Combined Earthquake & Tsunami Losses for Wellington

Jim Cousins, William Power, Umut Destegul, Andrew King
Question from the Prime Minister (in 2005):
… what about NZ?
Question from Benfield (in 2006):

… do we need to rethink our old favourite PML for New Zealand – the Wellington Fault Earthquake?

(c. $10-15 b event)
... most costly sources – earthquake shaking alone

<table>
<thead>
<tr>
<th>Source</th>
<th>Loss ($ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wellington Fault (magnitude 7.5)</td>
<td>12 ± 5</td>
</tr>
<tr>
<td>Wairarapa Fault (8.2)</td>
<td>8 ± 5</td>
</tr>
<tr>
<td>Ohariu Fault (7.5)</td>
<td>6 ± 4</td>
</tr>
<tr>
<td><em>Subduction Zone (8+ ?)</em></td>
<td>5+ (?)</td>
</tr>
<tr>
<td>Pukerua-Shepherds Gully Fault (7.5)</td>
<td>5 ± 2</td>
</tr>
<tr>
<td>Napier 1931 Fault (7.8)</td>
<td>4 ± 2</td>
</tr>
</tbody>
</table>
... add tsunami to the scenarios

- Wellington Fault
- Wairarapa Fault
- BooBoo Fault
- Plate interface

Note: BooBoo Fault was embellished a bit!
... assets at risk

... elevation & bathymetry
Rock ledge, seaside cliffs

Low-lying, flat
Wellington – CBD – waterfront
Wellington – expensive stuff
Assets Model

• 160,000 residential
  20,000 non-residential

• data sources
  … councils (footprints, earthquake-risk buildings)
  … QV property
  individual for 12,000 large (300 m²) properties
  aggregated by meshblock for all of NZ
  … site visits & personal knowledge

• composite model
  … footprint, property, meshblock aggregate
Fragility Model
Mean Damage Ratio - Tsunami

Water Depth (m above floor)

- Timber 1-storey small (100 sqm)
- Timber 1-storey large (400 sqm)
- Concrete 1-storey large (400 sqm)
Uncertainty in fragility function

Water Depth (m above floor)

Tsunami Damage Ratio

- Red: High Fragility
- Black: Standard Fragility
- Blue: Low Fragility

Timber, 1 storey, small
Inundation Modelling – ANUGA

• Developed by scientists at Geoscience Australia and ANU

• Solves non-linear shallow water equations, and models wetting-drying of land

• Finite element method allows modelling to take place on an unstructured mesh
  – Arbitrary boundary shapes
  – Various boundary conditions available
  – Variable triangle density
  – One unstructured mesh - no need for nested grids – easy to incorporate co-seismic uplift

• Python scripting permits great flexibility

• Open source software – quick feedback
Wellington Fault - vertical deformation in metres
Wairarapa Fault Vertical deformation in metres
1855 reconstruction
Subduction zone

- Variation of near surface rupture
  - Termination at ‘seismic front’
  - Splay fault rupture
  - Rupture to trench

- Return time
  - 400 to 1200 years

- Southern termination
  - Limit of GPS confirmed locking
    ~ Cape Palliser
  - Extending into Cook Strait

Distribution of slip rate deficit on the Hikurangi subduction interface, estimated from ~12 years of campaign Global Positioning System (GPS) site velocities (Wallace et al., 2004).
Subduction-interface rupture extending into Cook Strait

- 1200 year return time
- Rupture to seabed on interface
- 12-18m slip in this region
- Mw 8.9
## Estimated Losses

<table>
<thead>
<tr>
<th>Tsunami Source</th>
<th>Shaking Loss</th>
<th>Tsunami Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>($m)</td>
<td>($m)</td>
</tr>
<tr>
<td></td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>Wellington, mag. 7.5 (base case)</td>
<td>13,700</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>0.05</td>
</tr>
<tr>
<td>Wairarapa, mag. 8.2</td>
<td>9,200</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0.02</td>
</tr>
<tr>
<td>BooBoo (embellished), mag. 7.4</td>
<td>800</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Subdn to Cook, mag. 8.9, 1200 y RI</td>
<td>6,100</td>
<td>2,300</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Subdn to Cook, mag. 8.9, 1200 y RI</td>
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<tr>
<td>Subdn to Cook, mag. 8.9, 1200 y RI</td>
<td>Worst-case tsunami</td>
<td>3,500</td>
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<tr>
<td></td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td>Subdn to Cook, mag. 8.9, 1200 y RI</td>
<td>Best-case tsunami</td>
<td>1,200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
</tr>
</tbody>
</table>

- fragility function: high / low
- floor height: 0 / 1 m above ground
- prior quake damage: increases / does not increase tsunami fragility
Scenario:
• Subduction to Cook
• Mag. 8.9
• 1200 yr recurrence interval
Main Findings

• tsunami does not add significantly to New Zealand’s most costly earthquake

• or to the second most costly

• Porirua and Kapiti experience very little tsunami damage in the scenarios considered here

• a very large subduction zone earthquake is the worst local tsunami source

• losses from the most costly earthquake, magnitude 7.5 Wellington Fault, are greater than the combined losses from the worst tsunami-causing earthquake

• tsunami from very large South American earthquakes might be able to cause higher losses

• we haven’t looked at casualties