

MAPPING OF LATERAL SPREAD DISPLACEMENT HAZARD, WEBER COUNTY, UTAH

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EERI

Outline

- Modification to Lateral Spread Model
- Interpreting and Use CPT Data in Revised Model
- Monte Carlo Method
- Mapping Inputs
- Map Examples

Youd et al. (2002) Empirical Model

$$\text{Log}D_H = b_o + b_{off}\alpha + b_1M + b_2\text{Log}R^* + b_3R + b_4\text{Log}W + b_5\text{Log}S + b_6\text{Log}T_{15} + b_7\text{Log}(100 - F_{15}) + b_8\text{Log}(D50_{15} + 0.1 \text{ mm})$$

Seismic Factors

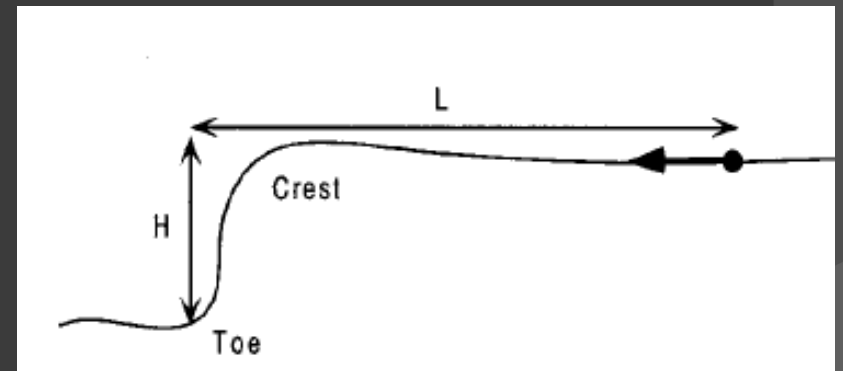
- M, R

Topographic Factors

- W, S

Geotechnical Factors

- $T_{15}, F_{15}, D50_{15}$



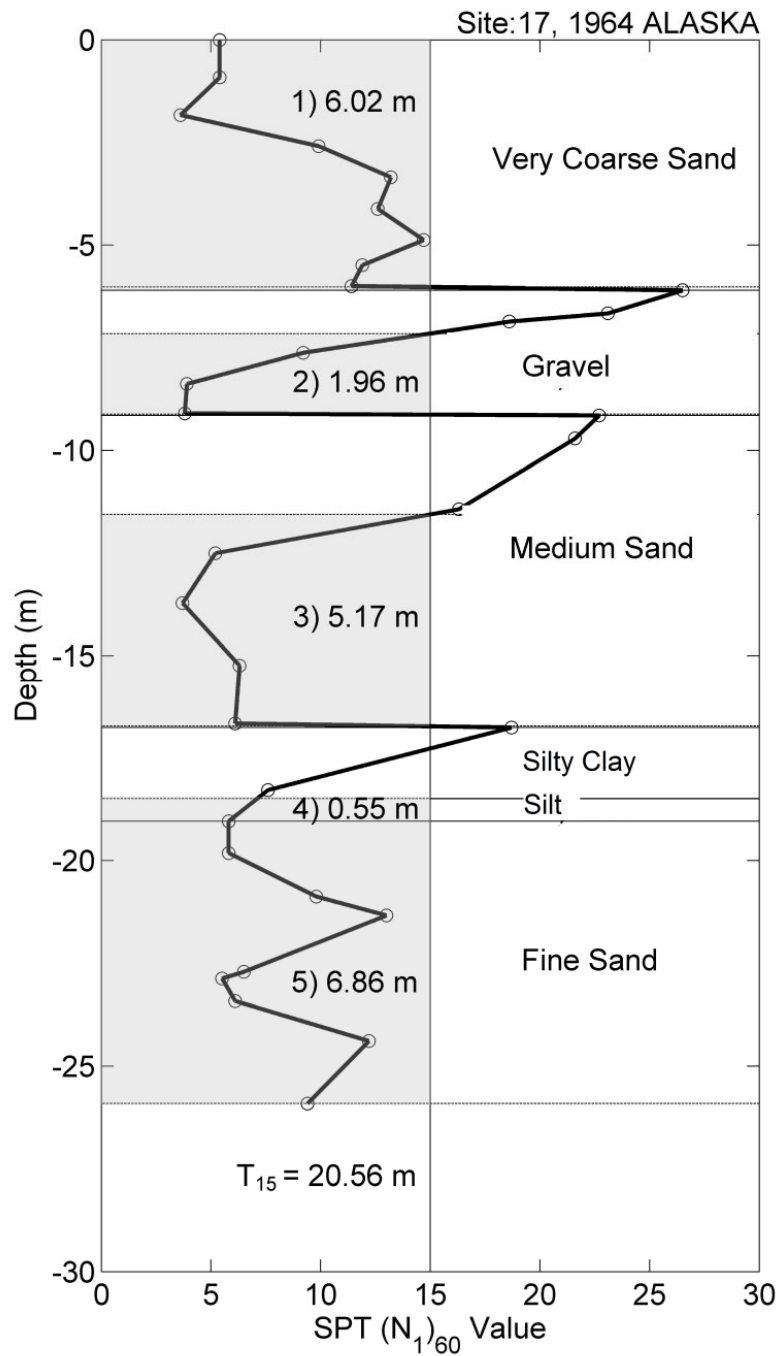
Free-face ratio: $W (\%) = H / L * 100$

New Empirical Model

$$\text{Log}D_H = b_o + b_{off}\alpha + b_1M + b_2\text{Log}R^* + b_3R + b_4\text{Log}W + b_5\text{Log}S + b_6\text{Log}T_{15} + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5$$

x_i = the portion (decimal fraction) of T_{15} in a borehole that has a soil index corresponding to the table below

Soil Index (SI)	Typical Soil Description in Case History Database	General USCS Symbol
1	Silty gravel, fine gravel	GM
2	Coarse sand, sand and gravel	GM-SP
3	Medium to fine sand, sand with some silt	SP-SM
4	Fine to very fine sand, silty sand	SM
5	Low plasticity silt, sandy silt	ML
6	Clay (not liquefiable)	CL-CH



represented as a decimal. For example, the borehole plotted in Fig. 2 has $x_1 = 1.96/20.6 = 0.10$, $x_2 = 6.02/20.6 = 0.29$, $x_3 = 0.25$, $x_4 = 0.33$, and $x_5 = 0.03$. Of course, the sum of all values of x in the borehole equals 1.

Comparing the Models

Model	R^2 (%)	MSE	$\sigma_{\log DH}$	P-Value
Full: Youd et al. (2002)	83.6	0.0388	0.1970	0.000
Reduced: no F_{15} or $D50_{15}$	66.6	0.0785	0.2802	0.000
New: with soil type terms	80.0	0.0476	0.2182	0.000

* 1906 San Francisco	☆ 1971 San Fernando	◇ 1987 Superstition Hills	
△ 1964 Alaska	+ 1979 Imperial Valley	□ Ambraseys' Data	○ 1995 Kobe
• 1964 Niigata	× 1983 Nihonkai-Chubu	☆ 1983 Borah Peak, Idaho	▽ 1989 Loma Prieta

