US – New Zealand – Japan International Workshop
"Liquefaction-Induced Ground Movements Effects"
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Liquefaction-Induced Lateral Spreading

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Outline

WORKSHOP PROMPTS

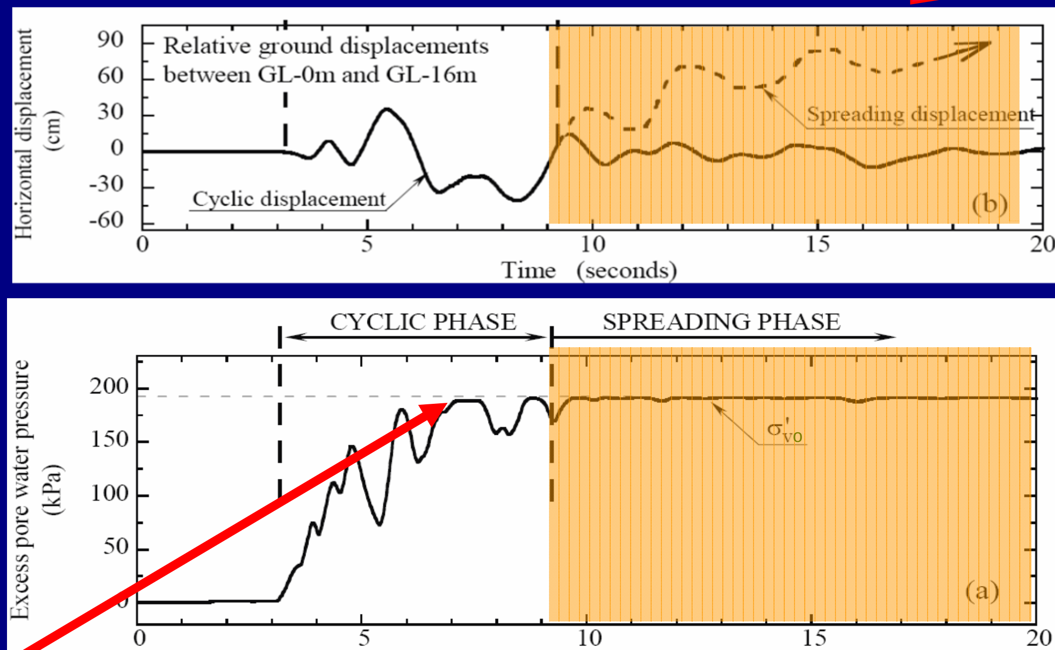
1. What is the current state-of-the-art for evaluating this problem today?
2. What are the key underlying geologic processes that affect it?
3. What are the primary mechanisms involved in the phenomenon?
4. What are the key challenges to developing better evaluation procedures?
5. What is the best path forward for advancing understanding and procedures to address it?

Lateral Spreading Mechanism: Dynamic Nature & Interactions

SPREADING

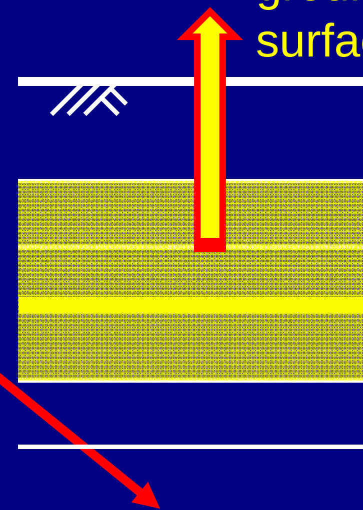
Lateral ground displacement

Excess pore water pressure



Time (sec)

Ejecta reaches ground surface



Dissipation

Liquefaction triggered (at a certain depth)

Thickness of liquefied zone increases

SPREADING

Combined Gravity-induced and Seismic Effects

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- Intricate interplay of gravity-induced and earthquake loads, and mechanisms of ground deformation

- Earthquake loading:
  - (i) Governs the development of liquefaction, and influences stress-strain relationships post liquefaction (during spreading)
  - (ii) Contributes to permanent ground displacements

