# Geotechnical Lessons from Recent Earthquakes

## Moderator: Russell Green, Virginia Tech

- 2010, $M_w$7.0 Haiti Earthquake

  ***Dr. Brady Cox, University of Arkansas***

- 2010, Mw8.8 Maule, Chile Earthquake

  ***Dr. Scott Olson, University of Illinois at Urbana-Champaign***

- 2010-2011, Canterbury New Zealand Earthquake Sequence

  ***Dr. Russell Green, Virginia Tech***

- 2011, $M_w$9.0 Tohoku-Oki, Japan Earthquake

  ***Dr. Shideh Dashti, University of Colorado, Boulder***

- Potential impact of lessons learned on practice

  ***Dr. Ellen Rathje, University of Texas at Austin***

# An Overview of the Geotechnical Aspects of the 2010-2011 Canterbury, New Zealand Earthquake Sequence


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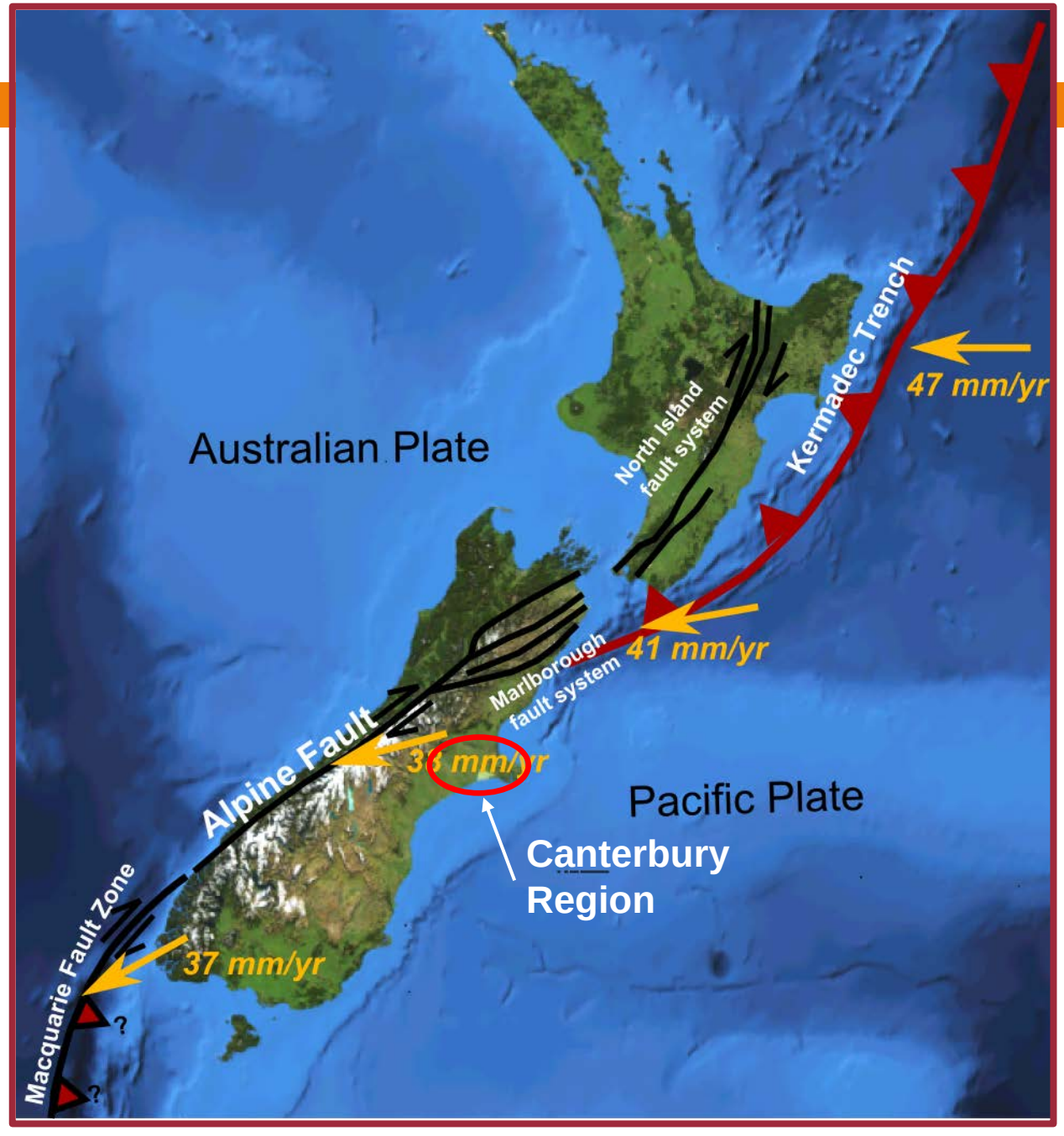
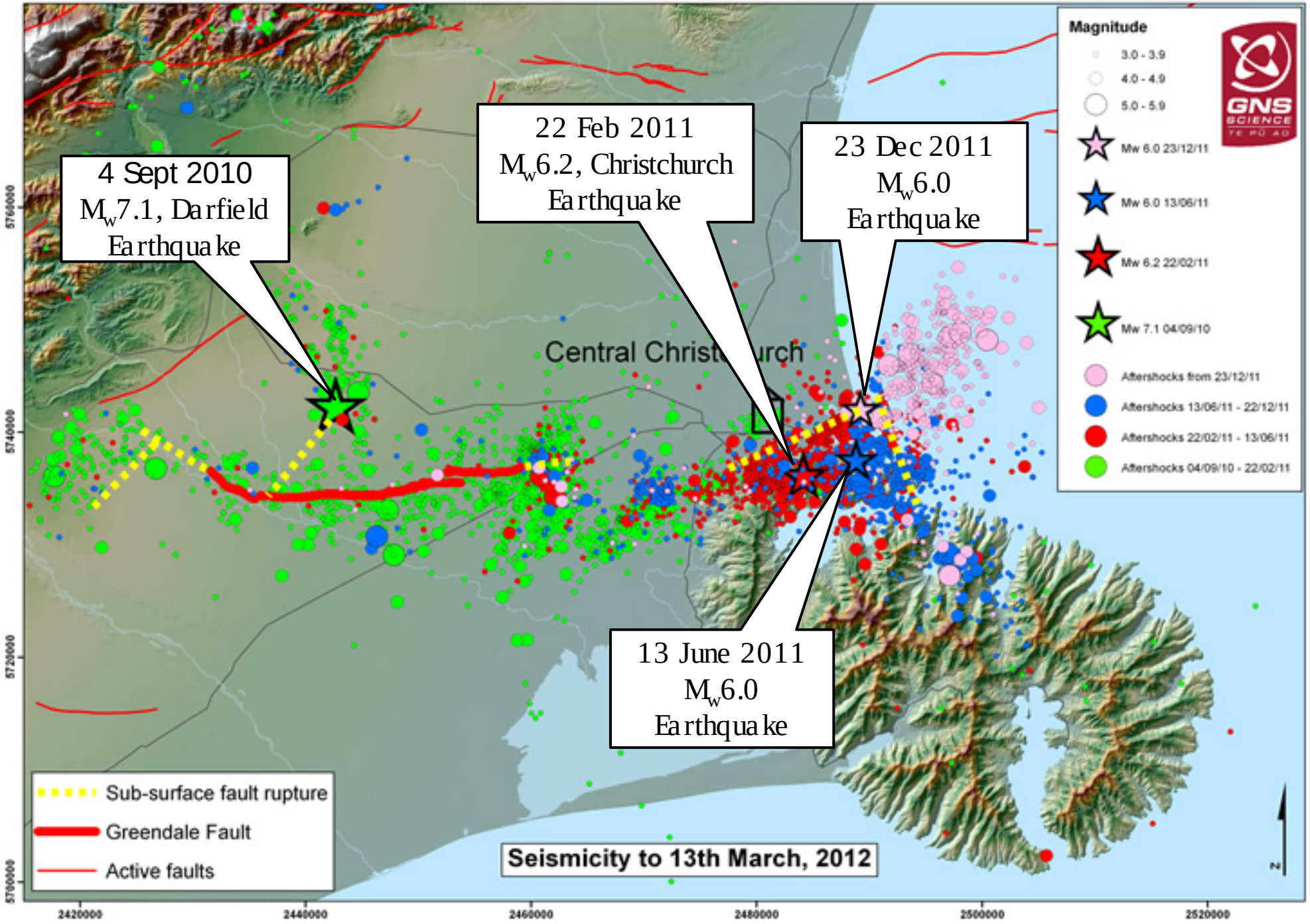
# Outline

