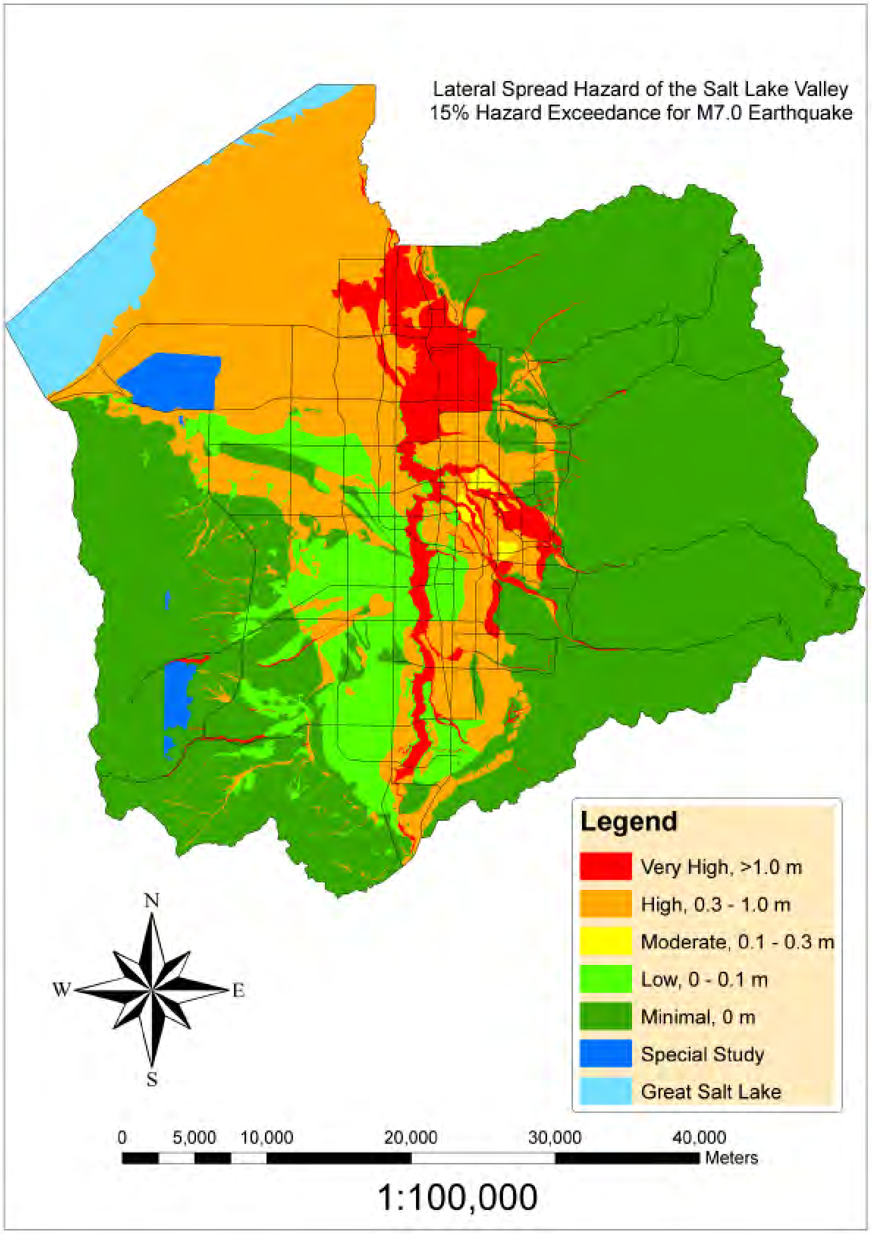
Utah Liquefaction Advisory Group (ULAG)



Progress Report on Liquefaction Working Group

February 15, 2011
Salt Lake City, Utah

Steven F. Bartlett, Ph.D., P.E.
Associate Professor
University of Utah

ULAG Members and Participants

Members

Steve Bartlett, UU CE, Facilitator

Mike Hylland, UGS liaison

Mark Petersen, USGS liaison

Les Youd, BYU CE

Travis Gerber, BYU CE

Kyle Rollins, BYU CE

Loren Anderson, USU CEE

Jim Bay, USU CEE

John Rice, USU CEE

Aurelian Trandafir, UU G&G

Michael Olsen, UCSD

David Simon, SBI

Grant Gummow, UDOT

Aurelian Trandafir, UUGG

Jim Higbee, UDOT

Bill Turner, Earthtec

Ryan Cole, Gerhart-Cole

Utah’s Plan for Developing the Next Generation of Liquefaction Hazard Maps

Objective 1

Develop Probabilistic Liquefaction Hazard Maps for Urban Counties in Utah

Salt Lake County

Utah County

Davis County

Weber County

Cache County

Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps

Objective 1 (cont.)

Types of Maps

(1) Liquefaction Triggering Maps

(2) Lateral Spread Displacement Hazard Maps

(3) Liquefaction-Induced Ground Settlement Maps

Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps

Objective 2

Develop ARC GIS Programs for Implementing Probabilistic Mapping Procedures for Other Regions in U.S.

- **Strong ground motion hazard estimates from PSHA and National Strong Motion Mapping Program**
- **User methods based on ArcGIS algorithms**

Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps

Objective 3

Establish and Populate a Subsurface Geotechnical Database for Public Use

- **Geotechnical Evaluations**
- **Land Use Planning**
- **Research**
- **Potential Partners**
  - **UDOT**
  - **Salt Lake County and Cities**

Utah's Plan for Developing the Next Generation of Liquefaction Hazard Maps

Objective 4

Education and Public Outreach

- User Friendly Maps
- Assist Counties in Implementation and Ordinances
- Outreach Seminars and Website

Status Previous Work

FY 2004

- **Geotechnical Database (N. Salt Lake Co.)**
- **M7.0 lateral spread displacement hazard map (N. Salt Lake Co.) published in *Earthquake Spectra.***

