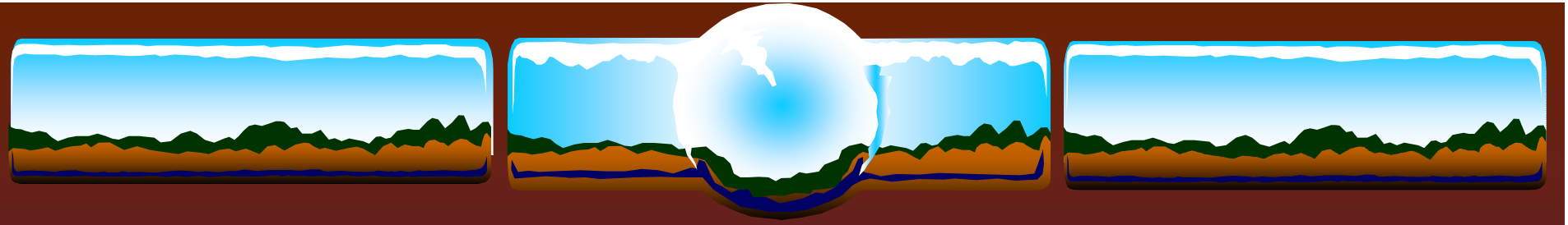
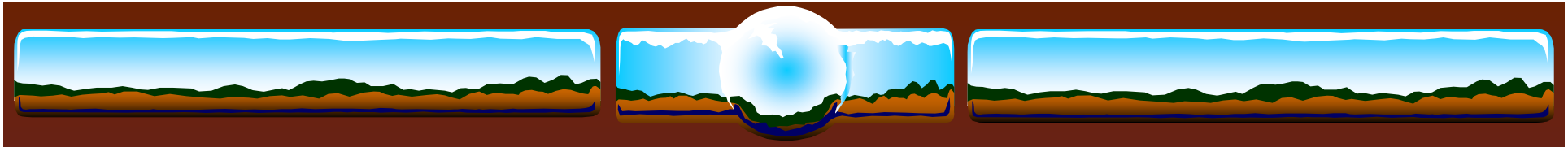


Lateral Spreading Hazard Mapping of Northern Salt Lake County for a Magnitude 7.0 Scenario Earthquake

Michael Olsen

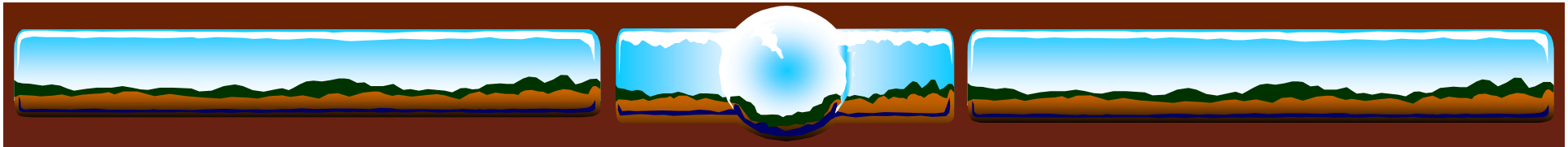
Steven Bartlett

Feb. 16, 2006



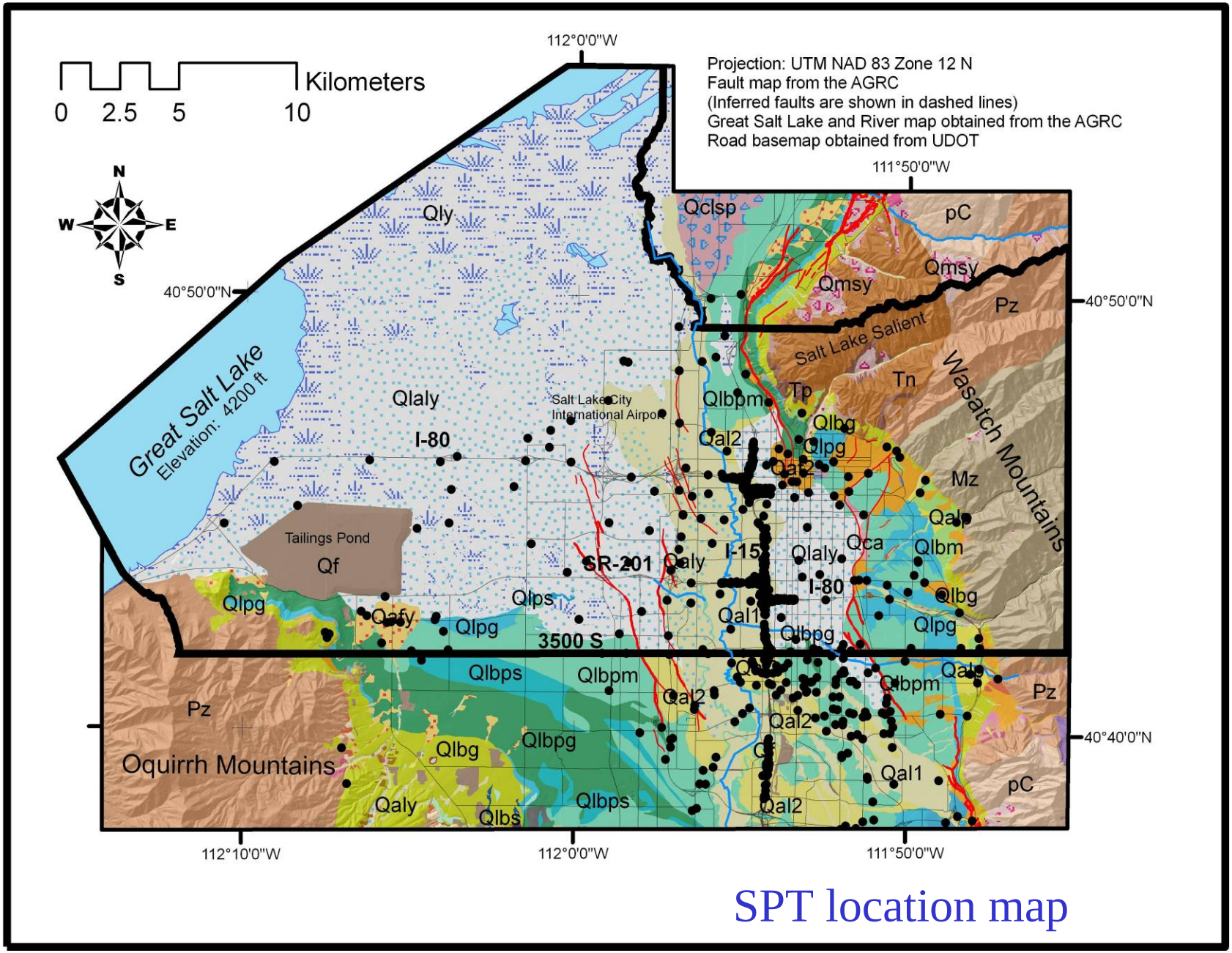
Map production

- Data collection efforts
- Visual Basic for Applications routines
- Analysis and map creation

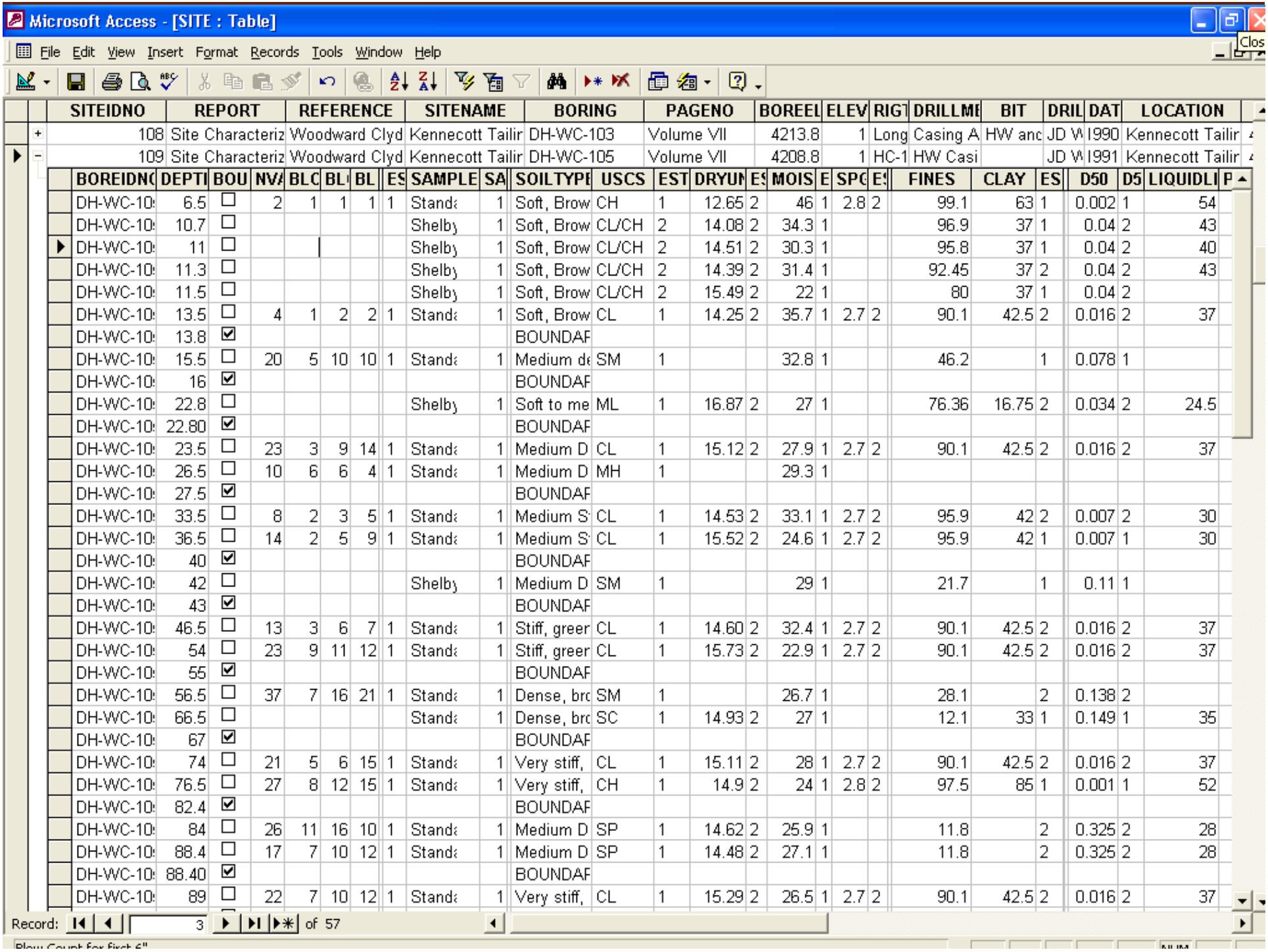


Subsurface data collection

- Standard Penetration Testing (SPT)
- Cone Penetrometer Testing (CPT)
- Shear Wave Velocity Testing (VS)