- Tectonics and seismicity of New Zealand
- 2010-2011 Canterbury Earthquake Sequence
- Geotechnical Related Damage
  - Soils of Christchurch
  - Impact of liquefaction and lateral spreading
    - Building structures
    - Buried pipelines
    - Bridges
  - Rockfalls and landslides
  - Port of Lyttelton
- The Future
- Summary and Conclusions

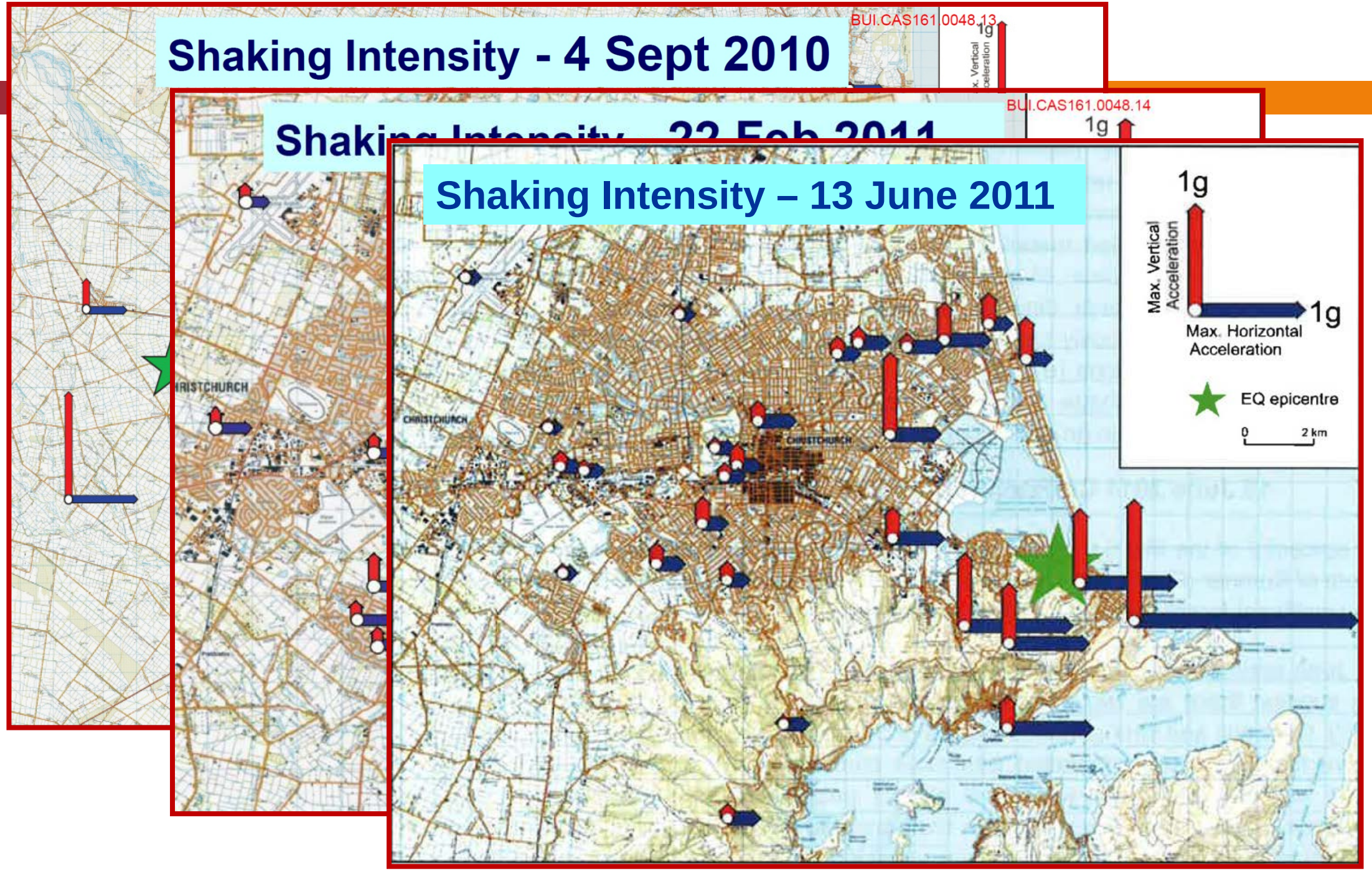
# Tectonics


Australian Plate
Pacific Plate
North Island fault system
Kermadec Trench
47 mm/yr
41 mm/yr
Marlborough fault system
Alpine Fault
Canterbury Region
Macquarie Fault Zone
37 mm/yr
?
?

# 2010-2011 Canterbury Earthquake Sequence



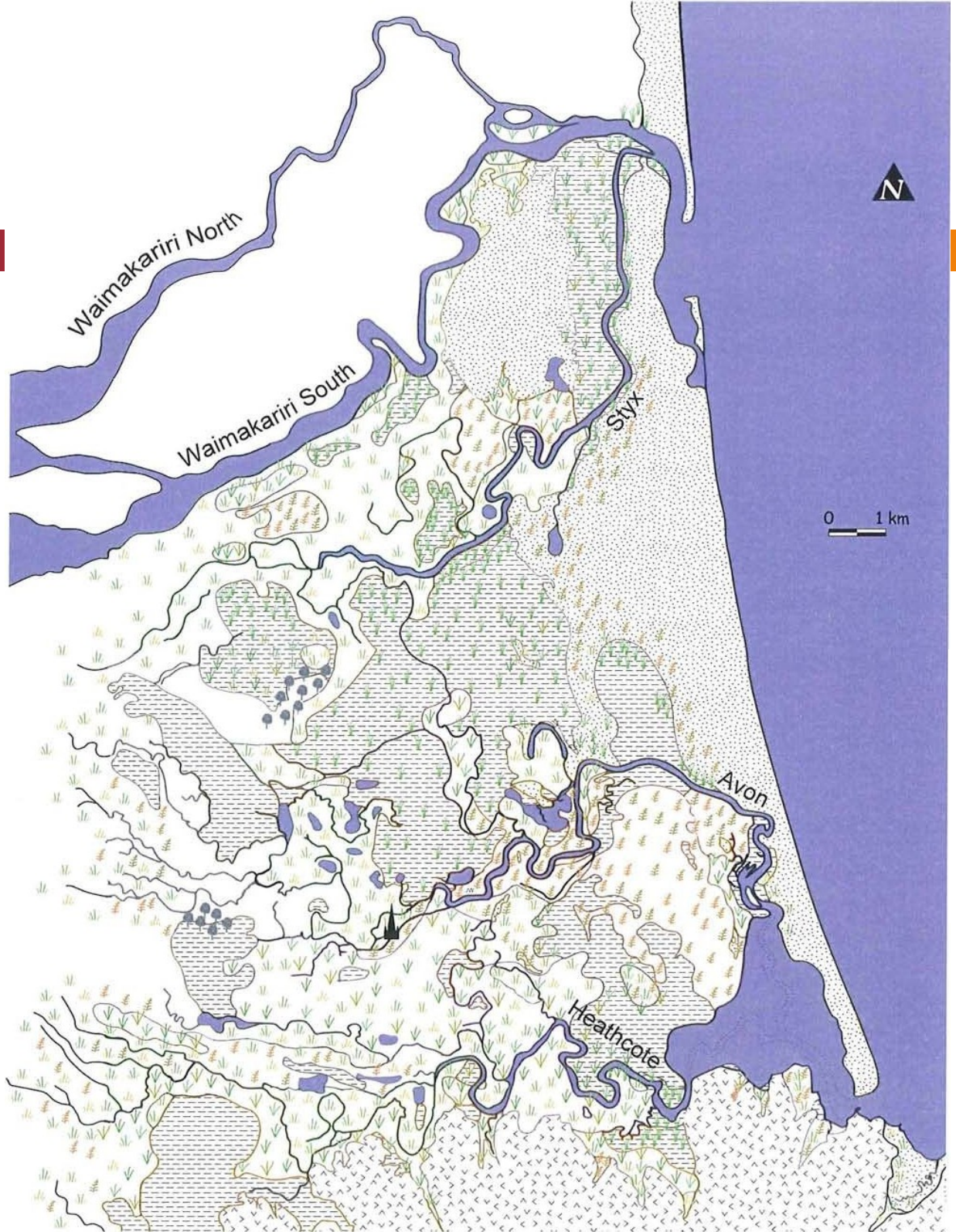
# Peak Ground Accelerations (PGA)