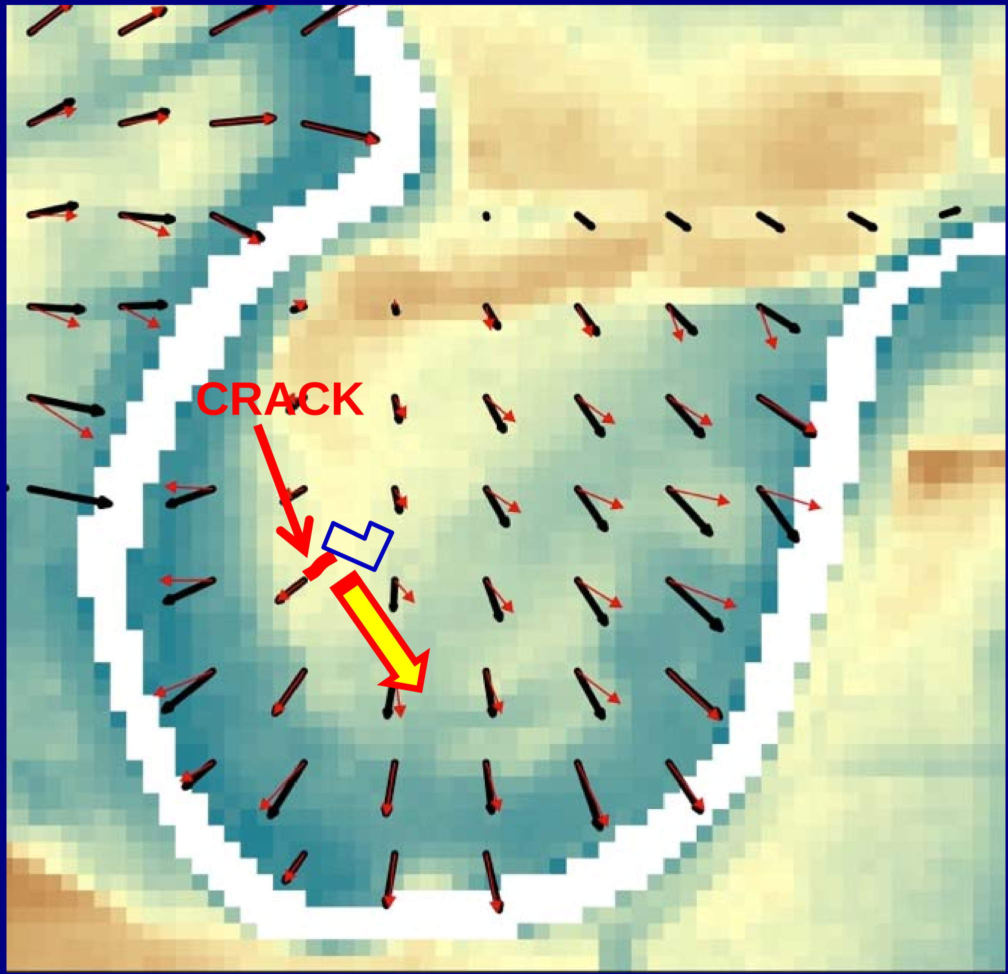
- The proportion of gravity-induced and earthquake-induced displacements depends on:
  - (i) The characteristics of these loads, and
  - (ii) Dynamic response of critical soil layers, and deposit as a whole

We have a reasonably good understanding of processes, but have problems in quantifying them in the engineering assessment.

Gravity-Induced Driving Stresses

Gravity-induced shear stresses due to:

- Global topographic features (slope gradient at ground surface)
- Free face (e.g. river channel)



Topographic features:

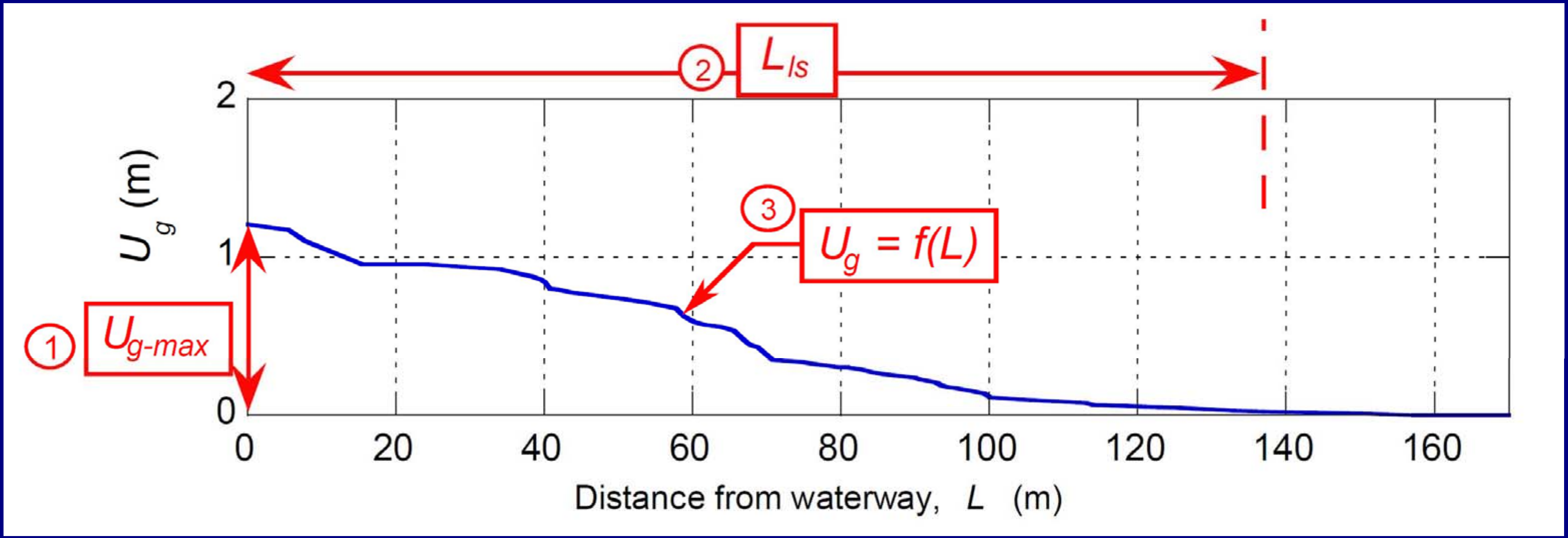
- High elevation areas (ridges in local topography) define the direction of spreading (away and downslope)
- Slumping mode of deformation

Dominant effects of:

- Global topographic features in the far field
- Free face in the near field

Key Challenges for Developing Better Evaluation Procedures

Engineering Evaluation of Lateral Spreading



Cubrinovski and Robinson (2016)

Principal targtes in the assessment:

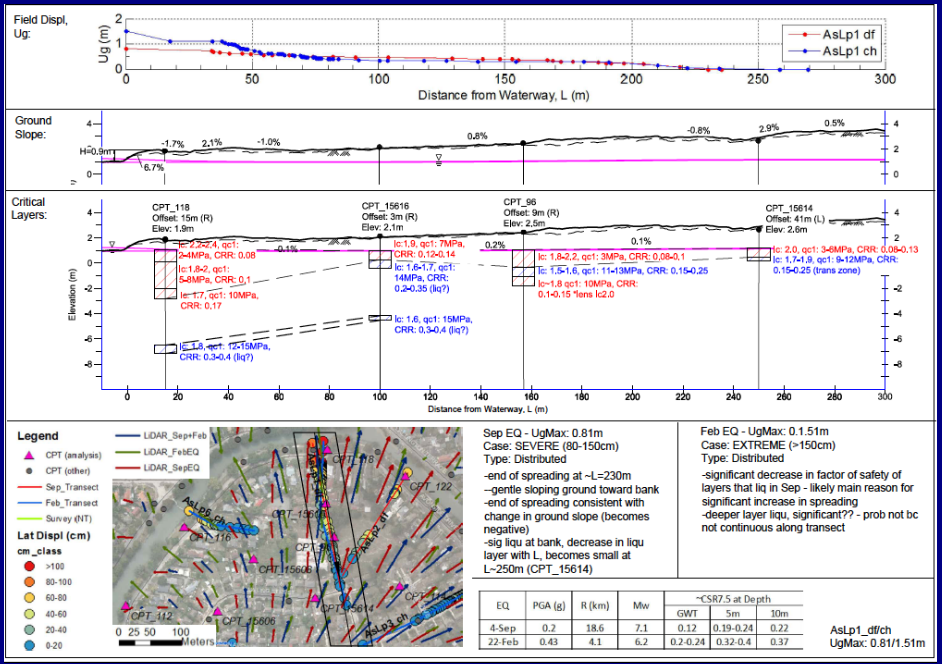
1) Maximum magnitude of ground displacement, $U_{g\text{-}max}$
2) Zone affected by lateral spreading, L_{ls}
3) Distribution of spreading *displacements,* $U_g = f(L)$
   (i.e. ground strains and angular distortion)

