THE UNIVERSITY OF AUCKLAND
NEW ZEALAND
Te Whare Wānanga o Tāmaki Makaurau

Tsunami Resilience of New Zealand Wharf Structures

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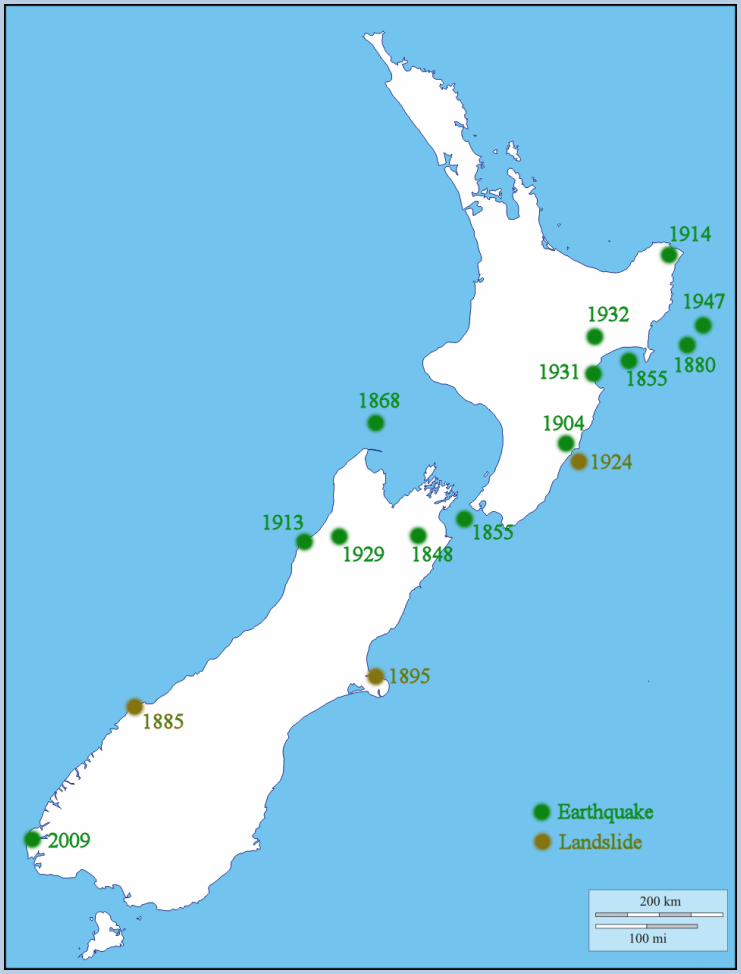
In Conjunction With:

NATURAL HAZARDS RESEARCH PLATFORM

GNS SCIENCE TE PŪ AO

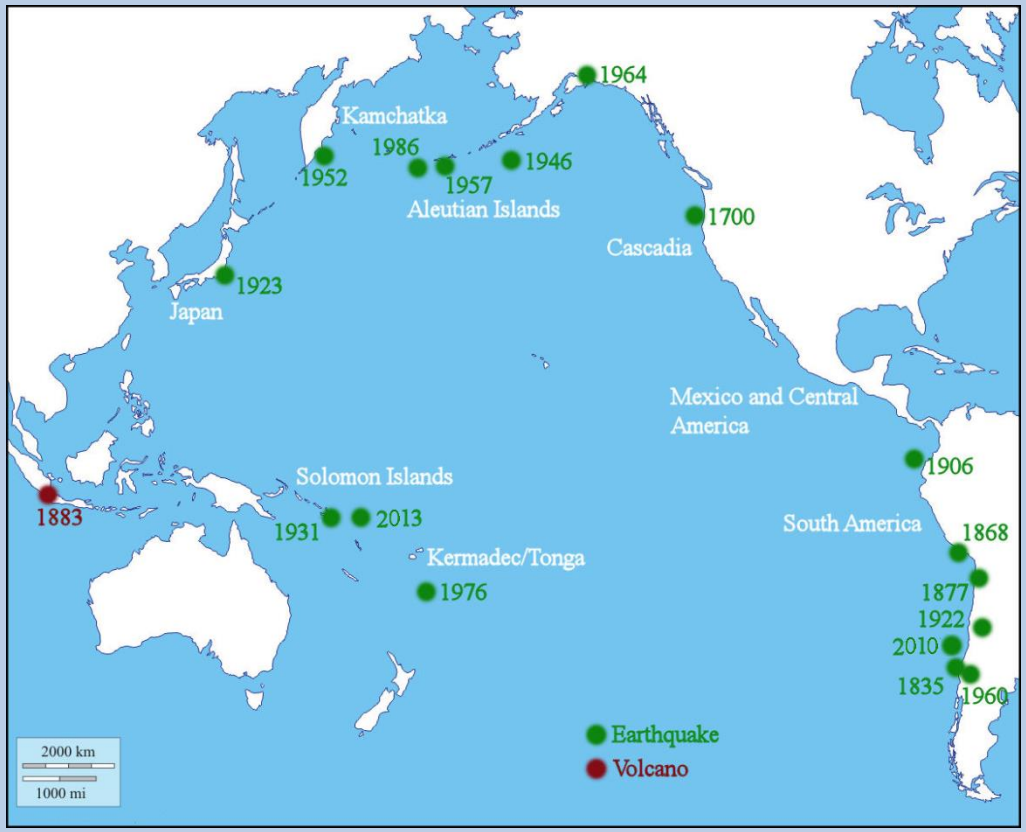
eCoast

NZ Tsunami History - Local



Date	Location	M_w
16 October 1848	Marlborough Region, South of Picton	7.5
23 January 1855	Cook Straight	8.2
12 February 1855	Northern Hawkes Bay	5.5
19 October 1868	Tasman Sea, Northwest of Nelson	7.2
8 September 1880	East of Gisborne	6.0
December 1885	North of Fiordland	Landslide
9 July 1895	Christchurch/Lyttleton	Landslide
8 August 1904	South of Napier	7.0
22 February 1913	Westport	5.0
7 October 1914	North of Gisborne	6.7
4 October 1924	South of Napier	Landslide
16 June 1929	East of Westport	7.8
3 February 1931	Hawkes Bay	7.8
16 September 1932	West of Gisborne	6.9
26 March 1947	East of Gisborne, Hikurangi Trench	5.9
15 July 2009	Dusky Sound	7.8