# Statistics

- 186 fatalities: 0 – $M_w$7.1 Darfield eqk; 185 – $M_w$6.2 Christchurch eqk; 1 – $M_w$6.0 June eqk; 0 – $M_w$6.0 Dec eqk (~400,000 people live in the Christchurch region)
- ~$25 - 30 billion NZ in damage (or 15 to 18% of New Zealand's GDP)
- ~20,000 residential properties/ houses severely impacted (~7,000 beyond repair)
- ~1300-1400 buildings in CBD designated for demolition (>1/3 of buildings in CBD)
- 300 km of sewer pipes and 124 km of water pipes are being fixed
- 2900 "port-a-loos" issued to residents

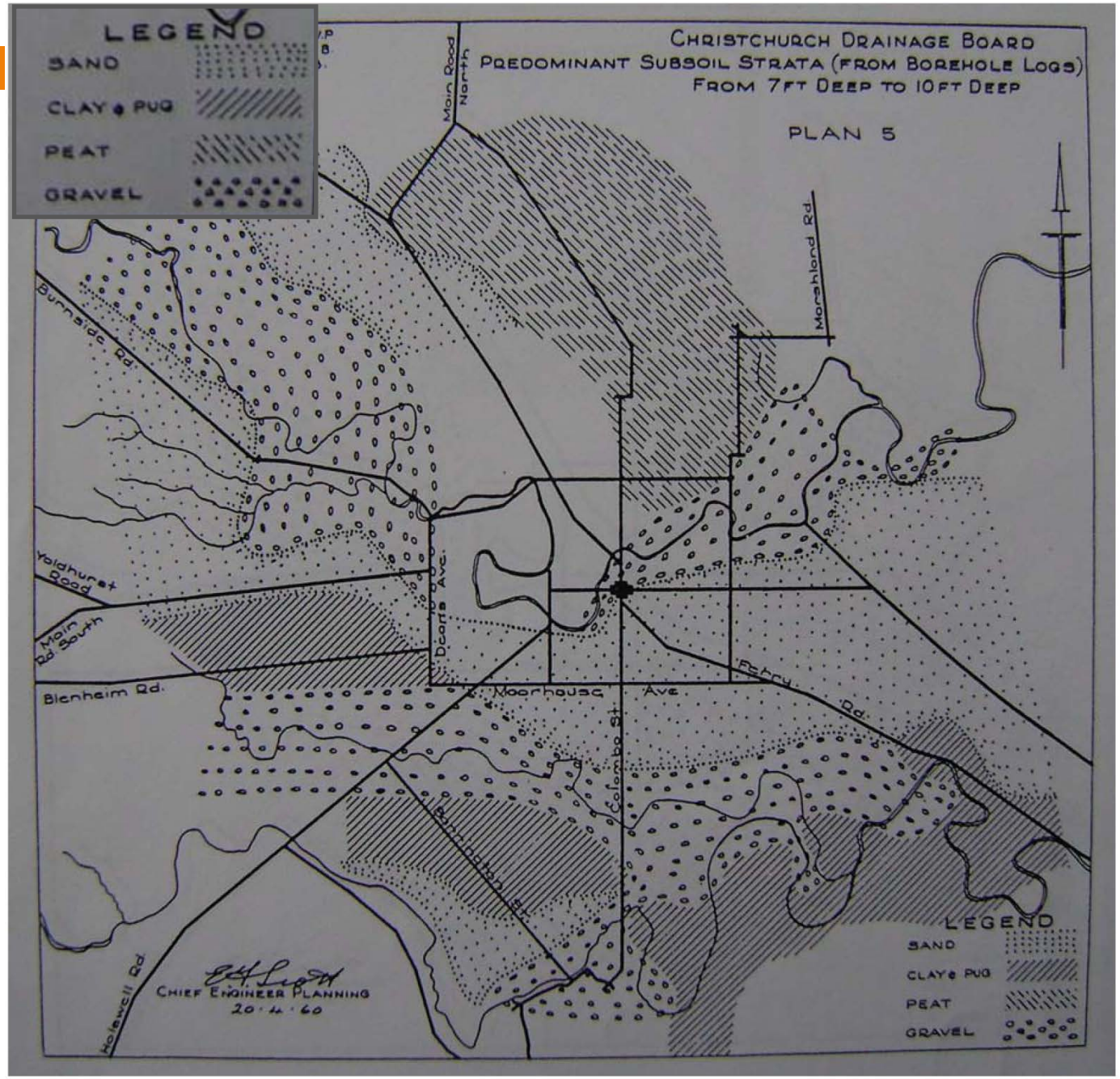
# Ground Cover: 1856



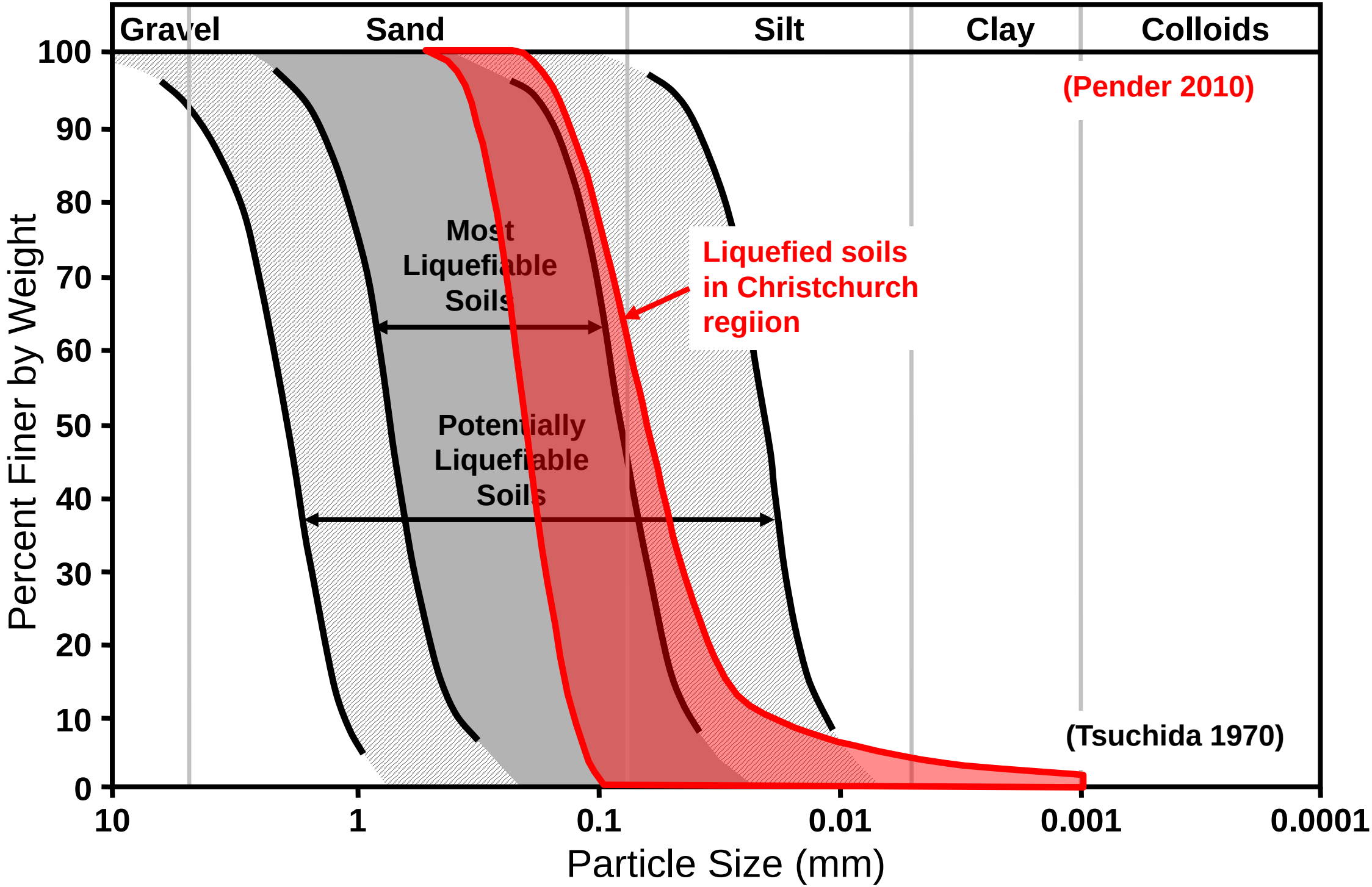

Rock
Sand
Swamp
Trees
Flax
Raupo
Grass
Ferns
Cathedral Square

(Christchurch City Council 2003)