FY 2005

- **Geotechnical Database (S. Salt Lake Co.)**

Status Previous Work

FY 2006

2.1.1 Done

2.1.2 Done

2.1.3 Done

2.1.4 Done

2.1.5 Done

2.1.6 Done

2.1.7 Done

2.1.8 Done

2.1.9 Done

Status Previous Work

FY 2007

2.1.1 Unfunded

2.1.2 Done

2.1.3 Done

2.1.4 Ongoing

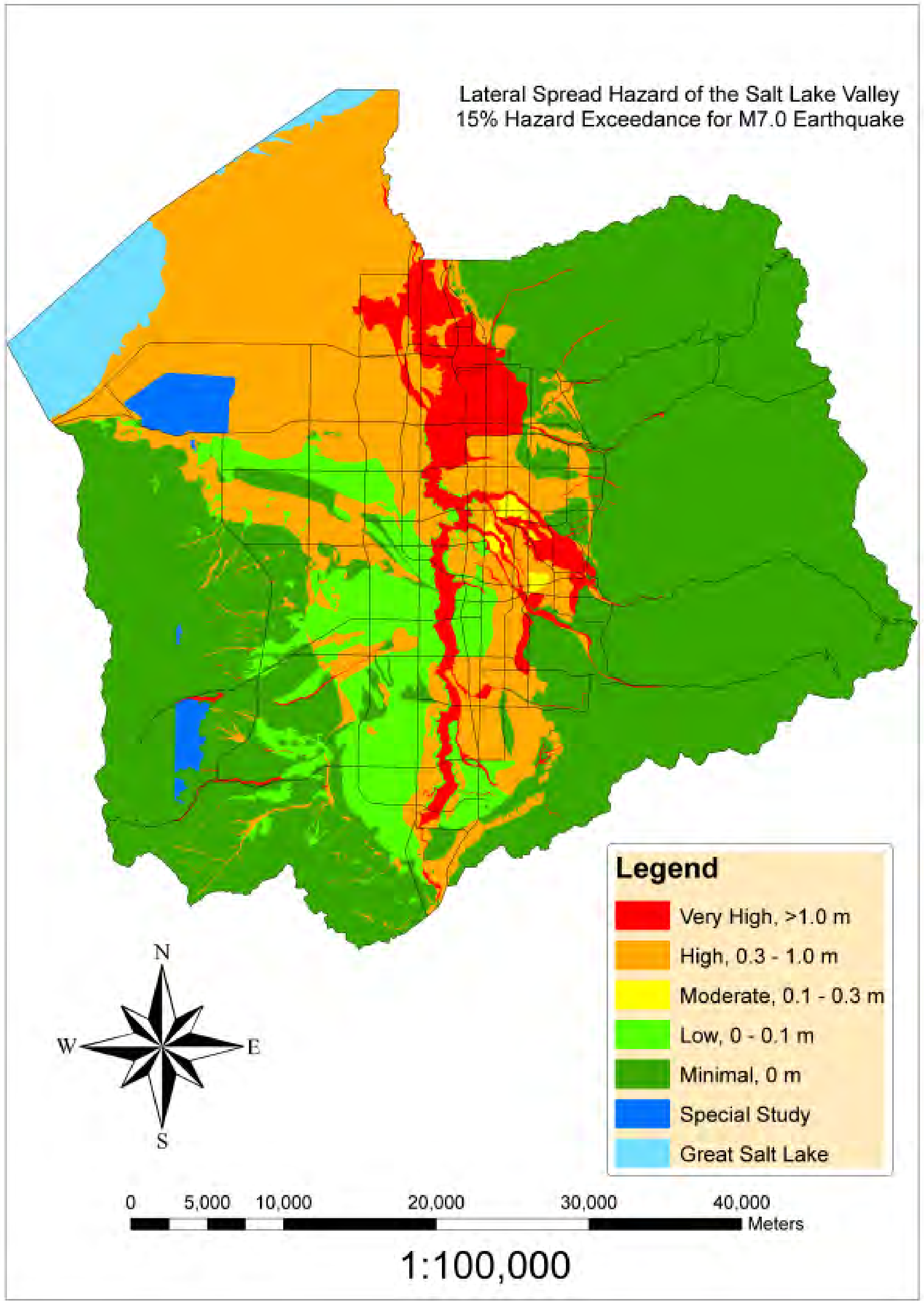
FY 2008 (No Funding)

FY 2009 (No Funding)

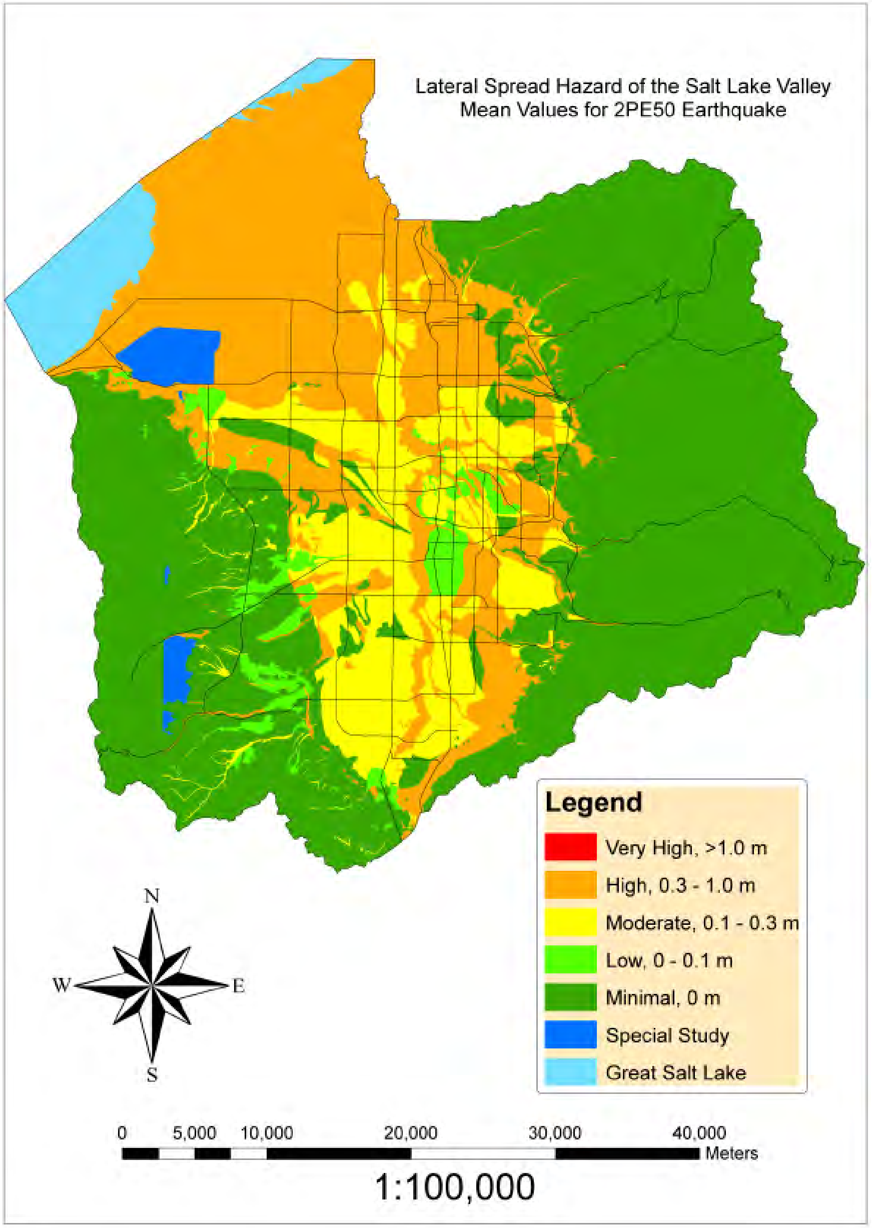
FY 2010 (No Funding)

