Modeling Lateral Spread Displacements using Data from the 2011 Christchurch Earthquake

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Introduction

Lateral spreading displacements during the 2011 Christchurch Earthquake were extensive and provide an excellent opportunity to study the factors that influence lateral spread movements. The objective of this research are:

- Identify key factors that influence lateral spreading displacements
- Evaluate effectiveness of empirical lateral spread displacement models
- Demonstrate ability of Finite Element Modeling to capture complex displacement patterns

Study Areas

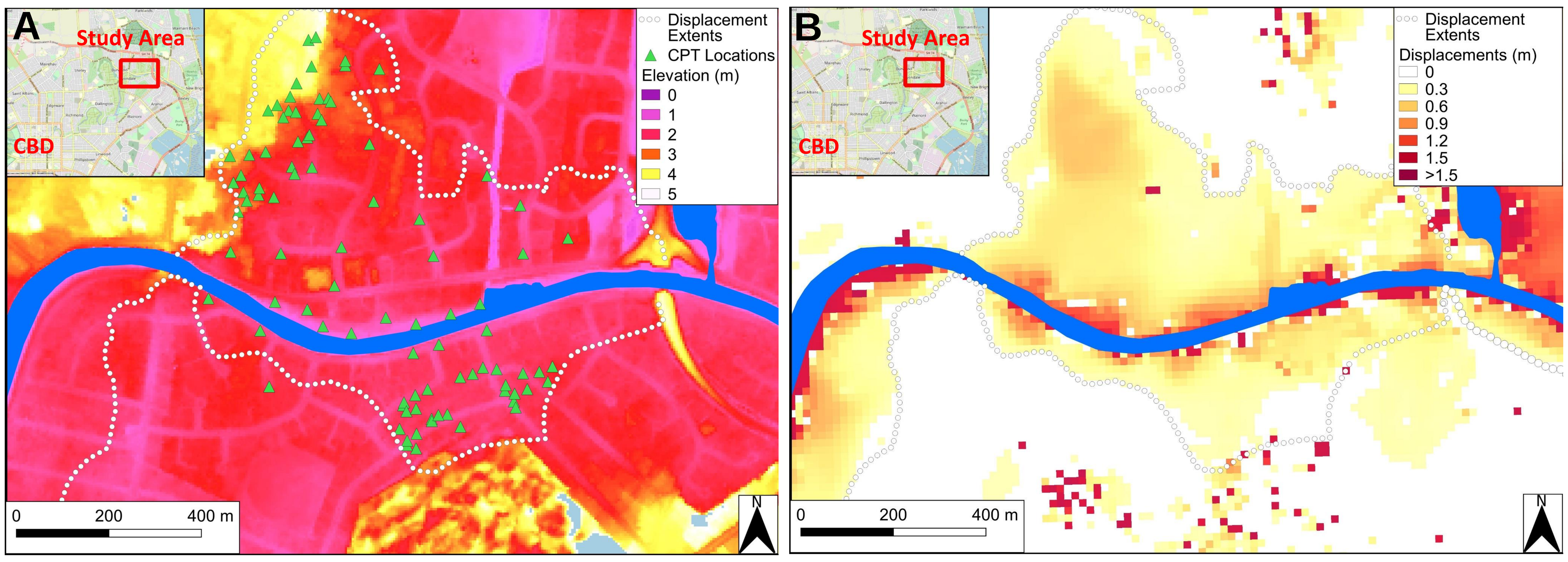

Figure 1: Study area with A) LIDAR derived DEM and B) horizontal displacements (Rathje et al. 2017)