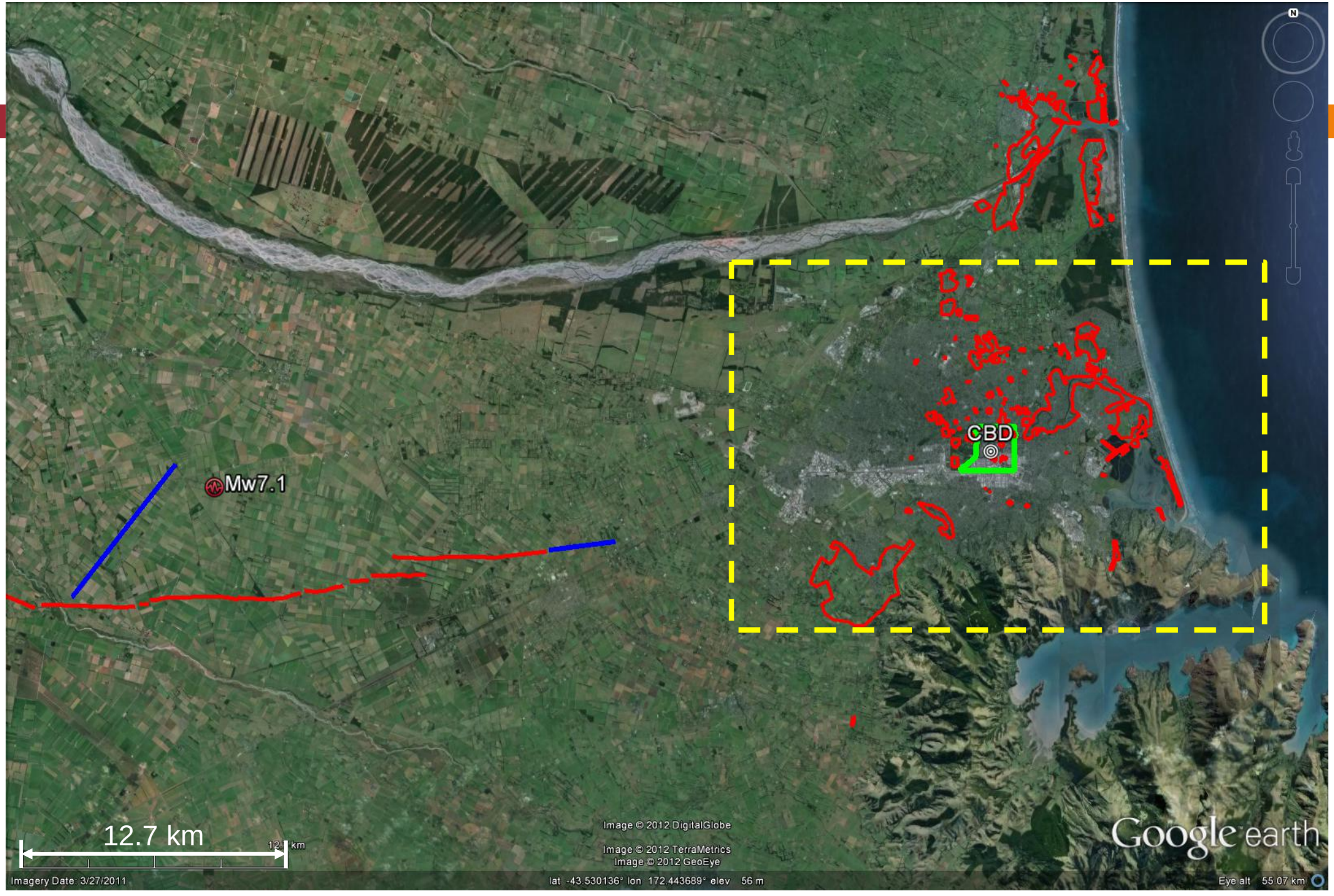
# Soil Conditions: 7 to 10 ft Deep



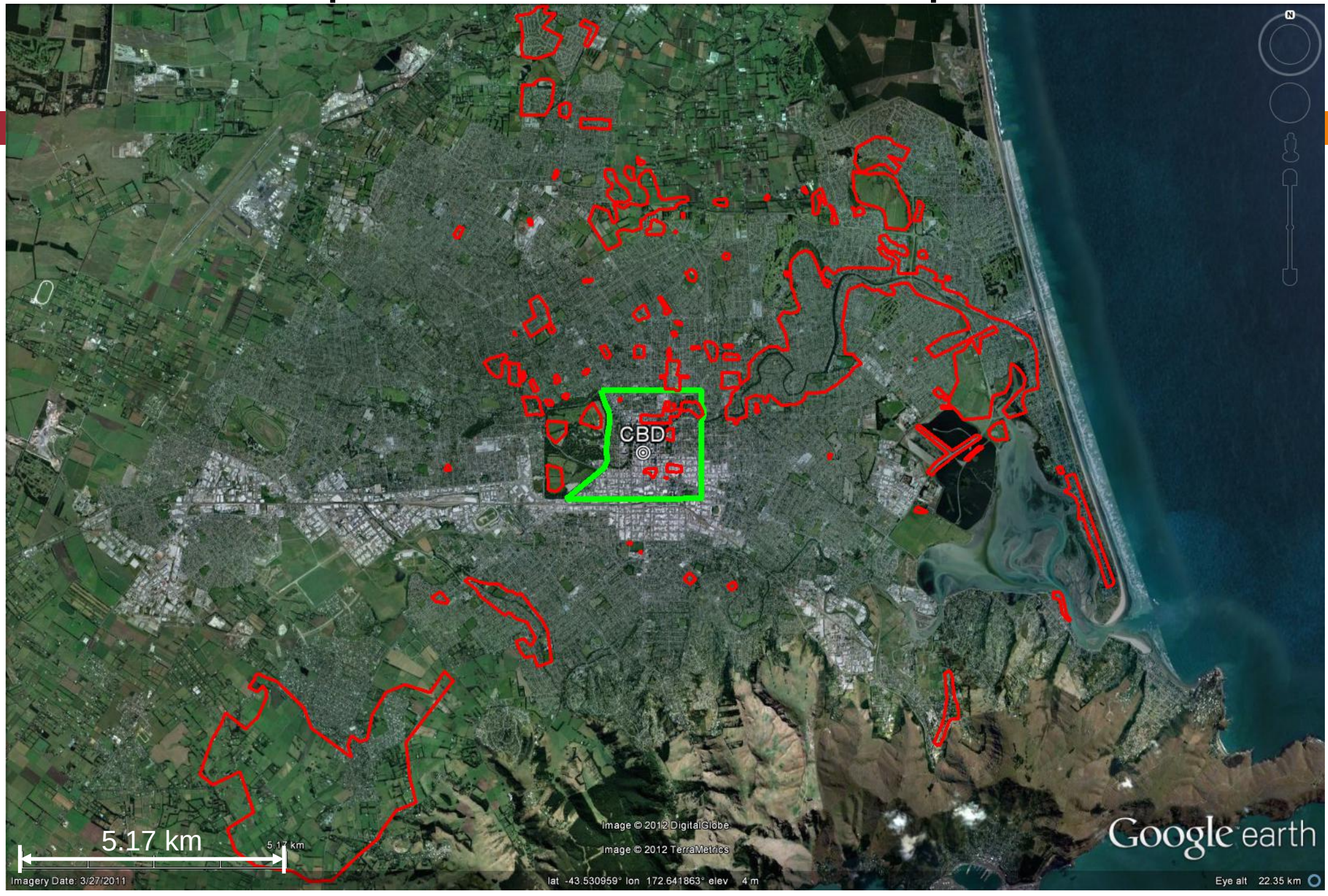
# Liquefaction: Grain-size Distributions