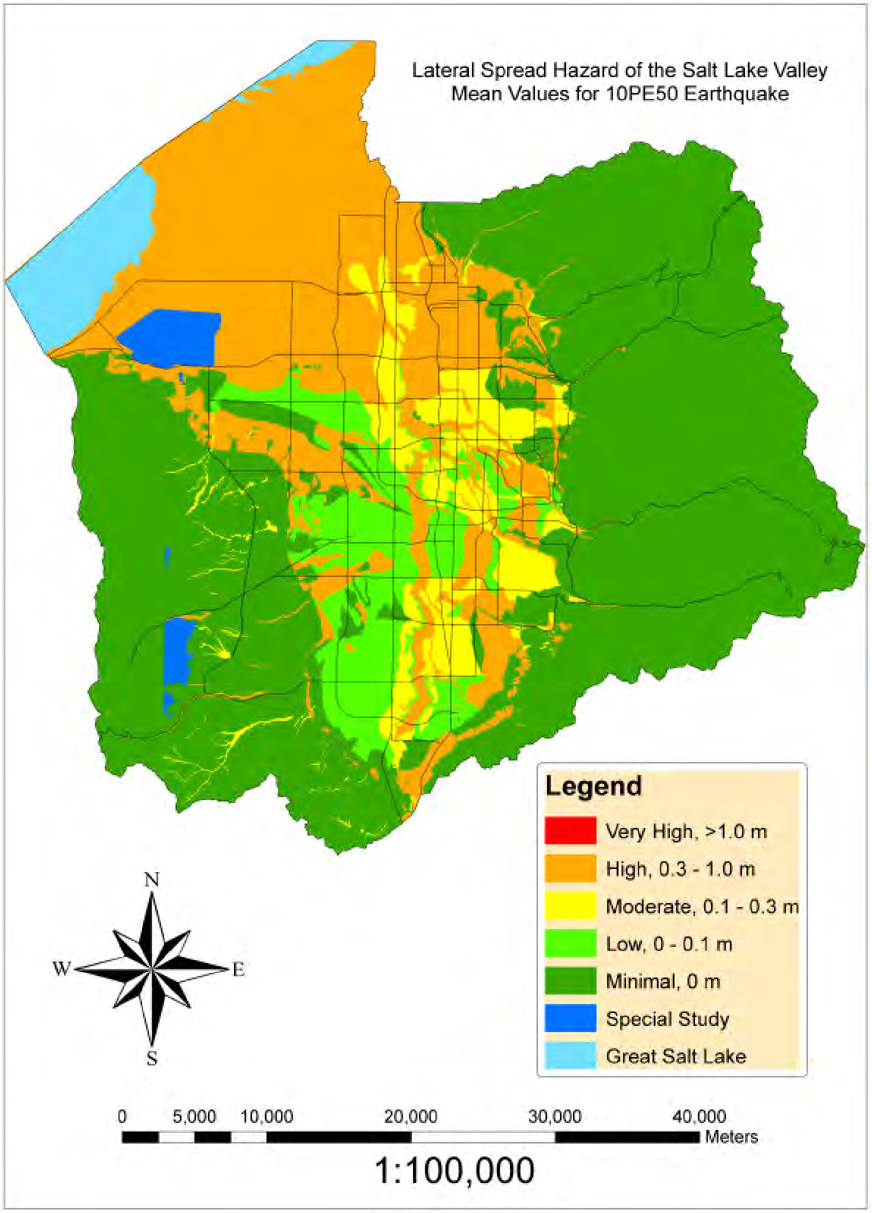
FY 2010 (Partial Funding from WBWCD)