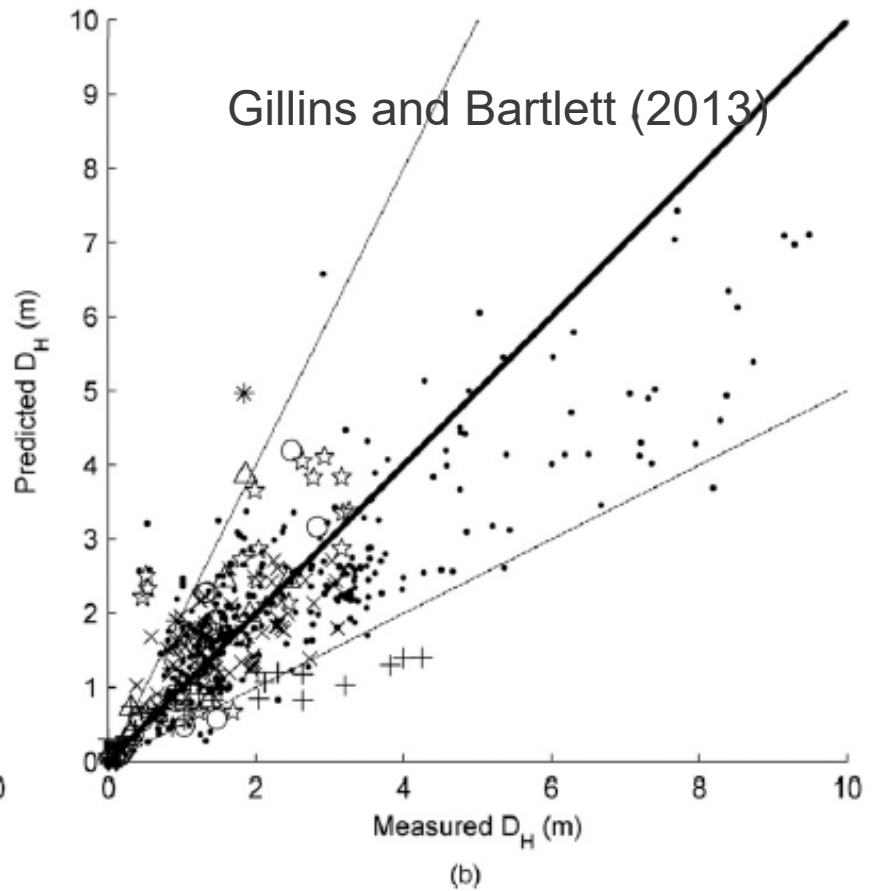
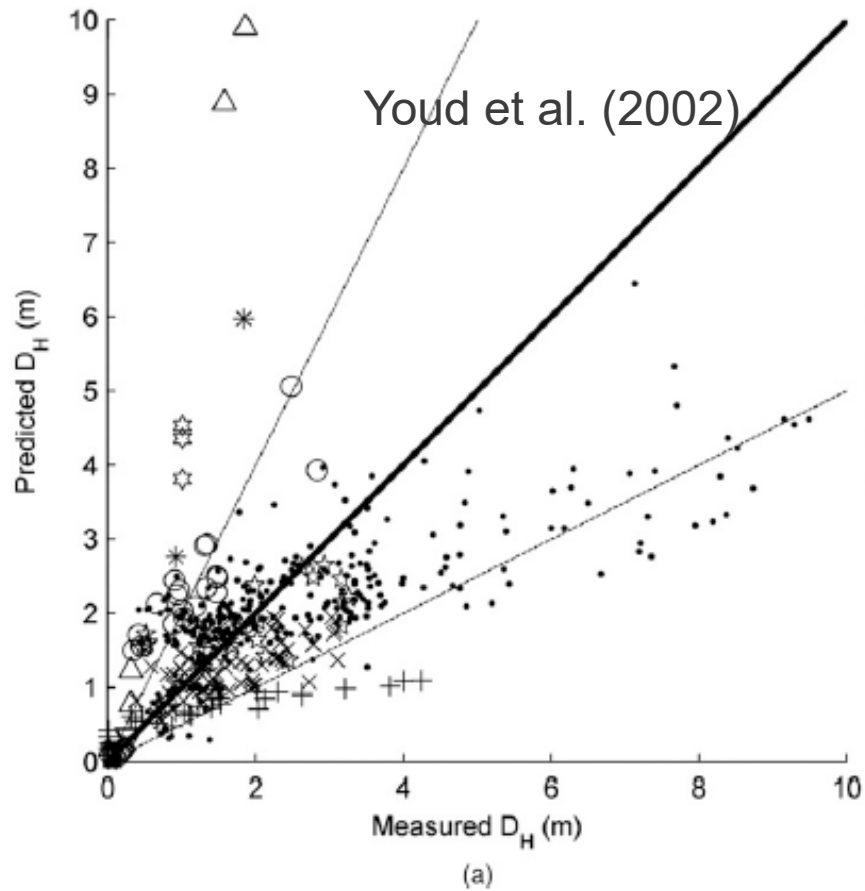
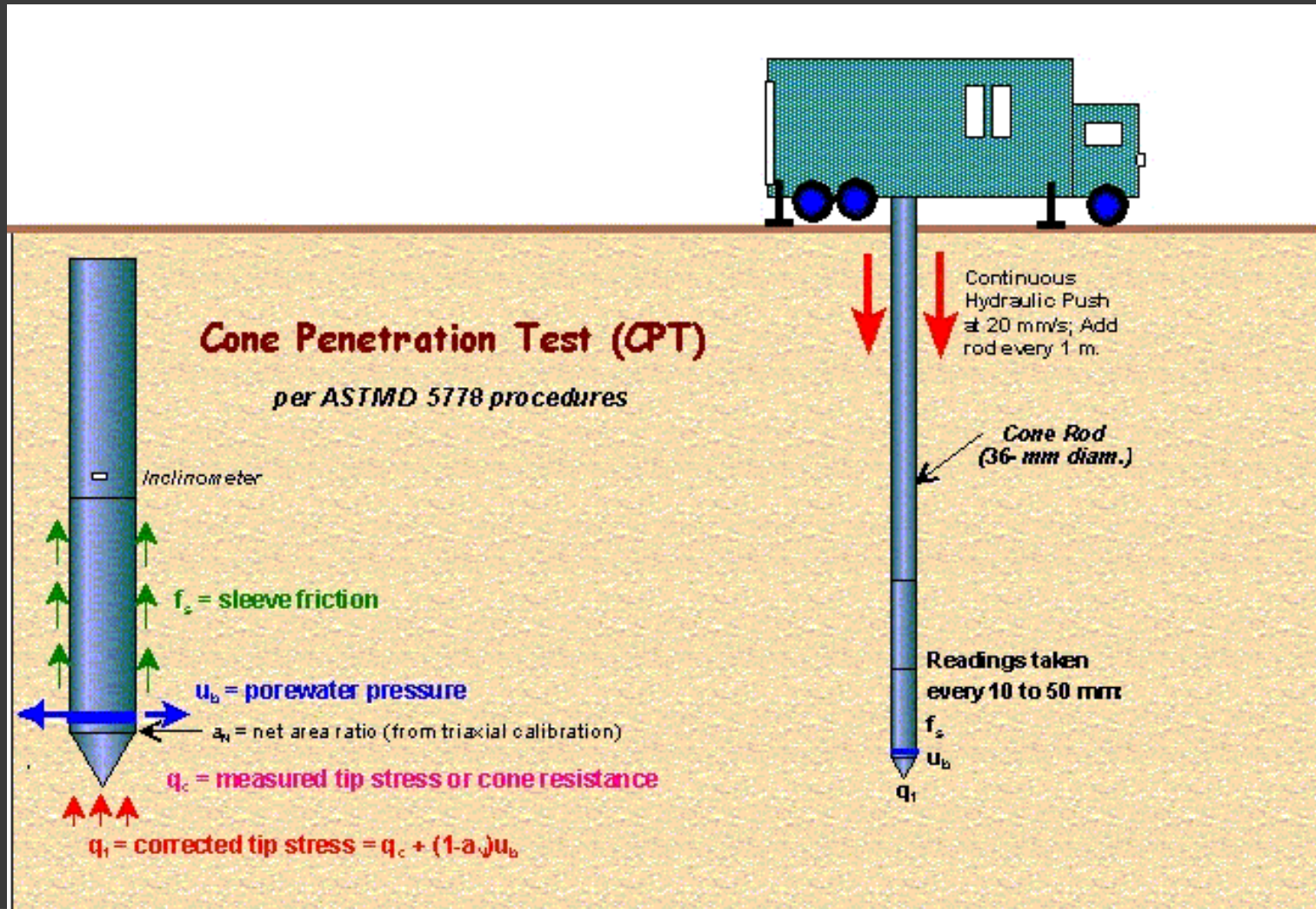
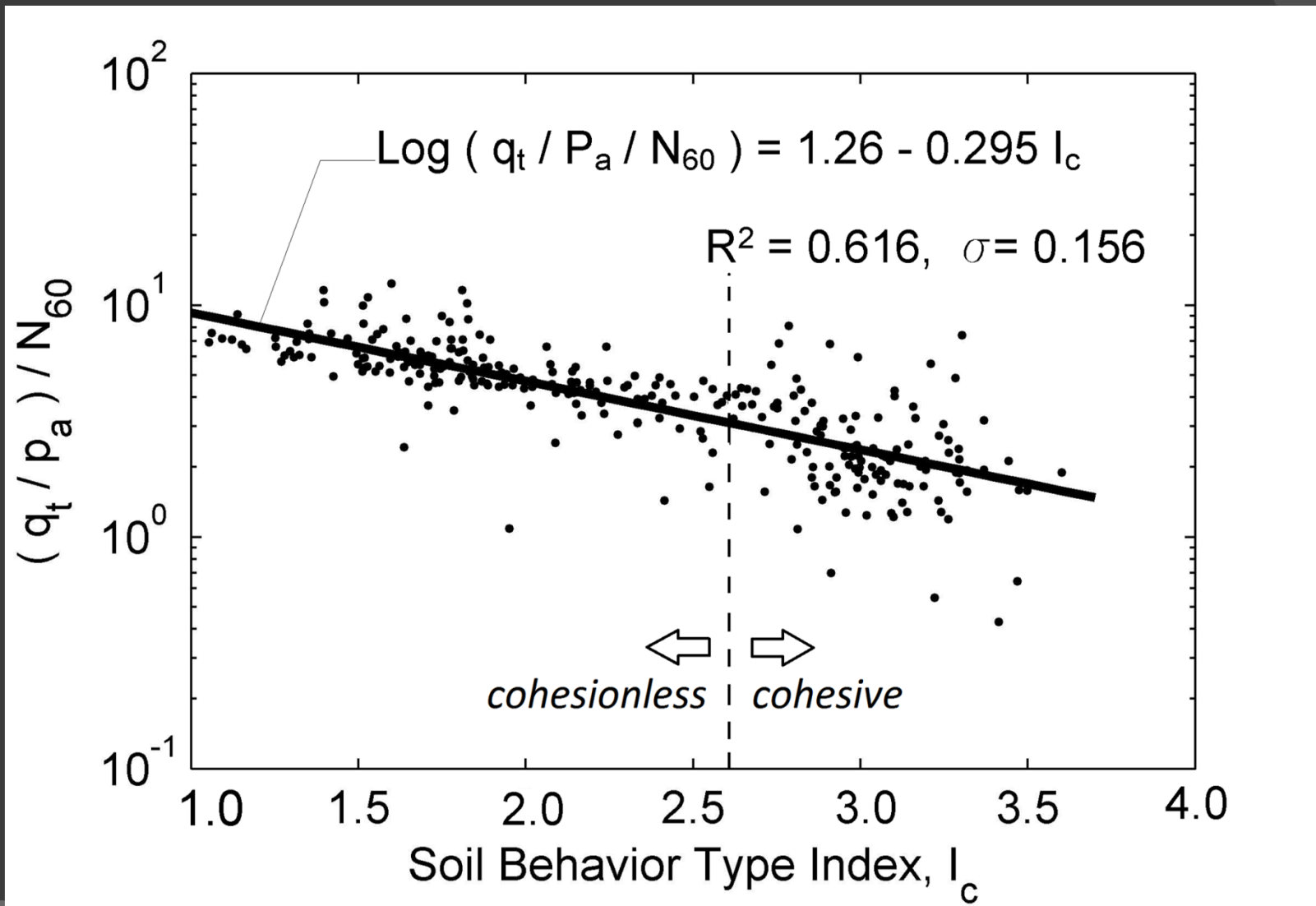