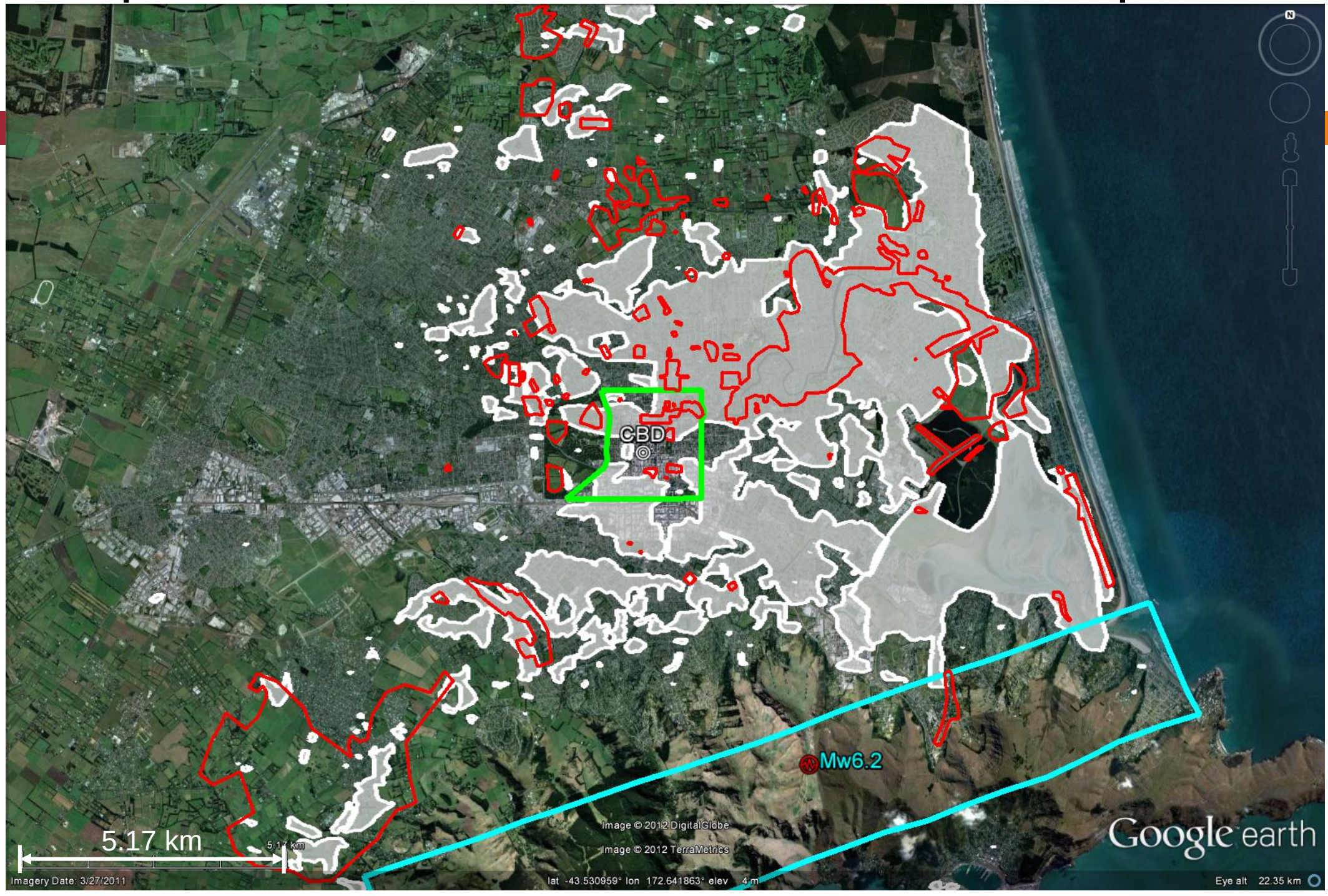
# Liquefaction: Darfield Earthquake



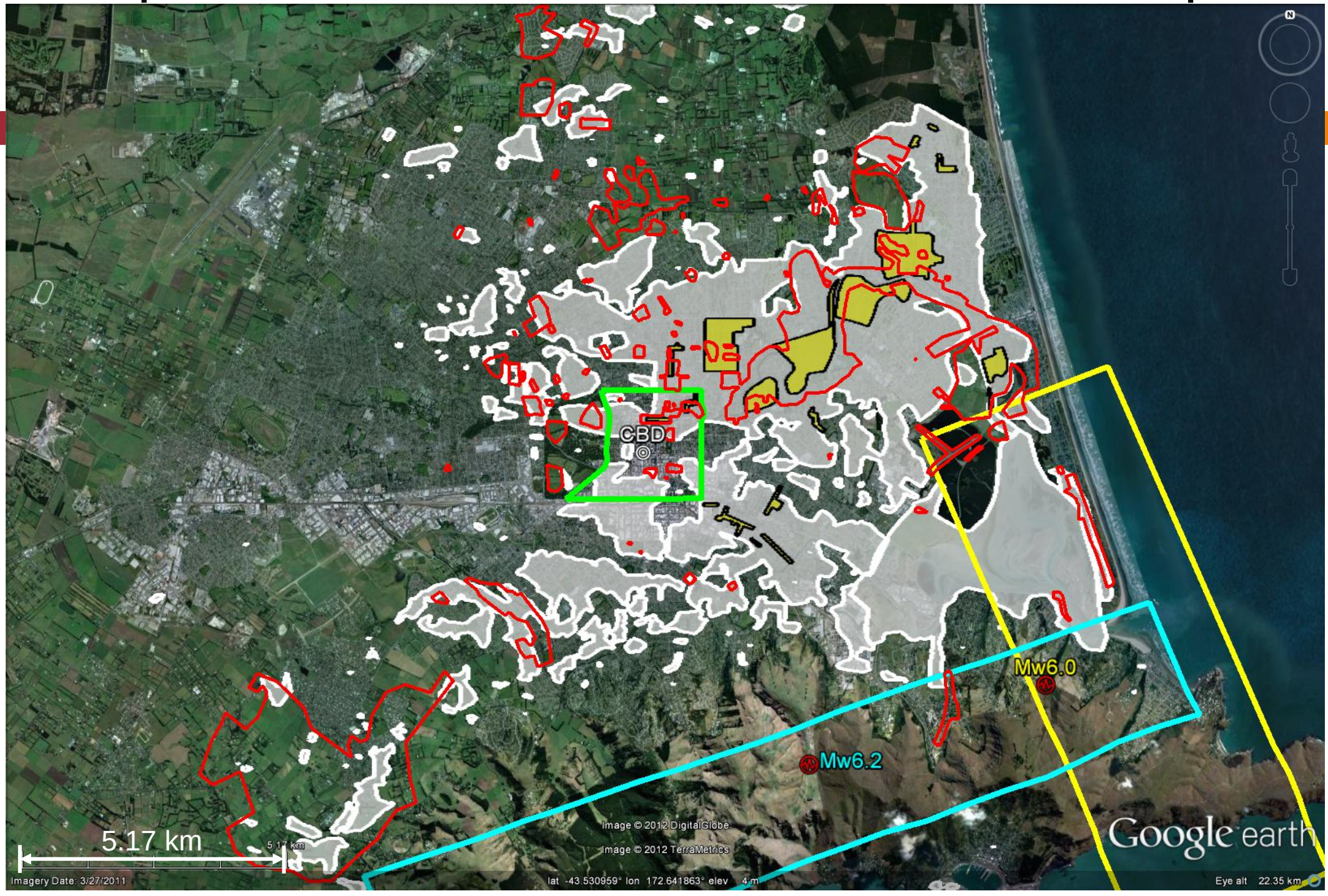
# Liquefaction: Darfield Earthquake



# Liquefaction: Darfield and Christchurch