M 7.0 Lateral spread displacement map

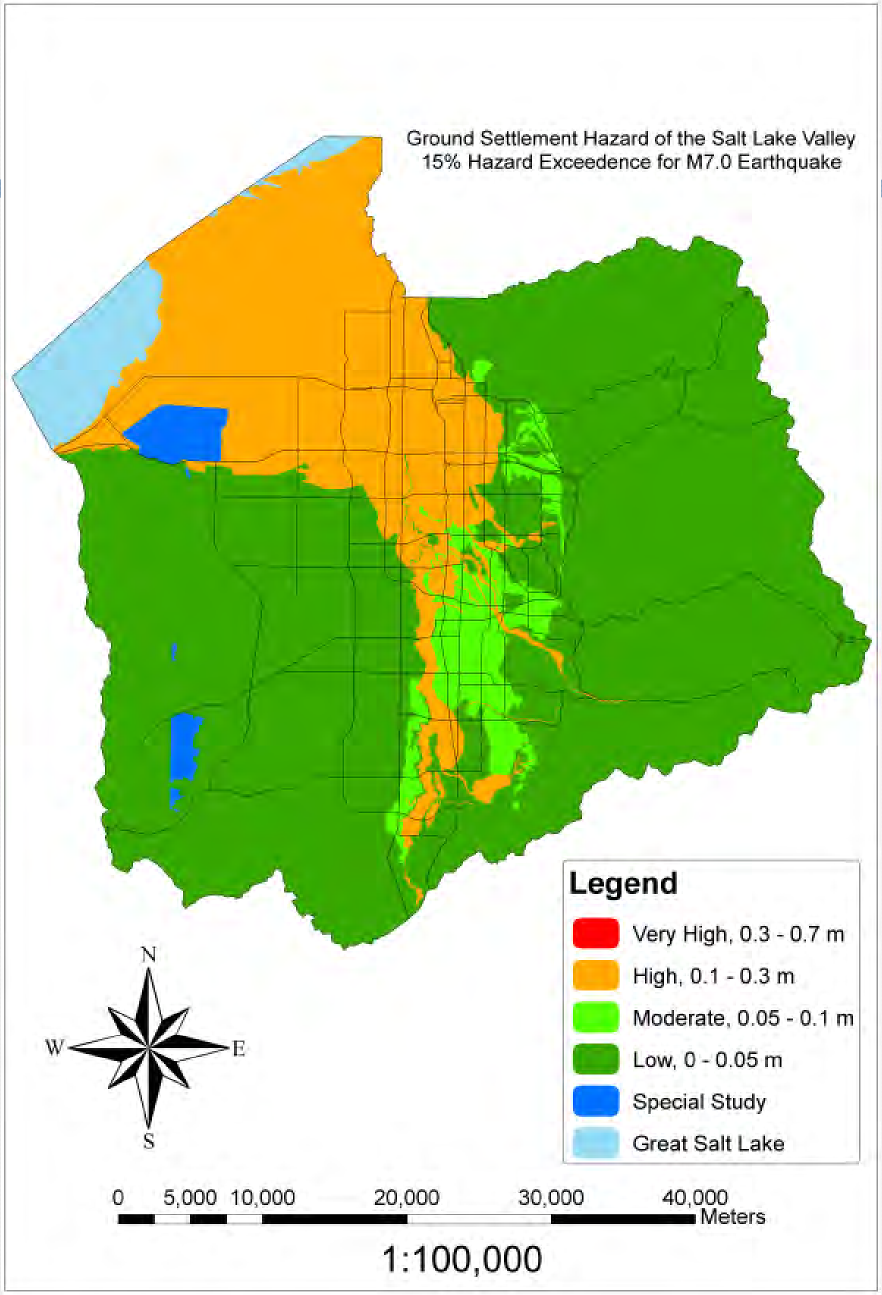


Probabilistic liquefaction potential maps for 2500 and 500-year return periods

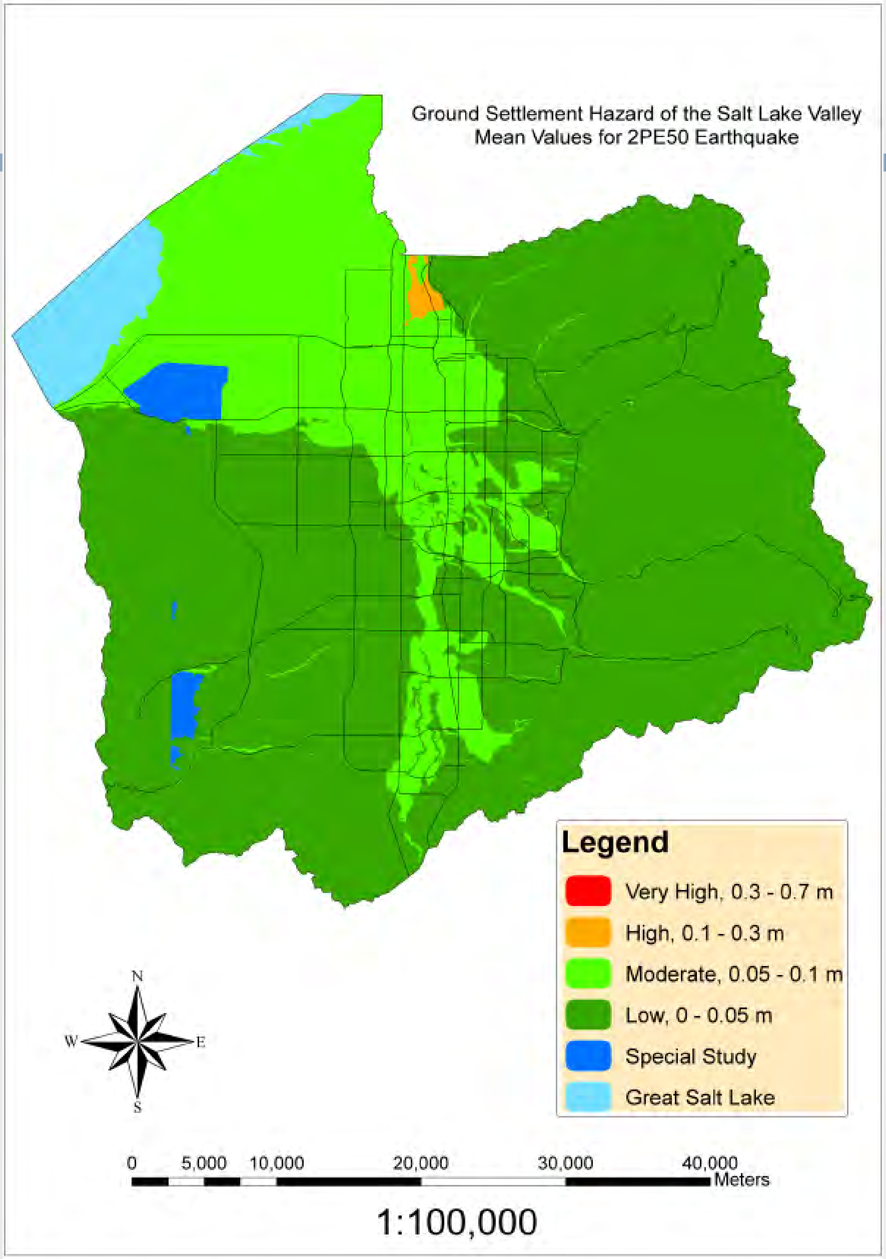


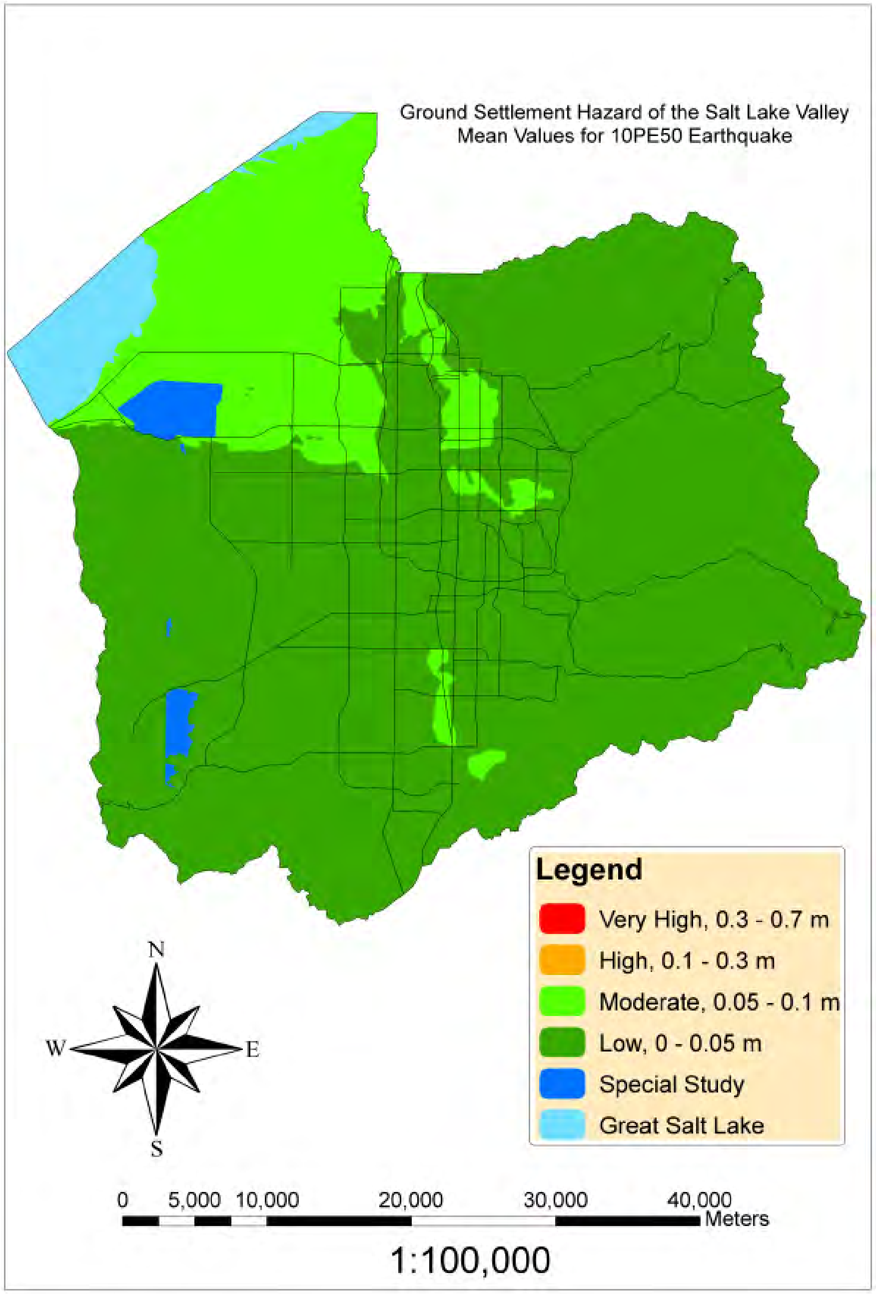


M 7.0 ground settlement map

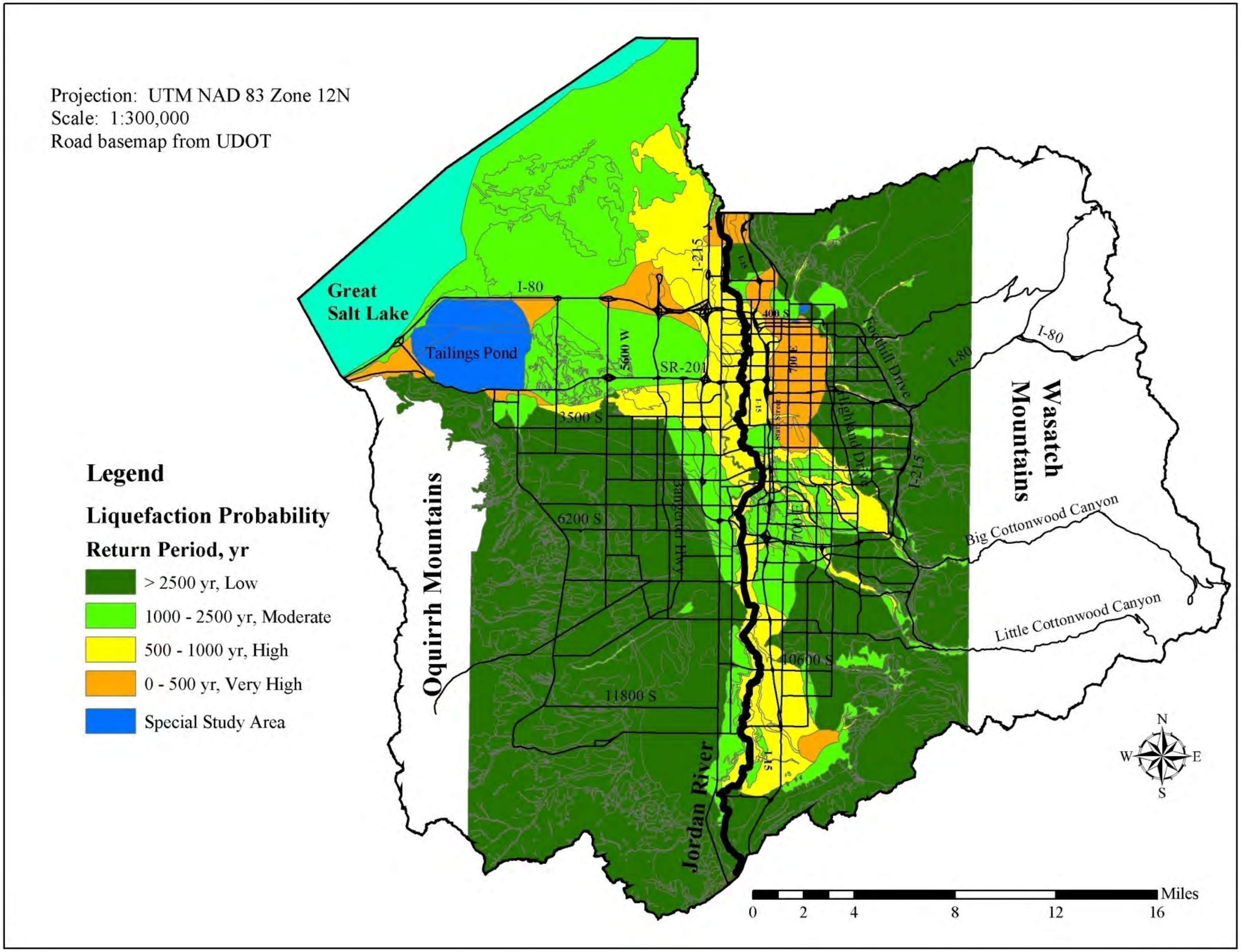