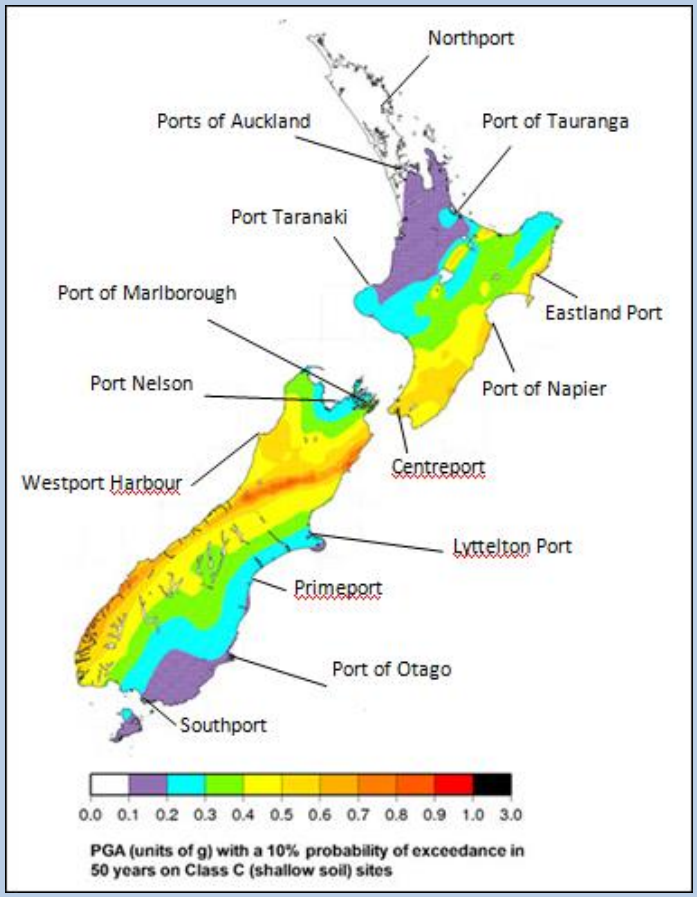
NZ Tsunami History - Distant



Date	Location	M_w
26 January 1700	Cascadia	9.2
21 February 1835	Chile	8.2
15 August 1868	Peru	9.2
11 May 1877	Chile	8.9
26 August 1883	Krakatoa, Indonesia	Volcano
2 February 1906	Ecuador	8.9
12 November 1922	Chile	8.5
4 September 1923	Japan	7.9
4 October 1931	Solomon Islands	7.9
2 April 1946	Aleutian Islands	8.6
5 November 1952	Kamchatka, Russia	8.3
9 March 1957	Aleutian Islands	8.6
23 May 1960	Chile	9.5
29 March 1964	Alaska	9.2
15 January 1976	Kermadec	8.0
9 May 1986	Aleutian Islands	7.9
22 February 2010	Maule, Chile	8.8
6 February 2013	Solomon Islands	8.0

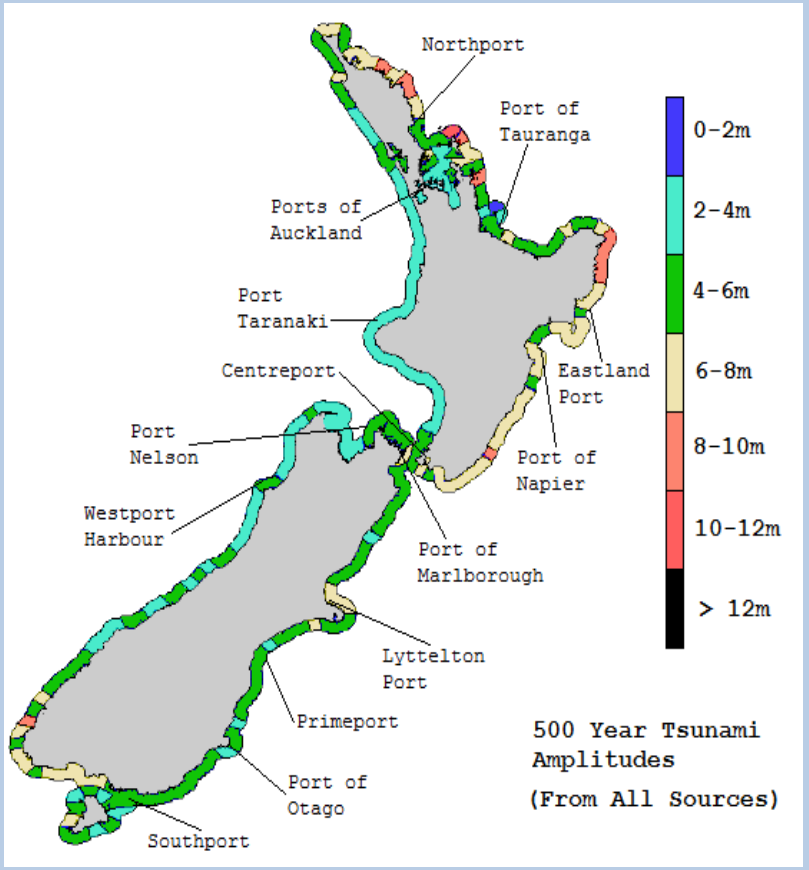
New Zealand Ports – Preliminary Exposure

NZ Seismic Hazard



From GNS Science

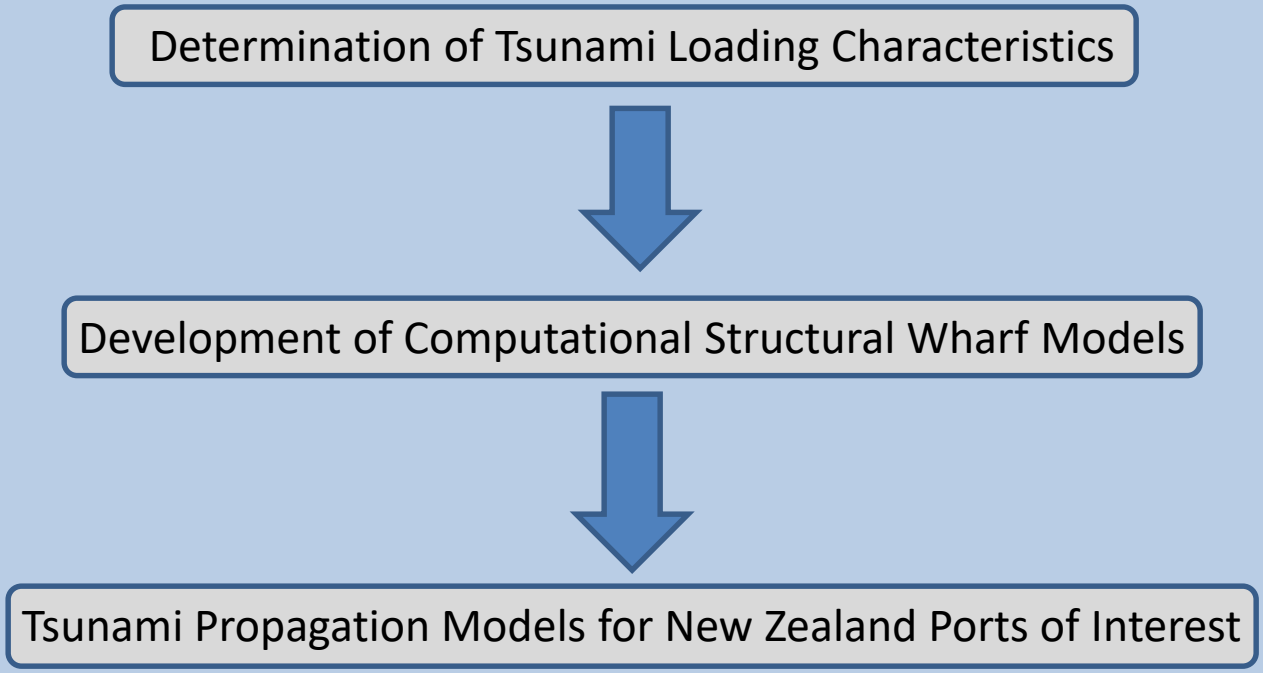
Tsunami Exposure



Reproduced from: Power, W. (2013). *Review of Tsunami Hazard in New Zealand (2013 Update)*. GNS Science.