Fig. 1. Predicted lateral spread displacement using (a) Eq. (3) or (b) Eq. (4), versus measured lateral spread displacement from the case history database of Youd et al. (2002)

Cone Penetrometer Test (CPT)



Estimating $N_{1,60}$ from CPT Data



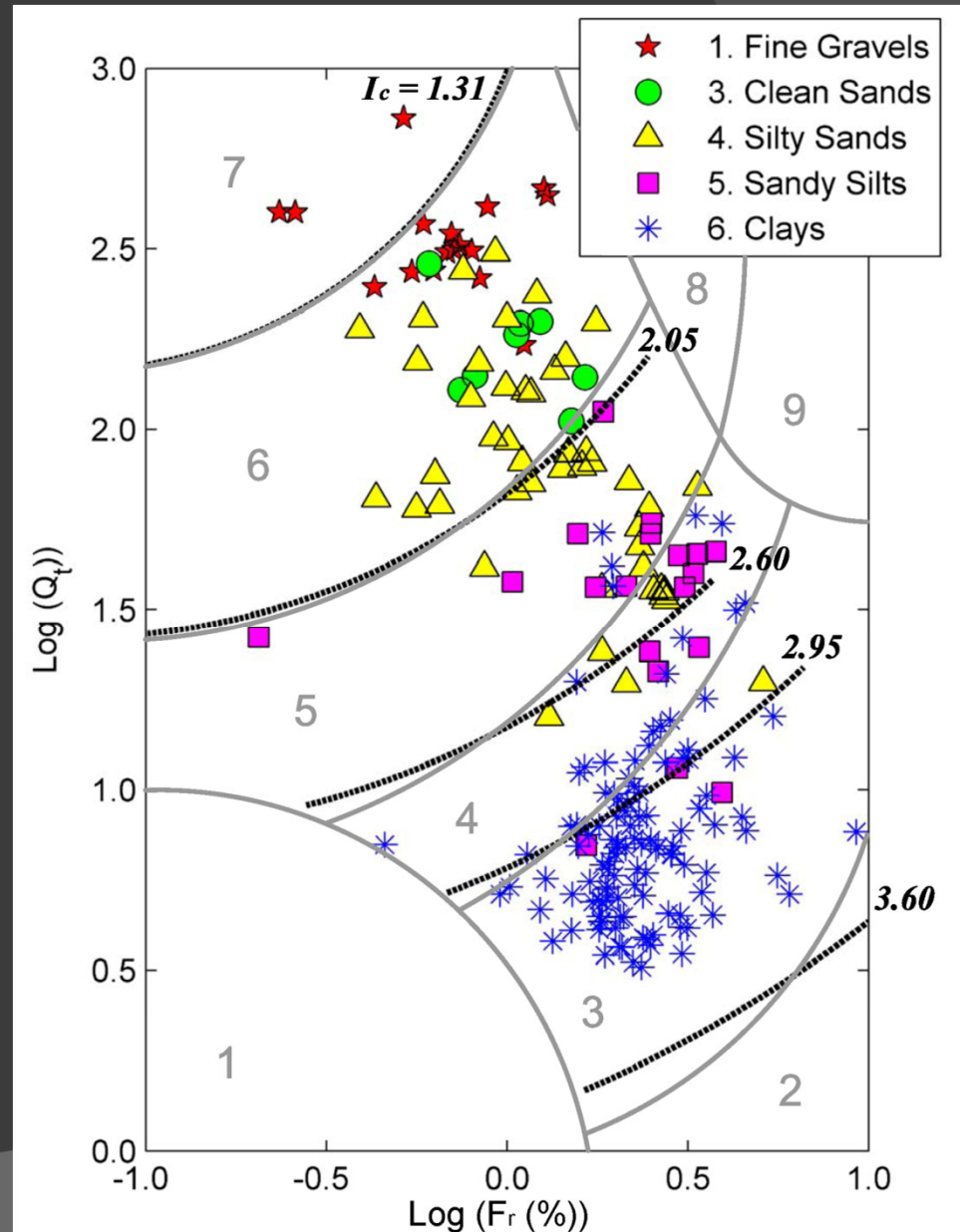
Estimating x_i Variables with CPT

Zone	Soil Behaviour Type (SBT)
1	Sensitive fine-grained
2	Clay - organic soil
3	Clays: clay to silty clay
4	Silt mixtures: clayey silt & silty clay
5	Sand mixtures: silty sand to sandy silt
6	Sands: clean sands to silty sands
7	Dense sand to gravelly sand
8	Stiff sand to clayey sand*
9	Stiff fine-grained*

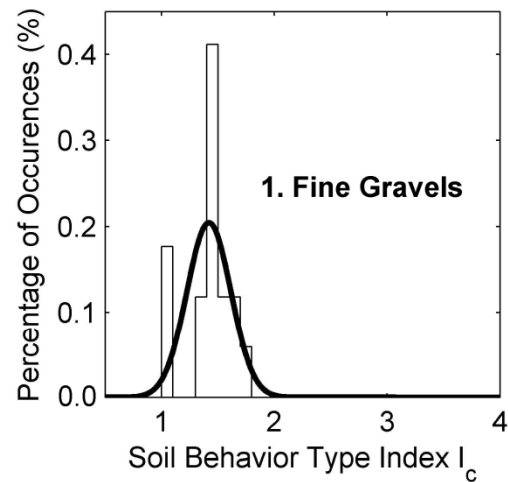
* Overconsolidated or cemented

$$I_c = [(3.47 - \text{Log}Q_{tn})^2 + (\text{Log}F_r + 1.22)^2]^{0.5}$$

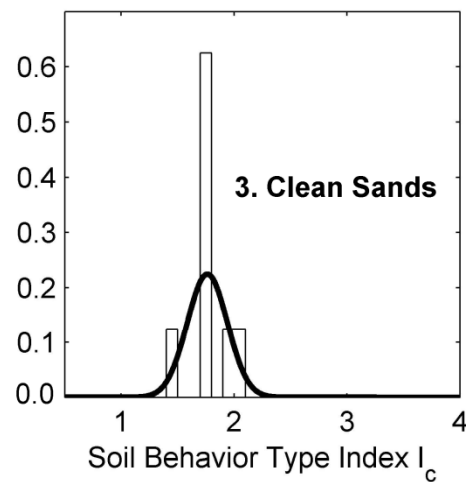
Robertson (1990) Soil Behavior Type Chart
 Boundaries of each zone estimated by circles with radius = I_c



