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Informing the development of tsunami vertical evacuation strategies in New Zealand

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ABSTRACT

Tsunami education and evacuation planning promote evacuation to high ground in the event of tsunami. In some low-lying coastal areas, the distance to safety on high ground or inland of the hazard zone may exceed the travel distance possible in the time before wave arrival. This is a particular problem in local-source tsunami with arrival times of less than one hour. Vertical evacuation provides alternative refuge within the inundation zone. Buildings, towers or berms can provide refuge at elevations above the tsunami flow depth, but must be designed to be effective in the maximum credible tsunami. The potential benefits and costs of vertical evacuation buildings were demonstrated during the 2011 Great East Japan earthquake and tsunami, when thousands of people took refuge in such structures.

The aim of this thesis is to enhance the current theoretical and methodological basis for development of vertical evacuation strategies in New Zealand. To achieve this aim, numerical simulation of local-source tsunami is conducted at Napier, Hawke's Bay, New Zealand, to establish the maximum credible inundation extent, flow depth and arrival times. Interview data describe the use of vertical evacuation in the 2011 Great East Japan tsunami, and surveys are used to investigate intended evacuation behaviour in a local-source tsunami. Finally, an existing geo-spatial evacuation analysis method, augmented with temporally-variable exposure and distributed travel speeds, is used to assess pedestrian evacuation potential in local-source tsunami. The method is demonstrated in an assessment of the need for vertical evacuation in Napier.

The outputs of the four stages of research enhance the theoretical basis for planning evacuations in local-source tsunami, extends Geographic Information System-based evacuation modelling methods, and provides empirical advances in tsunami hazard and evacuation planning at Napier. The proposed methodology is applicable to other locations, thus contributes to tsunami risk reduction in New Zealand and internationally.

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LIST OF ACRONYMS

ABM Agent Based Model.

ADA Americans with Disabilities Act.

AEP Annual Exceedance Probability.

ANUGA Australian National University-Geoscience Australia.

API Application Programming Interface.

ASCE American Society of Civil Engineers.

BP Years before present.

CAPI Computer-Assisted Personal Interviewing.

CDEM Civil Defence Emergency Management.

COMCOT Cornell Multi-grid COupled Tsunami.

DART Deep-Ocean Assessment and Reporting of Tsunamis.

DEM Digital Elevation Model.

DRR Disaster Risk Reduction.

EEFIT Earthquake Engineering Field Investigation Team.

EQC New Zealand Earthquake Commission.

FEMA Federal Emergency Management Agency.

GIS Geographic Information System.

GPS Global Positioning System.

HFA The Hyogo Framework for Action 2005–2015.

IBC International Building Code.

IL Importance Levels.

ISO International Standards Office.

IStructE UK Institution of Structural Engineers.

JMA Japanese Meteorological Agency.

LCD Least-Cost Distance.

LiDAR Light Detection and Ranging.

MCDEM Ministry of Civil Defence and Emergency Management.

MHW Mean High Water.

MMI Modified Mercalli Intensity.

MOST Method of Splitting Tsunami.

MSL Mean Sea Level.

NIWA National Institute of Water and Atmospheric Research.

NOAA National Oceanic and Atmospheric Administration.

NPO-CeMI Crisis and Environment Management Policy Institute.

NSHM National Seismic Hazard Map.

NTHMP National Tsunami Hazard Mitigation Program.

NWS National Warning System.

NZCPS New Zealand Coastal Policy Statement.

NZTA New Zealand Transport Agency.

PEP Public Education Programme.

PTHA Probabilistic Tsunami Hazard Assessment.

PTWC Pacific Tsunami Warning Center.

PTWS Pacific Tsunami Warning System.

RC Reinforced Concrete.

RiCOM River and Coastal Ocean Model.

RMA Resource Management Act.

SMS short message service.

SRC Steel Reinforced Concrete.

SWE Shallow Water Equations.

TEP Tsunami Expert Panel.

TUNAMI Tohoku University's Numerical Analysis Model for Investigation of Near-field tsunamis.

TVEB Tsunami Vertical Evacuation Buildings.

URP Usually Resident Population.

US United States.

USD United States Dollars.

USGS United States Geological Survey.

VBA Visual Basic for Applications.

WREMO Wellington Regional Emergency Management Office.

WTPS 'What's The Plan Stan?'.