Research Overview

3 Key Phases:



Tsunami Loads

Horizontal Loads

Design Standards

- FEMA (2012) – Design of Structures for Vertical Evacuation from Tsunami (Primary Source)
- FEMA (2010) – Coastal Construction Manual
- CCH (2000) – City and County of Honolulu Building Code

Vertical/Uplift Loads

Design Standards

- FEMA (2012)

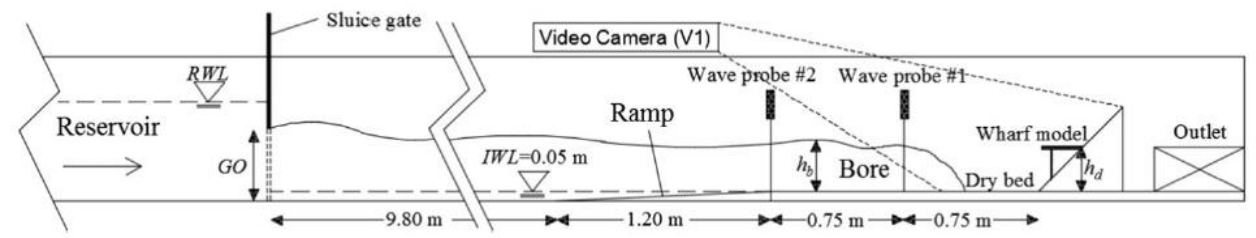
Laboratory Flume Tests

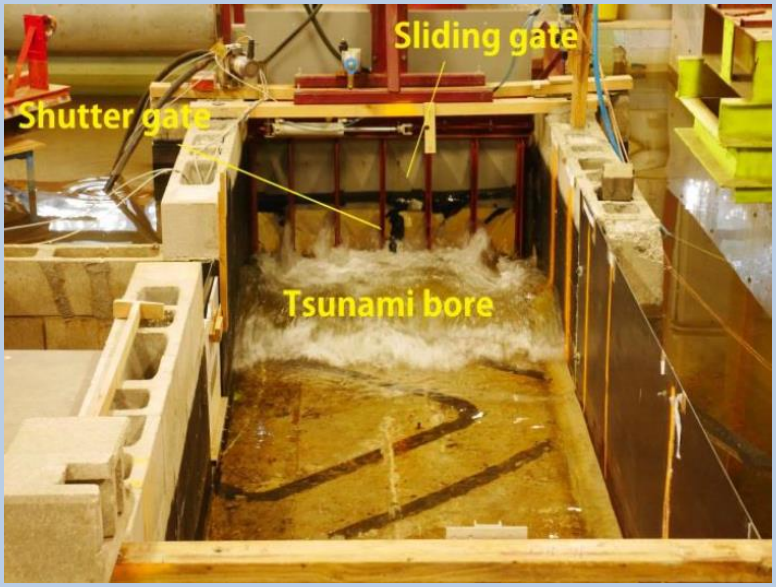
- Tsunami Bore Tests
- Solitary Wave Tests