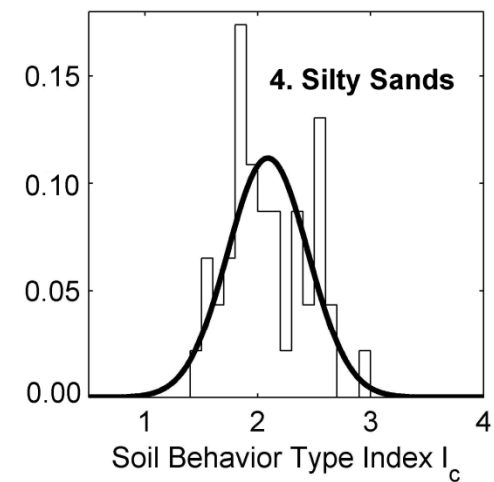
Histograms of I_c for each S_l



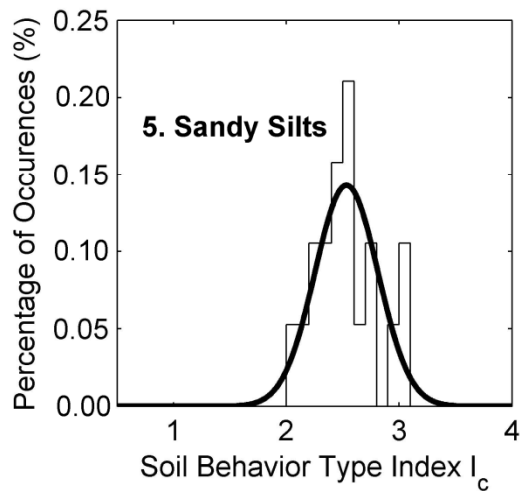
(a)



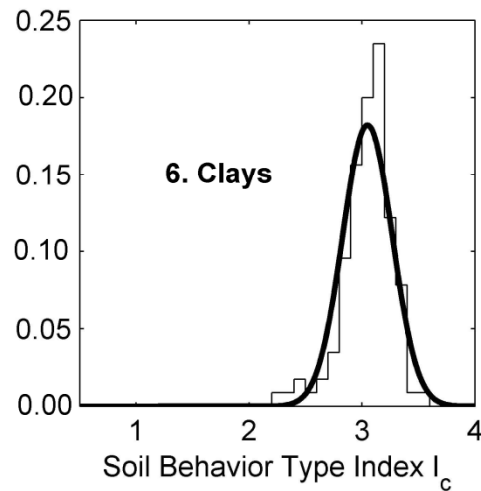
(b)



(c)

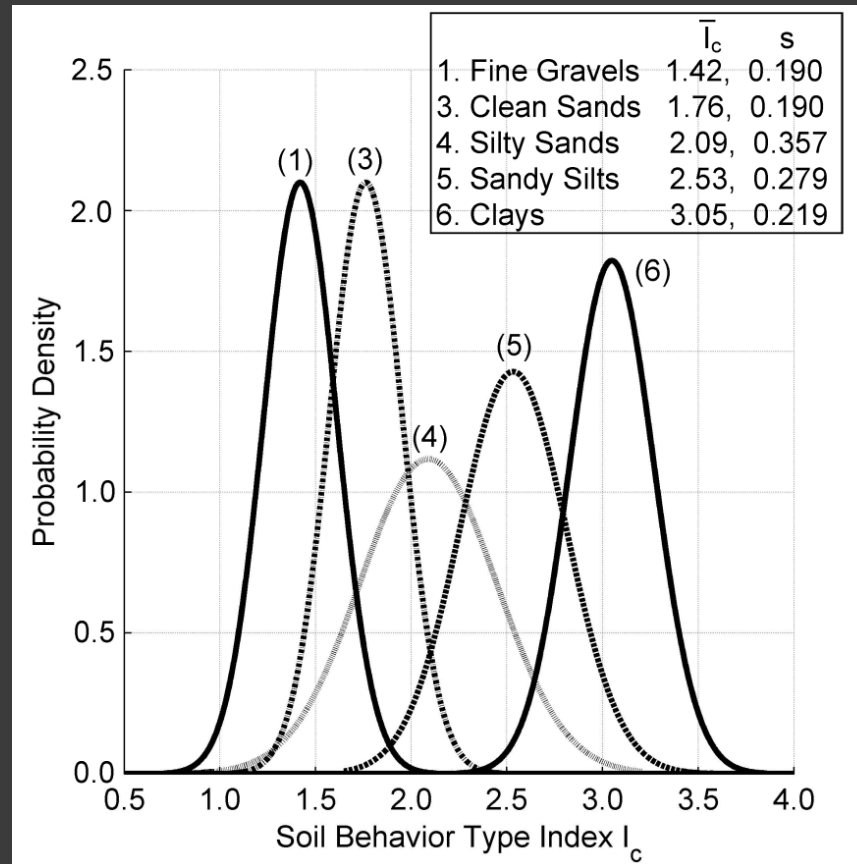


(d)



(e)

Charts to Estimate S_I given I_c



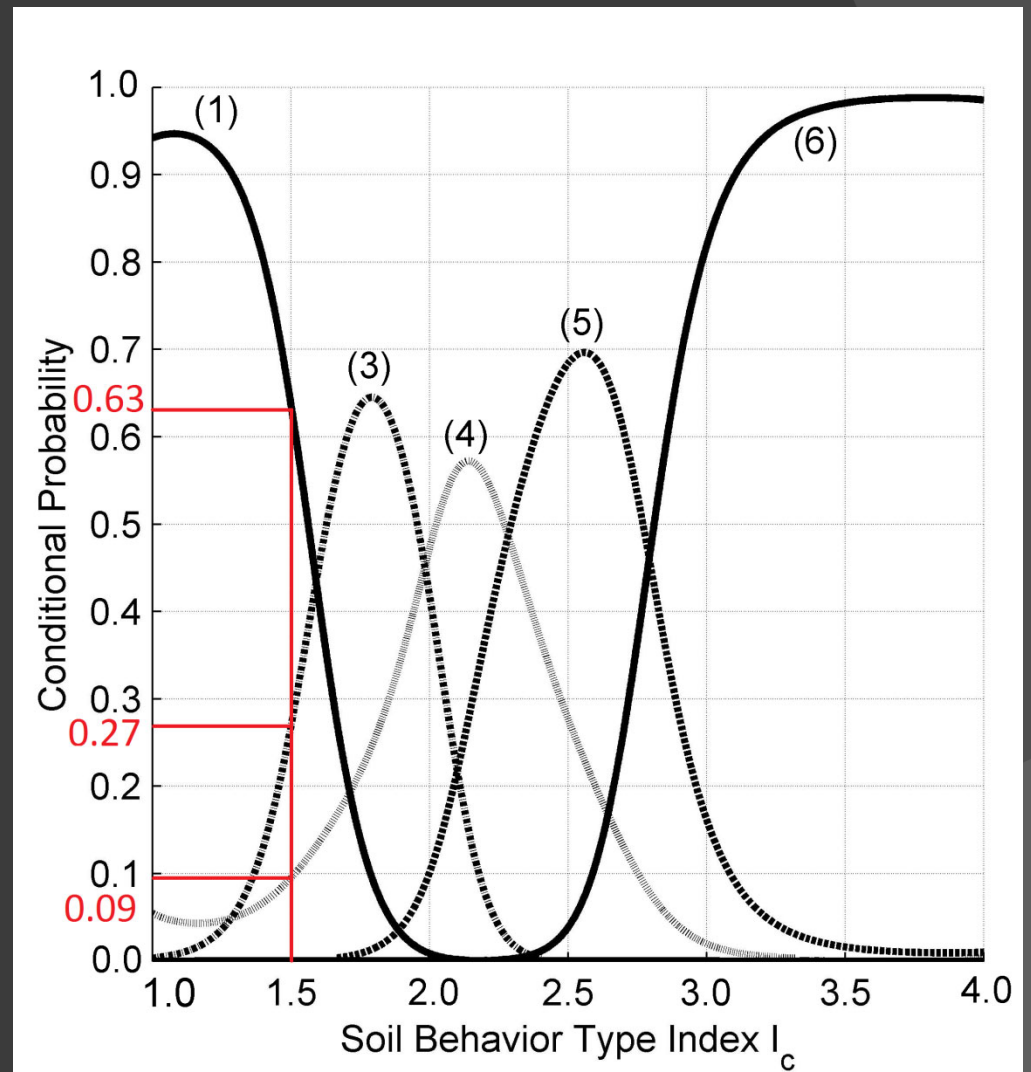
Recommended normal probability density functions; Weber County

Example 1

Find probability that:
 $SI = 1$ (i.e., fine gravel)
given $I_c = 1.5$

$P(SI = i | I_c = 1.5)$:

i	P
1. Fine Gravels	0.63
3. Clean Sands	0.27
4. Silty Sands	0.09
5. Sandy Silts	0.00
6. Clays	0.00

