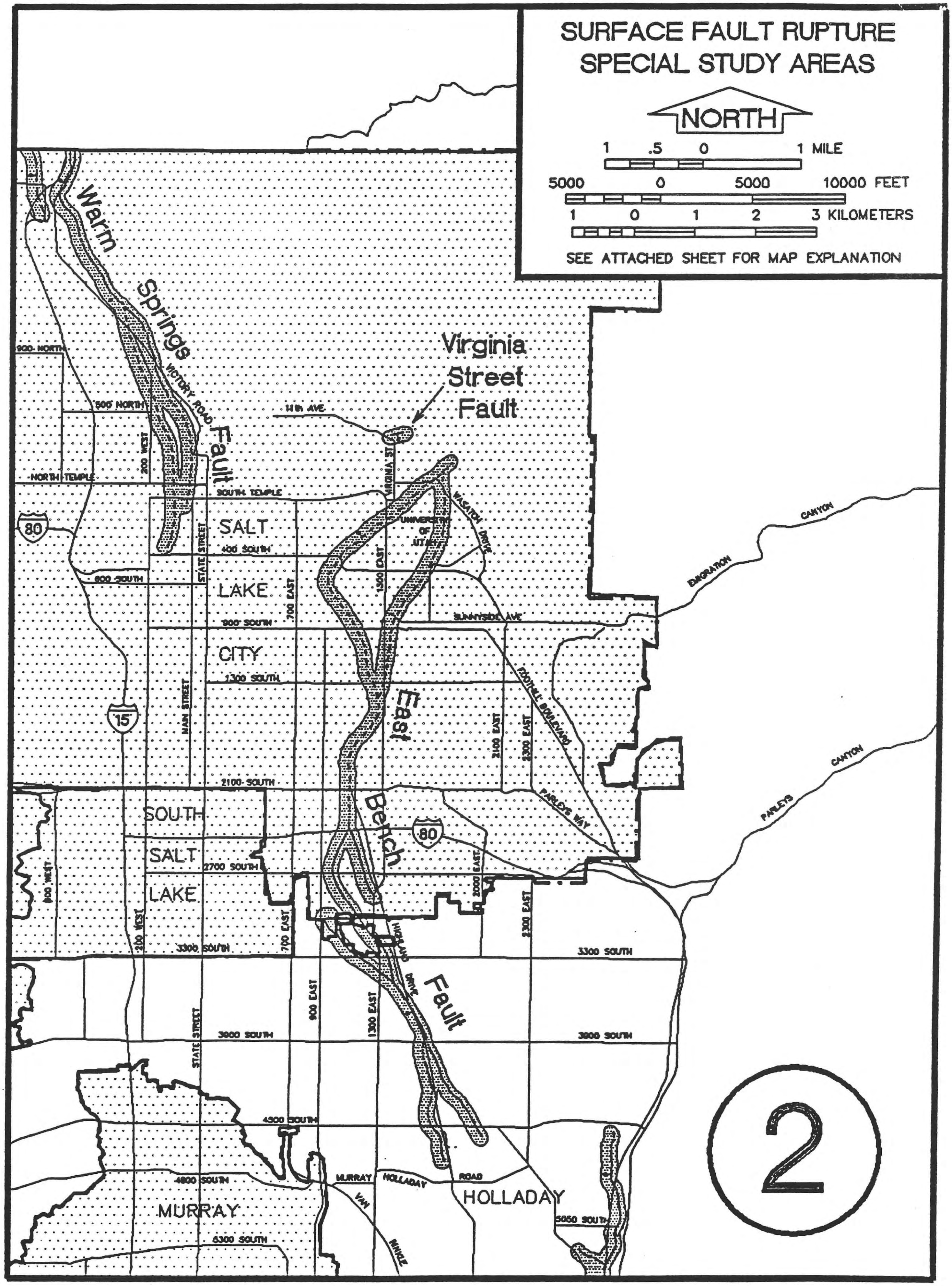
REFERENCES

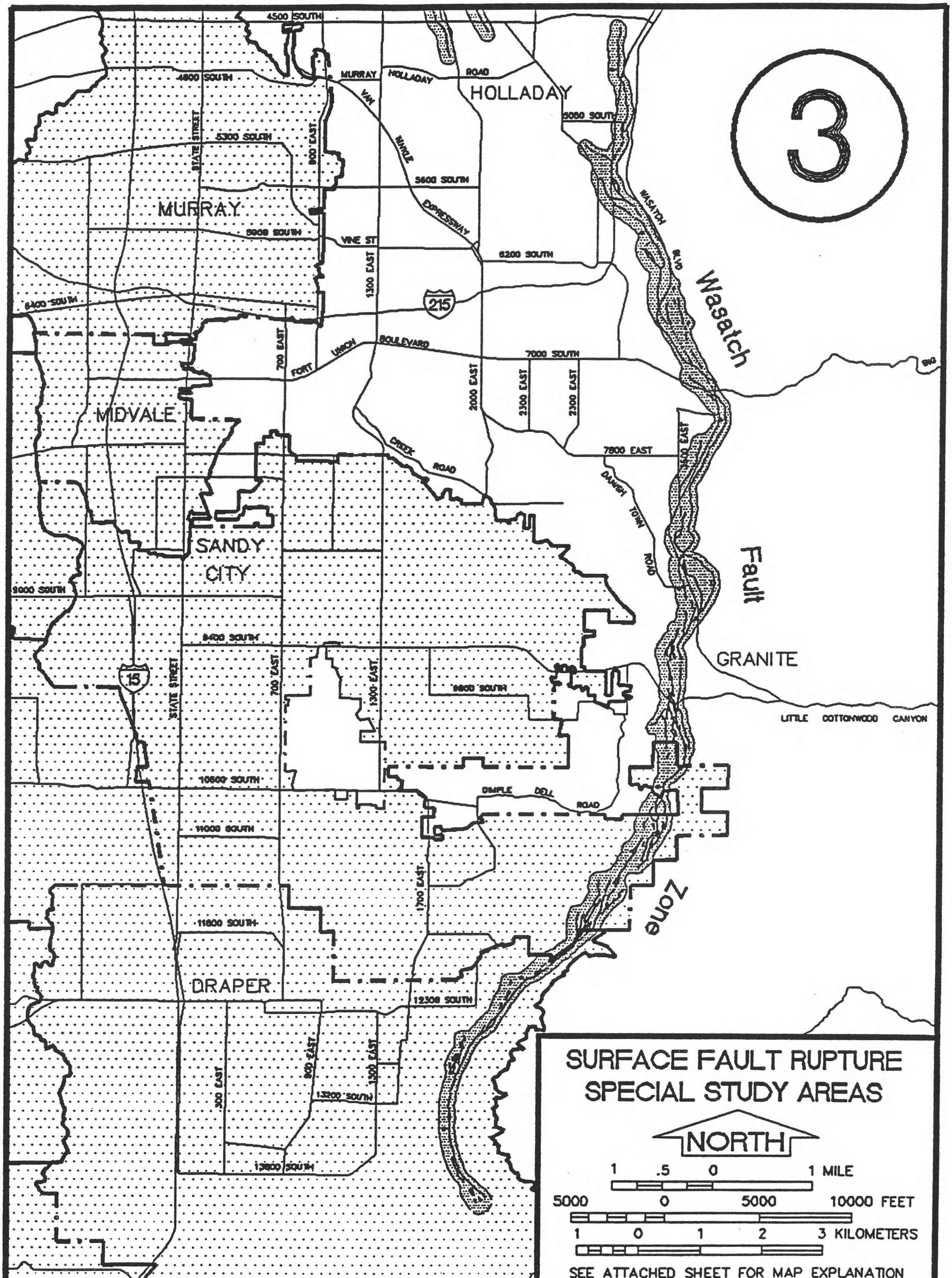
CLUFF, L.S., BROGAN, G.E., and GLASS, C.E., 1970, Vasatch Fault, northern portion, earthquake fault investigation and evaluation: Woodward-Clyde & Associates, Oakland, CA, map 1:24,000.