Tsunami Loads - Experimentation

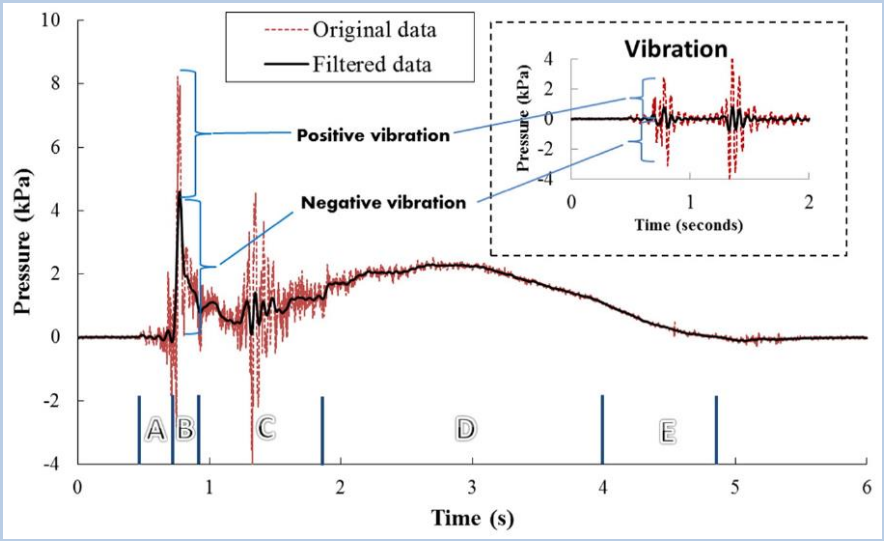
Tsunami Bore Uplift Load Tests

Flume Profile

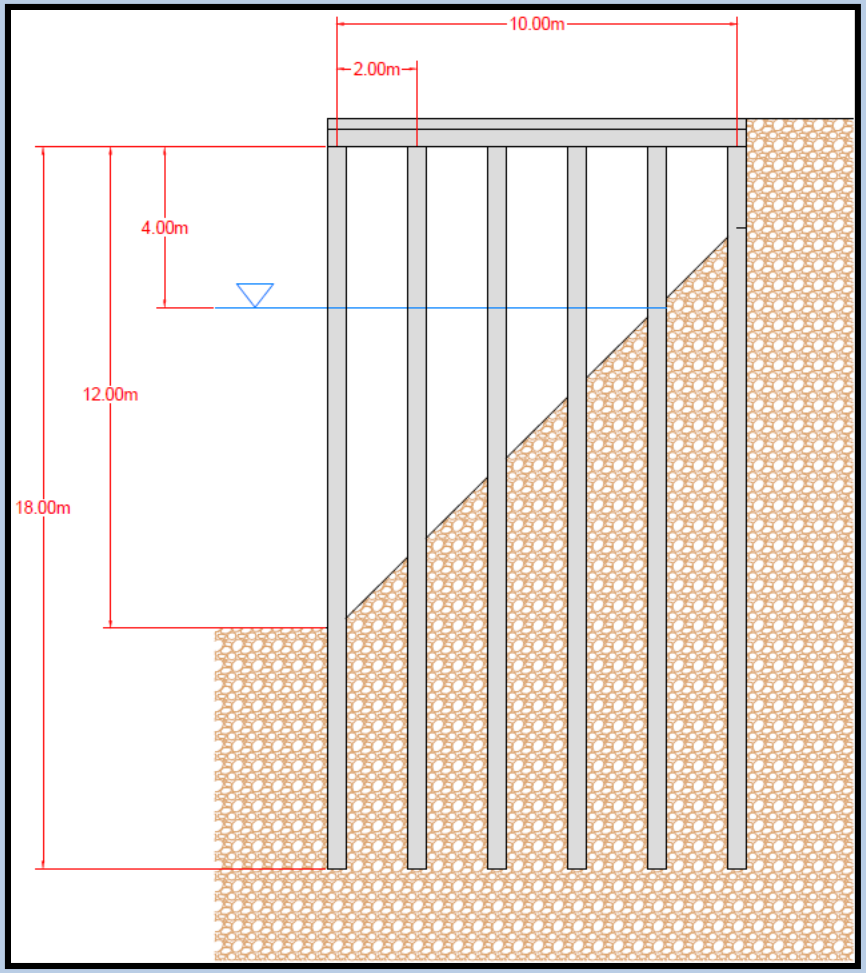




Sample Data Profile



Structural Modelling



- Modelling performed in OpenSEES
- Generic wharf models. Connected to specific ports through propagation models
- Incorporates wave amplitudes from 2-10 metres

Structural Modelling

Geometric Characteristics	Material Characteristics	Soil Properties	Static Loads
Deck Width	Steel Rebar	Clayey Soils	Self-Weight
Bay Sizes	Cover Concrete	Sandy Soils	Live Loads
Pile Sections	Core Concrete		Hydrostatic Loads
Slope Properties			Buoyancy
Still Water Level			
Etc.			

