GLOBAL EARTHQUAKE MODEL
working together to assess risk

PSHA input model documentation for New Zealand (NZL)

GEM Hazard Team

Version history

Table 1 summarises version history for the NZL input model, named according to the versioning system described here, and indicating which version was used in each of the global maps produced since 2018. Refer to the GEM Products Page for information on which model versions are available for various use cases. The changelog describes the changes between consecutive versions and are additive for all versions with the same model year.

Table 1 – Version history for the NZL input model.

Version	2018.1	2019.1	2022.1	2023.1	Changelog
v2010.0.0	X	X	X		First version of the model implemented in OpenQuake.
v2010.0.1				X	Mmin extended to M4 for crustal distributed seismicity. Source ids were revised to work with disaggregation by source.

The following text describes v2010.0.1.

Authors: E.R. Abbott, N. Horspool, M. Gerstenberger, R. Huso, C. Van Houtte, G. McVerry, S. Canessa **Authors** (2010 model): M. Stirling, G. McVerry, M. Gerstenberger, N. Litchfield, R. Van Dissen, K. Berryman, P. Barnes, L. Wallace, P. Villamor, R. Langridge, G. Lamarche, S. Nodder, M. Reyners, B. Bradley, D. Rhoades, W. Smith, A. Nicol, J. Pettinga, K. Clark, K. Jacobs

This text was prepared by the GEM secretariat and Elizabeth Abbott of GNS Science, New Zealand. For any queries about the model development or how to implement it, please contact GNS Science directly at: nshm@gns.cri.nz

1 Summary

The development of the 2010 seismic hazard model for New Zealand was led by GNS Science, New Zealand (Stirling et al. 2012). It has been translated from its original format into the OpenQuake (OQ) engine by GNS Science. A corrected version of the model was made available in 2018, and a summary of these updates are provided below. The corrected version was used in the GEM Global Model v.2018.1. The model covers the North, South, and Stewart Islands. The Chatham Islands to the east are excluded.

2 Tectonic overview

New Zealand sits across the boundary between the Australian and Pacific plates, where relative plate motion is obliquely convergent across the plate boundary at rates of 48 to 40 mm/year from north to south (Wallace et al. 2007).

The plate boundary can be divided into three main components from north to south, namely: 1) the oblique westward subduction of the oceanic Pacific Plate beneath the continental Australian Plate east of the North Island (Hikurangi Margin); 2) the oblique continent-continent boundary in the South Island (South Island continental transpression zone) where the two plates collide and slip laterally; and 3) the northeastward subduction of the oceanic Australian Plate beneath the continental Pacific Plate southwest of the South Island (Puysegur Margin). These three major components of the plate boundary are further subdivided in tectonic regions (Litchfield et al. 2014).

Recent large earthquakes include the 2010 M7.1 Darfield, the 2011 M6.2 and M6.0 Christchurch earthquakes, the M5.7 – M6.5 Central New Zealand earthquakes in 2013-2014, the 2016 M7.1 East Cape earthquake, and the November 2016 M7.8 Kaikōura earthquake.

3 Basic Datasets

See Stirling et al. (2012) for a description of the datasets used for developing the hazard model.

4 Hazard Model

4.1 Seismic Source Characterisation

The seismic source characterisation (SSC) consists of various seismic source typologies to describe earthquake occurrence in different tectonic settings. Distributed seismicity is used to model active shallow, volcanic, and intraslab seismicity, while fault sources are used to model seismicity occurring on shallow crustal faults and large subduction interface events. A 'floor level' minimum rate of 0.0008 is applied to the first depth layer (0 – 20 km) of the distributed seismicity model to account for uncertainties in the poorly constrained rates of low-seismicity regions of New Zealand.

The OQ implementation uses two OQ source typologies. The background (gridded) seismicity models are implemented as collections of **Point Sources**, while faults are modelled as **Characteristic Fault Sources** with complex geometries. The OQ sources are depicted in the

Epistemic Uncertainties Epistemic uncertainties of the SSM are not considered.