KEATON, J.R., CURREY, D.R., and OLIG, S.J., 1987, Paleoseismicity and earthquake hazards evaluation of the West Valley Fault Zone, Salt Lake urban area: in press, map 1:24,000.

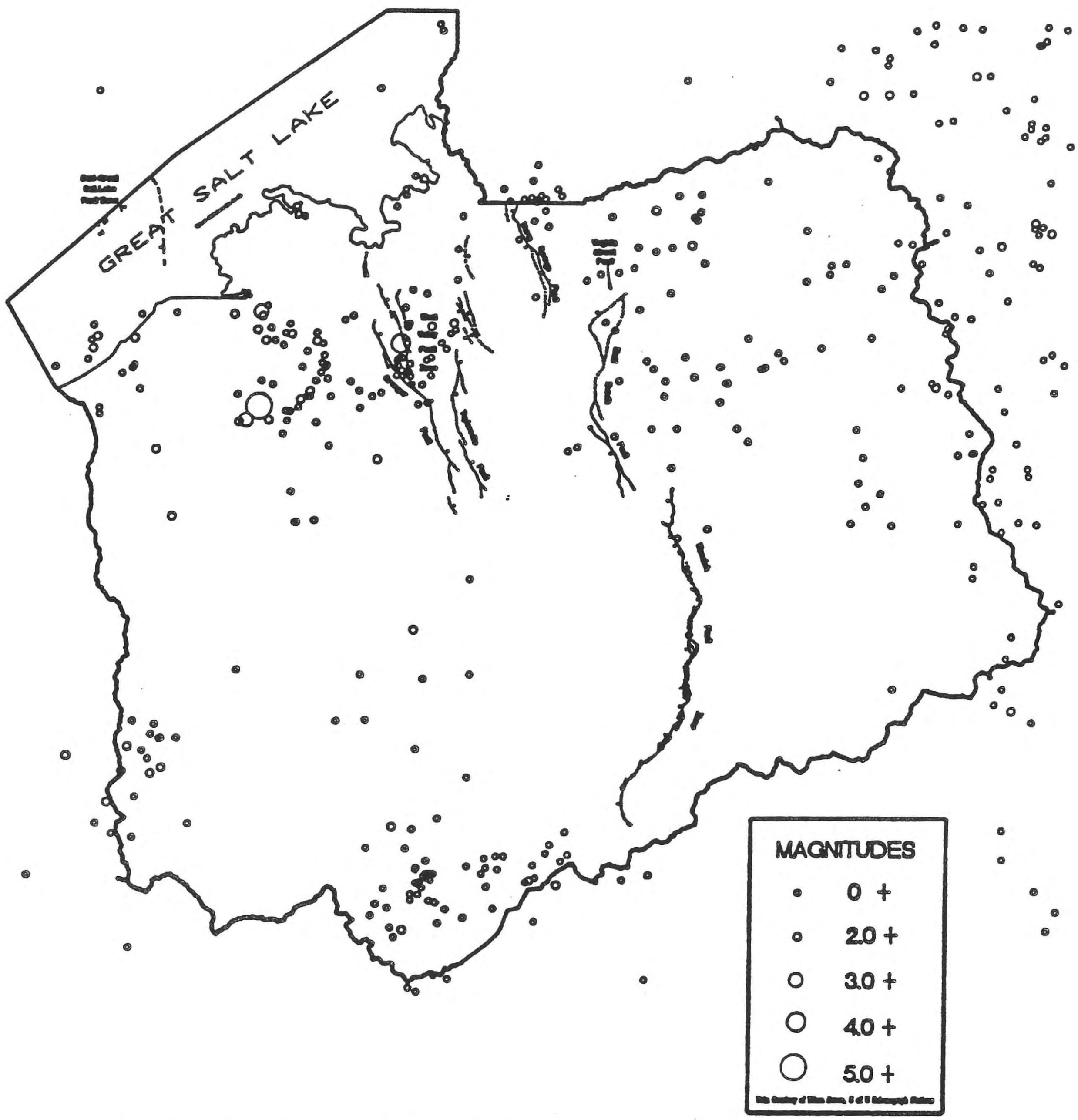
SCOTT, V.E., and SHROBA, R.R., 1985, Surficial geologic map of an area along the Vasatch Fault zone in the Salt Lake Valley, Utah: U.S. Geological Survey Open-File Report 85-448, map 1:24,000.


1
SALT LAKE CITY
INTERNATIONAL
AIRPORT
215
REDWOOD ROAD
900 NORTH
600 NORTH
NORTH TEMPLE
80
500 SOUTH
700 SOUTH
West
Valley
Fault
Zone
2100 SOUTH
2400 SOUTH
2700 SOUTH
MAGNA
7200 WEST
5600 WEST
Granger
Taylorsville
WEST VALLEY CITY
3100 SOUTH
3500 SOUTH
4800 WEST
Fault
215
4100 SOUTH
Fault
4010 WEST
3600 WEST
3200 WEST
2200 WEST
REDWOOD ROAD
4700 SOUTH
KEARNS
5400 SOUTH
TAYLORSVILLE
SURFACE FAULT RUPTURE
SPECIAL STUDY AREAS
NORTH
1 .5 0 1 MILE
5000 0 5000 10000 FEET
1 0 1 2 3 KILOMETERS
SEE ATTACHED SHEET FOR MAP EXPLANATION


SURFACE FAULT RUPTURE
SPECIAL STUDY AREAS
NORTH
1 .5 0 1 MILE
5000 0 5000 10000 FEET
1 0 1 2 3 KILOMETERS
SEE ATTACHED SHEET FOR MAP EXPLANATION
Warm Springs Fault
Virginia Street Fault
East Bench Fault
SALT LAKE CITY
SOUTH SALT LAKE
MURRAY
HOLLADAY
900 NORTH
500 NORTH
NORTH TEMPLE
SOUTH TEMPLE
400 SOUTH
600 SOUTH
900 SOUTH
1300 SOUTH
2100 SOUTH
2700 SOUTH
3300 SOUTH
3900 SOUTH
4500 SOUTH
4800 SOUTH
5050 SOUTH
5300 SOUTH
11th AVE
SUNNYSIDE AVE
VICTORY ROAD
200 WEST
800 WEST
MAIN STREET
STATE STREET
700 EAST
900 EAST
1300 EAST
2000 EAST
2100 EAST
2300 EAST
VIRGINIA ST
UNIVERSITY OF UTAH
WASATCH DRIVE
FOOTHILL BOULEVARD
PARLEYS WAY
HIGHLAND DRIVE
MURRAY HOLLADAY ROAD
VAN WINKLE
EMIGRATION CANYON
PARLEYS CANYON
80
15
2