- Stiffeness and strength of spreading soils (→ LS loads)

Difficult to Characterize

Lateral spreads

- Complex and difficult to characterize
- Often manifest considerable *non-uniformity and spatial variability* on a local scale
- Global and local surveying methods measure *different* displacement features



EQ	PGA (g)	R (km)	Mw	~CSR7.5 at Depth		
				GWT	5m	10m
4-Sep	0.2	18.6	7.1	0.12	0.19-0.24	0.22
22-Feb	0.43	4.1	6.2	0.2-0.24	0.32-0.4	0.37

Robinson (2016)

High-quality global and local surveying data are needed to estimate with reasonable level of confidence key engineering parameters of lateral spreads:

$U_{g\text{-}max}$, L_{ls}, *and* $U_g = f(L)$.

Difficult to Interpret

Lateral spreads and associated displacements are affected by:

- Soil type, in situ state, and behaviour under earthquake loading
- Stratification and *'system response'* of the deposit
  (effects of ground water flow and dynamic response effects)
- Free face conditions, geomorphology and topographic effects
- Ground motion characteristics
- The interaction of all of the above

→ A unique combination for each case history

Well-documented case studies are needed with:

- Good estimates for $U_{g\text{-}max}$, L_{ls}, *and* $U_g = f(L)$,
- Detailed geotechnical, geologic and ground motion data, and interpretation are needed.