SPT location map


Microsoft Access - [SITE : Table]
File Edit View Insert Format Records Tools Window Help
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108 Site Characteriz Woodward Clyd Kennecott Tailir DH-WC-103 Volume VII 4213.8 1 Long Casing A HW anc JD W 1990 Kennecott Tailir
109 Site Characteriz Woodward Clyd Kennecott Tailir DH-WC-105 Volume VII 4208.8 1 HC-1 HW Casi JD W 1991 Kennecott Tailir
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DH-WC-10 11 Shelby 1 Soft, Brow CL/CH 2 14.51 2 30.3 1 95.8 37 1 0.04 2 40
DH-WC-10 11.3 Shelby 1 Soft, Brow CL/CH 2 14.39 2 31.4 1 92.45 37 2 0.04 2 43
DH-WC-10 11.5 Shelby 1 Soft, Brow CL/CH 2 15.49 2 22 1 80 37 1 0.04 2
DH-WC-10 13.5 4 1 2 2 1 Stand 1 Soft, Brow CL 1 14.25 2 35.7 1 2.7 2 90.1 42.5 2 0.016 2 37
DH-WC-10 13.8 BOUNDAF
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DH-WC-10 26.5 10 6 6 4 1 Stand 1 Medium D MH 1 29.3 1
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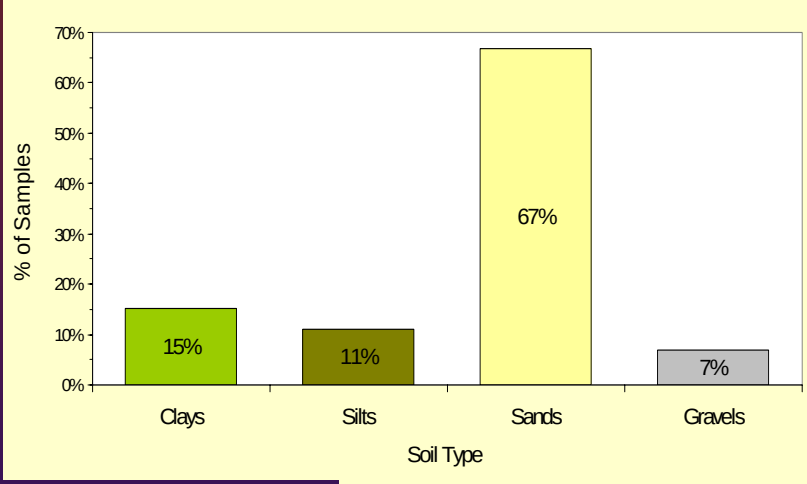
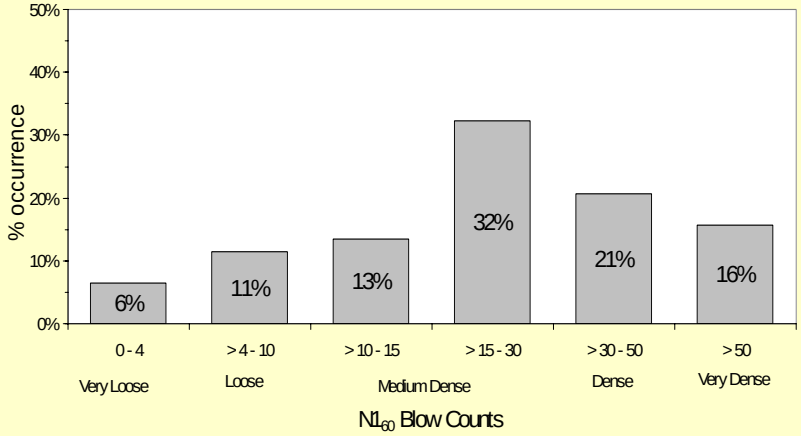
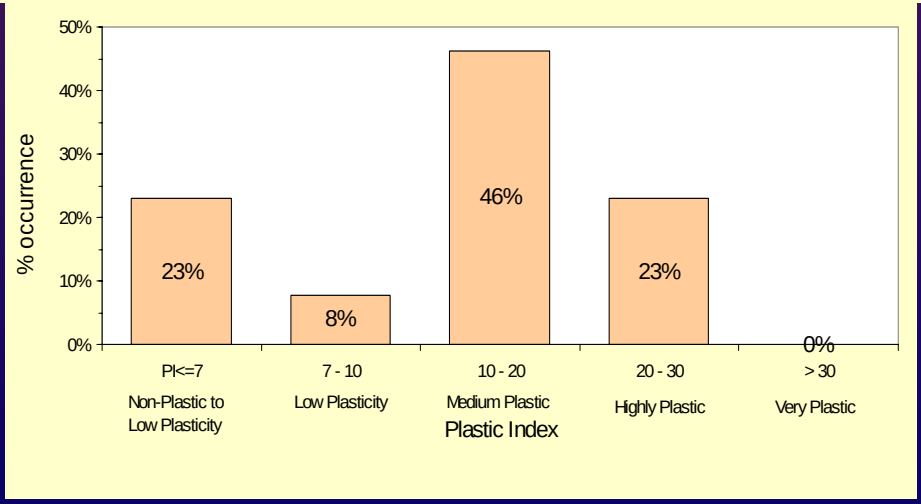
DH-WC-10 40 BOUNDAF
DH-WC-10 42 Shelby 1 Medium D SM 1 29 1 21.7 1 0.11 1
DH-WC-10 43 BOUNDAF
DH-WC-10 46.5 13 3 6 7 1 Stand 1 Stiff, greer CL 1 14.60 2 32.4 1 2.7 2 90.1 42.5 2 0.016 2 37
DH-WC-10 54 23 9 11 12 1 Stand 1 Stiff, greer CL 1 15.73 2 22.9 1 2.7 2 90.1 42.5 2 0.016 2 37
DH-WC-10 55 BOUNDAF
DH-WC-10 56.5 37 7 16 21 1 Stand 1 Dense, brc SM 1 26.7 1 28.1 2 0.138 2
DH-WC-10 66.5 Stand 1 Dense, brc SC 1 14.93 2 27 1 12.1 33 1 0.149 1 35
DH-WC-10 67 BOUNDAF
DH-WC-10 74 21 5 6 15 1 Stand 1 Very stiff, CL 1 15.11 2 28 1 2.7 2 90.1 42.5 2 0.016 2 37
DH-WC-10 76.5 27 8 12 15 1 Stand 1 Very stiff, CH 1 14.9 2 24 1 2.8 2 97.5 85 1 0.001 1 52
DH-WC-10 82.4 BOUNDAF
DH-WC-10 84 26 11 16 10 1 Stand 1 Medium D SP 1 14.62 2 25.9 1 11.8 2 0.325 2 28
DH-WC-10 88.4 17 7 10 12 1 Stand 1 Medium D SP 1 14.48 2 27.1 1 11.8 2 0.325 2 28
DH-WC-10 88.40 BOUNDAF
DH-WC-10 89 22 7 10 12 1 Stand 1 Very stiff, CL 1 15.29 2 26.5 1 2.7 2 90.1 42.5 2 0.016 2 37
Record: 3 of 57