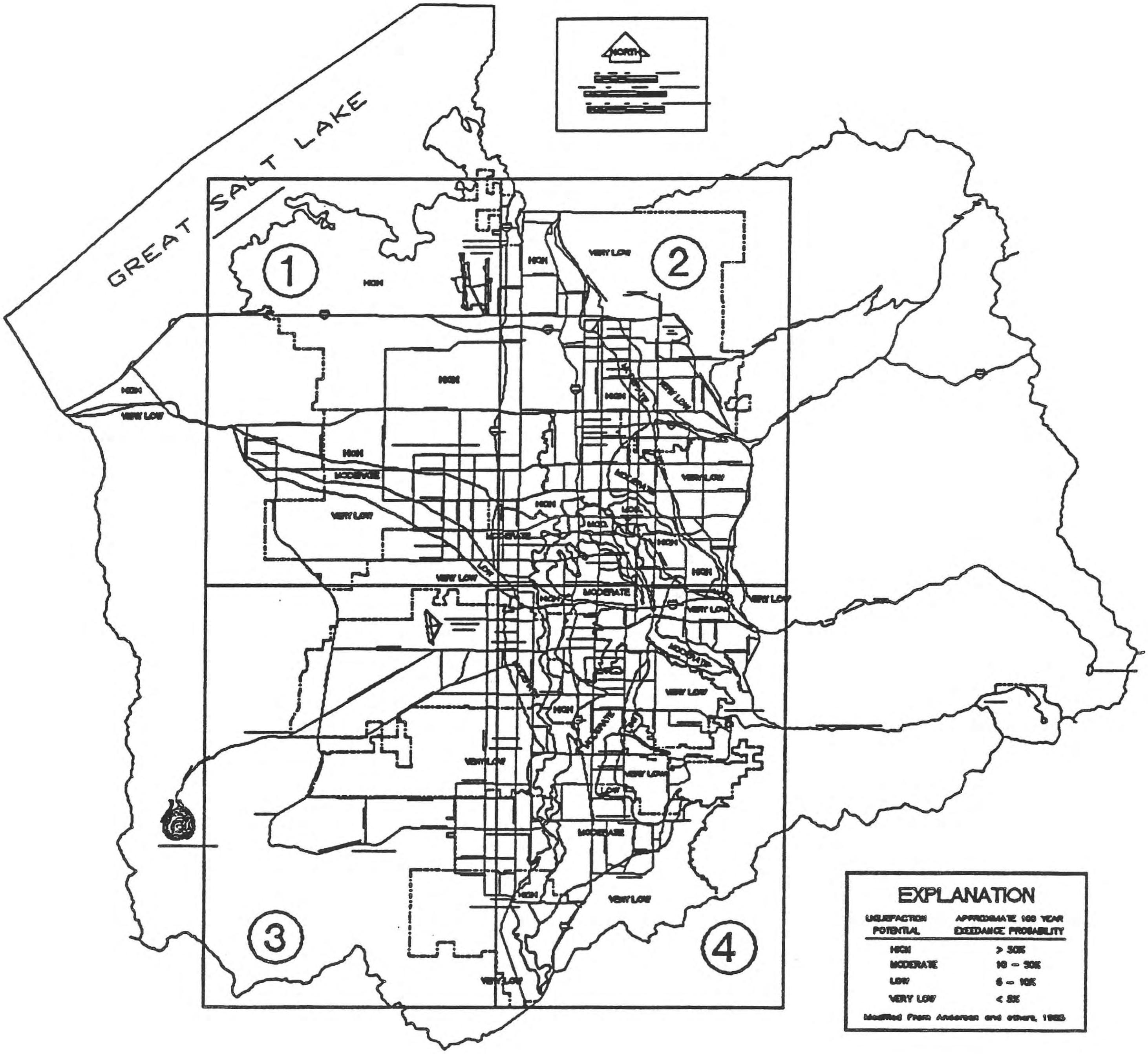

3
4500 SOUTH
4800 SOUTH
MURRAY HOLLADAY ROAD
HOLLADAY
VAN WINKLE EXPRESSWAY
5300 SOUTH
STATE STREET
900 EAST
5600 SOUTH
MURRAY
5900 SOUTH
VINE ST
6200 SOUTH
1300 EAST
WASATCH BLVD
Wasatch
6400 SOUTH
215
FORT UNION BOULEVARD
700 EAST
7000 SOUTH
2000 EAST
2300 EAST
BIG
MIDVALE
CREEK ROAD
7800 EAST
DANISH TOWN ROAD
SANDY CITY
Fault
9000 SOUTH
9400 SOUTH
GRANITE
15
9800 SOUTH
LITTLE COTTONWOOD CANYON
10600 SOUTH
DIMPLE DELL ROAD
11000 SOUTH
1700 EAST
Zone
11600 SOUTH
DRAPER
12300 SOUTH
300 EAST
800 EAST
13200 SOUTH
13800 SOUTH
SURFACE FAULT RUPTURE SPECIAL STUDY AREAS
NORTH
1 .5 0 1 MILE
5000 0 5000 10000 FEET
1 0 1 2 3 KILOMETERS
SEE ATTACHED SHEET FOR MAP EXPLANATION

EARTHQUAKE EPICENTER LOCATIONS
SALT LAKE COUNTY, UTAH



Salt Lake County Public Works Planning Division, Craig Nelson County Geologist, 468-2061

LIQUEFACTION POTENTIAL - SALT LAKE COUNTY, UTAH



EXPLANATION

LIQUEFACTION POTENTIAL	APPROXIMATE 100 YEAR EXCEEDANCE PROBABILITY
HIGH	> 50%
MODERATE	10 – 50%
LOW	5 – 10%
VERY LOW	< 5%

Modified From Anderson and others, 1985

SALT LAKE COUNTY PUBLIC WORKS, PLANNING DIVISION - JUNE 1988

SALT LAKE COUNTY
PLANNING DIVISION

CRAIG V NELSON
County Geologist

2001 S State St #N3700
Salt Lake City, Utah 84190-4200

(801) 468-2061

LIQUEFACTION POTENTIAL

EXPLANATION

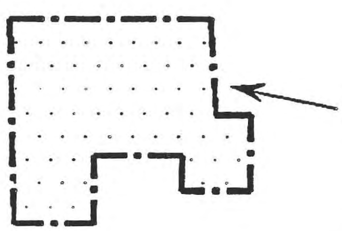
LIQUEFACTION POTENTIAL		
HIGH	> 50%	Approximate probabilities that the critical ground acceleration (from earthquake ground shaking) needed to induce liquefaction will be exceeded in 100 years.
MODERATE	50 – 10%	
LOW	10 – 5%	
VERY LOW	< 5%	

SPECIAL STUDY AREA GUIDELINES

Should a Site Specific Engineering Geology Study be Performed Prior to Building Permit Approval?

Land Use (Type of Facility)	Liquefaction Area HIGH	MOD.	LOW	V. LOW
Essential Facilities (UBC 2312(k)) and High Occupancy Buildings (UBC A-1, A-2, A-2.1)	YES	YES	YES	YES
Industrial & Commercial Buildings (>2 stories or >5,000 square feet)	YES	YES	NO	NO
Multi-Family Residential (4 or more units/acre) Other Industrial & Commercial	YES	YES	NO	NO
Residential Subdivisions	NO*	NO*	NO	NO
Residential Single Lots & Muti-Family Developments (less than 4 units/acre)	NO*	NO*	NO	NO