Best Path Forward

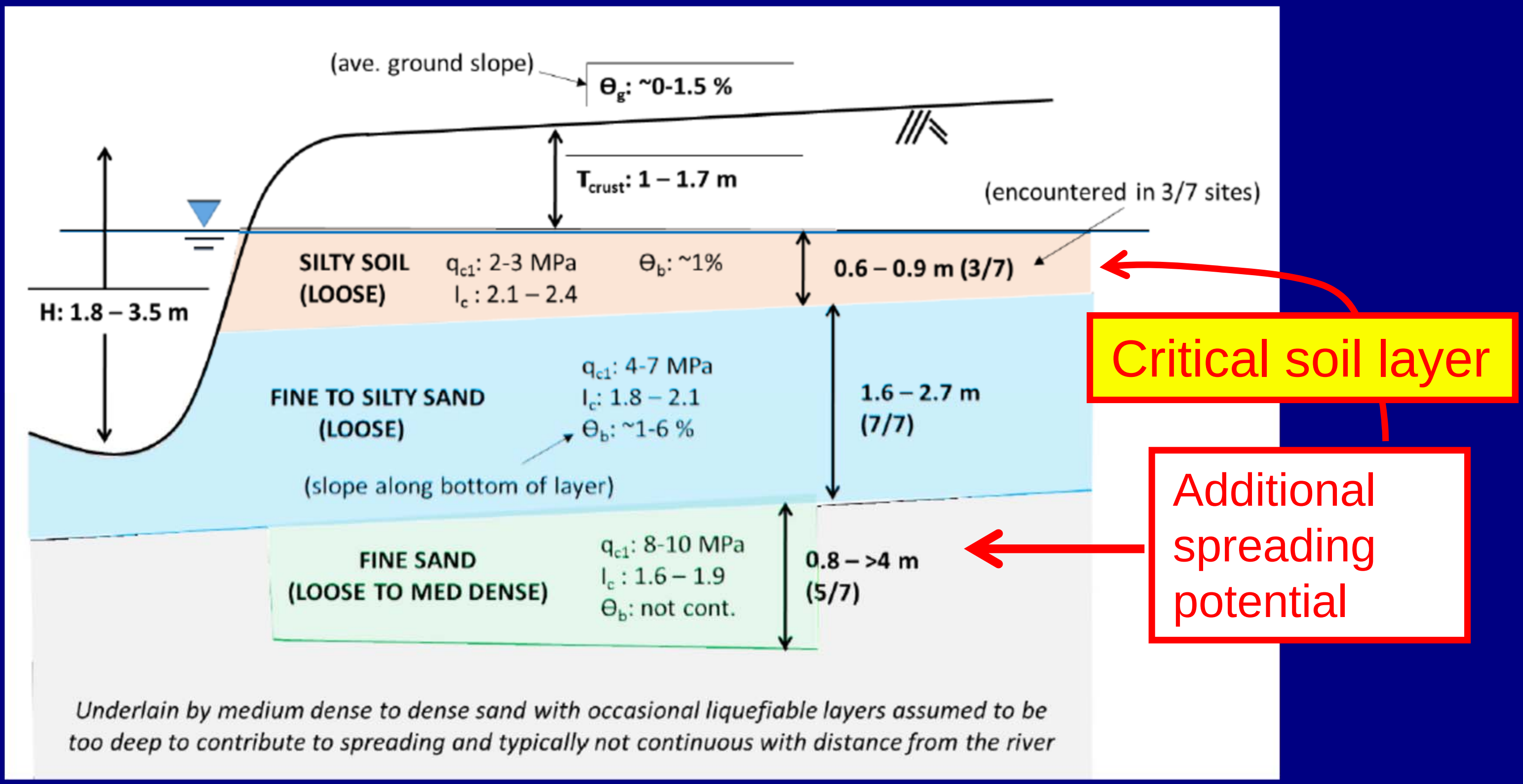
Systematic Modelling Approach

1) Well documented case studies
   - characterization of lateral spreads [$U_{g\text{-}max}$, L_{ls}, $U_g = f(L)$]
   - interpretation of lateral spreads
   (geotechnical, geologic, EQ engineering aspects;
   seismic demand: pre- and post-triggering)

2) Classification of lateral spreads
   - critical soils characteristics; critical layer (thickness; location)
   - stratigraphy ('system response')
   - geomorphology, free face characteristics (river geometry), and topographic features

3) Class-specific predictive models

Christchurch Case Histories



Cubrinovski and Robinson (2016)