4.2 Ground Motion Characterisation

The table below shows the ground motion characterisation (GMC), which is comprised of a set of ground motion prediction equations (GMPEs). The GMM for New Zealand distinguishes between four main tectonic regions: *Active Shallow Crust*, *Volcanic*, *Subduction Interface*, and *Subduction IntraSlab*. The GMM below represents that published in Stirling et al. (2012), which was used in the hazard model included in the GEM Global Model v.2018.1. For a more modern GMM recommendation for New Zealand, please refer to Van Houtte (2017).

Subduction Interface	**Weight**
McVerry2006SInter	1.0
Active Shallow Crust	**Weight**
McVerry2006Asc	1.0
Subduction Intraslab	**Weight**
McVerry2006SSlab	1.0
Volcanic	**Weight**
McVerry2006Volc	1.0

Table 2 *– GMPEs used in the NZL model.*

5 Updates to the 2010 Model

Corrections and changes to the 2010 model include:

- Revision of seismotectonic zones as shown in Litchfield et al. 2014. Zone 1, the extensional western North Island fault zone, was expanded to include a larger offshore region around Auckland.
- Corrected recurrence intervals for the Hikurangi and Fiordland subduction zone sources. Previously, slip-rate was incorrectly allocated across modelled subduction zone source events. Subduction interface source recurrence intervals now reflect appropriate moment balancing across all/overlapping subduction zone events represented in the model (McVerry in prep).
- A correction was made to the combination of the three different recurrence-time distributions used to develop time-dependent recurrence intervals (pers. comm. David Rhoades) for 4 fault sources. The following sources now have revised time-dependent recurrence intervals: OhariuC, OhariuS, WellWHV, and WairarapNich.

6 Results

Hazard curves were computed with the OQ engine for the following:

- Intensity measure types (IMTs): peak ground acceleration (PGA) and spectral acceleration (SA) at 0.2s, 0.3s, 0.6s, 1.0s, and 2s
- reference site conditions with shear wave velocity in the upper 30 meters (Vs30) of 760-800 m/s, as well as for Vs30 derived from a topography proxy (Allen and Wald, 2009)

Hazard maps were generated for each reference site condition-IMT pair for 10% and 2% probabilities of exceedance (POEs) in 50 yrs. Additionally, disaggregation by magnitude, distance, and epsilon was computed for the following cities: Wellington. The results were produced as csv files and bar plots for each of the following combinations:

- hazard levels for 10% and 2% POE in 50 yrs
- PGA and SA at 0.2s, 0.3s, 0.6s, and 1.0s
- Vs30=800 m/s

All calculations used a ground motion sigma truncation of 5. Results were computed for sites with 6 km spacing

Visit the GEM Interactive Viewer to explore the Global Seismic Hazard Map values (PGA for Vs30=800 m/s, 10% poe in 50 years). For a comprehensive set of hazard and risk results, see the GEM Products Page.

7 References

Allen, T. I., and Wald, D. J., 2009, On the use of high-resolution topographic data as a proxy for seismic site conditions $Vs30$, Bulletin of the Seismological Society of America, 99, no. 2A, 935-943

Litchfield NJ, Van Dissen RJ, Sutherland R et al (2014) A model of active faulting in New Zealand. New Zeal J Geol Geop 57:32-56

Stirling M, McVerry G, Gerstenberger M et al (2012) National seismic hazard model for New Zealand: 2010 update. Bull Seismol Soc Am 102:1514–1542. doi: 10.1785/0120110170

Van Houtte C (2017) Performance of response spectral models against New Zealand data. Bull New Zeal Soc Earthq Eng 50:21-38.

Wallace LJ, Beavan RJ, McCaffrey R et al (2007) Balancing the plate motion budget in the South Island, New Zealand using GPS, geological and seismological data. Geophys J Int 168:332-351 doi: 10.1111/j.1365-246X.2006.03183.x

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