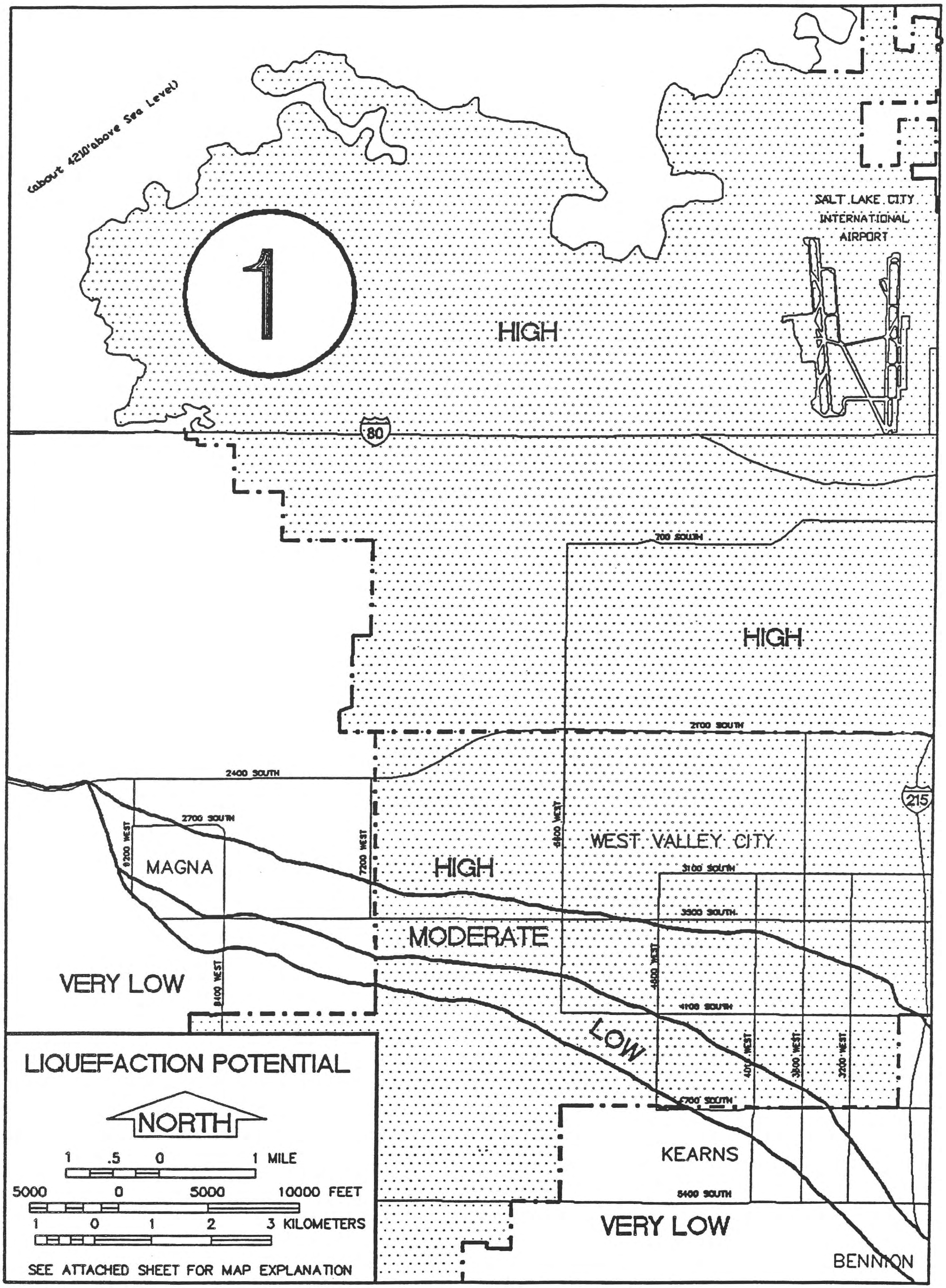
* Disclosure of Potential Hazard to Buyers/Residents is Recommended