Geotechnical Interpretation

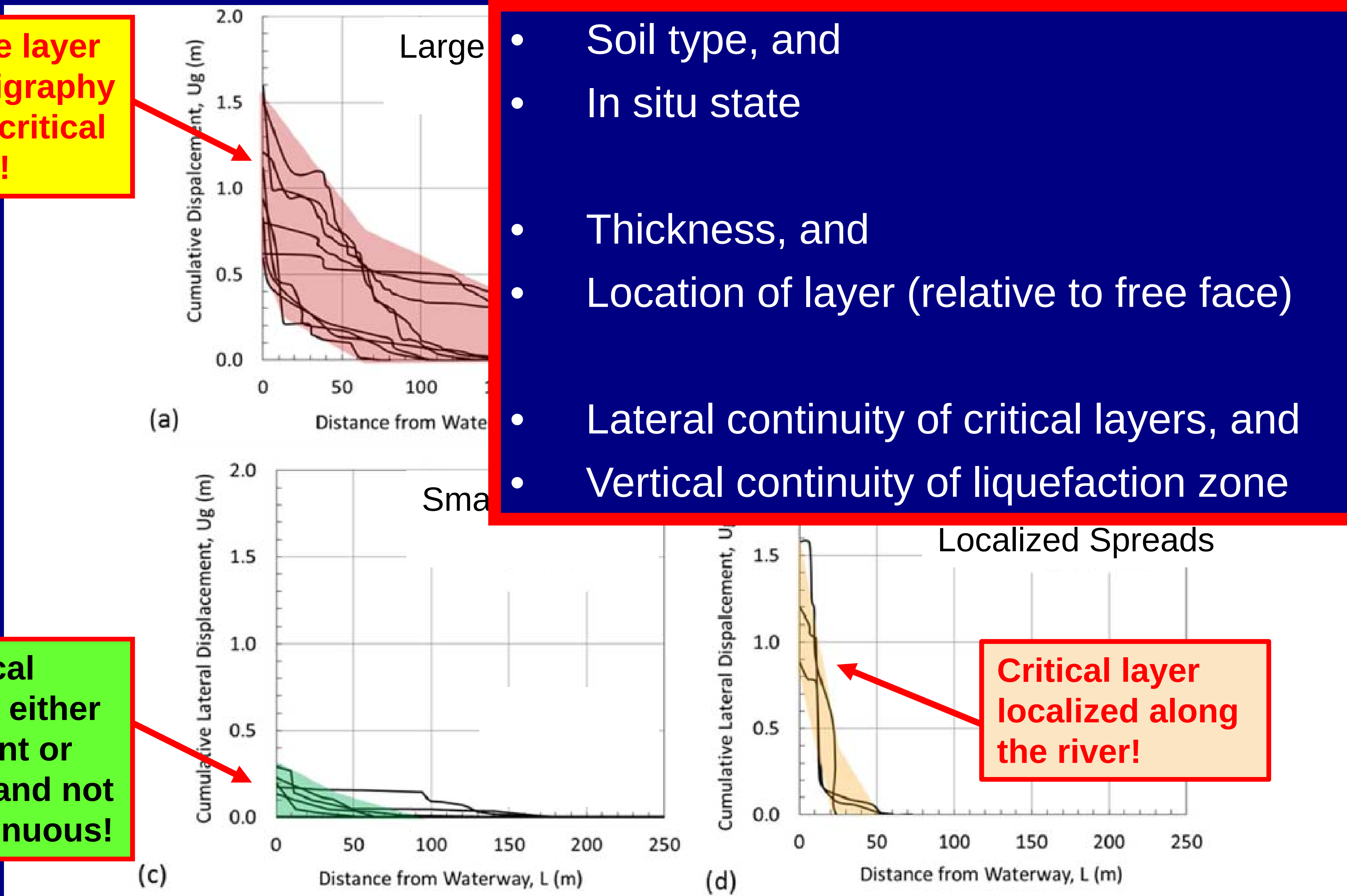
Three layer stratigraphy with critical layer!

Critical layer either absent or thin and not continuous!

- Soil type, and
- In situ state

- Thickness, and
- Location of layer (relative to free face)

- Lateral continuity of critical layers, and
- Vertical continuity of liquefaction zone