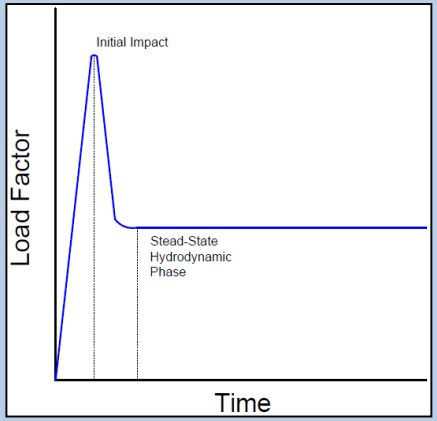
3 Time Periods

Prior to 1963

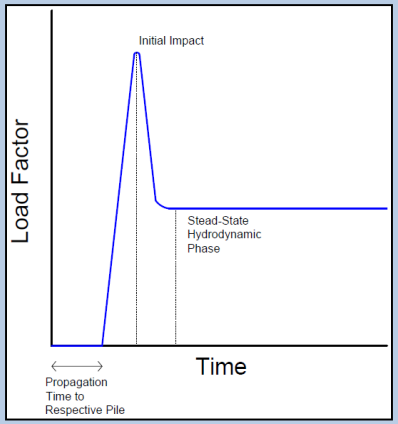
1963 - 1989

1989- Present

Tsunami Load Application

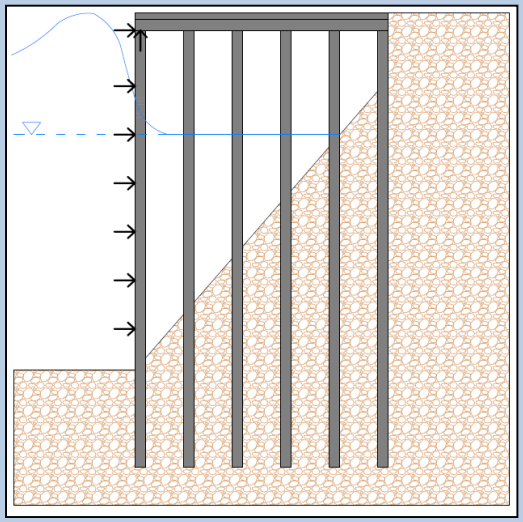


Time Series Applied to First Pile

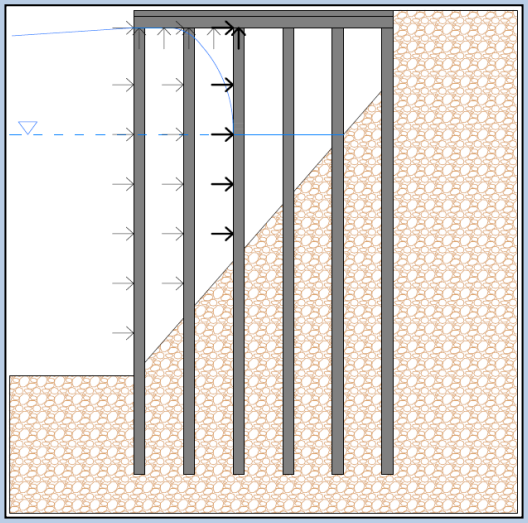


Time Series Applied to Subsequent Piles

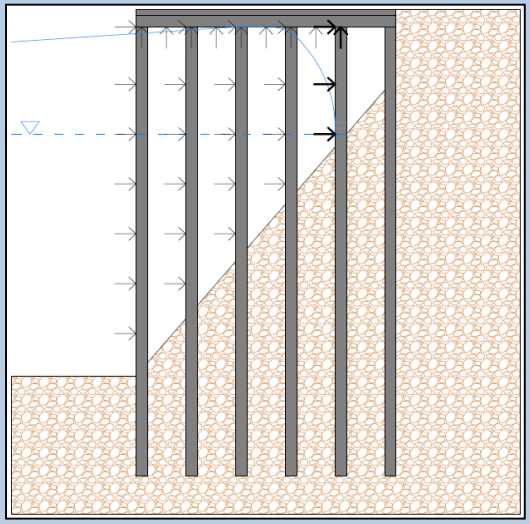
Time = 0.0s



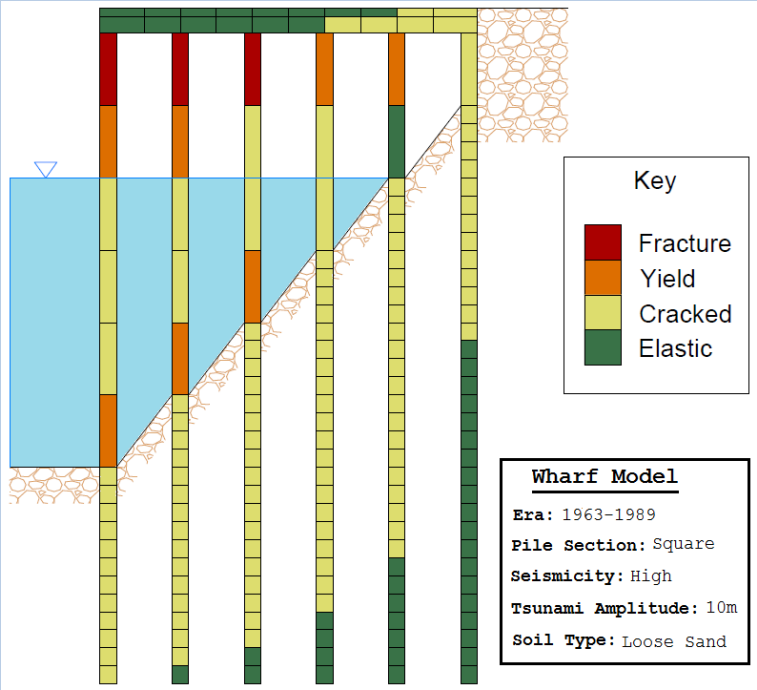
Time = 0.4s



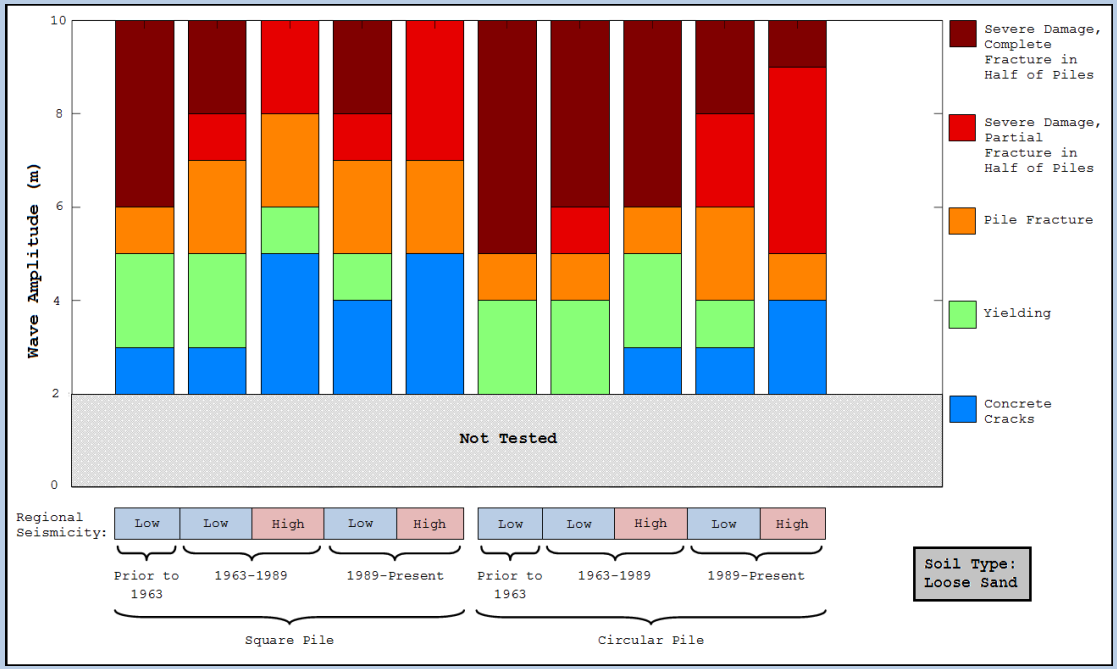
Time = 0.8s



Structural Modelling Results



Breakdown of wharf damage



Comparative damage

University of Auckland Tsunami Propagation Modeling

Inputs:

1. High resolution bathymetric and topographic maps of Marlborough Region and Picton Harbour

2. Earthquake source model for tsunami generation

Outputs:

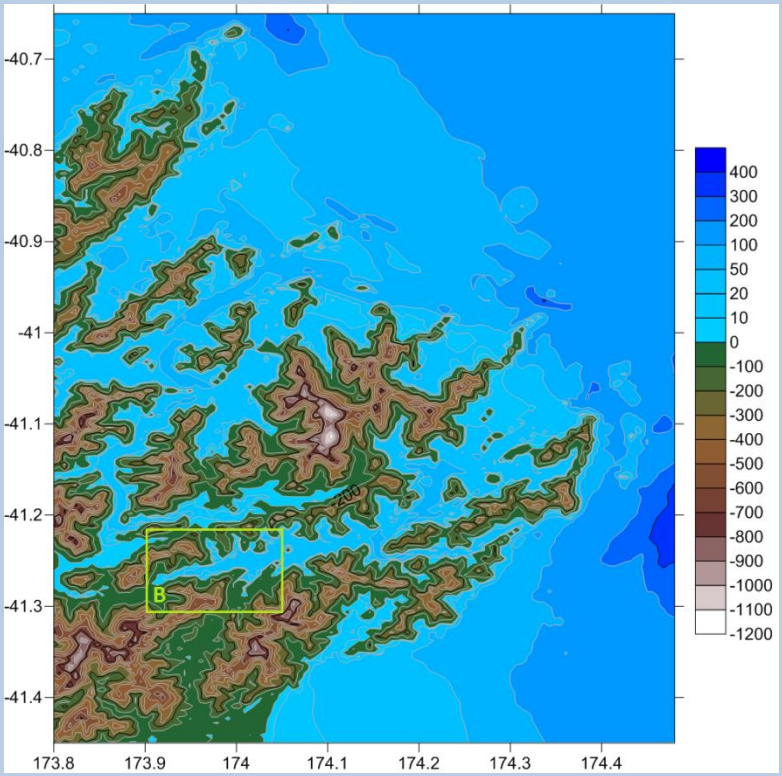
1. Tsunami water level profile including maximum tsunami amplitude over grid, number of wave cycles anticipated, and arrival times