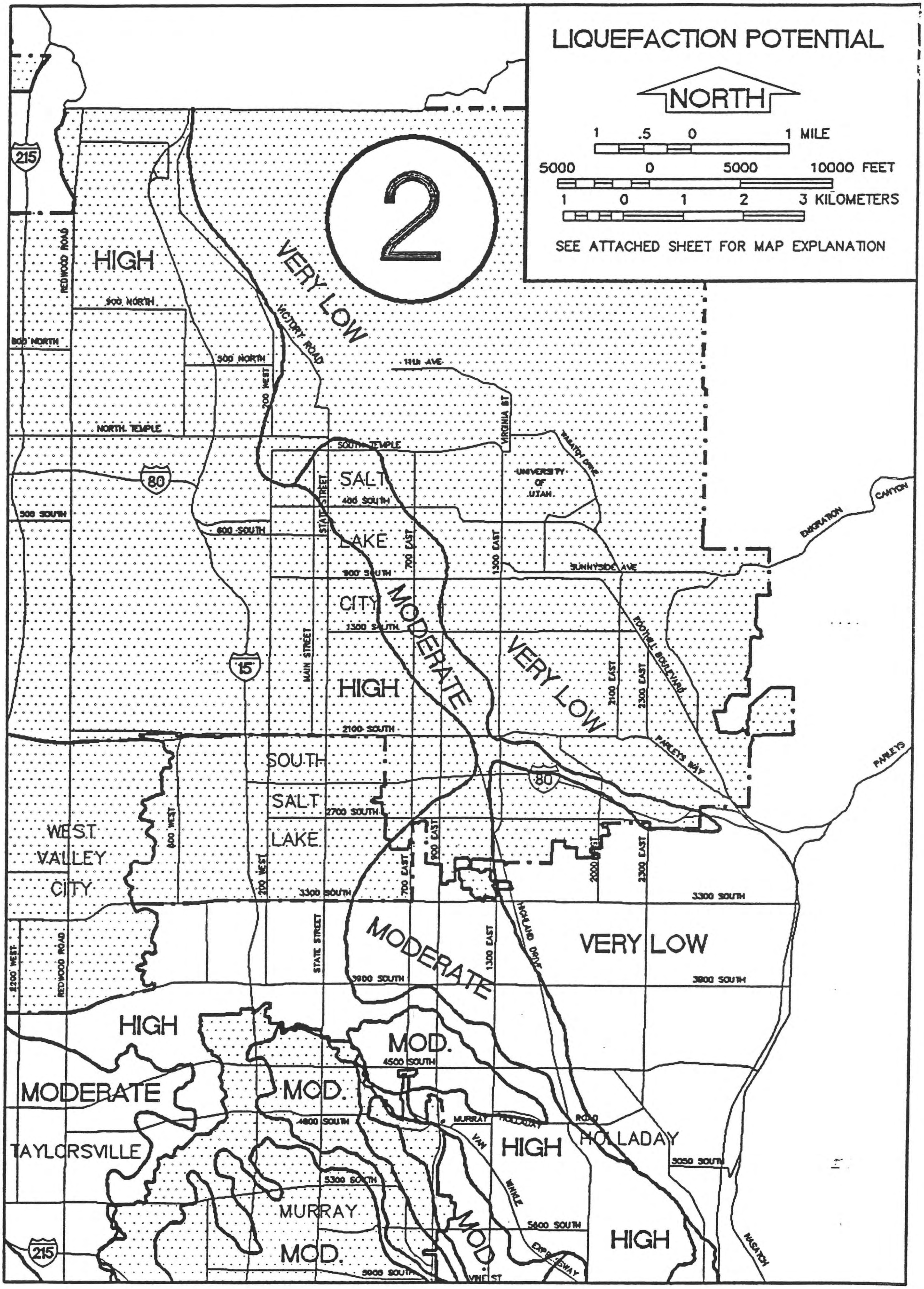
INCORPORATED CITY BOUNDARIES

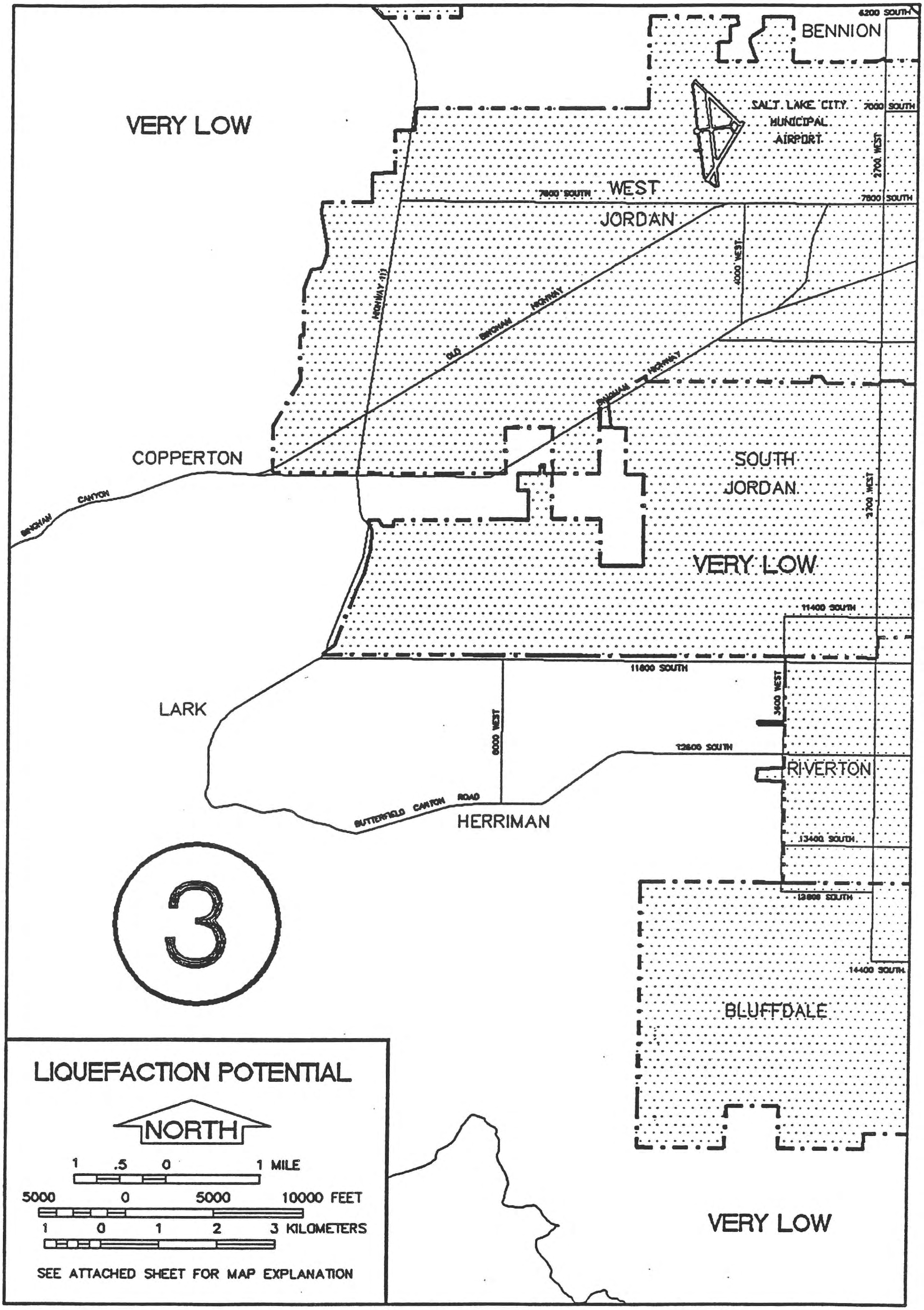
REFERENCE

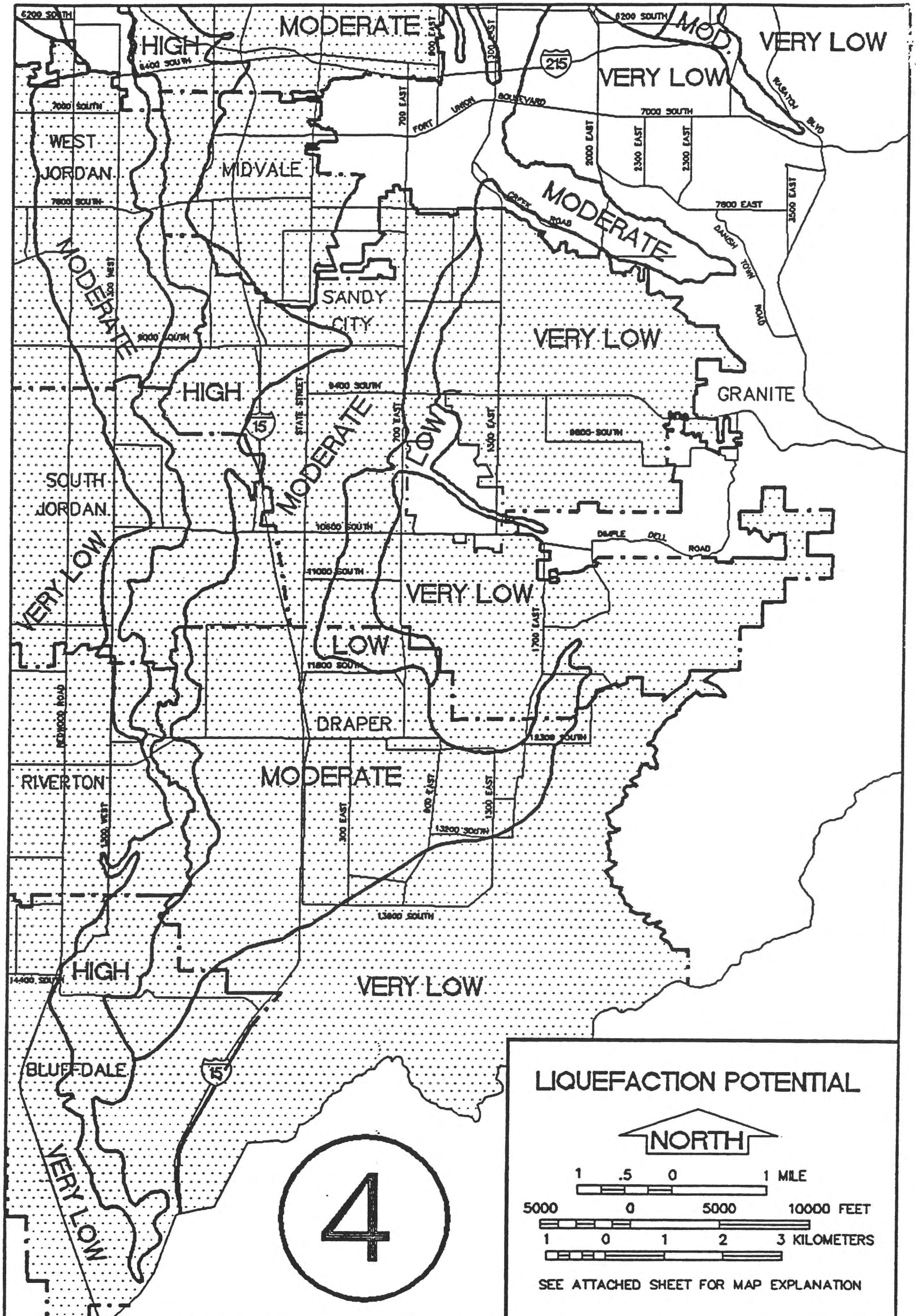
ANDERSON, L.R., KEATON, J.R., SPITZLEY, J.E., and ALLEN, A.C., 1985, Liquefaction potential map for Salt Lake County Utah State University and Dames & Moore, Final Report for U.S. Geological Survey Earthquake Hazards Reduction Program, Contract #14-08-0001-19910, map 1:48,000.