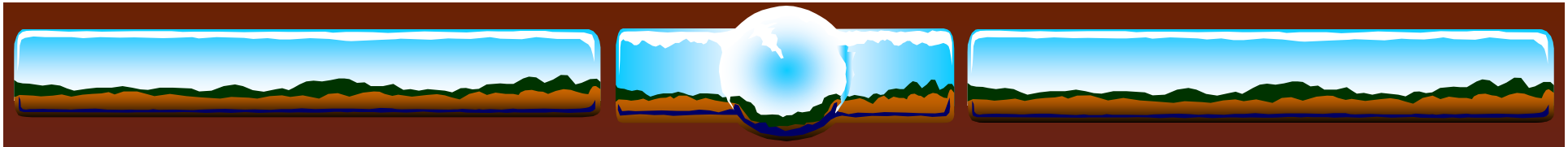
Characterization of geologic units

Qal_1 – Stream alluvium 1

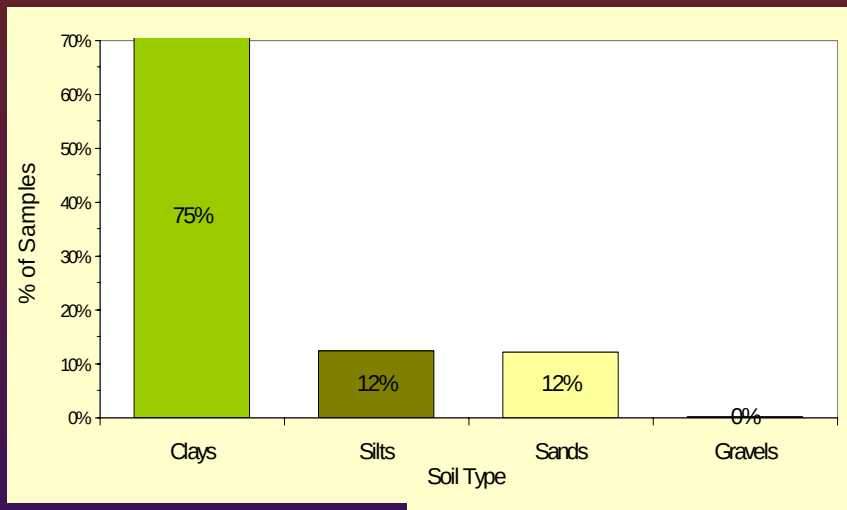


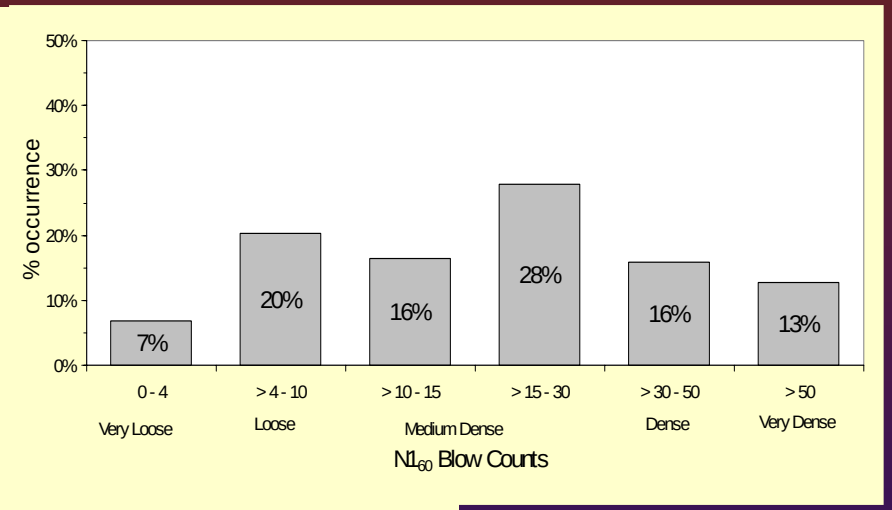


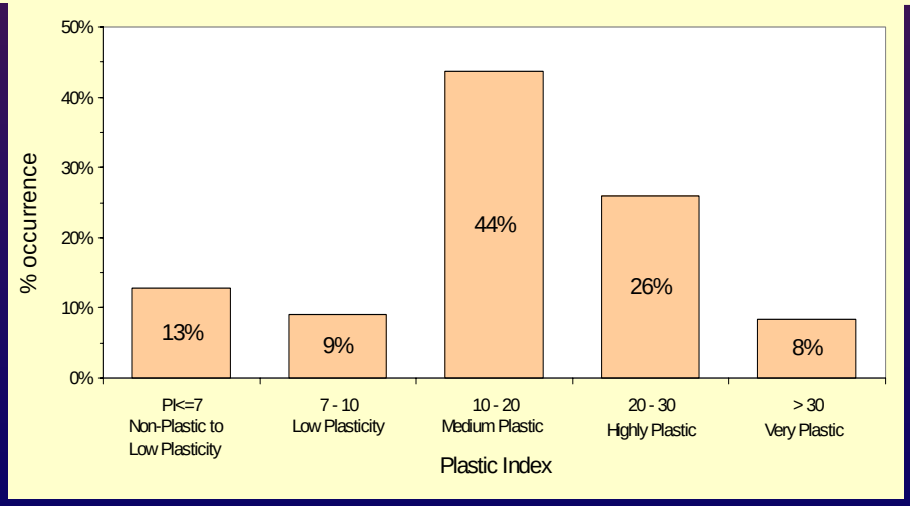


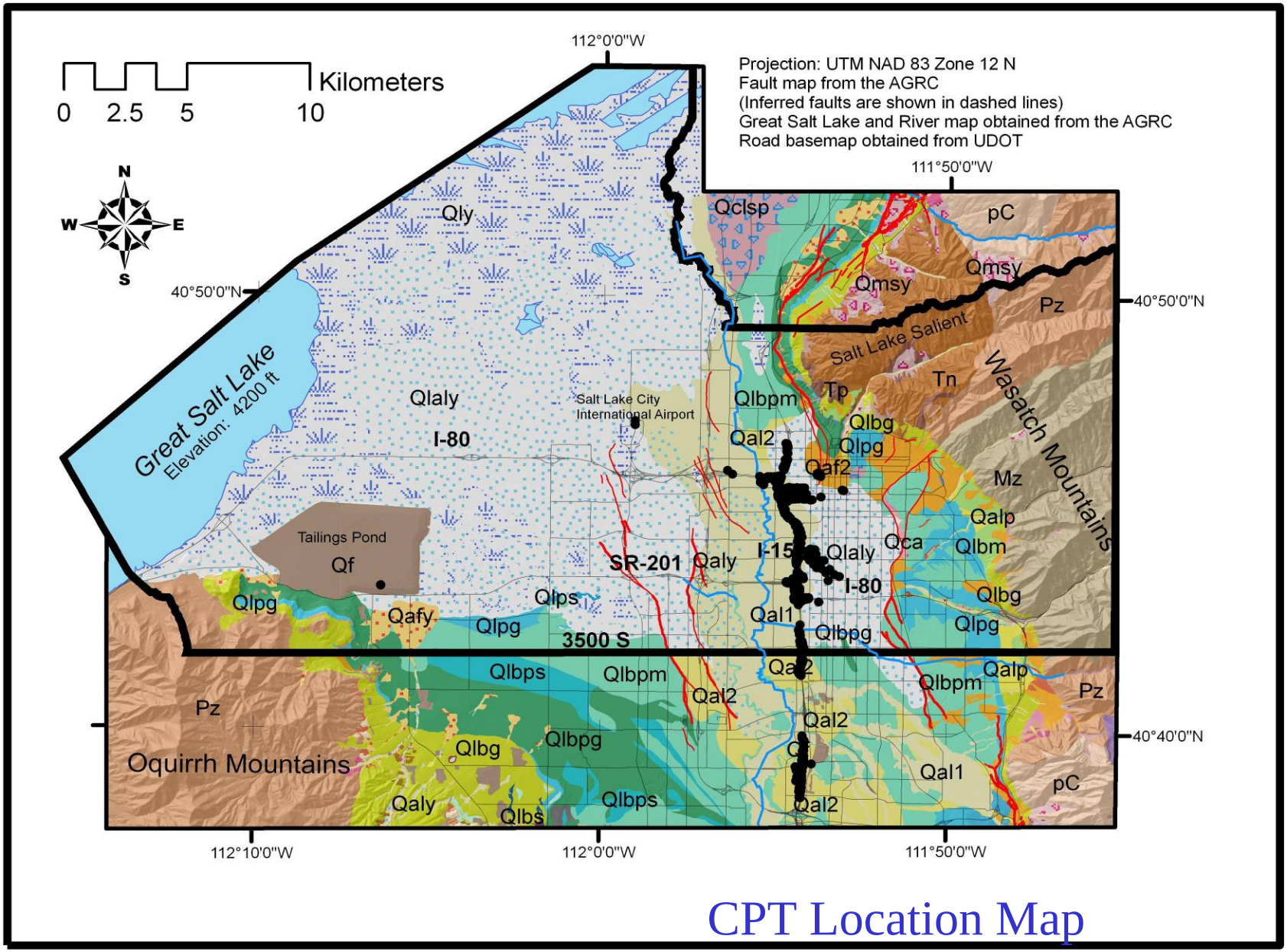


Qlbpm – **Lacustrine silt and clay of the Provo and Bonneville lake cycles, undivided**