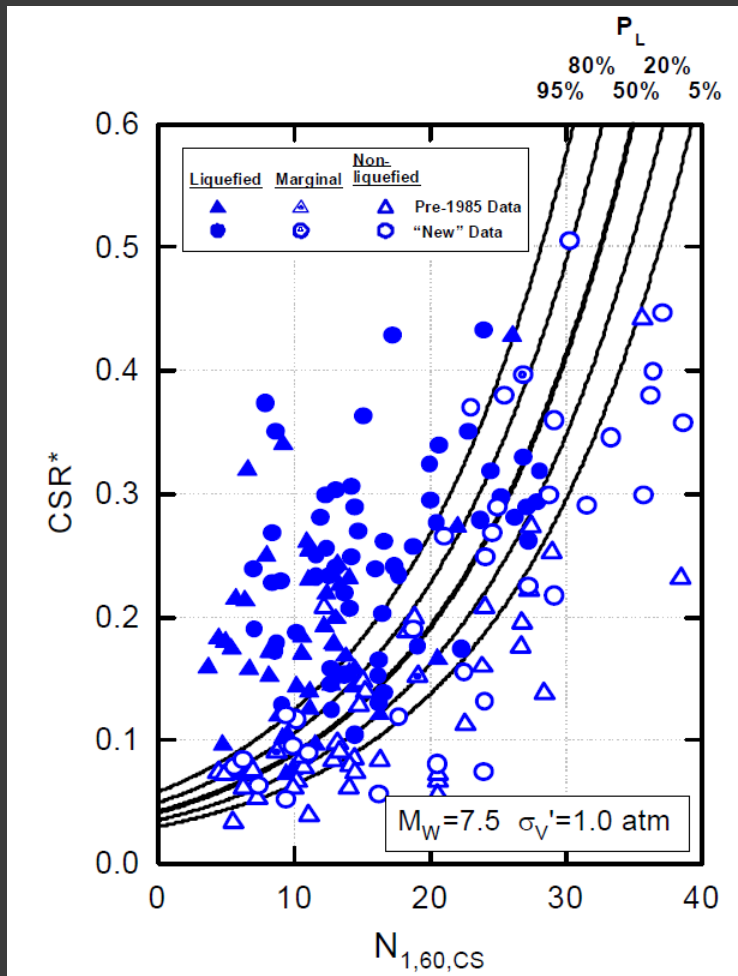


Probabilistic Framework

$$P[D_H > y] = P[D_H > y | L] \cdot P_L$$

1. Select a threshold distance, y
2. Find $P[D_H > y | L]$ using new empirical model
3. Find P_L from liquefaction potential curves of Cetin et al. (2004) and Moss et al. (2006)

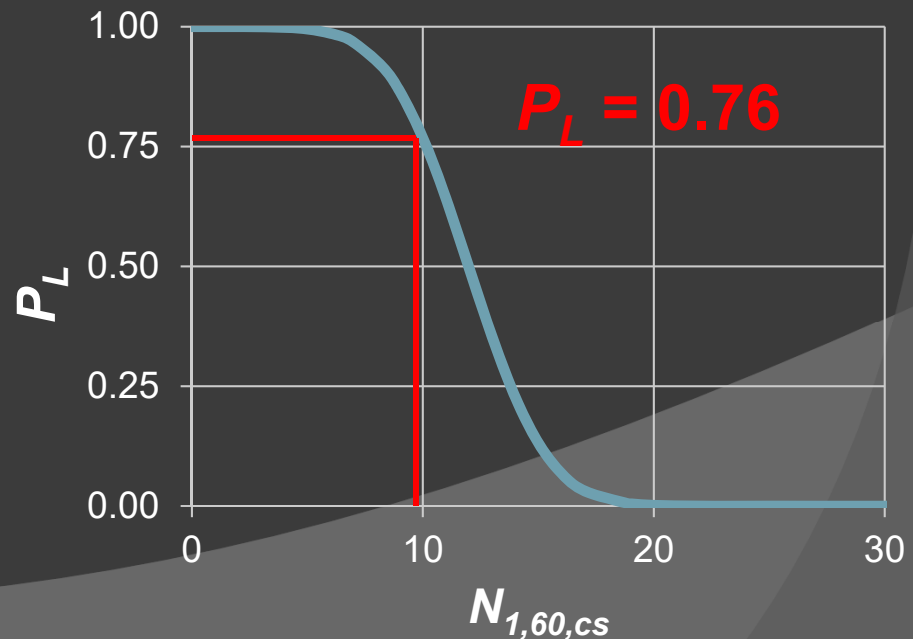
Example 2



SPT-based Liquefaction Potential Curves (Cetin et al., 2004)

Find $P [D_H > 1 \text{ m}]$ given:

- $CSR = 0.1; N_{1,60,cs} = 10$
- $M = 7.5; R = 20 \text{ km}$
- $S = 0.5 \%$
- $T_{15,cs} = 1 \text{ m}; \sigma'_v = 1 \text{ atm}$

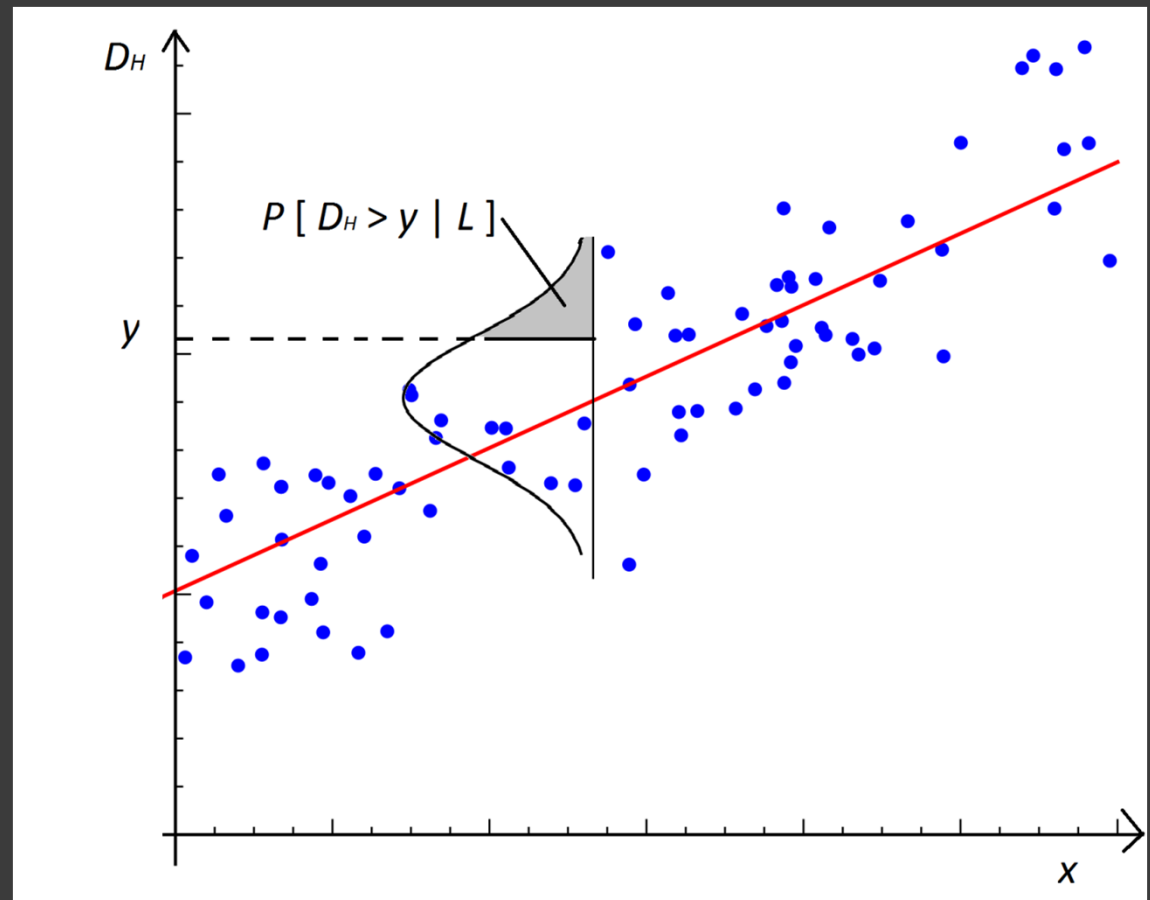


Example 2 (cont.)

$$P[D_H > y | L] = \Phi\left(-\frac{\text{Log}(y) - \overline{\text{Log}(D_H)}}{\sigma_{\text{Log}(D_H)}}\right)$$

$$= \Phi(-z)$$

$$= \underline{0.33}$$



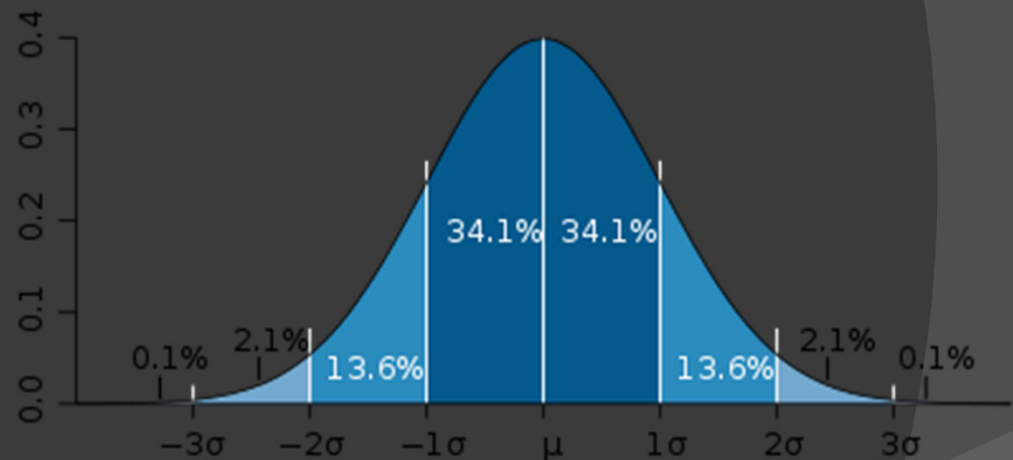
$$P[D_H > y] = (0.33) * (0.76) = \underline{0.25}$$

“Simple calculations based on a range of variables are better than elaborate ones based on limited input.”