(about 4210' above Sea Level)
1
HIGH
SALT LAKE CITY
INTERNATIONAL
AIRPORT
80
700 SOUTH
HIGH
2700 SOUTH
2400 SOUTH
215
2700 SOUTH
8400 WEST
9200 WEST
MAGNA
7200 WEST
HIGH
WEST VALLEY CITY
3100 SOUTH
3500 SOUTH
MODERATE
4800 WEST
VERY LOW
8400 WEST
4100 SOUTH
LOW
4000 WEST
3600 WEST
3200 WEST
4700 SOUTH
KEARNS
5400 SOUTH
VERY LOW
BENNION
LIQUEFACTION POTENTIAL
NORTH
1 .5 0 1 MILE
5000 0 5000 10000 FEET
1 0 1 2 3 KILOMETERS
SEE ATTACHED SHEET FOR MAP EXPLANATION


LIQUEFACTION POTENTIAL
NORTH
1 .5 0 1 MILE
5000 0 5000 10000 FEET
1 0 1 2 3 KILOMETERS
SEE ATTACHED SHEET FOR MAP EXPLANATION
2
HIGH
VERY LOW
MODERATE
VERY LOW
SALT
LAKE
CITY
HIGH
SOUTH
SALT
LAKE
WEST
VALLEY
CITY
MODERATE
VERY LOW
HIGH
MOD.
MODERATE
MOD.
TAYLORSVILLE
HIGH
HOLLADAY
MURRAY
MOD.
MOD.
HIGH
215
80
15
80
215
REDWOOD ROAD
900 NORTH
800 NORTH
500 NORTH
VICTORY ROAD
700 WEST
11th AVE
VIRGINIA ST
NORTH TEMPLE
SOUTH TEMPLE
WASATCH DRIVE
UNIVERSITY OF UTAH
STATE STREET
400 SOUTH
500 SOUTH
600 SOUTH
800 SOUTH
700 EAST
1300 EAST
SUNNYSIDE AVE
EMIGRATION CANYON
FOOTHILL BOULEVARD
1300 SOUTH
MAIN STREET
2100 EAST
2300 EAST
2100 SOUTH
PARLEYS WAY
PARLEYS
2700 SOUTH
800 WEST
200 WEST
700 EAST
900 EAST
2000 EAST
2300 EAST
3300 SOUTH
3300 SOUTH
2200 WEST
REDWOOD ROAD
STATE STREET
1300 EAST
HIGHLAND DRIVE
3900 SOUTH
3900 SOUTH
4500 SOUTH
4800 SOUTH
MURRAY HOLLADAY ROAD
VAN WINKLE
5050 SOUTH
5300 SOUTH
5600 SOUTH
EXPRESSWAY
NASATCH
5900 SOUTH
VINE ST


VERY LOW
BENNION
SALT LAKE CITY MUNICIPAL AIRPORT
6200 SOUTH
7000 SOUTH
7800 SOUTH
2700 WEST
WEST JORDAN
4000 WEST
HIGHWAY 111
OLD BINGHAM HIGHWAY
BINGHAM HIGHWAY
COPPERTON
BINGHAM CANYON
SOUTH JORDAN
VERY LOW
11400 SOUTH
11800 SOUTH
LARK
6000 WEST
3400 WEST
12600 SOUTH
RIVERTON
BUTTERFIELD CANYON ROAD
HERRIMAN
13400 SOUTH
13800 SOUTH
14400 SOUTH
3
BLUFFDALE
VERY LOW
LIQUEFACTION POTENTIAL
NORTH
1 .5 0 1 MILE
5000 0 5000 10000 FEET
1 0 1 2 3 KILOMETERS
SEE ATTACHED SHEET FOR MAP EXPLANATION


MODERATE
HIGH
6200 SOUTH
6400 SOUTH
7000 SOUTH
WEST JORDAN
MIDVALE
7800 SOUTH
215
VERY LOW
MOD.
VERY LOW
FORT UNION BOULEVARD
7000 SOUTH
700 EAST
900 EAST
1300 EAST
2000 EAST
2300 EAST
WASATCH BLVD
MODERATE
CREEK ROAD
7800 EAST
DANISH TOWN ROAD
3500 EAST
MODERATE
1300 WEST
SANDY CITY
9000 SOUTH
VERY LOW
GRANITE
HIGH
9400 SOUTH
15
STATE STREET
MODERATE
700 EAST
LOW
1300 EAST
9800 SOUTH
SOUTH JORDAN
10600 SOUTH
DIMPLE DELL ROAD
VERY LOW
11000 SOUTH
VERY LOW
LOW
11800 SOUTH
1700 EAST
REDWOOD ROAD
DRAPER
12300 SOUTH
RIVERTON
MODERATE
1300 WEST
300 EAST
900 EAST
1300 EAST
13200 SOUTH
13800 SOUTH
HIGH
14400 SOUTH
VERY LOW
BLUFFDALE
15
VERY LOW
4
LIQUEFACTION POTENTIAL
NORTH
1 .5 0 1 MILE
5000 0 5000 10000 FEET
1 0 1 2 3 KILOMETERS
SEE ATTACHED SHEET FOR MAP EXPLANATION

Date, location, MM intensity, and Richter magnitude of the largest earthquakes in the Utah region[1], 1850-June, 1987 (modified from Arabasz and others, 1987)

Date	Location	Maximum MMI	Magnitude[2] M_L	Reference
Nov 10,1884	Northeastern Utah	VIII	6-6.3	3
Dec 5,1887	Kanab	VII	5.5-5.7	4,5,6
Aug 1,1900	Eureka District	VII	5.5-5.7	3,4
Nov 13,1901	Beaver/Richfield	X	6.7-7.0	3,4,7
Nov 17,1902	Pine Valley	VIII	6.1-6.3	3,4,7
Oct 5,1909	Hansel Valley	IX	6.3-6.7	3,4,5,8
May 22,1910	Salt Lake City	VIII	5.5-5.7	3,4,5,7
May 13,1914	Ogden	VII	5.5-5.7	3,4,5,7,8
Oct 5,1915	Ibapah (instrumental location)	VII	4.3-5.5	3,4,5,7
Sep 29/Oct 1 1921	Elsinore	VIII	6.1-6.3	3,4,7,8
Mar 12,1934	Kosmo, Hansel Valley (instrumental location)	IX	6.6-7.0	3,4,5,9
Nov 18,1937	Lucin	VI	5.4	3,9
Jul 21,1959	UT-AZ border near Kanab (instrumental location)	VI	5.5-5.8	4,5,6
Aug 30,1962	Richmond, Cache Valley (instrumental location)	VII	5.7	4,5,6,8

Date	Location	Maximum MMI	Magnitude[2] M_L	Reference
Aug 16,1966	Nevada-SW Utah (instrumental location)	VI	5.6	6,10
Mar 27,1975	Pocatello Valley, ID (instrumental location)	VIII	6.0	6,10
Aug 14,1988	San Rafael Swell (instrumental location)	VI	5.3	11,12
Jan 29,1989	Salina (instrumental location)	VI[14]	5.4	13

Notes:

1 Earthquakes (aftershocks excluded) of Richter magnitude (M_L) 5.3 or greater and/or Modified Mercalli intensity (MMI) of VII or greater in the Utah region (Utah and areas slightly outside Utah's borders).