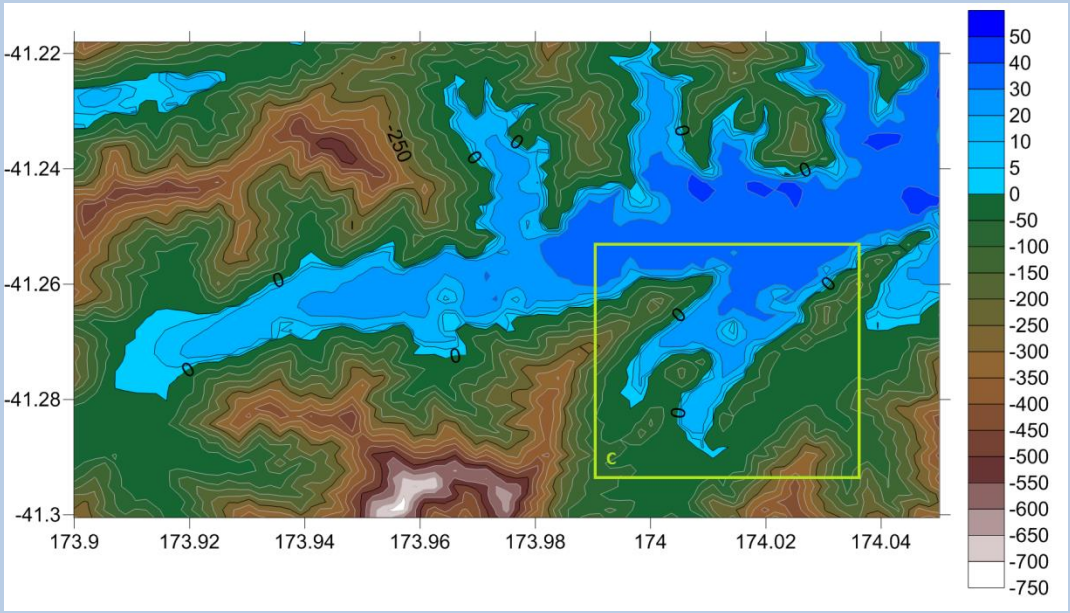
2. Current speeds in harbour

3. Rough estimate of runup extents

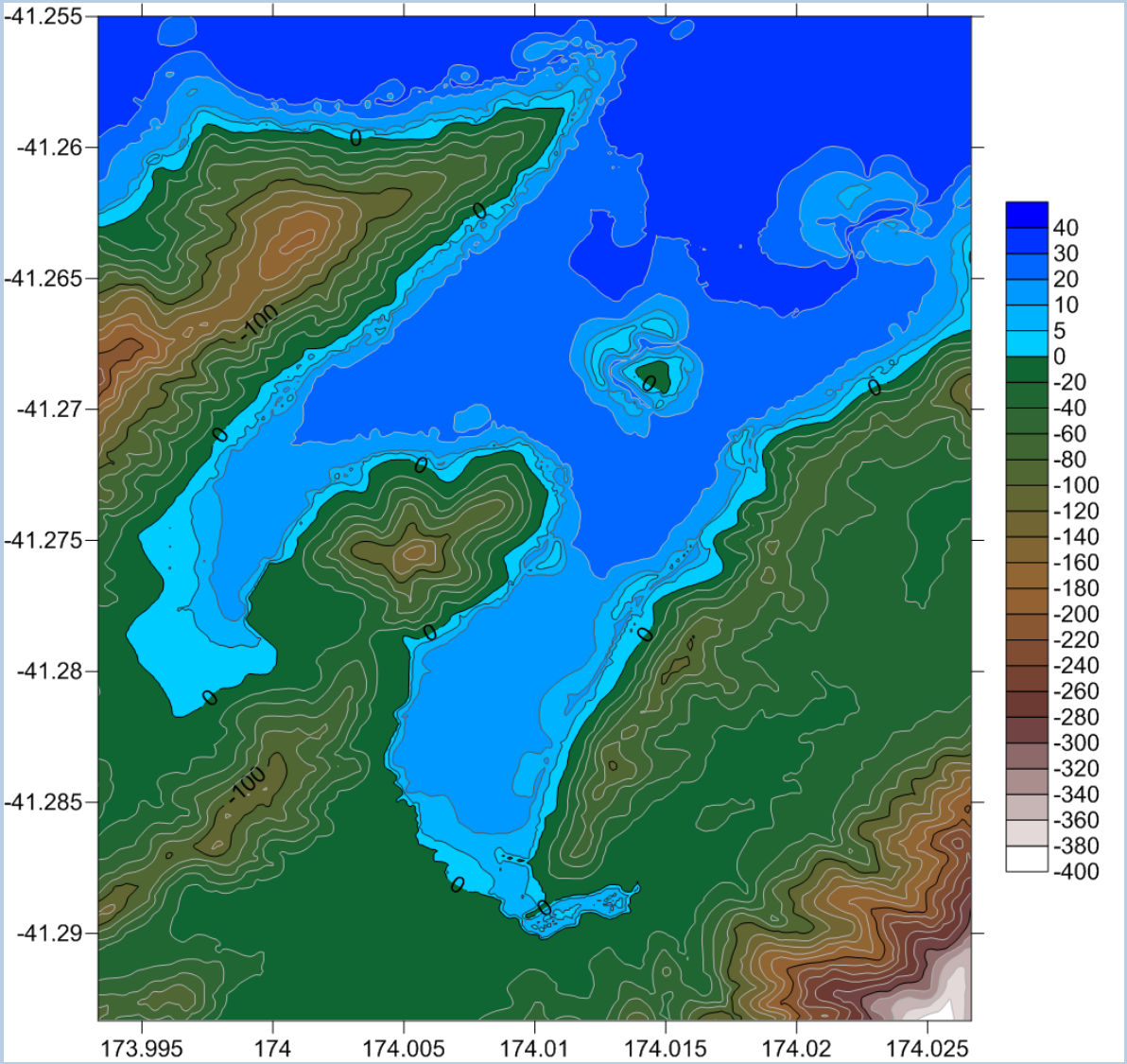
Propagation Modeling - Bathymetry

3-Layered Bathymetry Grids





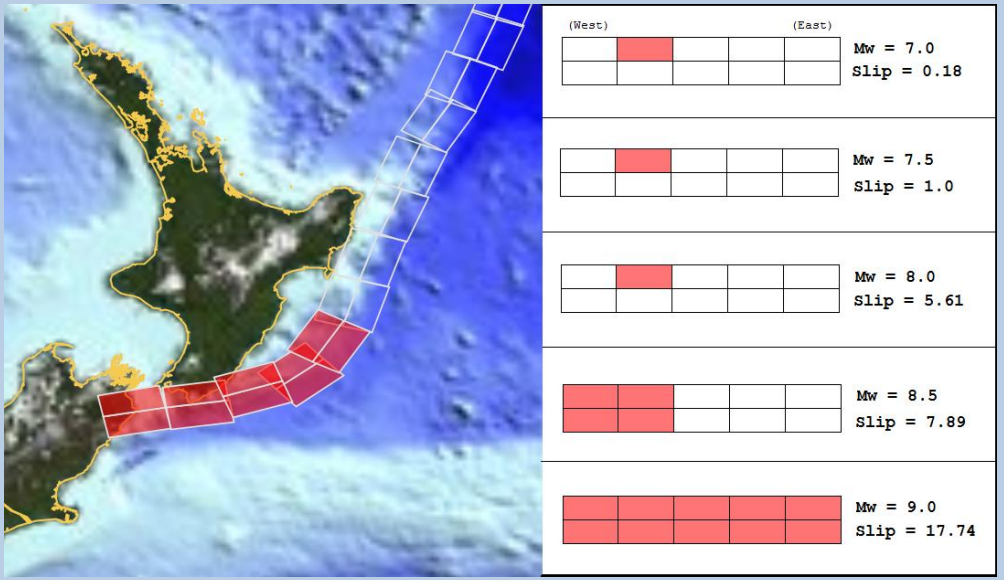
Propagation Modeling - Bathymetry