Probabilistic ground settlement maps for 2500 and 500-year return periods





Probabilistic liquefaction potential map – (2002 Input)



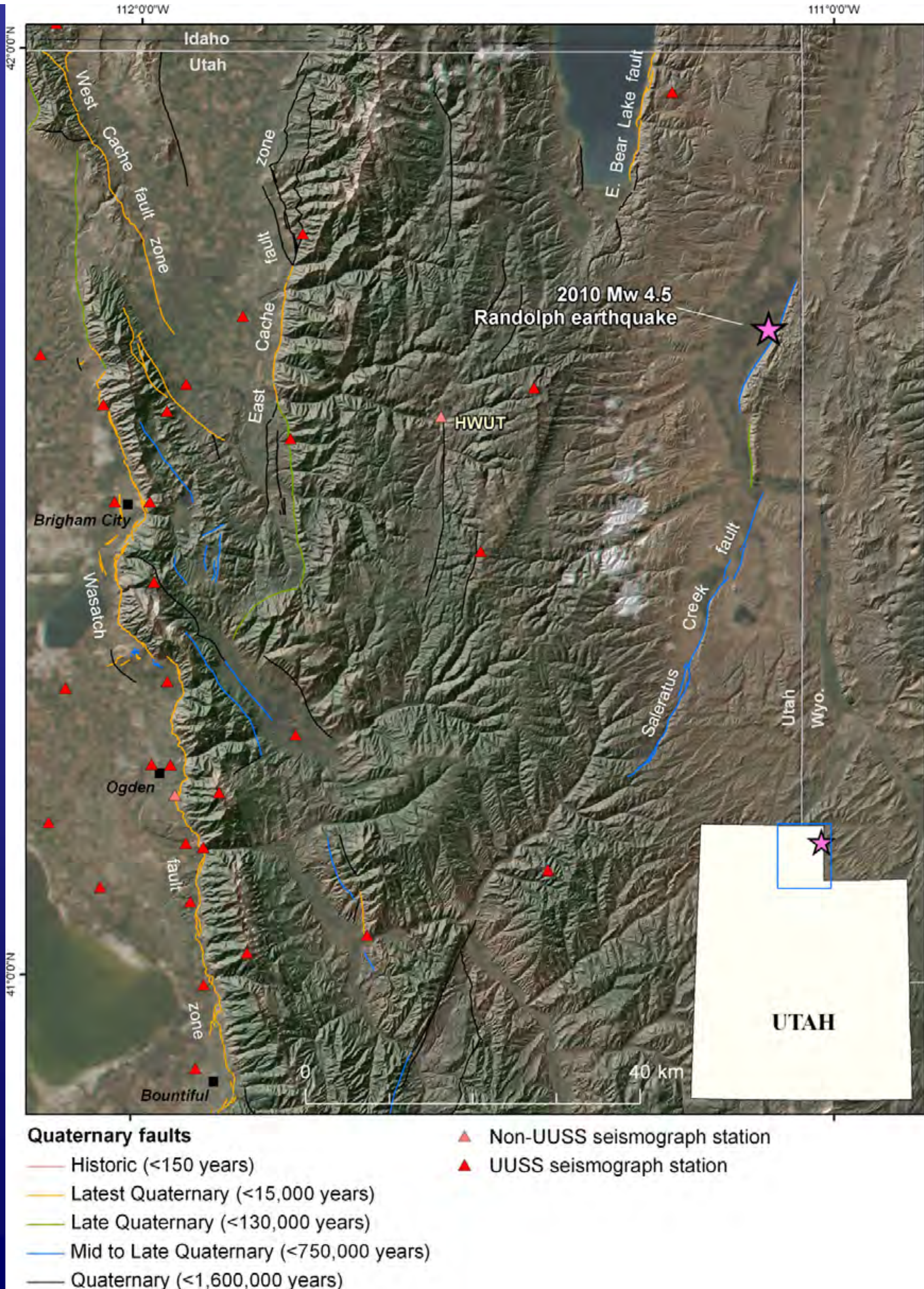
Liquefaction in the April 15, 2010, M 4.5 Randolph, Utah, Earthquake

Chris DuRoss (UGS)

Kristine Pankow (UUSS)