Earthquakes



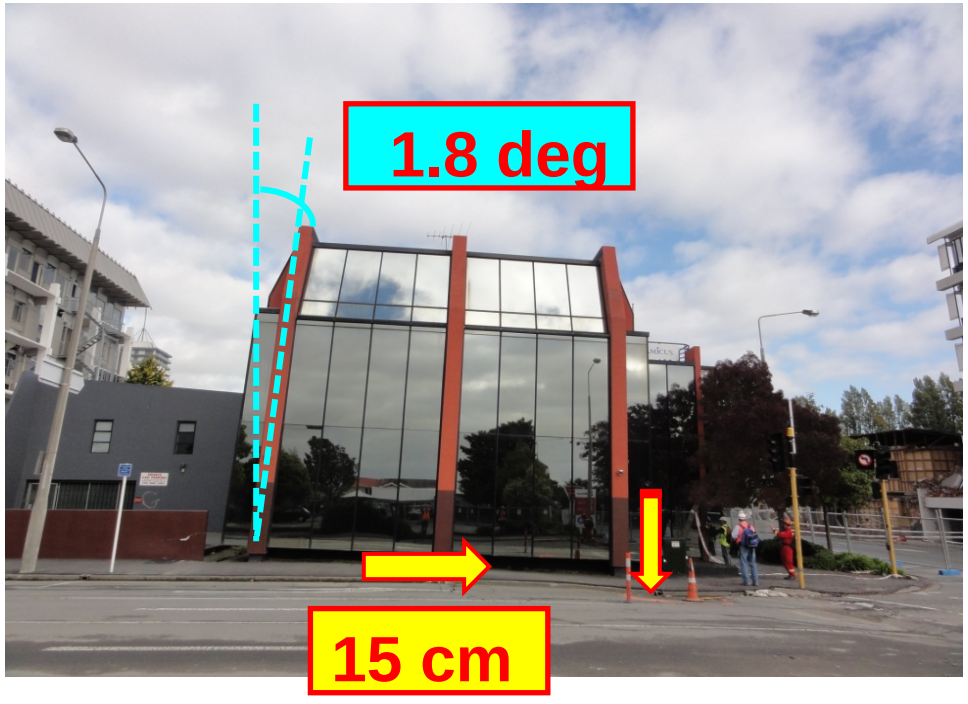
# Liquefaction: Darfield, Christchurch, and June Eqks

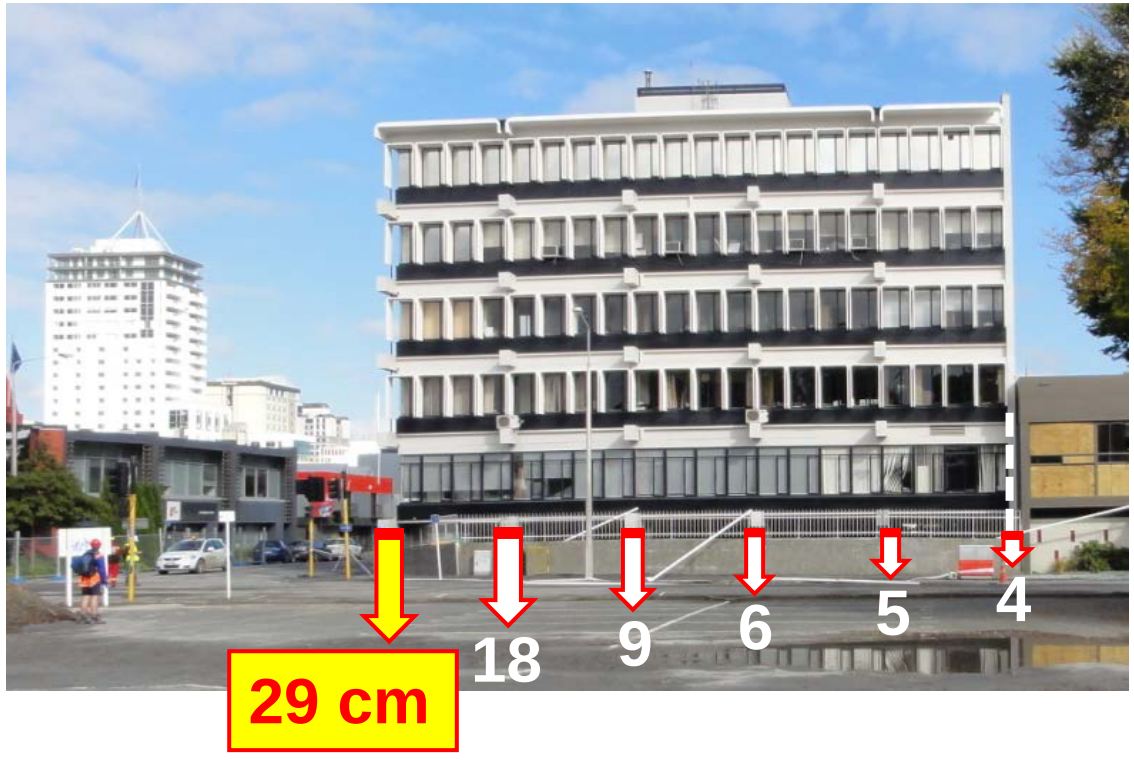


# CBD Liquefaction

(Misko Cubrinovski)