-Ralph B. Peck

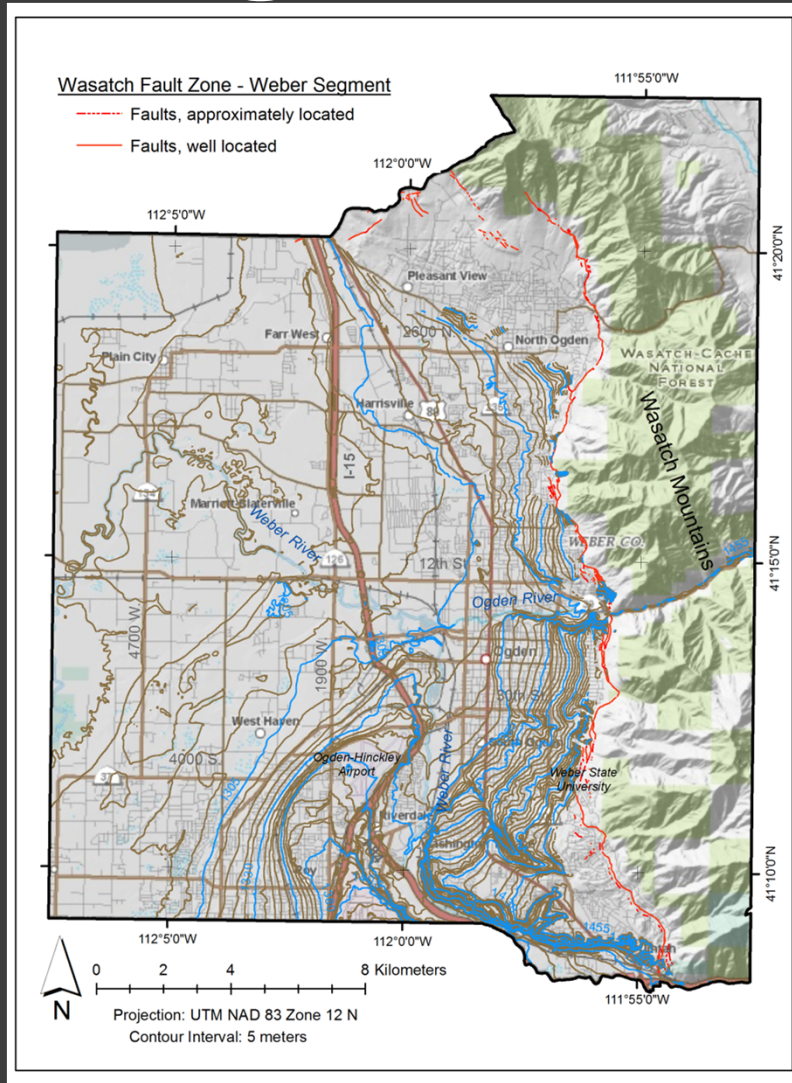
Monte Carlo Technique

- Used when:
 - Unable to compute results deterministically
 - Systems have many degrees of freedom
 - Modeling phenomena with significant uncertainty
- 1) Define a domain of inputs
- 2) Generate inputs randomly from a probability distribution over the domain;
- 3) Perform a deterministic computation on the inputs;
- 4) Aggregate the results to define the median values and their uncertainty

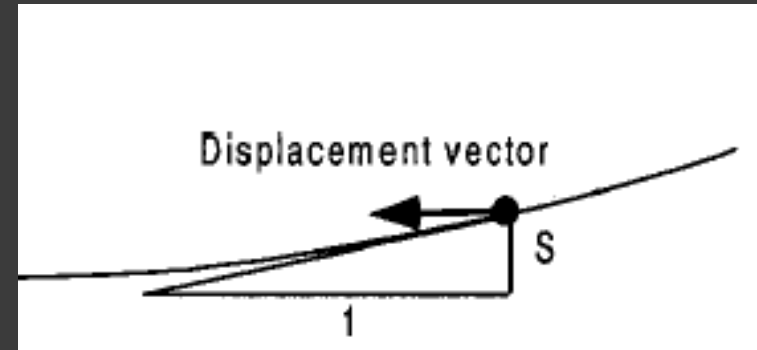


The Normal Distribution

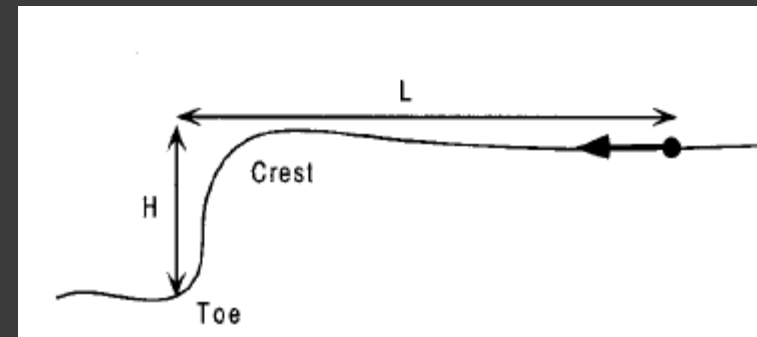
Topographic Variations



Contours Based on Digital Elevation Model (DEM) from USGS National Elevation Dataset



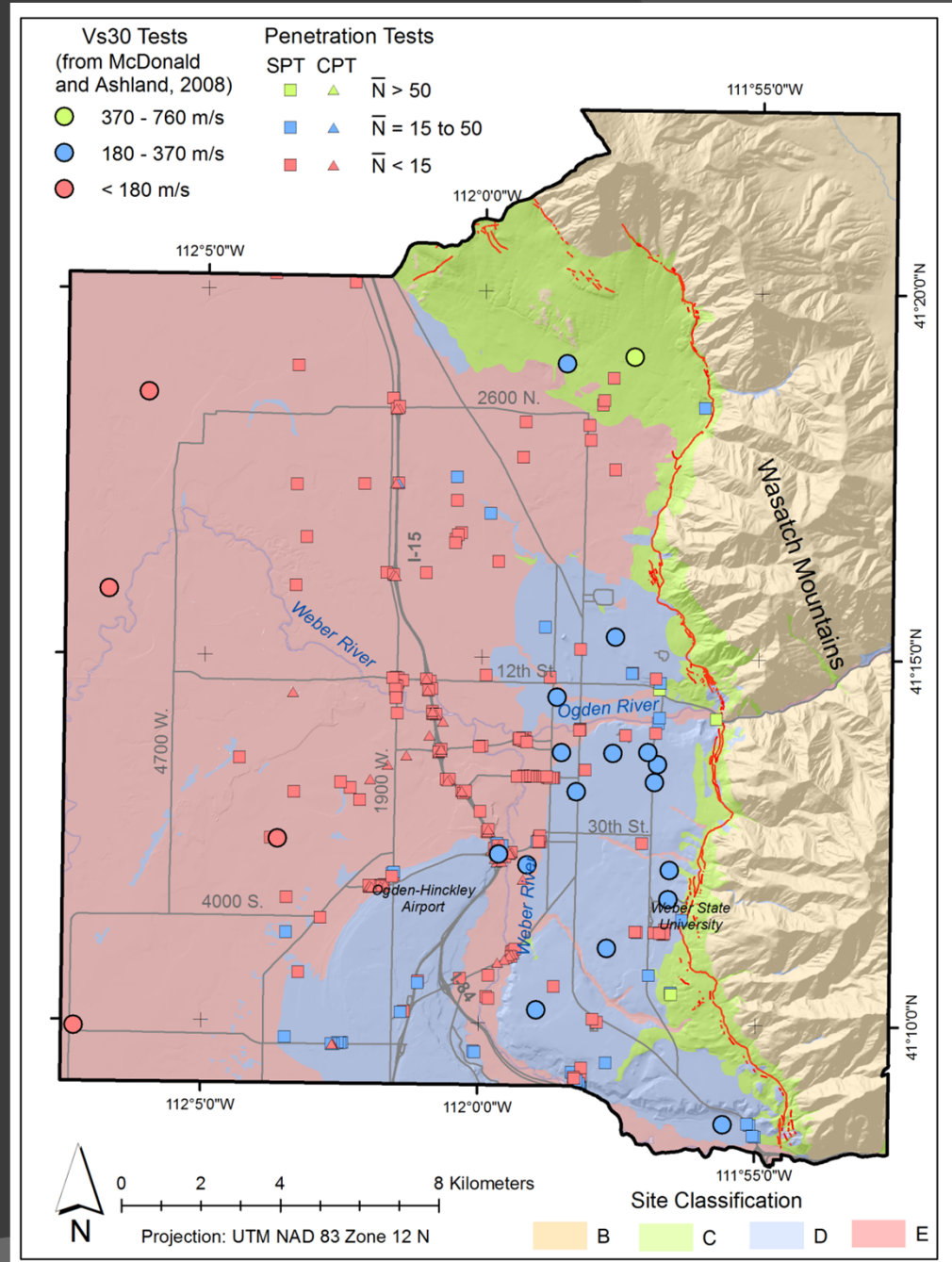
Percent ground slope: S (%)