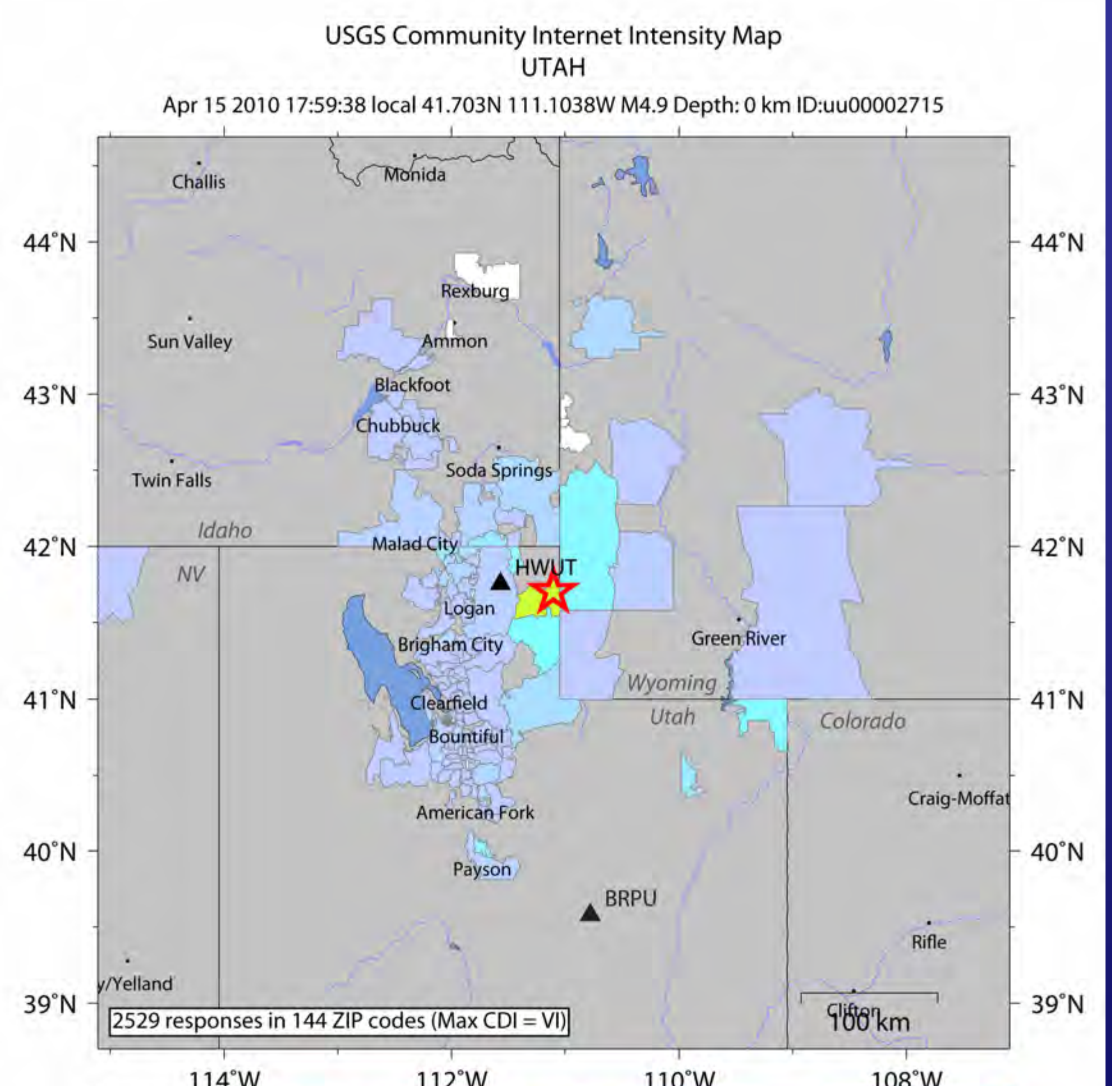
Mw 4.5 Randolph Earthquake

- 9 km northeast of Randolph, near late-Pleistocene-active Crawford Mountains fault
- Normal-faulting earthquake
  - Local magnitude 4.9
  - Moment magnitude 4.5
  - Depth 5 km
- Well recorded by Utah Regional Seismic Network
- Generated liquefaction (sand boils), which is rare for earthquakes of M<5



Mw 4.5 Randolph Earthquake

- Widely felt throughout northern Utah and surrounding states
- >2500 responses in a ~200-250 km radius
- Moderate to strong shaking in the epicentral region
- Only moderate, non-structural damage reported