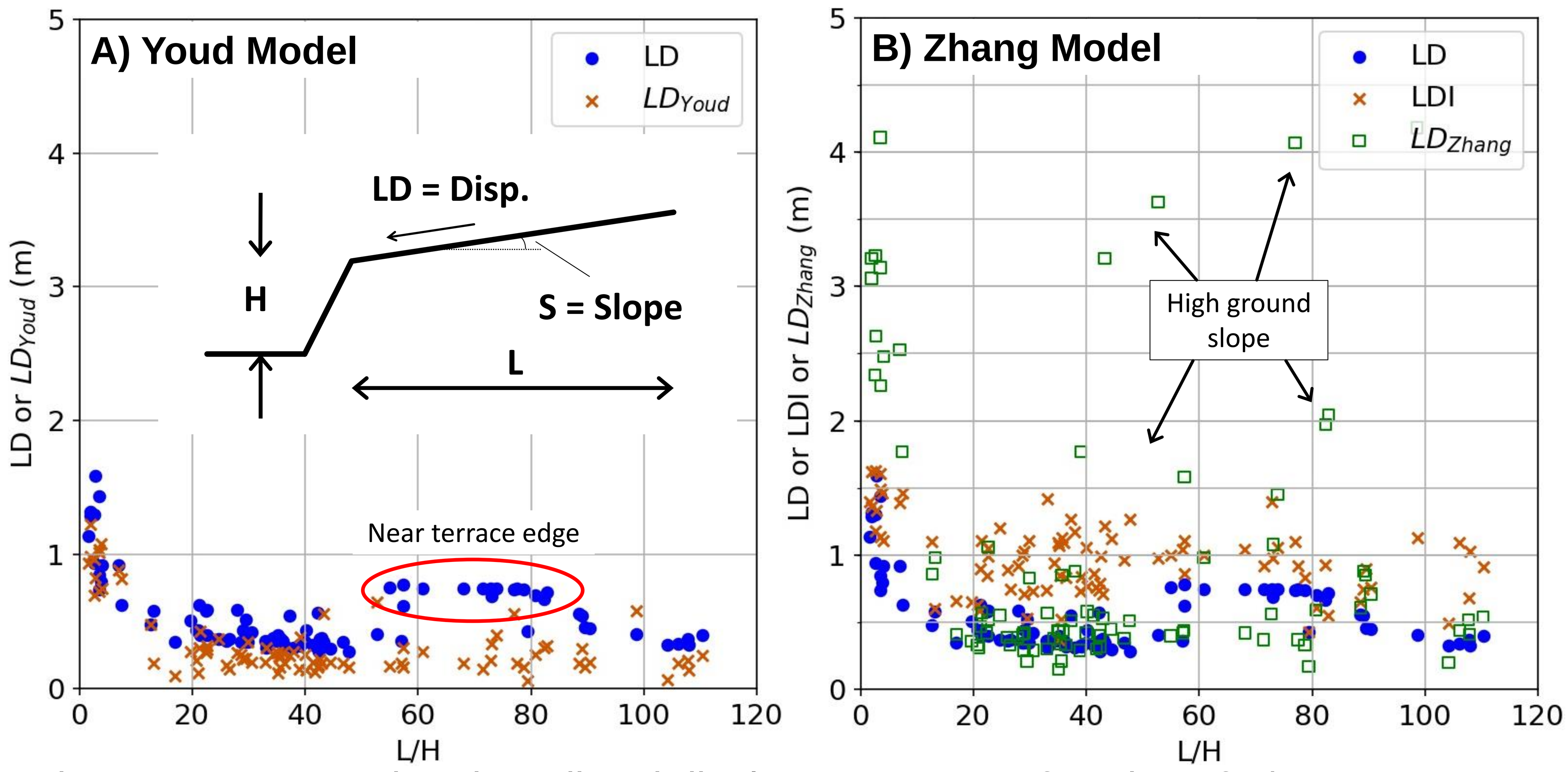

Figure 2: Measured and predicted displacements as a function of L/H

Empirical Model Performance

- Youd et al. (2002)
  - $LD = fxn(M, R, T15, L/H \text{ or } S, D15, F15)$
- Zhang et al. (2004)
  - $LD = LDI \cdot fxn\left(\frac{L}{H} \text{ or } S\right) = \int_0^{2H} \gamma_{max}\, dz \cdot fxn\left(\frac{L}{H} \text{ or } S\right)$
- Youd et al. (2002) performs well for L/H < 10 and under predicts for L/H > 10
- Zhang et al. (2004) over predicts for L/H < 10 and performs well for L/H > 10, except in cases of high ground slope
- Neither model captures well the large displacement zone from L/H ~ 55 – 90

Finite Element Modeling

- FEM models created in GiD using tools from McGann and Arduino (2010)
- Analysis Details
  - Modeling Program: OpenSees v3.0
  - Constitutive model: PM4Sand (Boulanger and Ziotopolou 2017)
  - Element: SSPquadUP (McGann et al. 2012)
- Post-processing with Python and GiD
- Horizontal displacement contours and surface profiles for two FEM models in Figure 3
- Models are identical except one model has a flat surface and the other has a terrace located about 100 m (L/H ~ 30) from the free face
- Indicates that a terrace located at distance from the free face impacts displacements along the entire spread, not just in areas where the immediate ground slope is increased