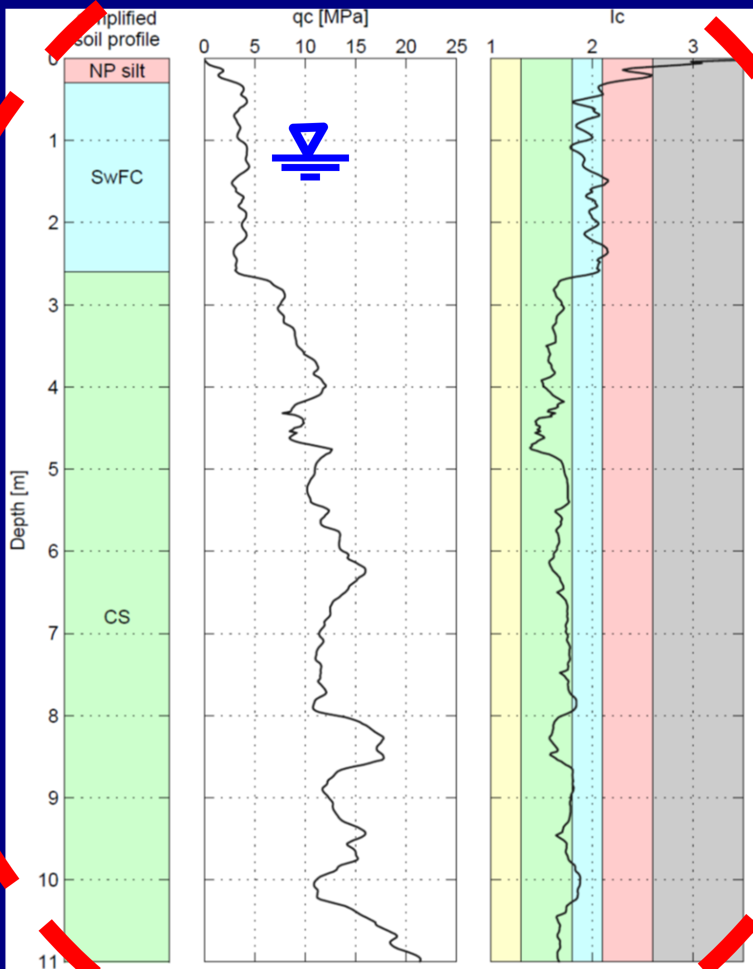


Critical layer localized along the river!

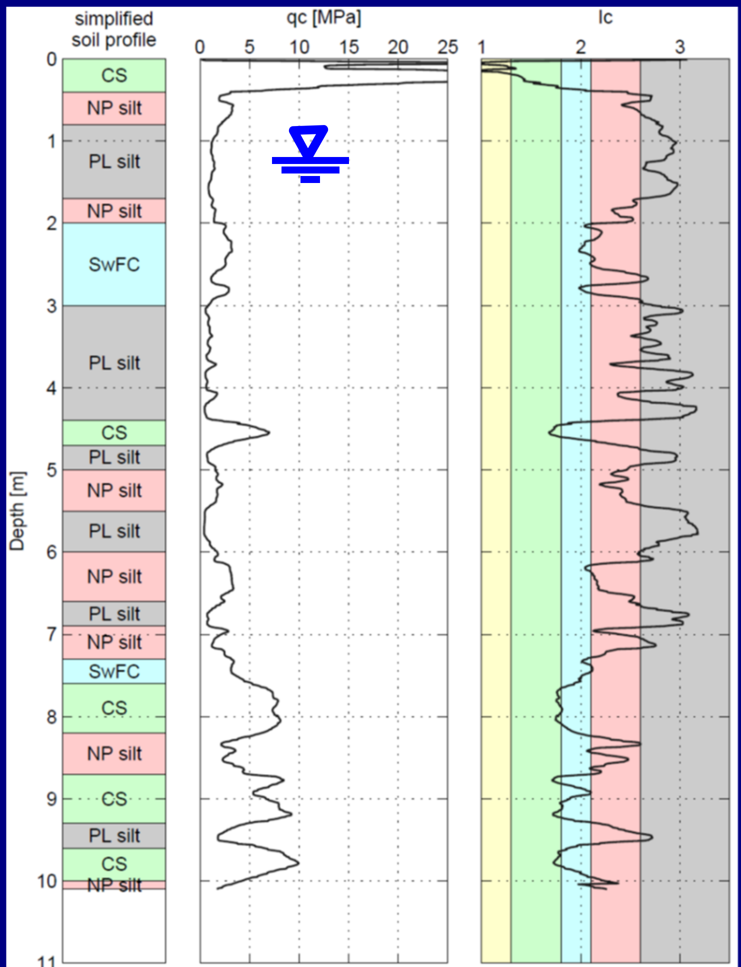
Cubrinovski and Robinson (2016)

Characteristic Soil Profiles in Christchurch

A) Uniform fine sand deposit



B) Highly stratified deposit (inter-bedded liquefiable and non-liquefiable layers)



Integrated Modelling Approach

1) Case studies (and associated simplified analysis)

Integrated geologic, geotechnical and earthquake engineering interpretation

2) Centrifuge studies

MECHANISMS of spreading and ground deformation / displacements

3) Numerical studies

PARAMETRIC and SENSITIVITY analyses for established mechanisms

DYNAMIC COMPONENT of ground displacements

Modelling Framework

FRAMEWORK FOR ADVANCED LATERAL SPREADING MODELS

1) Case studies (and simplified analysis)

Integrated geologic, geotechnical and earthquake engineering interpretation

2) Centrifuge studies

MECHANISMS of spreading and ground deformation / displacements

3) Numerical studies

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