2 Earthquake magnitudes from 1884-1921 were calculated from maximum MMI intensity due to lack of instrumental data.

3 Williams and Tapper, 1953

4 Cook and Smith, 1967

5 Coffman and von Hake, 1973

6 U.S. Dept Commerce

7 Townley and Allen, 1939

8 Hays and others, 1974

9 Jones, 1975

10 Arabasz and McKee, 1979

11 Case, 1988

12 Nava and others, 1988

13 University of Utah Seismograph Stations, 1989.

14 Preliminary MMI value (John Mimsch, National Earthquake Information Center, personal commun., 3 May, 1989).

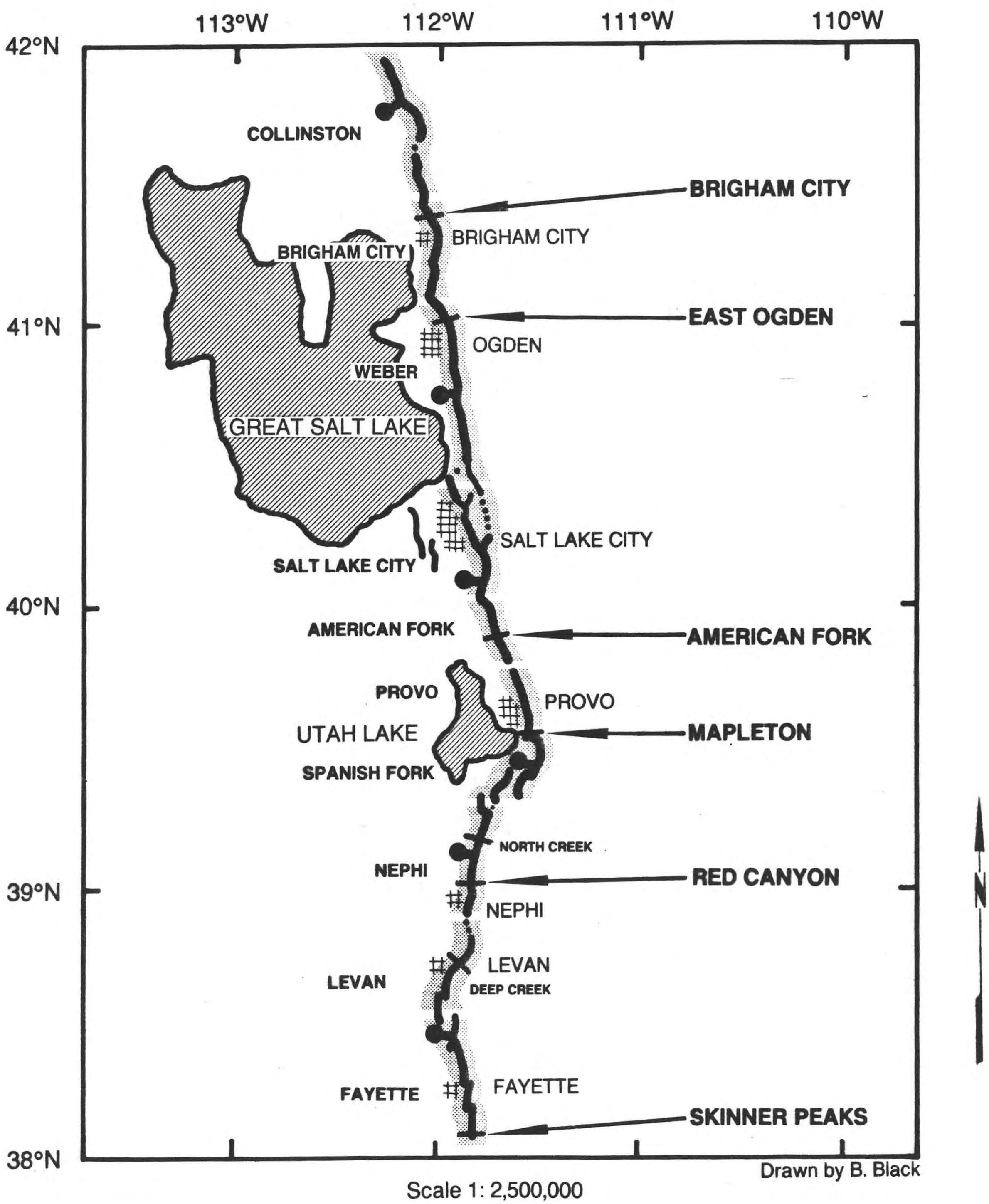
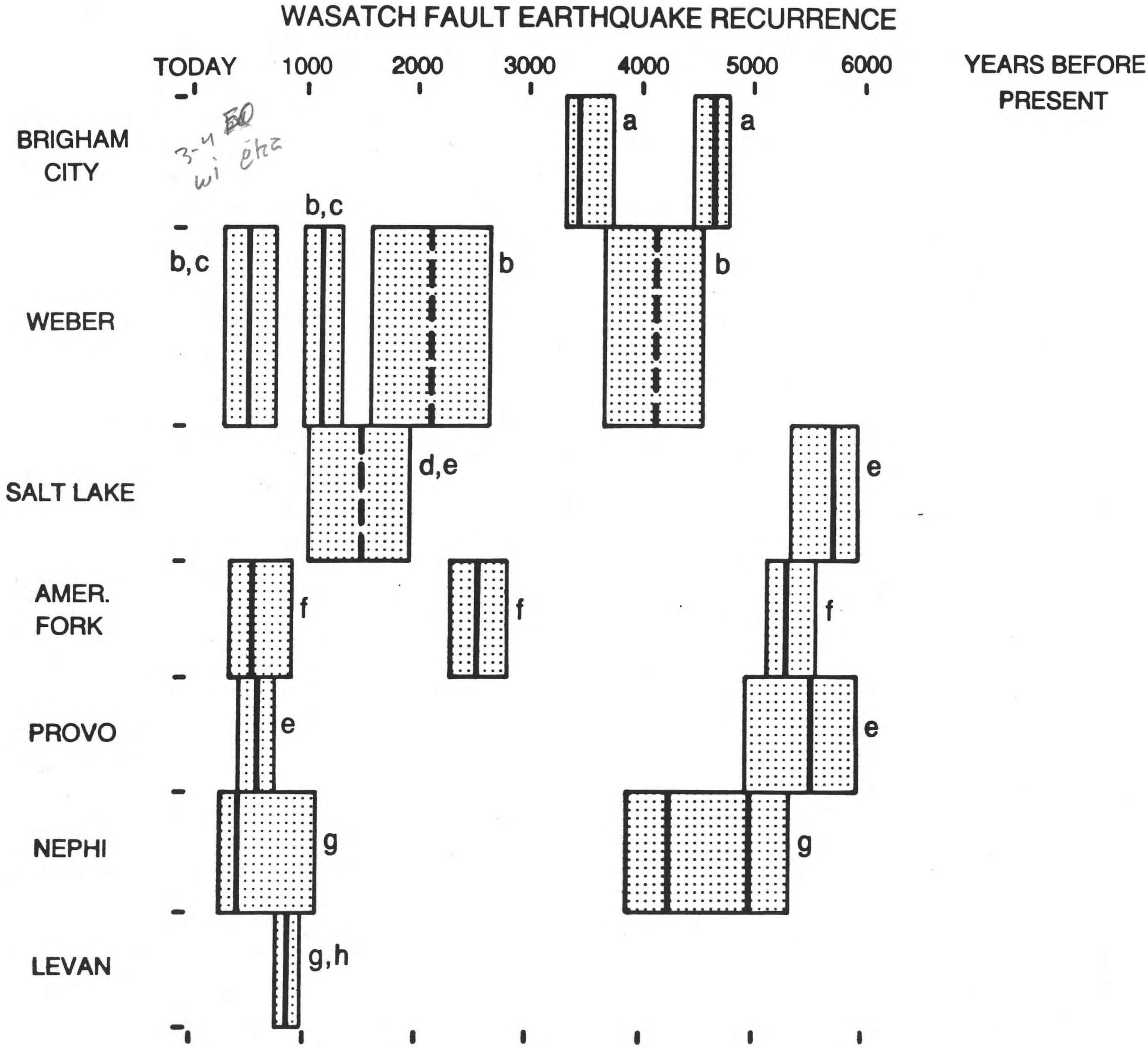


Figure 1. Location of 1986-1987 trench studies.