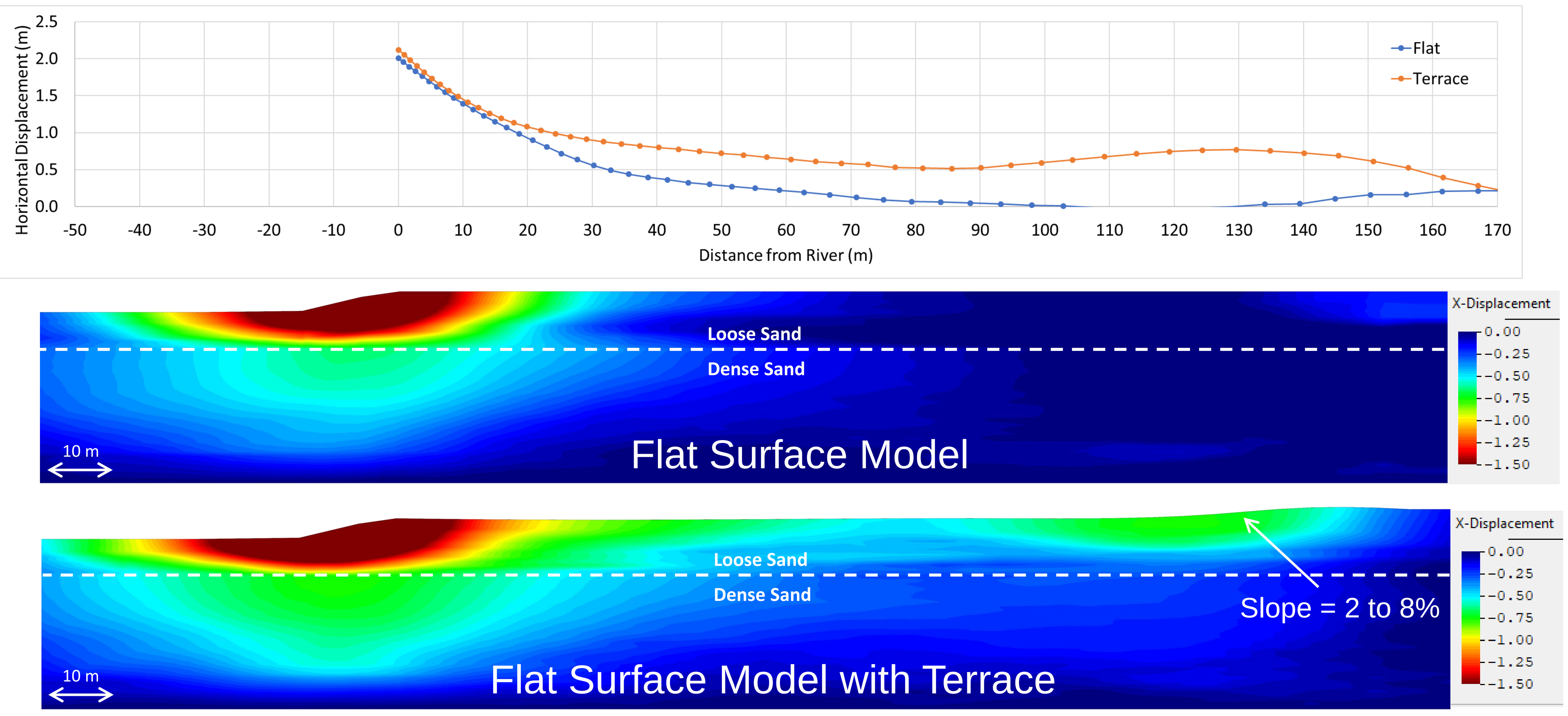

Figure 3: FEM analysis results of two models showing horizontal displacements.

Conclusions

- Current empirical models do not capture observed complex displacement patterns because each displacement prediction is independent
- Lateral spreads are complex events that must be analyzed as a system of interactions
- FEM modeling can be used to capture displacements patterns not captured by empirical models
- FEM analyses can be used to investigate the influence of key two-dimensional lateral spread factors (e.g. continuity of layers, presence of a terrace, height of the free face, etc..) that currently are not included in simplified empirical models

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