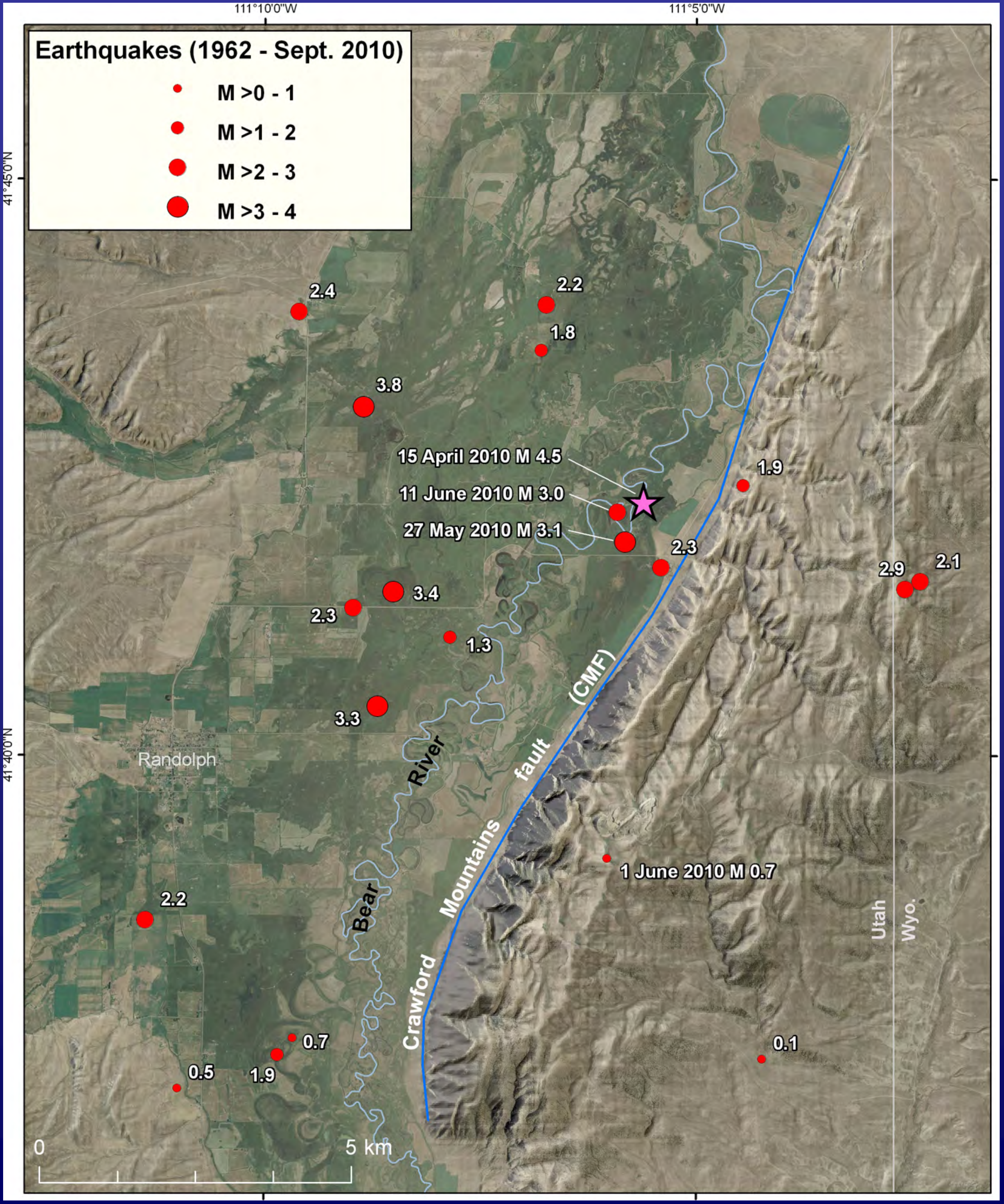


INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	V. Heavy

Processed: Wed Sep 8 21:20:15 2010

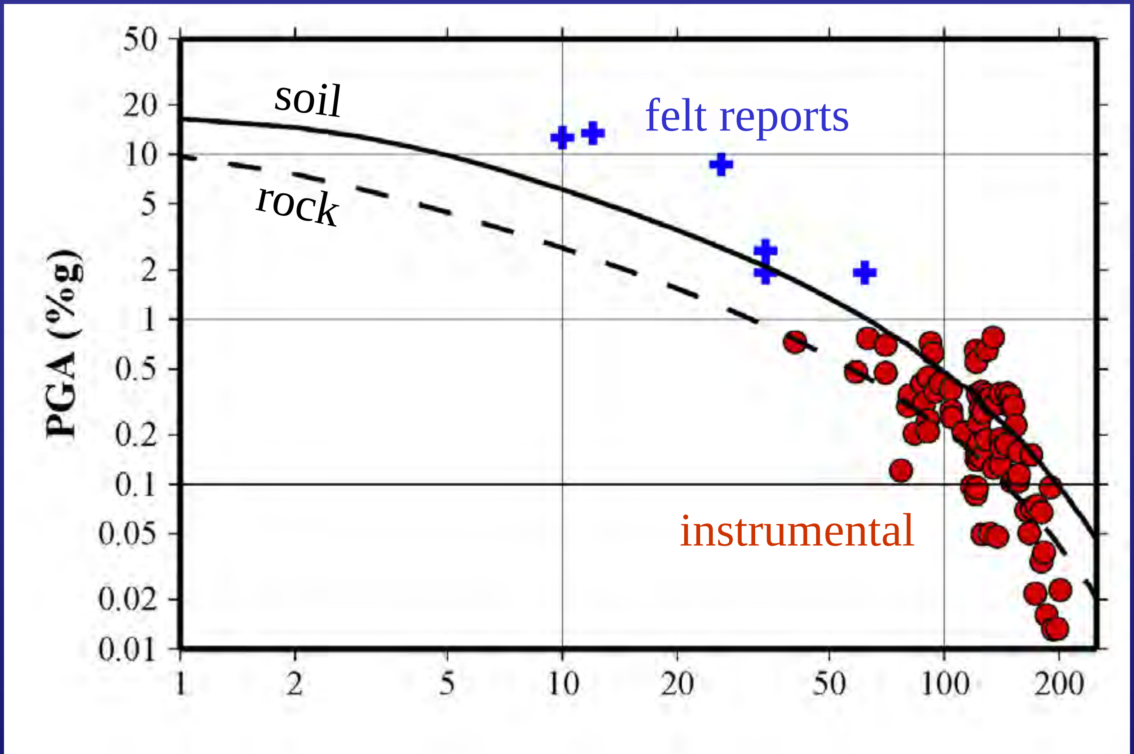
Seismology

- Only three aftershocks (two near mainshock epicenter)
- Focal mechanism:
  - NW strike, 66º E dip
  - NE strike, 35º W dip
- Stress drop: ~50 bars (circular rupture)



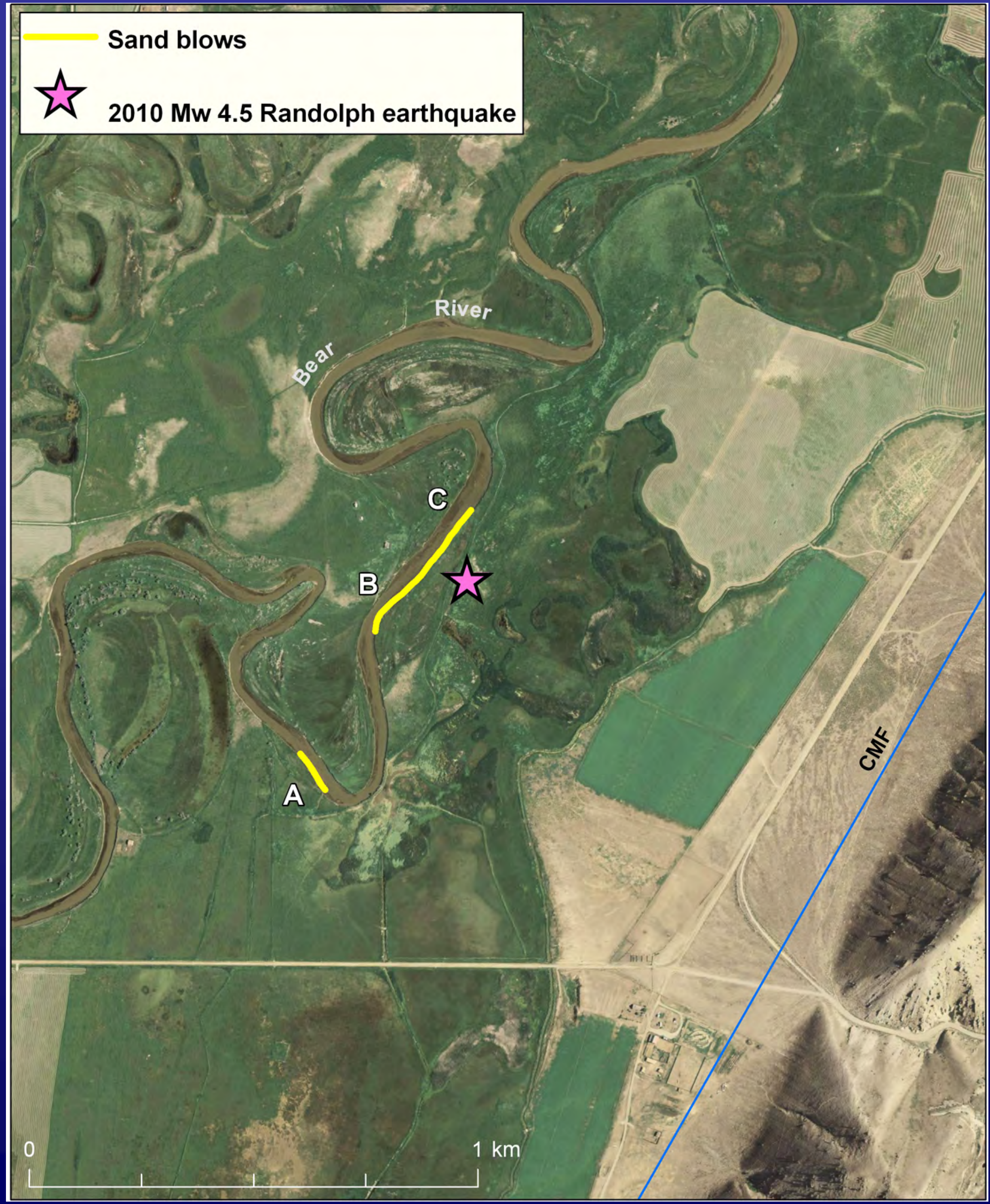
Ground Motion

- Instrumental ground motion (red circles) follow those predicted by Boore and Atkinson (2008)
- Felt intensities (blue crosses; based on CIIM map) are also consistent with empirical ground motions
- PGA at epicenter: likely ~20%g, using Boore and Atkinson (2008) soil regression



Liquefaction

- Sand boils in alluvial sediments
  - <1 km west of the epicenter along a 1-km stretch of the Bear River
  - <1 cm to ~1 m in diameter
  - Consisted of fine to coarse sand deposited on fine-grained, unconsolidated, and partly to fully saturated stream sediments