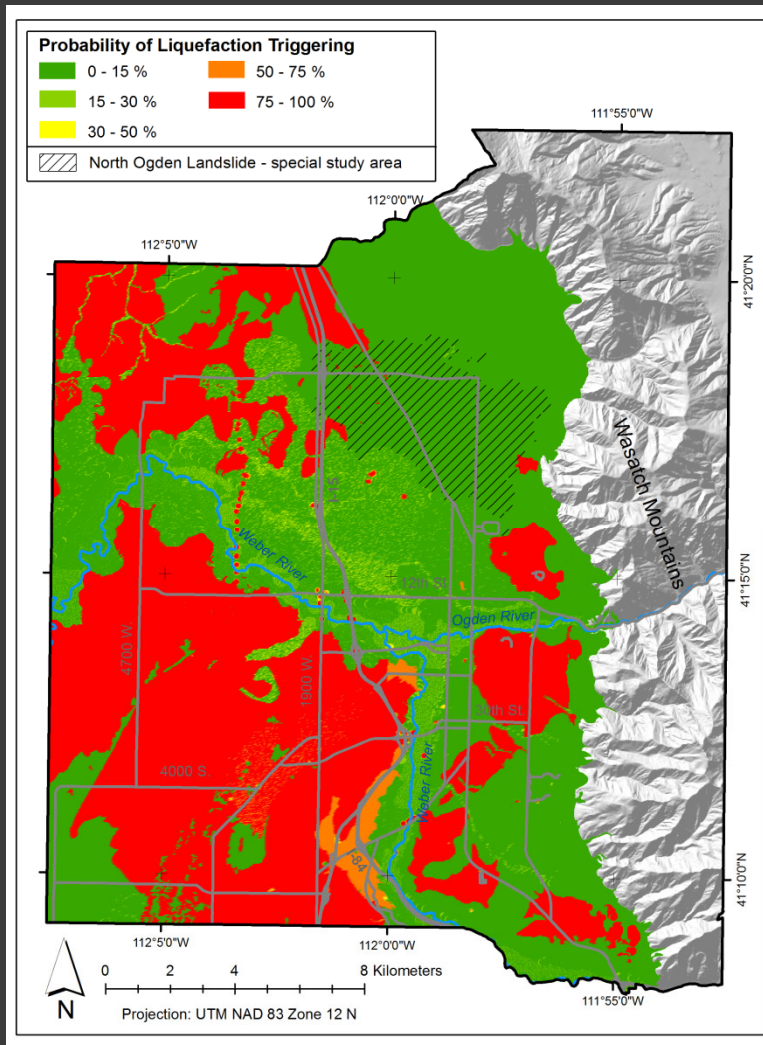
Free-face ratio: W (%) = $H / L * 100$

Seismic Inputs

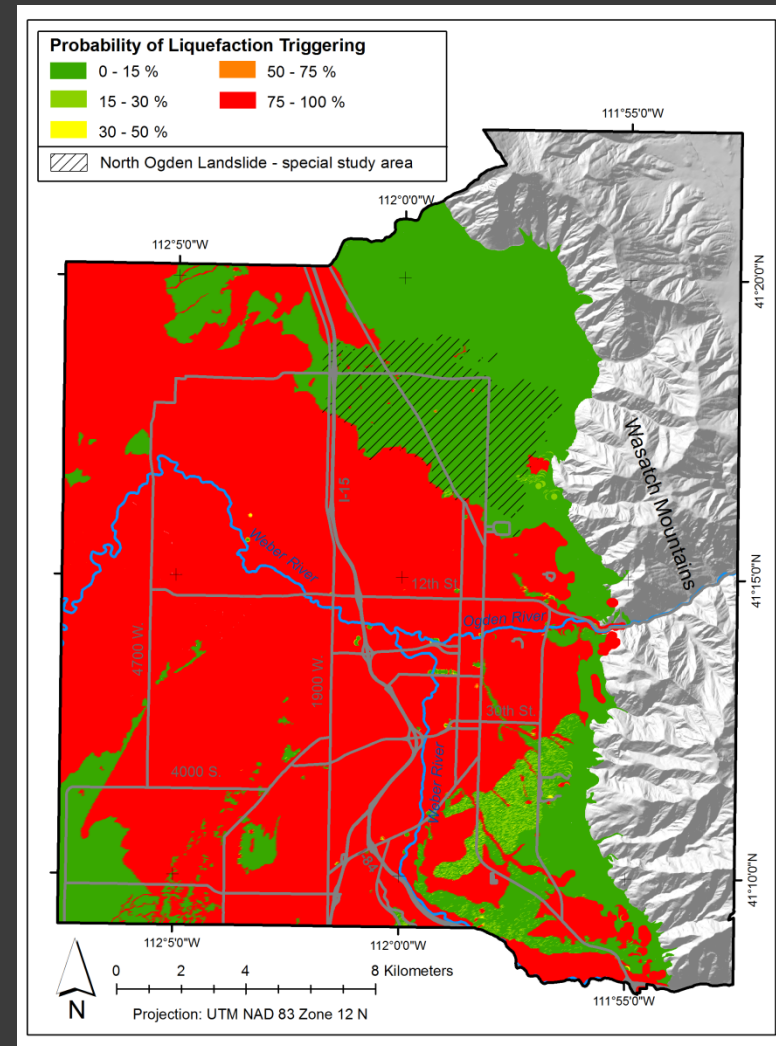
- Mean seismic variables from interactive deaggregation of the seismic hazard
- Seismic hazard based on 2008 source and attenuation models of the National Seismic Hazard Mapping Project (Peterson et al., 2008)