# CBD Liquefaction




(Misko Cubrinovski)

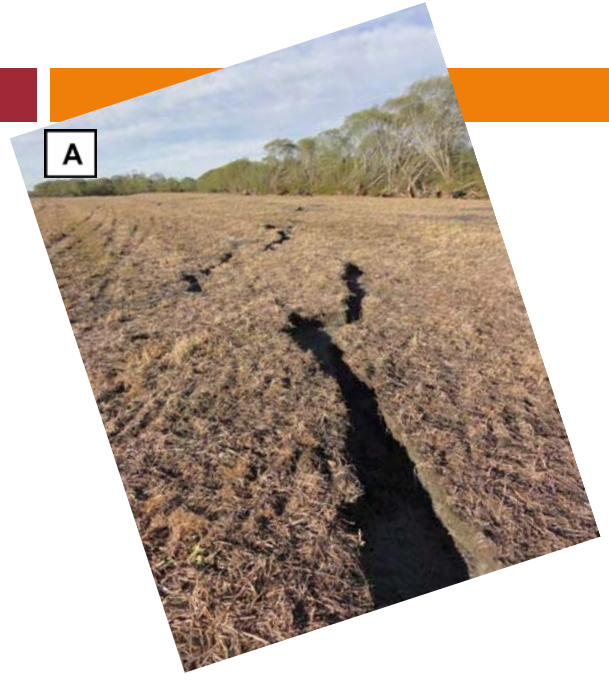
# Severe Liquefaction in Eastern Suburbs


– Large settlement of residential houses (total and differential)

(Misko Cubrinovski)

# Water and Wastewater Systems

# Lateral Spreading






- Low gradients at both locations (~3°)

(Misko Cubrinovski: South Kaiapoi)

# Lateral Spreading

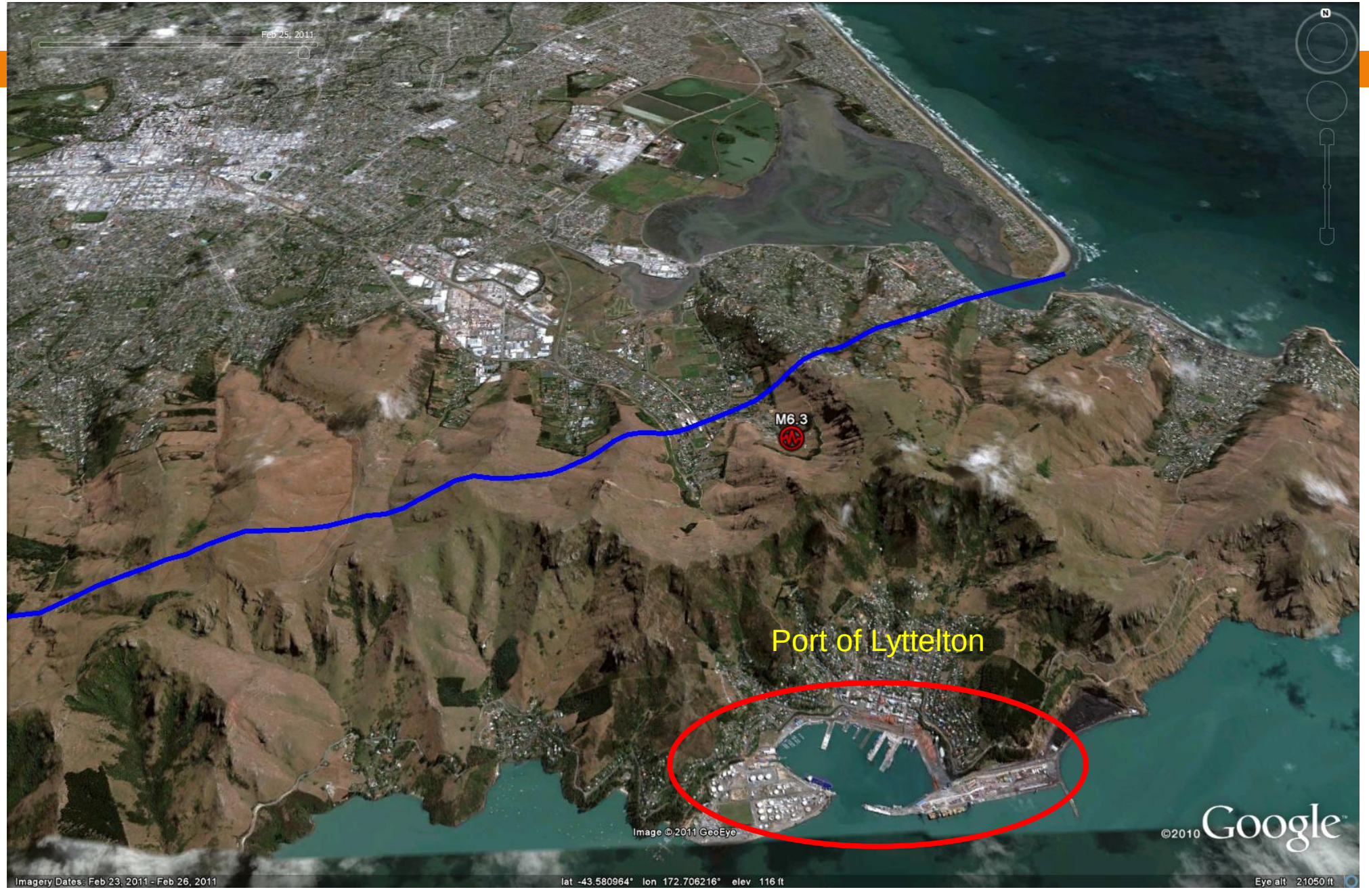
~ 1.5 m wide cracks

(Misko Cubrinovski: South Kaiapoi)