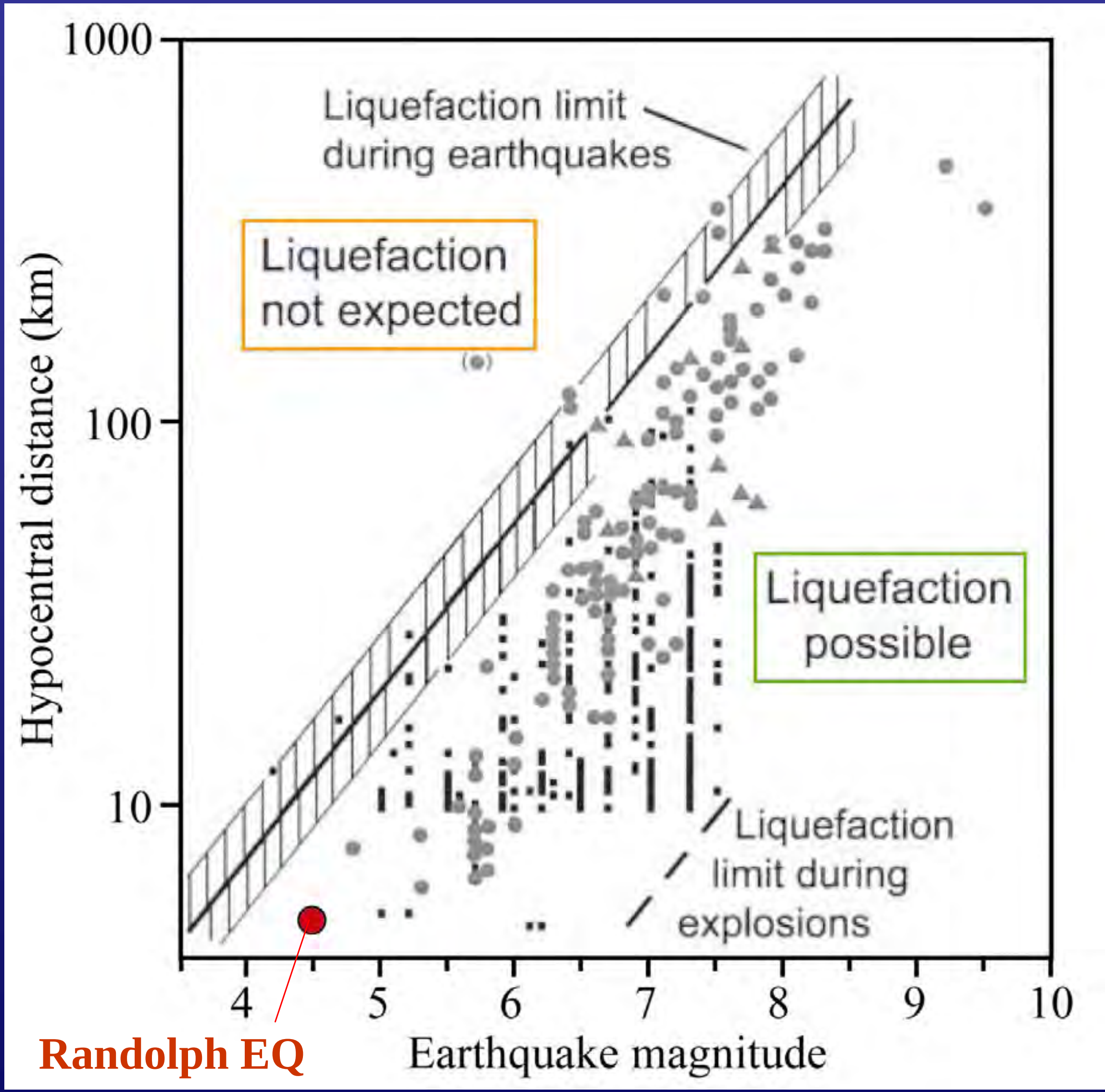

A


B


C

Liquefaction

- April 15 earthquake is one of the smallest earthquakes recorded with modern instrumentation to generate liquefaction
- Helps define lower-magnitude threshold for liquefaction

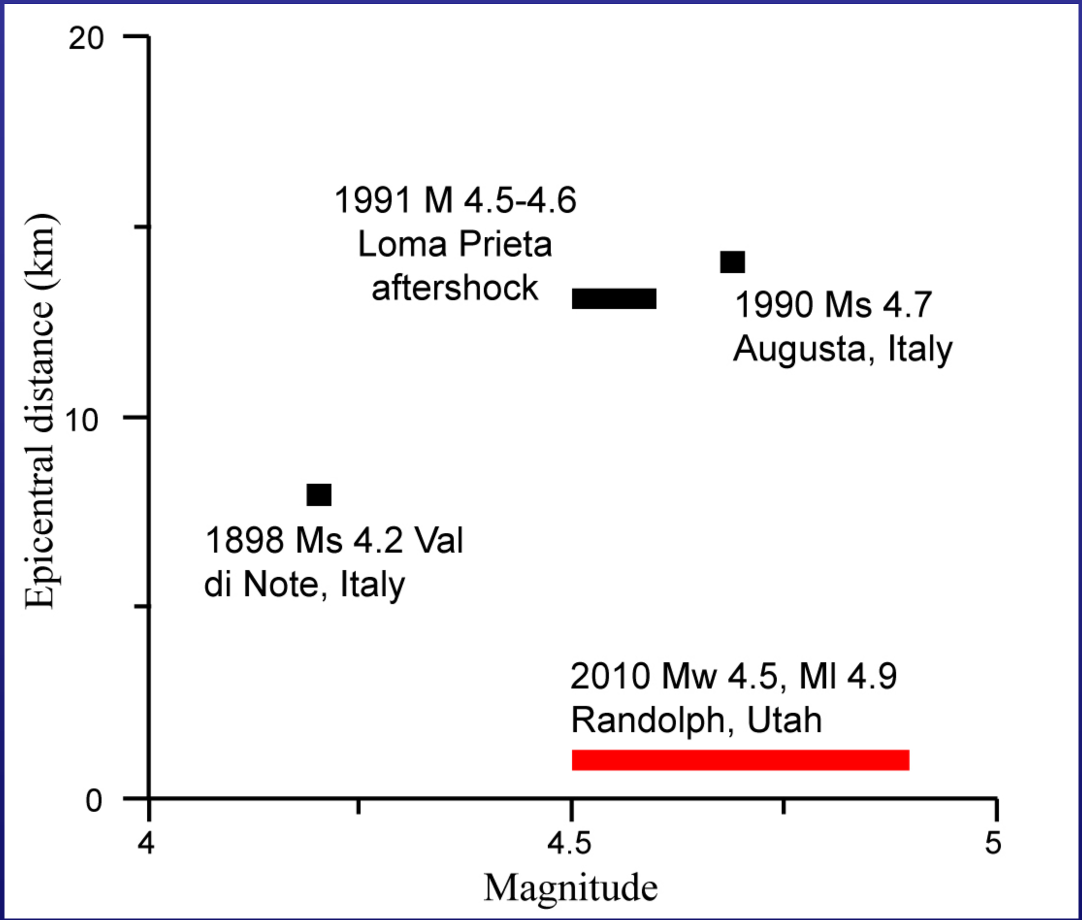


Wang and others (2006)

Liquefaction

- Earthquakes of M <5 that induced liquefaction:
  - 1898 Ms 4.2 Val di Noto, Italy (poorly documented; Galli, 2000)
  - 1990 Ms 4.7 Augusta, Italy earthquake (Galli, 2000)
  - 1991 M 4.5-4.6 aftershock to the Loma Prieta EQ (Sims and Garvin, 1995)

- In Utah?
  - 1992 M 5.8 St. George
  - 1934 M 6.6 Hansel Valley



Conclusions

- The Mw 4.5 Randolph earthquake is possibly the smallest earthquake recorded with modern instrumentation to generate liquefaction in undisturbed sediment
- We attribute the occurrence of liquefaction to highly susceptible sediments in close proximity to the epicenter
- The shallow depth of the mainshock (5 km) probably contributed to liquefaction production and the paucity of aftershocks
- Felt information and recorded ground motions are consistent with empirical ground motion relations; the main shock stress drop was ~50 bars.
- The Randolph earthquake helps refine the lower magnitude and ground-shaking limit for liquefaction, which is important for geotechnical engineering applications in areas underlain by highly susceptible soils and for interpretation of paleoliquefaction features in regions lacking fault evidence of paleoearthquakes