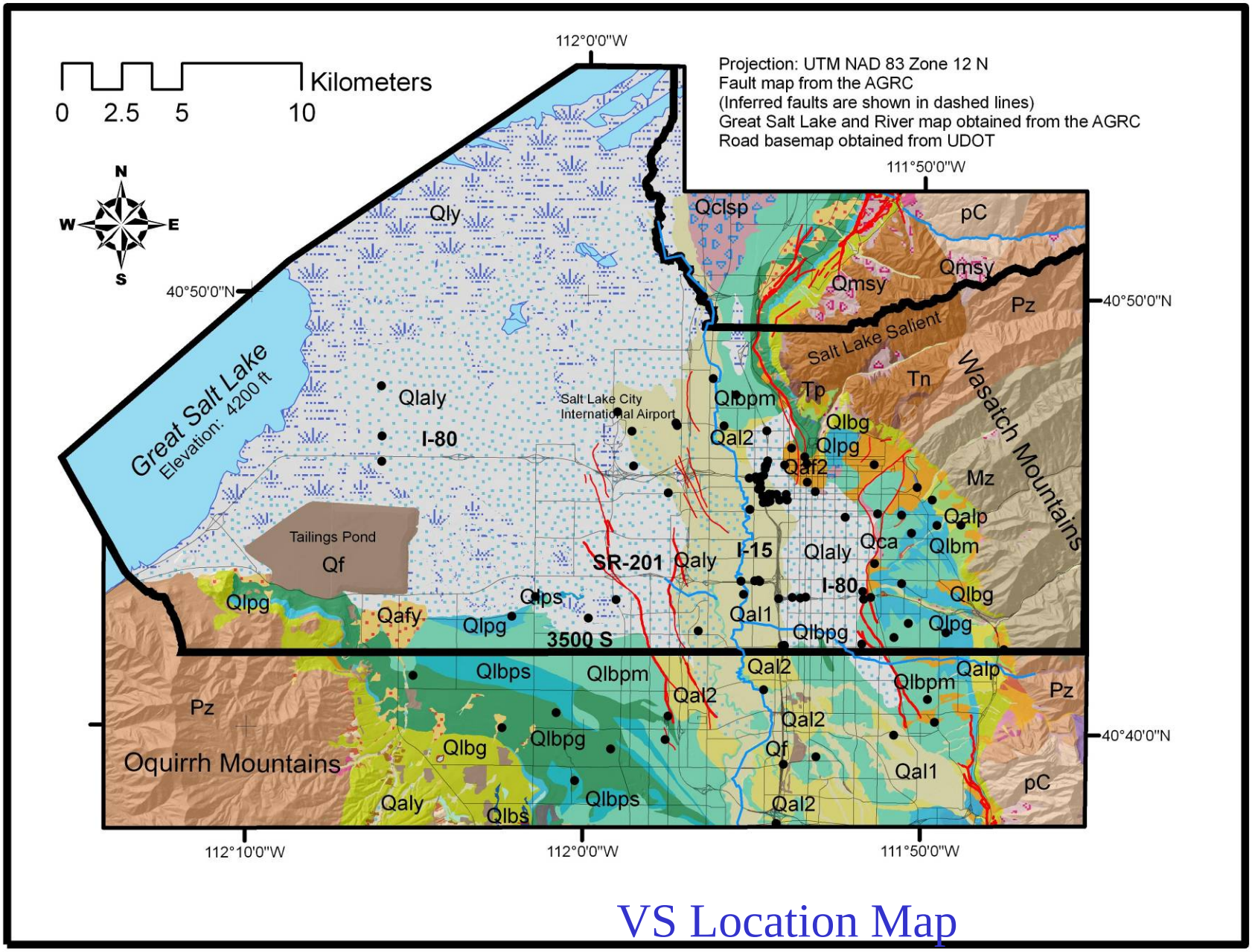




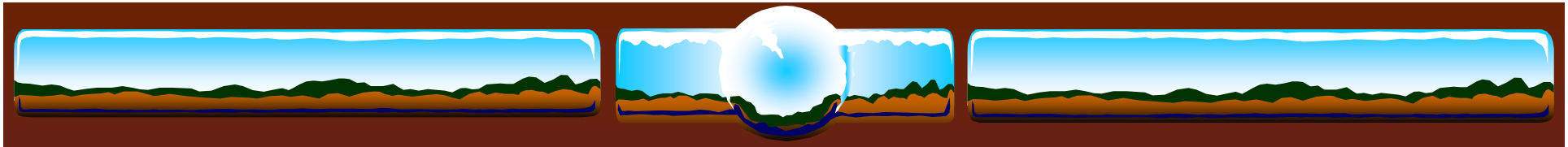




CPT Location Map



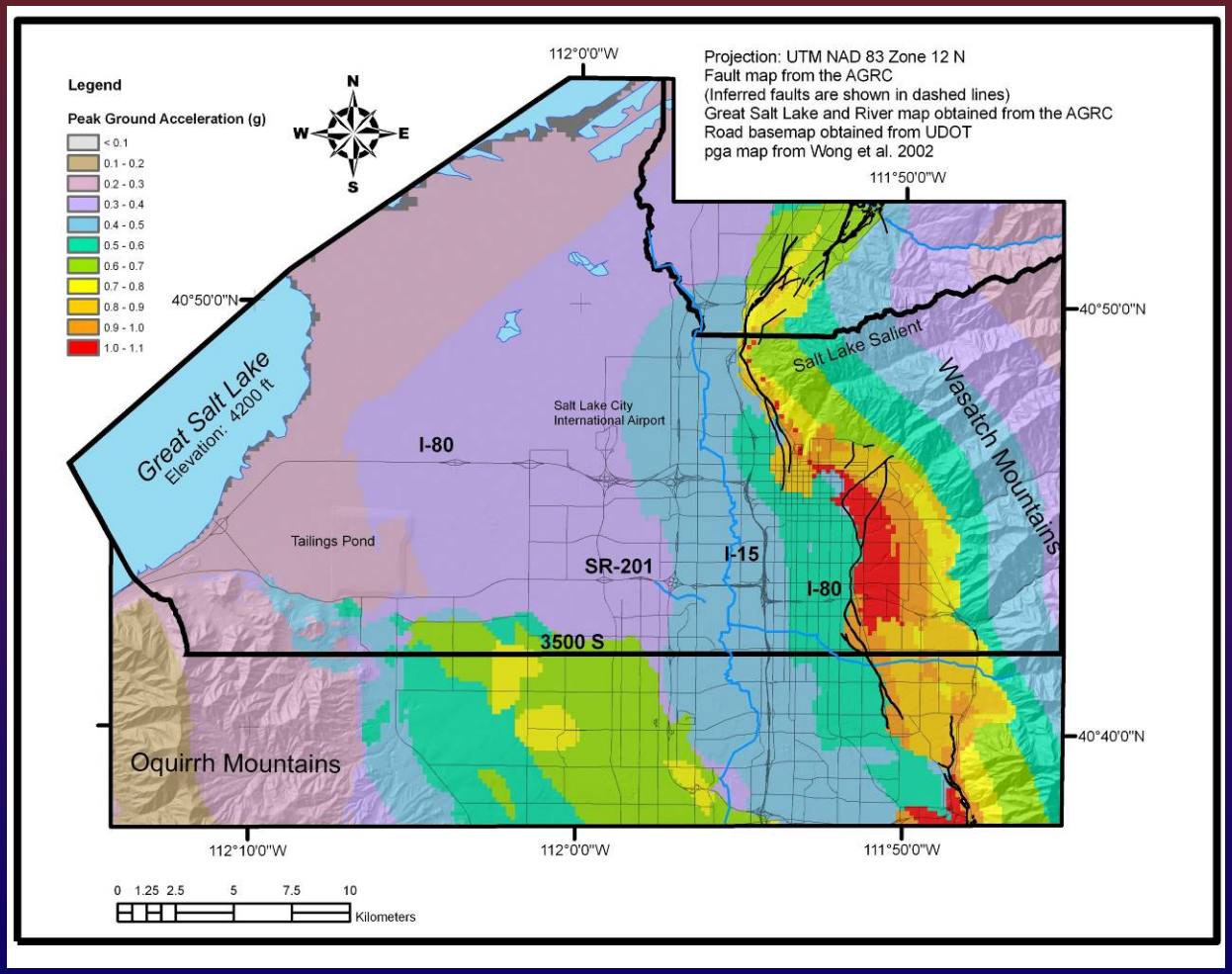
VS Location Map

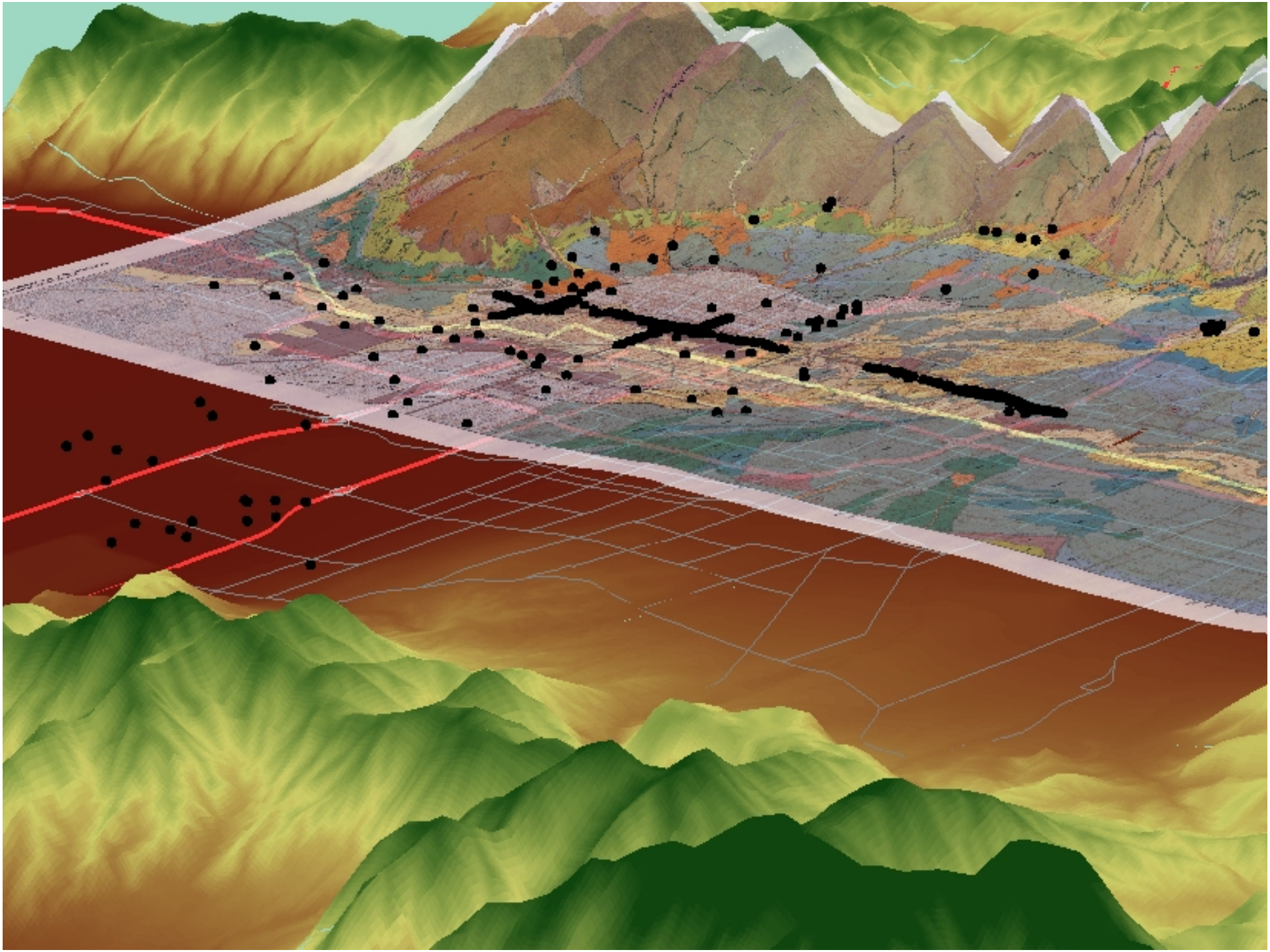


Other data collected

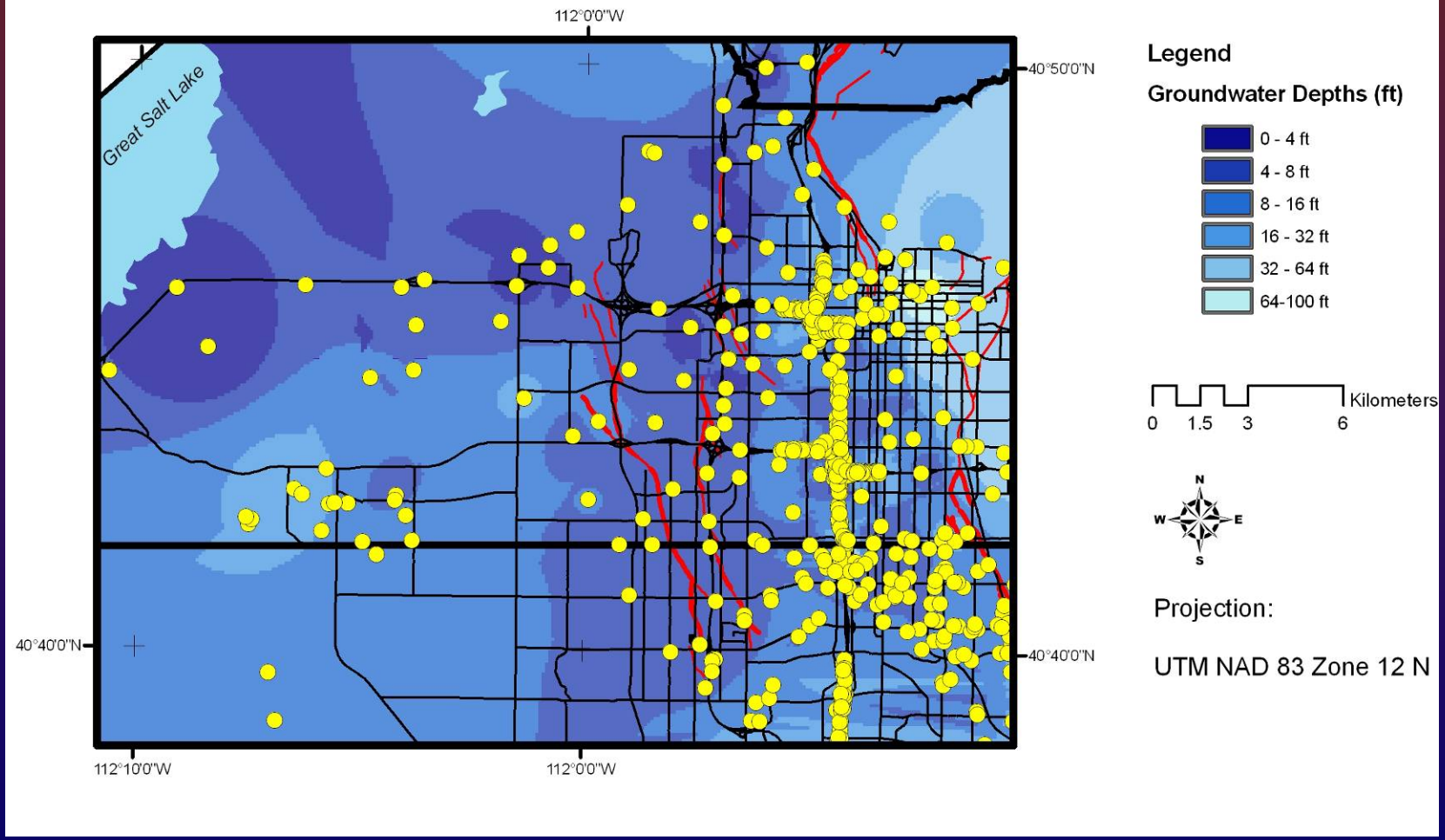
- Surficial geologic mapping (Personious and Scott, 1992, Biek et al. 2004, and Miller 1980)
- Fault location data
- River and channel locations and depths
- Great Salt Lake location
- Peak ground acceleration map (pga, Wong et al. 2002)
- Digital Elevation Model (DEM)
- Groundwater depths