# Fitzgerald Ave. Bridge: North Approach


# Redcliffs Quarry Wall Failure

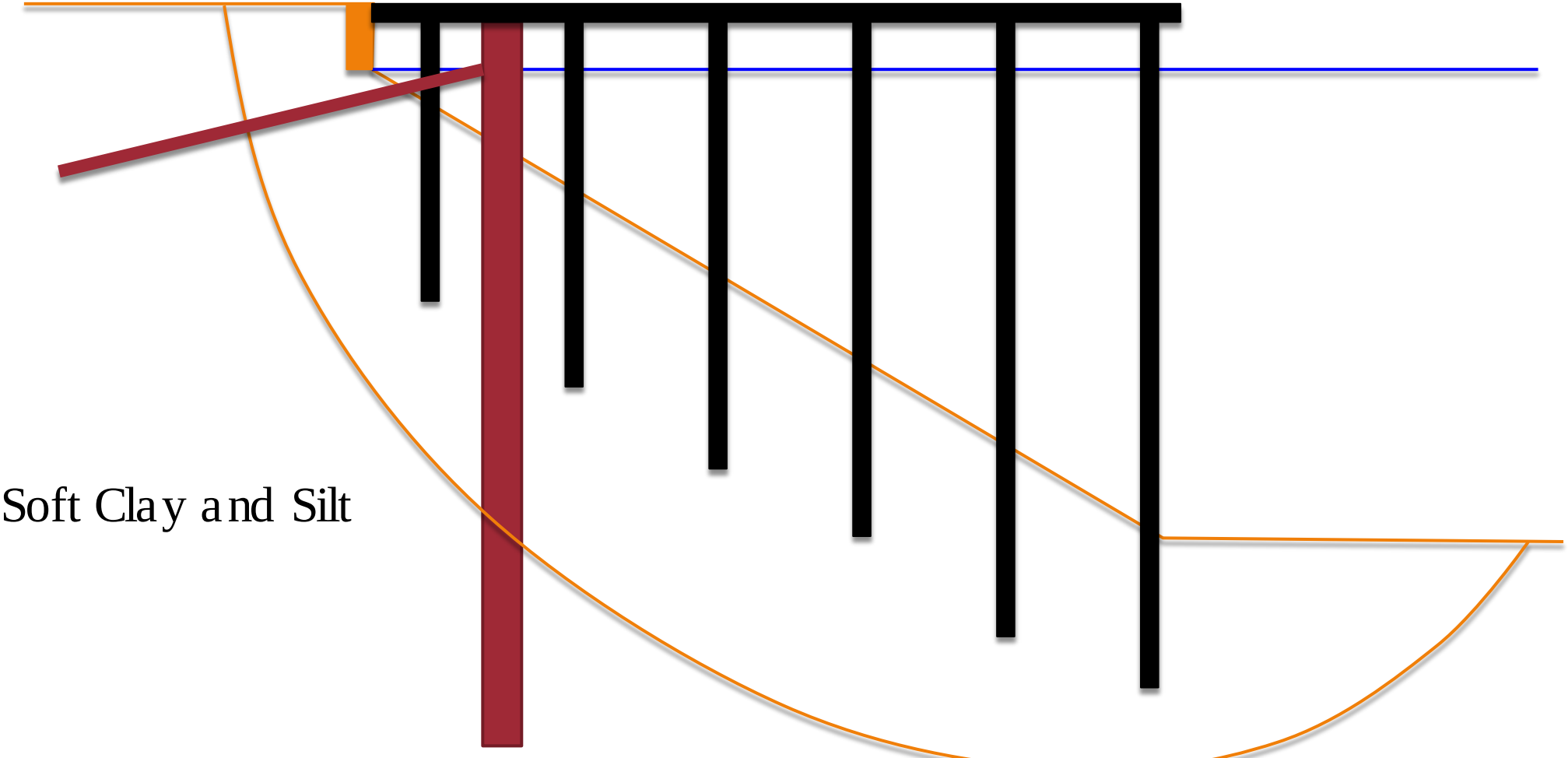
# Port of Lyttelton



# Port of Lyttelton – CQ1

(Glenn Rix)

# Port of Lyttelton – CQ1



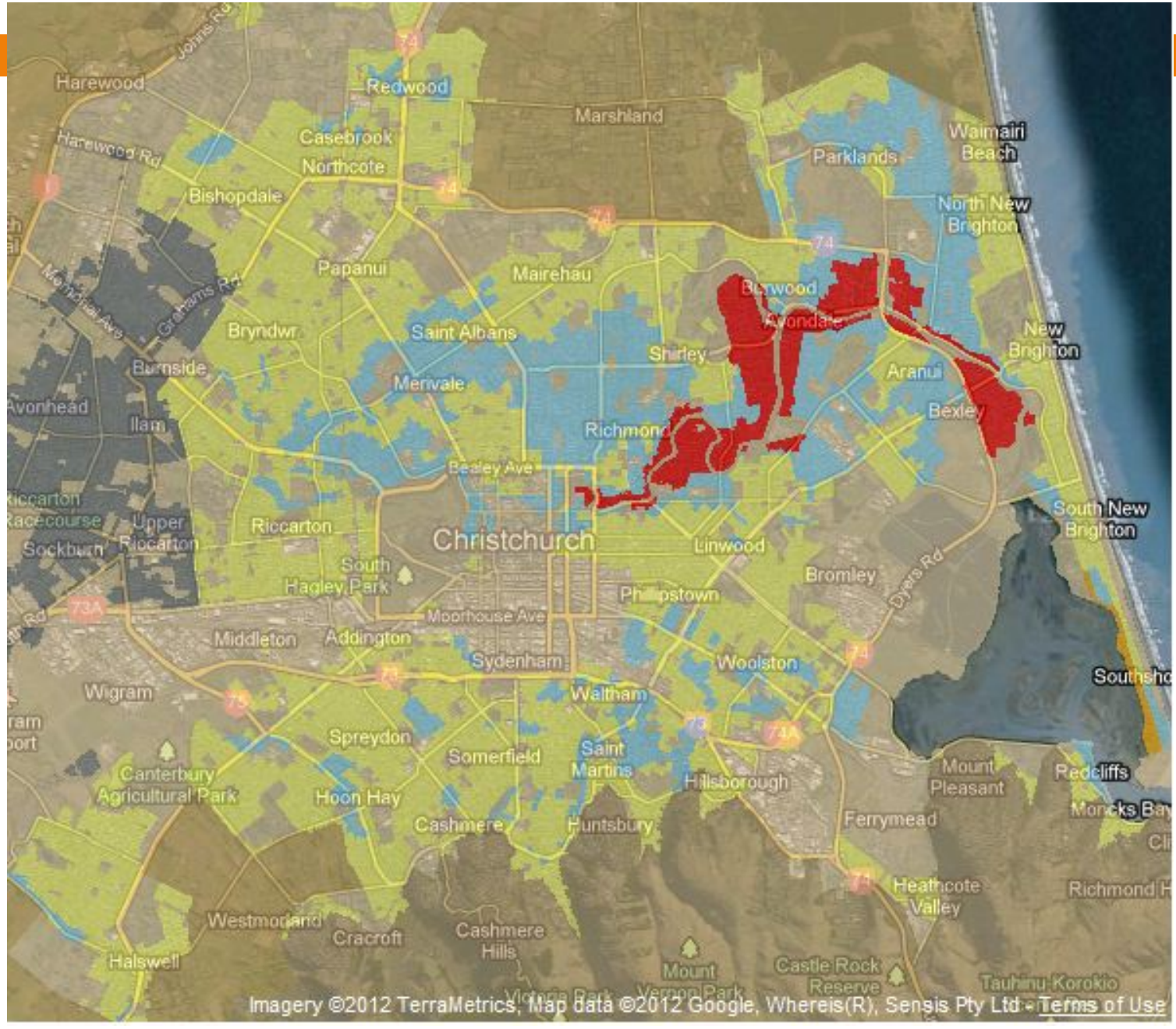

Not to scale

(Glenn Rix)

# Zones for Rebuilding: Christchurch

**Key**

- Technical Category 1
  Future land damage from liquefaction is unlikely.
- Technical Category 2
  Minor to moderate land damage from liquefaction is possible in future significant earthquakes.
- Technical Category 3
  Moderate to significant land damage from liquefaction is possible in future significant earthquakes.
- N/A - Urban Nonresidential
- N/A - Rural & Unmapped
- Port Hills & Banks Peninsula
- Orange Zone
  Further assessment required.
- Red Zone
  Land repair would be prolonged and uneconomic.



# Summary and Conclusions

- The intensity of the shaking was severe
- Soils in Christchurch and Kaiapoi are highly susceptible to liquefaction
- Significant geotechnical related damage due to widespread and severe liquefaction and lateral spreading (most economic damage) and rockfalls/ landslides in the Port Hills (6 fatalities)
  - Commercial and residential structural systems were distressed due to differential settlement and lateral spreading
  - Bridges distressed due to lateral spreading and slope failures at abutments
  - Buried pipelines experienced numerous breaks in liquefied ground; infiltration of liquefied sand
  - Levees (Stopbanks)…
- The Port of Lyttelton experienced some damage, but with only minimal impact on operations
- The Future: zonation based largely on observed liquefaction response

# Thank You