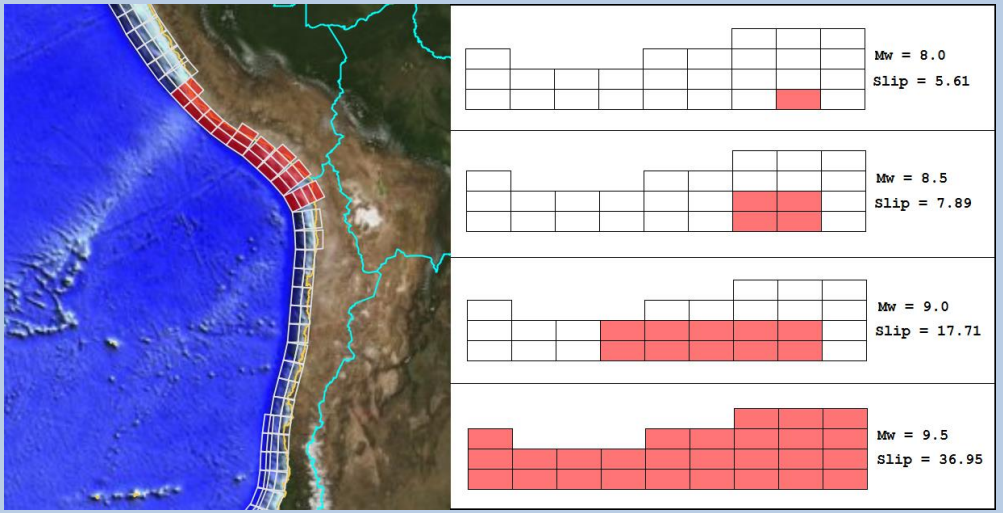
Propagation Modeling – EQ Sources

Local and Distant Sources Both Relevant

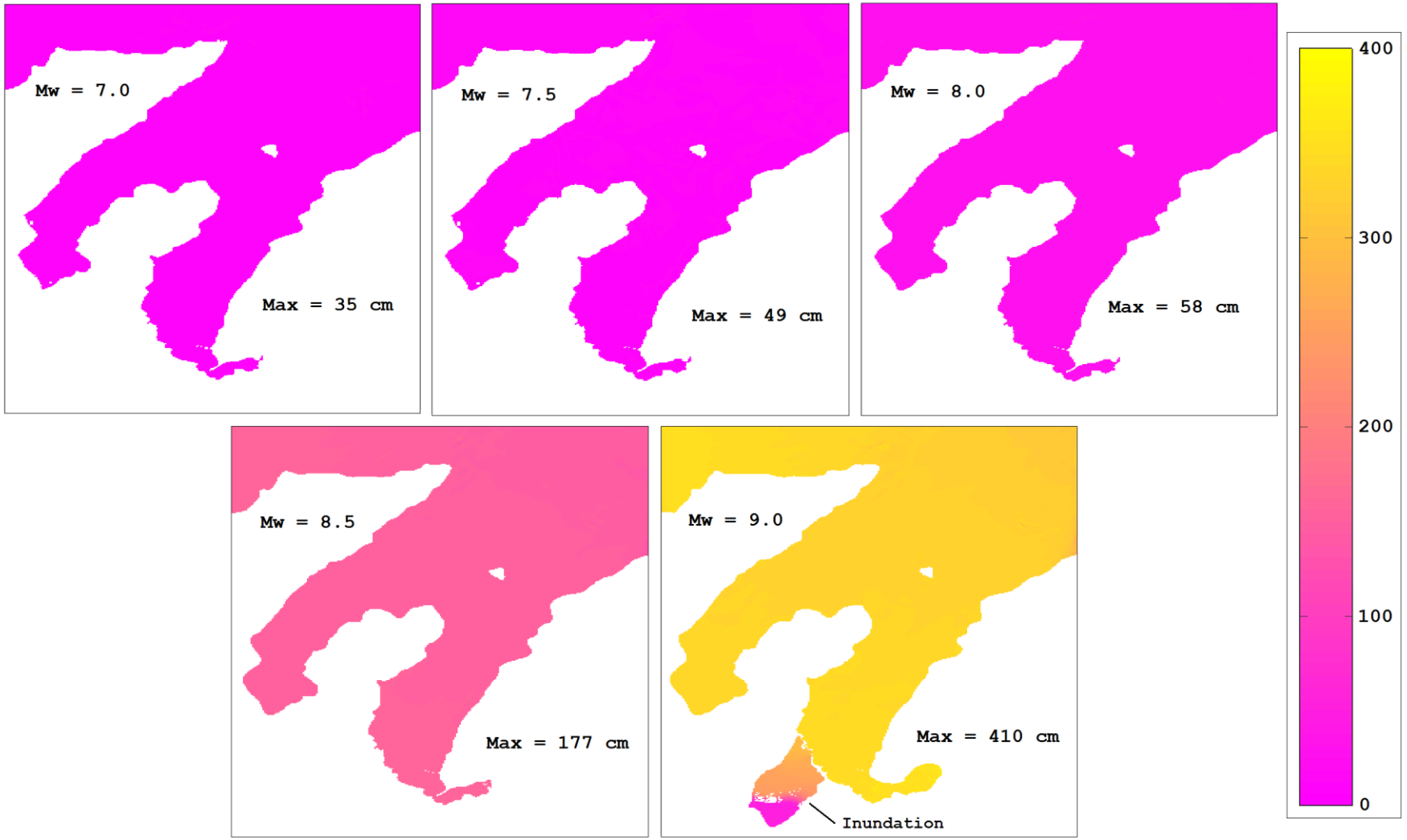
Modelled Local Source – Hikurangi Subduction Zone Earthquake ranging in magnitude from M_w 7.0 – 9.0