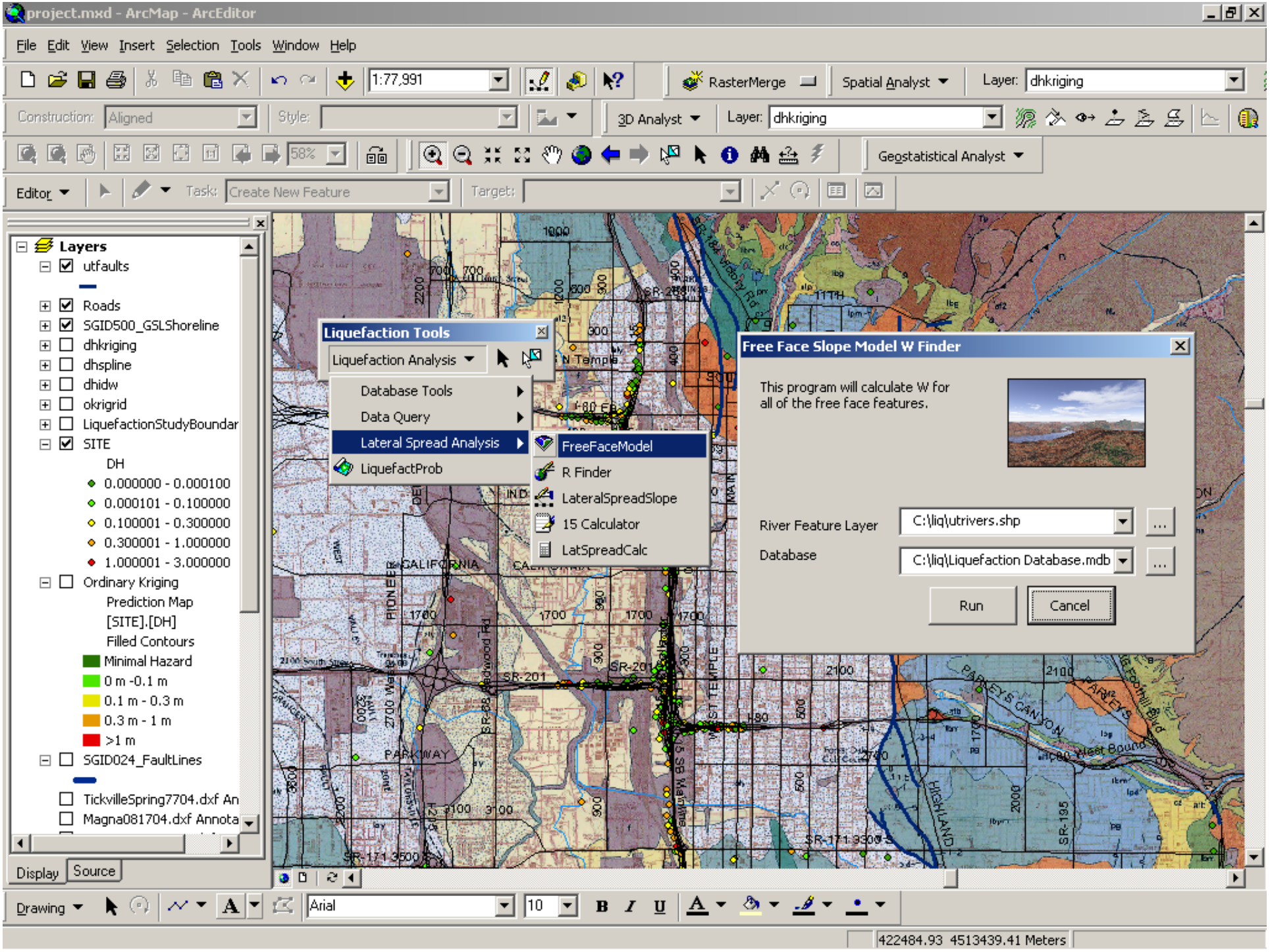
Peak Ground Acceleration Map





Groundwater map




project.mxd - ArcMap - ArcEditor
File Edit View Insert Selection Tools Window Help
1:77,991
RasterMerge
Spatial Analyst
Layer: dhkriging
Construction: Aligned
Style:
3D Analyst
Layer: dhkriging
58%
Geostatistical Analyst
Editor
Task: Create New Feature
Target:
Layers
utfaults
Roads
SGID500_GSLShoreline
dhkriging
dhspline
dhidw
okrigrid
LiquefactionStudyBoundar
SITE
DH
0.000000 - 0.000100
0.000101 - 0.100000
0.100001 - 0.300000
0.300001 - 1.000000
1.000001 - 3.000000
Ordinary Kriging
Prediction Map
[SITE],[DH]
Filled Contours
Minimal Hazard
0 m -0.1 m
0.1 m - 0.3 m
0.3 m - 1 m
>1 m
SGID024_FaultLines
TickvilleSpring7704.dxf An
Magna081704.dxf Annota
Display
Source
Liquefaction Tools
Liquefaction Analysis
Database Tools
Data Query
Lateral Spread Analysis
LiquefactProb
FreeFaceModel
R Finder
LateralSpreadSlope
15 Calculator
LatSpreadCalc
Free Face Slope Model W Finder
This program will calculate W for all of the free face features.
River Feature Layer
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Database
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Run
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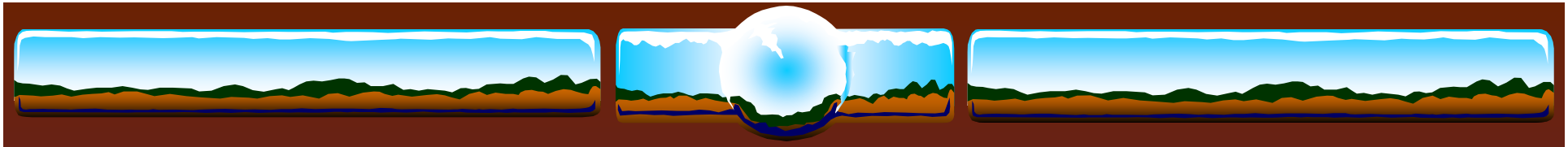
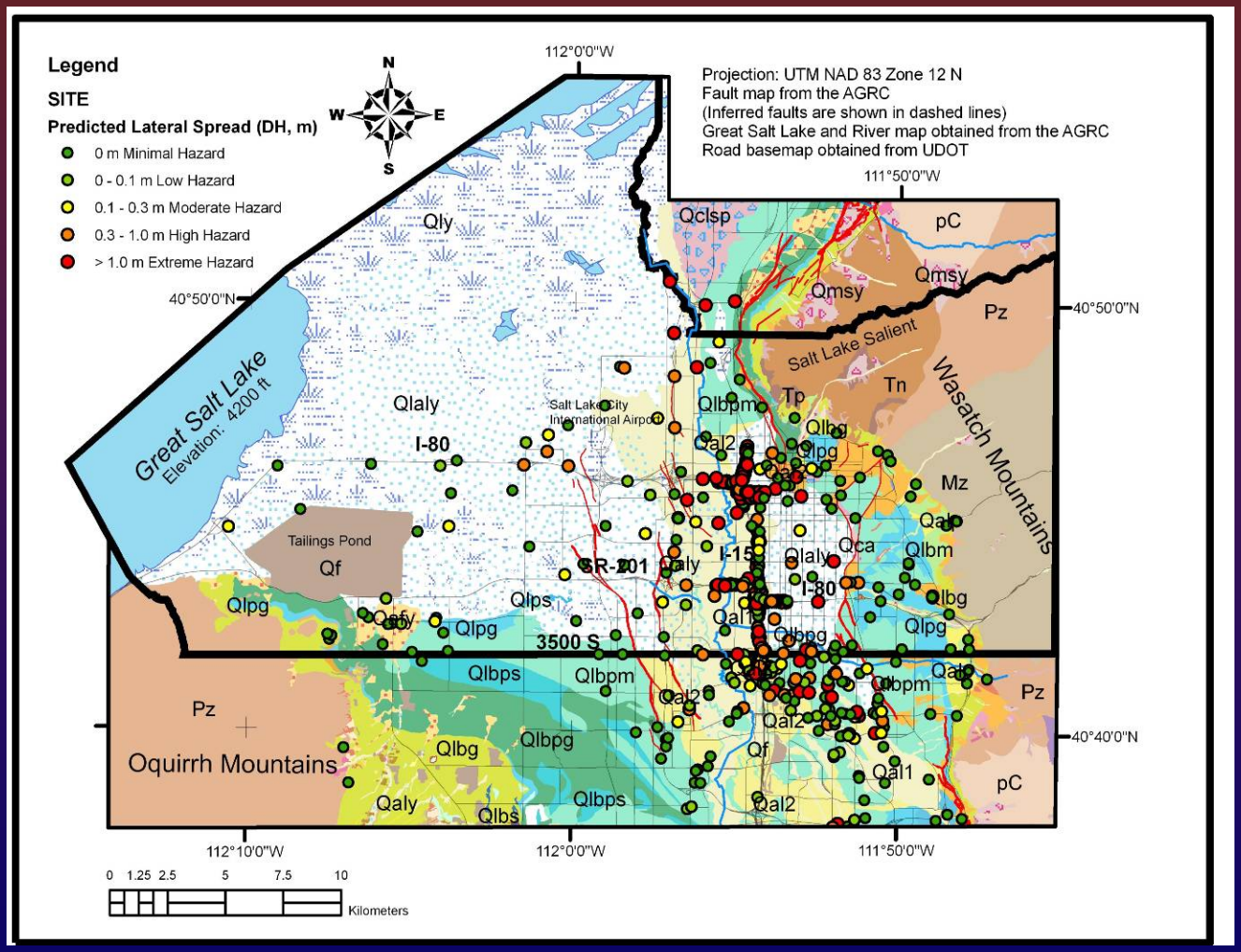


VBA routines

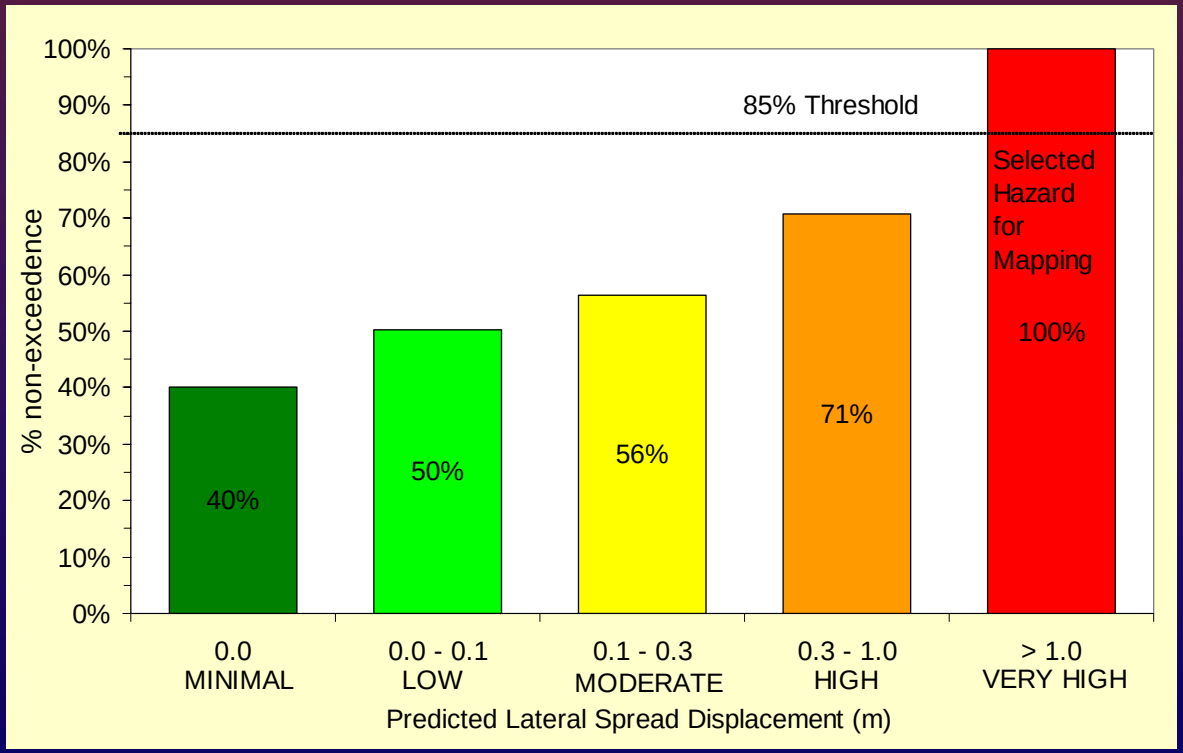
- Average calculator
- Average filler
- Groundwater query
- Stress calculator
- N160 calculator
- Liq screener
- W finder
- Slope finder
- R finder
- Acceleration reader
- Atrigger
- Layer merger (15 calc)
- Lateral spread calculator