Sources of data:

- a. S. Personius in Machette et al., in prep.
- b. A. Nelson in Machette et al., in prep.
- c. Swan et al. (1980)
- d. Lund and Schwartz (1986)
- e. Schwartz et al. (1988)
- f. Machette et al. (1987)
- g. Schwartz and Coppersmith (1984)
- h. M. Jackson, M.A. Thesis, U. Colorado, in prep.

CRI = 310-350 yrs.
6 m displacement max

Figure 2. Space-time plot of large magnitude earthquakes along the Wasatch fault zone during the past 6000 years. Heavy solid line indicates best estimate of timing; heavy dashed line is approximation. Stippled boxes reflect uncertainties in timing based on age dates and stratigraphic relationships (compiled by David Schwartz, U.S. Geological Survey, Menlo Park, CA.).

EARTHQUAKE TABLE

Date, location, MM intensity, and Richter magnitude of the LARGEST EARTHQUAKES IN THE UTAH REGION[1], 1850-June, 1987 (modified from Arabasz and others, 1987)

Date	Location (Lat.N, Long.W)	Maximum MMI	Magnitude[2] M_L	Reference
Nov 10,1884	Northeastern Utah (42 0, 111 16)	VIII	6- 6.3	3
Dec 5,1887	Kanab (37 2.8, 112 31.3)	VII	5.5- 5.7	4,5,6
Aug 1,1900	Eureka District (39 57.2, 112 6.8)	VII	5.5- 5.7	3,4
Nov 13,1901	Beaver/Richfield (38 46.2, 112 5.0)	X	6.7- 7.0	3,4,7
Nov 17,1902	Pine Valley (37 23.6, 113 31.2)	VIII	6.1- 6.3	3,4,7
Oct 5,1909 3,4,5,8	Hansel Valley (41 46.0, 112 40.0)	IX	6.3- 6.7	
May 22,1910 3,4,5,7	Salt Lake City (40 44.9, 111 51)	VIII	5.5- 5.7	
May 13,1914	Ogden (41 13.5, 111 57.6)	VII	5.5- 5.7	3,4,5,7,8
Oct 5,1915 3,4,5,7	Ibapah (40 6.0, 114 0)	VII	4.3- 5.5	
Sep 29/Oct 1 3,4,7,8 1921	Elsinore (38 41, 112 9)	VIII	6.1- 6.3	
Mar 12,1934 3,4,5,9	Kosmo, Hansel Valley (41 30.0, 112 30.0)	IX	6.6- 7.0	
Nov 18,1937	Lucin (42 6.0, 113 54.0)	VI	5.4	3,9
Jul 21,1959	UT-AZ border near Kanab (37 0, 112 30)	VI	5.5- 5.8	4,5,6

Date	Location	Maximum MMI	Magnitude[2] M_L	Reference
Aug 30,1962	Richmond, Cache Valley (42 2.4, 111 44.4)	VII	5.7	4,5,6,8
Aug 16,1966	Nevada-SW Utah (37 27.6, 114 9)	VI	5.6	6,10
Mar 27,1975	Pocatello Valley, ID (42 6, 112 31.2)	VIII	6.0	6,10
Aug 14,1988	San Rafael Swell (instrumental location)	VI	5.3	11,12
Jan 29,1989	Salina (instrumental location)	VI[14]	5.4	13

Notes:

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3 Williams and Tapper, 1953

4 Cook and Smith, 1967

5 Coffman and von Hake, 1973

6 U.S. Dept Commerce

7 Townley and Allen, 1939

8 Hays and others, 1974

9 Jones, 1975

10 Arabasz and McKee, 1979

11 Case, 1988

12 Nava and others, 1988

13 University of Utah Seismograph Stations, 1989.

14 Preliminary MMI value (John Mimsch, National Earthquake Information Center, personal communication, 3 May, 1989).

Arabasz, W. J., and McKee, M. E., 1979, Utah earthquake catalog 1850 - June 1962, in, Arabasz, W. J., Smith, R. B., and Richins, W. D., editors, Earthquake studies in Utah 1850 to 1978: University of Utah Seismograph Stations, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah, p. 119-251.

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EARTHQUAKE TABLE

Date, location, MM intensity, and Richter magnitude of the LARGEST EARTHQUAKES IN THE UTAH REGION[1], 1850-June, 1987 (modified from Arabasz and others, 1987)

Date	Location (Lat.N, Long.W)	Maximum MMI	Magnitude[2] M_L	Reference
Nov 10,1884	Northeastern Utah (42 0, 111 16)	VIII	6- 6.3	3
Dec 5,1887	Kanab (37 2.8, 112 31.3)	VII	5.5- 5.7	4,5,6
Aug 1,1900	Eureka District (39 57.2, 112 6.8)	VII	5.5- 5.7	3,4
Nov 13,1901	Beaver/Richfield (38 46.2, 112 5.0)	X	6.7- 7.0	3,4,7
Nov 17,1902	Pine Valley (37 23.6, 113 31.2)	VIII	6.1- 6.3	3,4,7
Oct 5,1909 3,4,5,8	Hansel Valley (41 46.0, 112 40.0)	IX	6.3- 6.7	
May 22,1910 3,4,5,7	Salt Lake City (40 44.9, 111 51)	VIII	5.5- 5.7	
May 13,1914	Ogden (41 13.5, 111 57.6)	VII	5.5- 5.7	3,4,5,7,8
Oct 5,1915 3,4,5,7	Ibapah (40 6.0, 114 0)	VII	4.3- 5.5	
Sep 29/Oct 1 3,4,7,8 1921	Elsinore (38 41, 112 9)	VIII	6.1- 6.3	
Mar 12,1934 3,4,5,9	Kosmo, Hansel Valley (41 30.0, 112 30.0)	IX	6.6- 7.0	
Nov 18,1937	Lucin (42 6.0, 113 54.0)	VI	5.4	3,9
Jul 21,1959	UT-AZ border near Kanab (37 0, 112 30)	VI	5.5- 5.8	4,5,6

Date	Location	Maximum MMI	Magnitude[2] M_L	Reference
Aug 30,1962	Richmond, Cache Valley (42 2.4, 111 44.4)	VII	5.7	4,5,6,8
Aug 16,1966	Nevada-SW Utah (37 27.6, 114 9)	VI	5.6	6,10
Mar 27,1975	Pocatello Valley, ID (42 6, 112 31.2)	VIII	6.0	6,10
Aug 14,1988	San Rafael Swell (instrumental location)	VI	5.3	11,12
Jan 29,1989	Salina (instrumental location)	VI[14]	5.4	13

Notes:

1 Earthquakes (aftershocks excluded) of Richter magnitude (M_L) 5.3 or greater and/or Modified Mercalli intensity (MMI) of VII or greater in the Utah region (Utah and areas slightly outside Utah's borders).

2 Earthquake magnitudes from 1884-1921 were calculated from maximum MMI intensity due to lack of instrumental data.

3 Williams and Tapper, 1953

4 Cook and Smith, 1967

5 Coffman and von Hake, 1973

6 U.S. Dept Commerce

7 Townley and Allen, 1939

8 Hays and others, 1974

9 Jones, 1975

10 Arabasz and McKee, 1979

11 Case, 1988

12 Nava and others, 1988

13 University of Utah Seismograph Stations, 1989.

14 Preliminary MMI value (John Mimsch, National Earthquake Information Center, personal communication, 3 May, 1989).

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