Liquefaction Triggering Maps

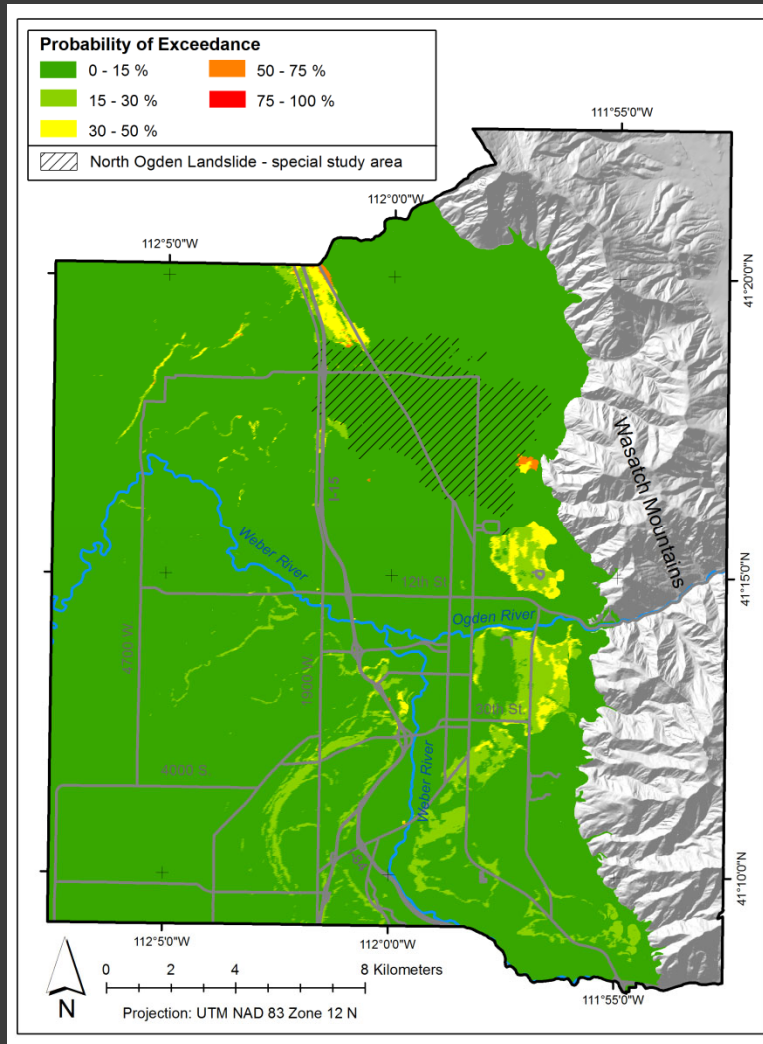


Median probabilities of P_L , 500-year seismic event

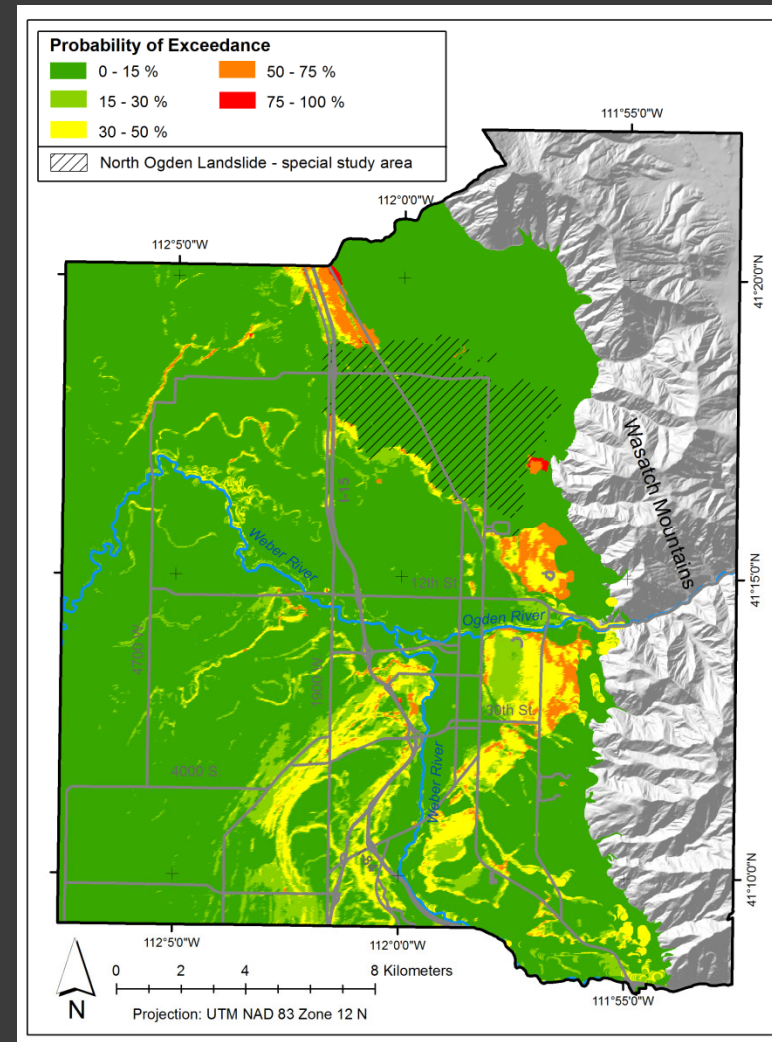


Median probabilities of P_L , 2,500-year seismic event

Lateral Spread Hazard Maps

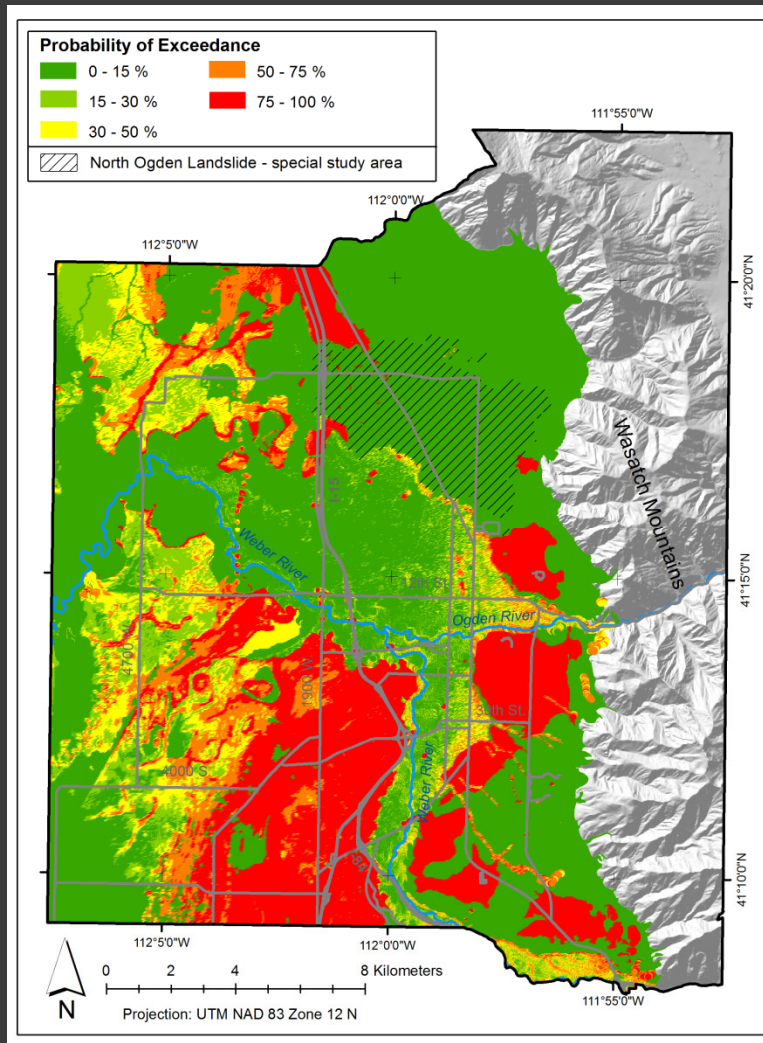


Median probabilities of exceeding 0.3 m, 500-year event

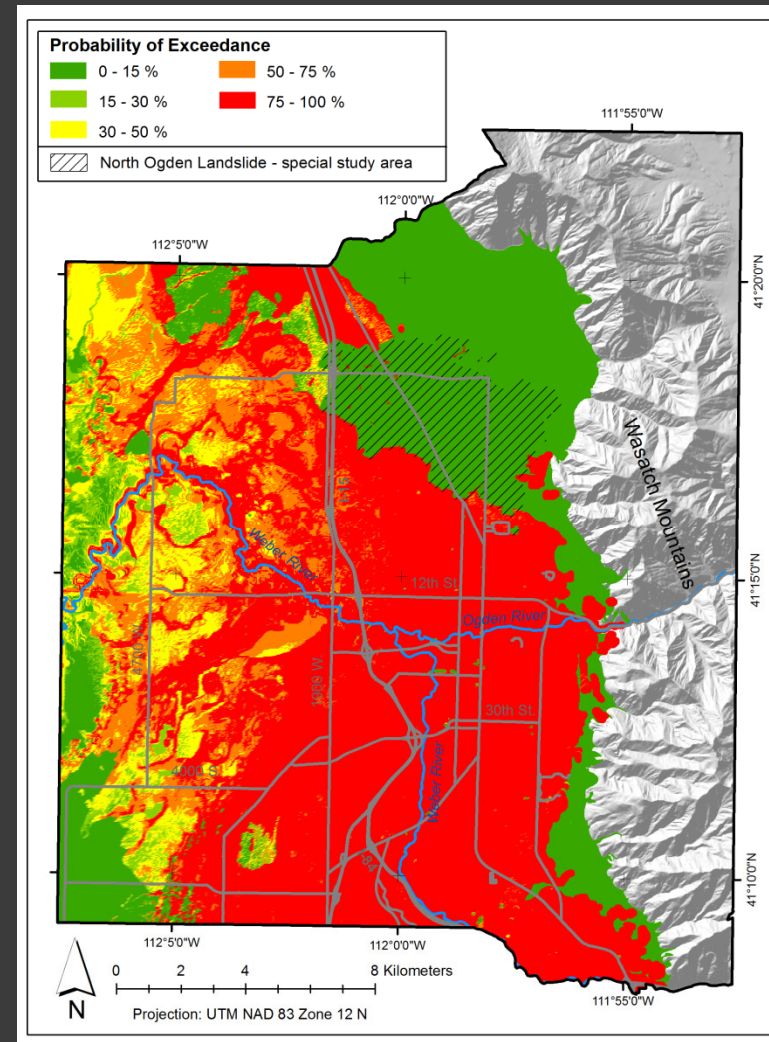


84th percentile probabilities, of exceeding 0.3 m, 500-year event

Lateral Spread Hazard Maps



Median probabilities of exceeding 0.3 m, 2,500-year event



84th percentile probabilities, of exceeding 0.3 m, 2,500-year event

For more information:

<http://www.civil.utah.edu/~bartlett/ULAG/>

Multilinear Regression Equations for Predicting Lateral Spread Displacement from Soil Type and Cone Penetration Test Data

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