Predicted lateral spread

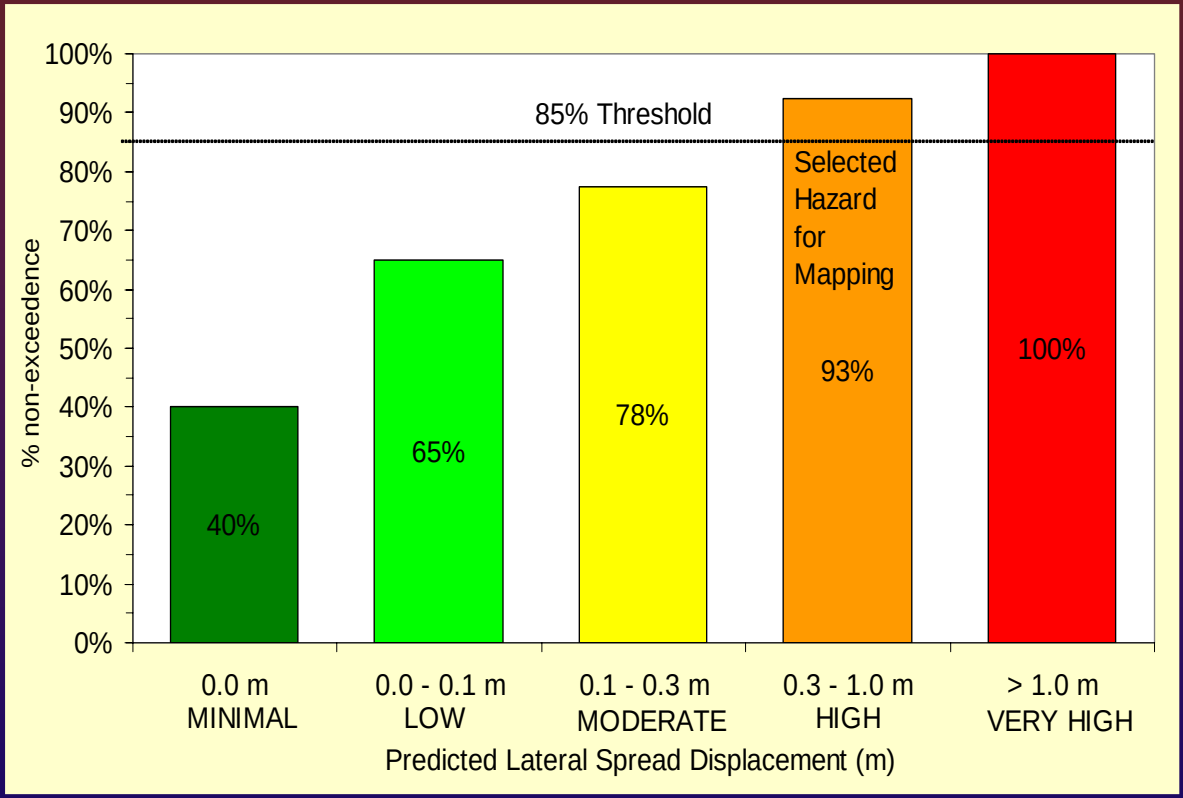


Analysis and map creation

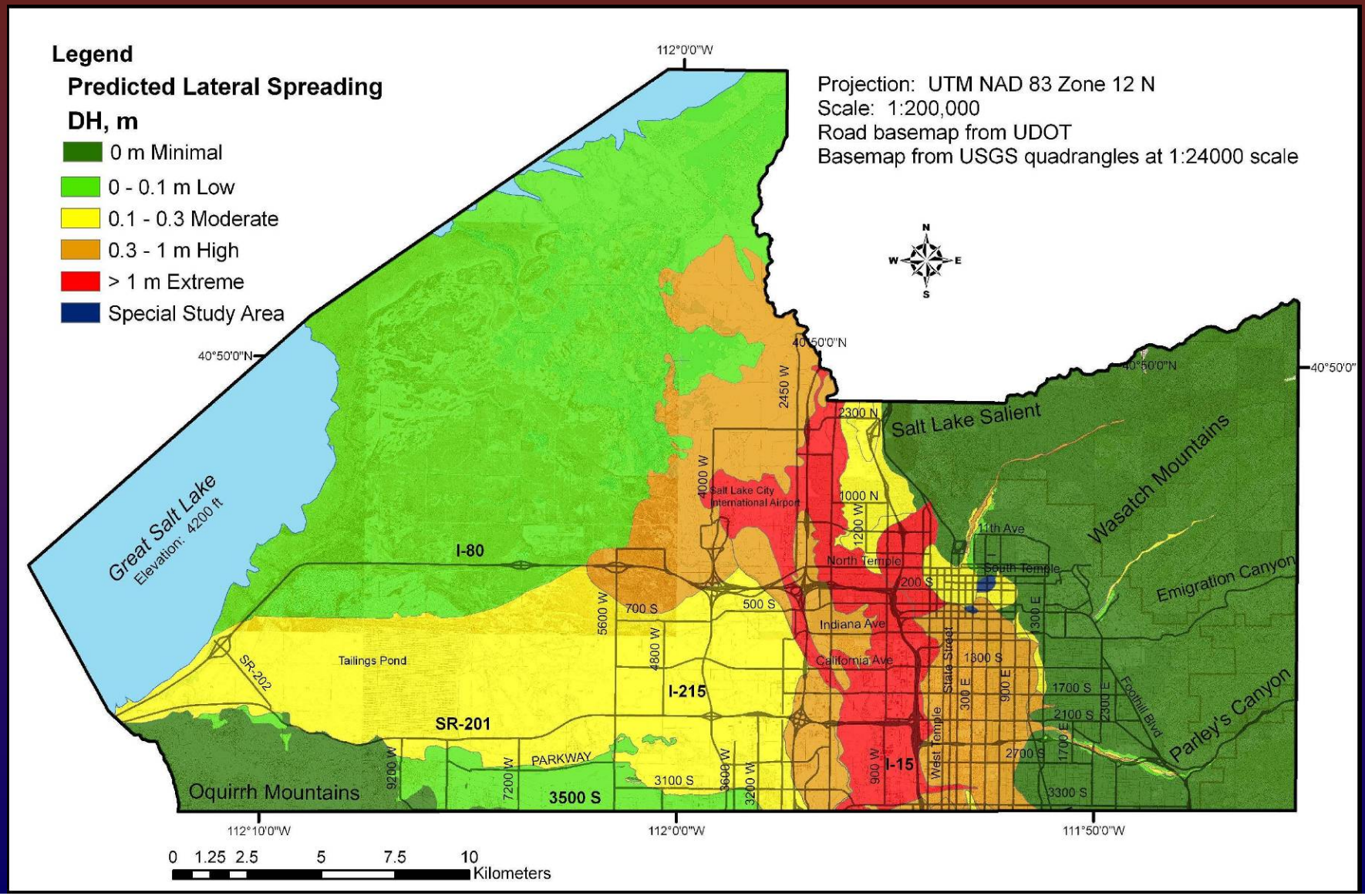
- 85% threshold – only 15% or less of the boreholes can exceed that hazard level

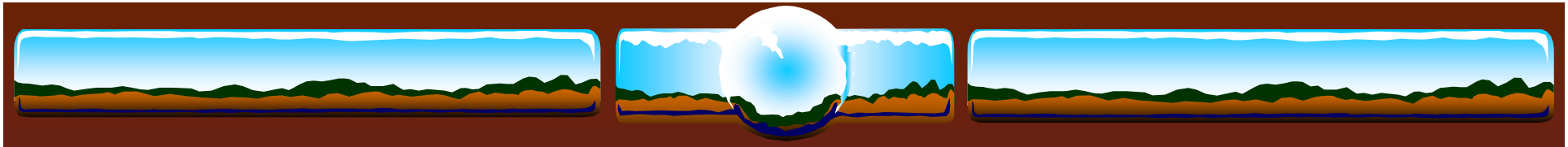


Qlbpm


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% non-exceedence
85% Threshold
Selected Hazard for Mapping
40%
65%
78%
93%
100%
0.0 m MINIMAL
0.0 - 0.1 m LOW
0.1 - 0.3 m MODERATE
0.3 - 1.0 m HIGH
> 1.0 m VERY HIGH
Predicted Lateral Spread Displacement (m)

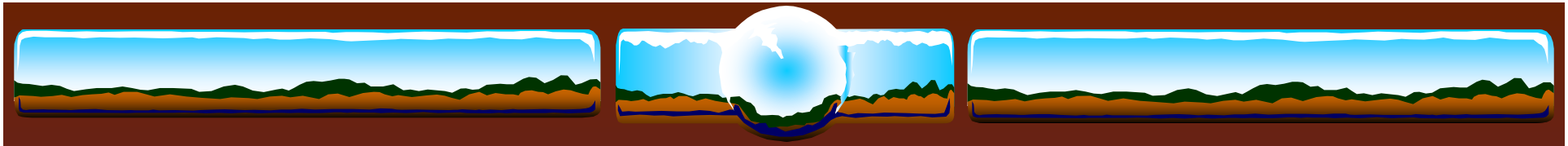
Lateral spread hazard map

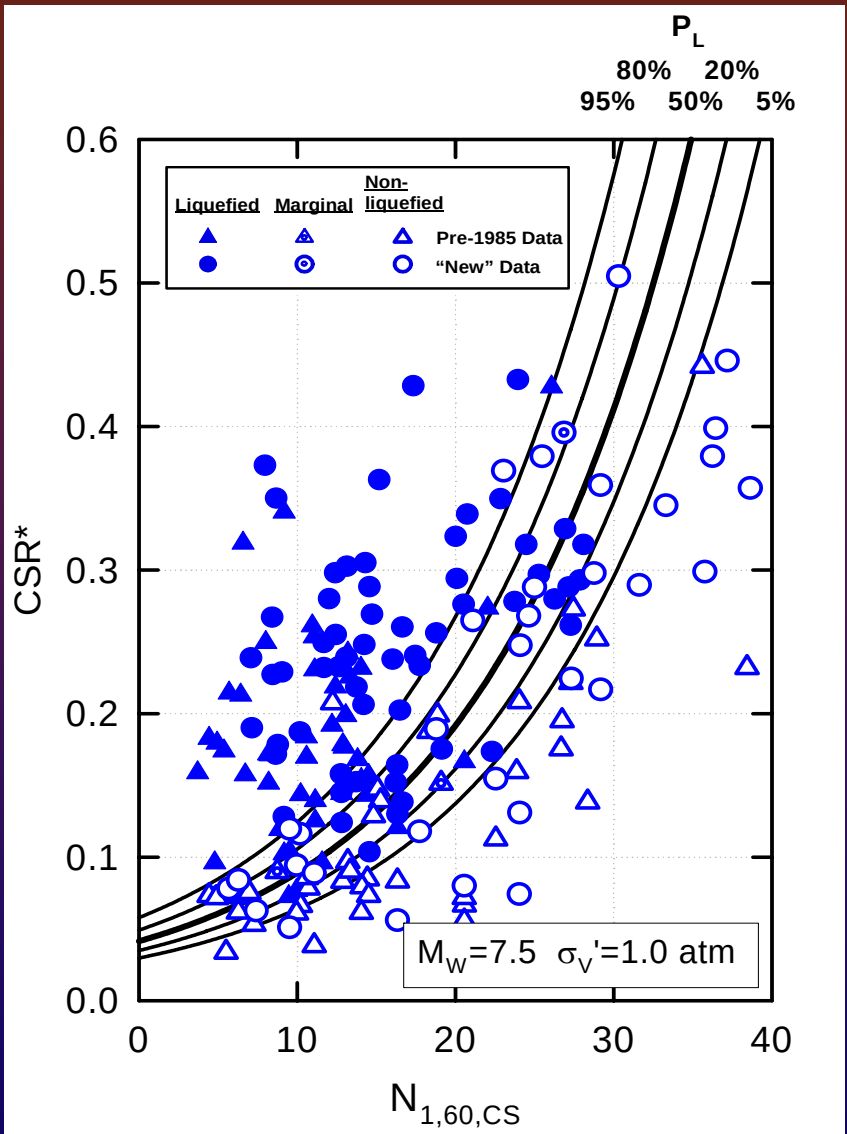




Future mapping efforts

- Fully probabilistic maps including:
  - Liquefaction triggering maps for Salt Lake Valley
  - Lateral Spread maps
  - Liquefaction-induced ground settlement maps



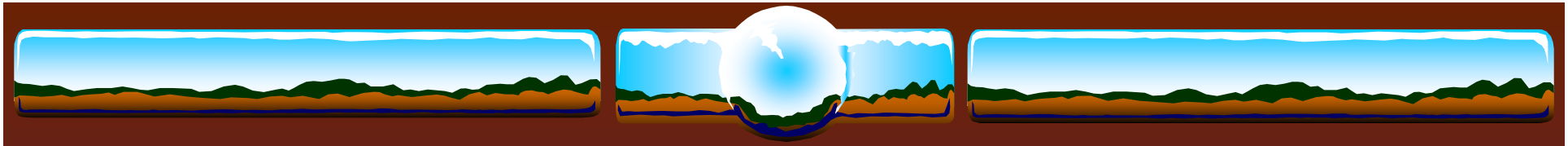


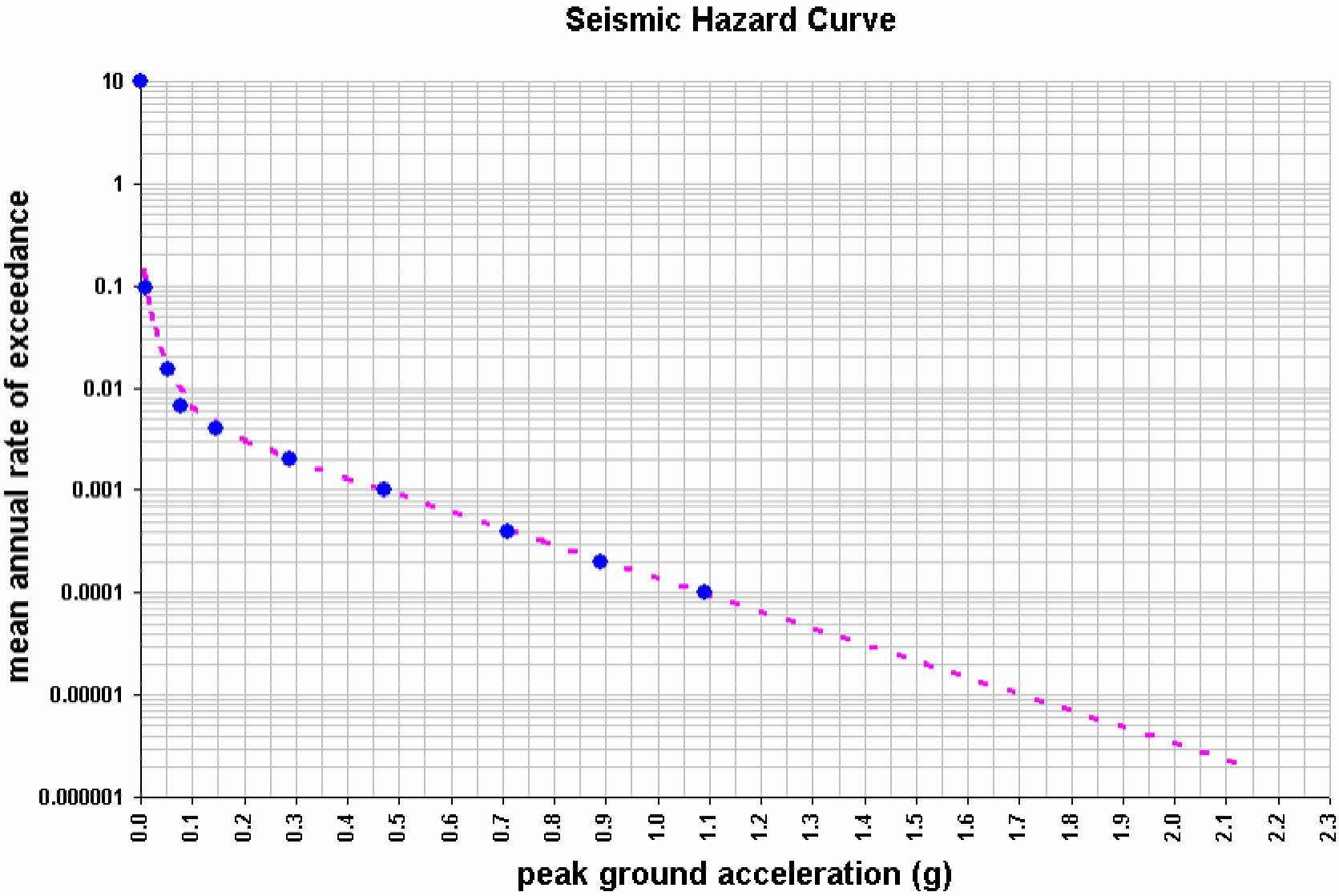
Probabilistic curves

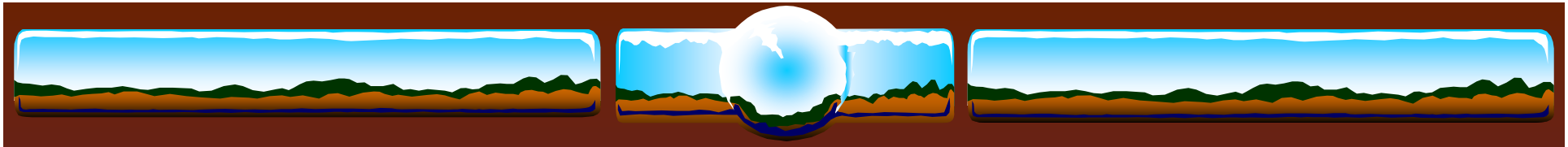
Recommended "Probabilistic" SPT-Based Liquefaction Triggering Correlation

(For MW=7.5 and sv'=1.0 atm)

(Seed et al. 2003)




Seismic Hazard Curve
mean annual rate of exceedance
10
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
peak ground acceleration (g)



Liquefaction probability aggregation

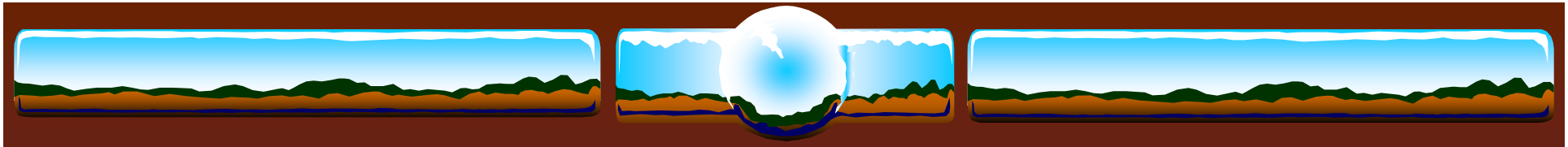
$$P(L) = \sum P[L \mid A,M]\ P[A,M]$$

where:

P(L) = annual probability of liquefaction,

P [L | A,M] = conditional probability of liquefaction given the peak ground acceleration and the earthquake magnitude,

P [A, M] = joint probability density function of peak ground acceleration and earthquake magnitude.



Lateral spread probability chain

- **P(DH > x) = ∑ P[(DH > x) | L] P[L | A, M, R] P[A, M, R]**

  Where:

  - **P(DH>x) = The probability of lateral spread exceeding a threshold value (x= 0.1 m and 0.3 m)**
  - **P[L| A,M,R] = the probability of liquefaction given an acceleration, magnitude, and distance.**
  - **P[A,M,R] = joint probability density function of peak ground acceleration, magnitude and distance.**