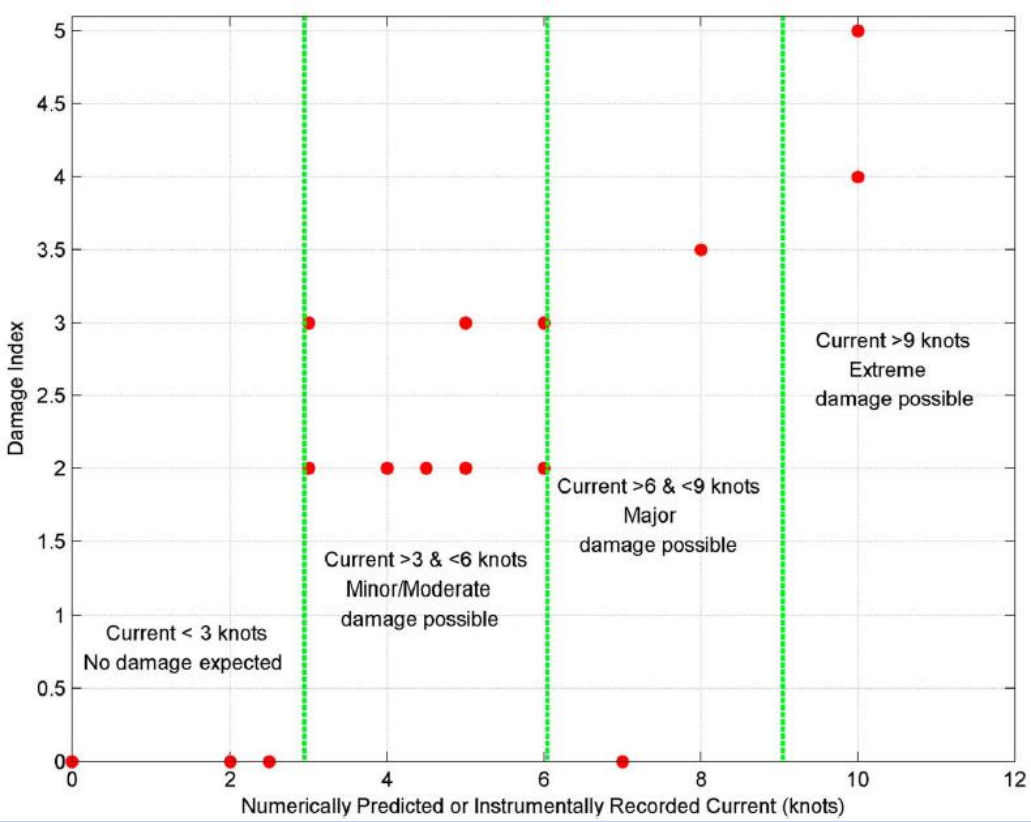
Modelled Distant Source – Peru Earthquake ranging in magnitude from M_w 8.0 - 9.5



Max Water Levels - Local



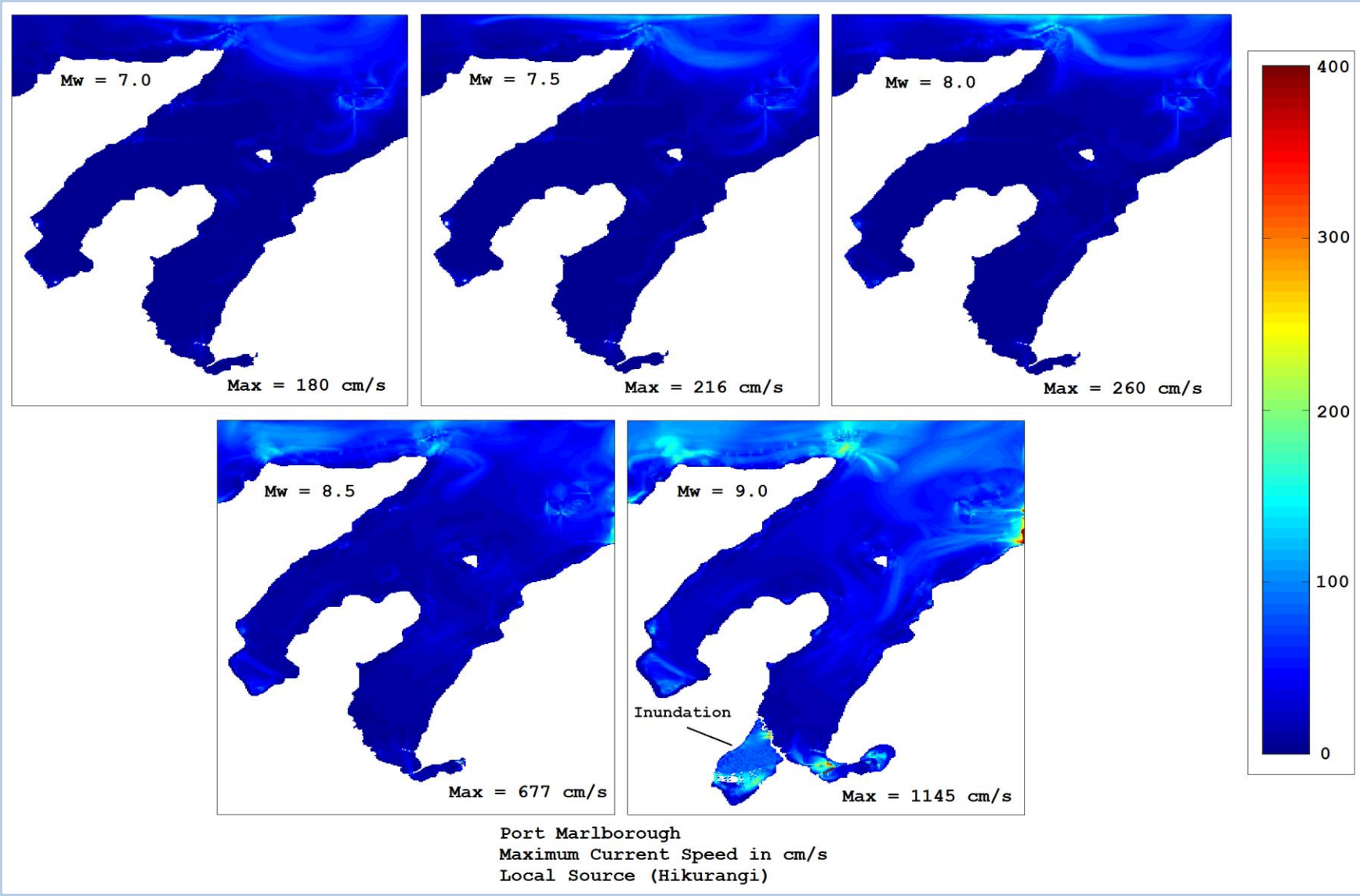
Tsunami Currents



Damage Index	Description/Characterising Features
0	No damage / Impacts
1	Small buoys moved
2	1-2 docks damaged / Small boats damaged / Large buoys moved
3	Moderate dock and boat damage (<25% of docks and vessels damaged) / Midsized vessels off moorings
4	Major dock and boat damage (<50% of docks and vessels damaged) / Large vessels off moorings
5	Extreme/complete damage (>50% of docks and vessels damaged)

From: Lynett, P., Borrero, J., Son, S., Wilson, R., & Miller, K. (2014). Assessment of the Tsunami-Induced Current Hazard. *Geophysical Research Letters*, 41, 2048-2055.

Max Current Speeds - Local



Scope of Modelling

Similar results collected for each of the indicated ports: