Recent Seismic Hazard Studies in SE Asia, Pacific, and USA

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ABSTRACT: We provide a summary of three internationally-based seismic hazard studies commissioned over the period 2013-14 as examples of technology transfer work being undertaken offshore by GNS Science. First, is the provision of a NZS1170.5-style Z-factor map for Fiji, which utilises the Global Earthquake Model's (GEM's) newly-developed global historical seismicity catalogue and python-based software OpenQuake. Second is the development of a preliminary seismic hazard model for northern Vietnam, utilizing the GEM global geodetic model as well as the more traditional fault and seismicity input datasets. The third is an application of fragile geologic features to constrain seismic hazard estimates at the Diablo Canyon nuclear power plant in central California. The adaptation of our New Zealand-based multidisciplinary skills to global problems is now a major part of our work, and the recent availability of the various GEM models and tools has been very timely.

1 INTRODUCTION

International seismic hazard studies are becoming a major component of technology transfer for GNS Science. These studies raise the international profile of New Zealand Inc, provide intellectually satisfying challenges for New Zealand scientists, and generate income from offshore. Three studies are described in this paper: The first is a seismic hazard model for Fiji; the second is a preliminary seismic hazard model for a province in northern Vietnam, and; the third is a study of fragile geologic features for evaluation of a seismic hazard model in central California. The Fiji and California studies are undertaken exclusively by GNS Science, and the Vietnamese study is undertaken by a collaborative partnership between GNS Science, Damwatch Services, and the Water Resources University and Institute of Geophysics in Vietnam.

2 FIJI Z-FACTOR

We have developed a probabilistic seismic hazard (PSH) model for Fiji (Stirling et al. 2014), and produced a map of the hazard factor Z (Fig. 1) according to the NZS1170.5 definition of the Z-factor (Standards New Zealand, 2004). The NZS1170.5 Z-factor is defined as half the 0.5 second spectral acceleration (0.5 * SA(0.5s)) expected with a 10% probability of exceedance in 50 years (equivalent to a 500 year return period) on shallow soil sites. The use of a Next Generation Attenuation (NGA) model for Fiji has required the Class C site conditions to be approximated by an average shear-wave velocity to 30m depth (Vs30) of 450m/s. The PSH model is based on a gridded seismicity model that is developed from the 1960-2009 component of the International Seismicity Catalogue of the Global Earthquake Model (ISC-GEM; globalquakemodel.org). Prior to developing the Z-factor map we briefly evaluated the suitability of the NZS1170.5 code spectral shape for Fiji by comparing the unsmoothed 500 year Class C spectrum for the city of Suva to the NZS1170.5 spectrum, and also to the Australian AS1170.4 and International Building Code (IBC) spectra (Fig. 2). These code spectra have different spectral shapes and, in the case of IBC, alternative hazard parameters for their construction. We found that neither AS1170.4 or IBC code spectra provide a better match to the unsmoothed spectrum than the NZS1170.5 spectrum (Fig. 2), so the NZS1170.5-based Z-factor definition has been used to construct the Z-factor map and associated spectra. The Z-factor map shows hazard that is lowest in the southeast of Fiji, and progressively increasing to the north and northwest (Fig. 1).

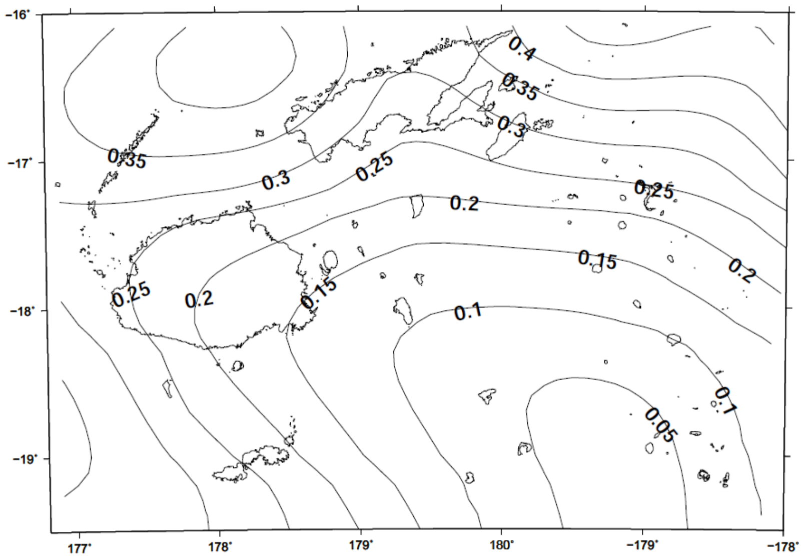

Figure 1. Z-factor map for Fiji. Accelerations are in units of g. See the text for further explanation.

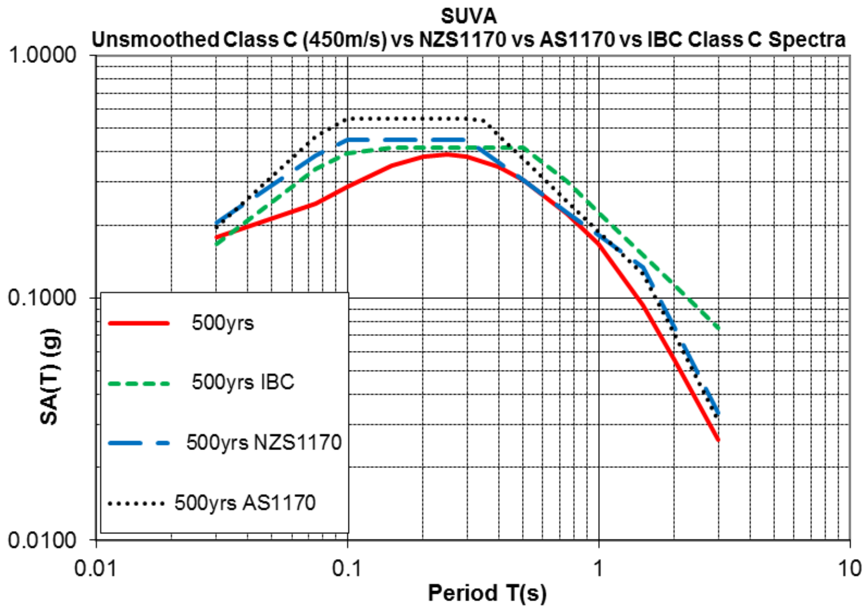

Figure 2. Unsmoothed horizontal Class C spectrum for the 500 year return period for Suva, with modified NZS1170.5, AS1170.4, and IBC code spectra shown for comparison. Note that SA(0.0s) is plotted at 0.03s as the plot is log-log.

3 VIETNAM SEISMIC HAZARD

A preliminary PSH model has been developed for northern-central Vietnam as part of a large Ministry of Foreign Affairs and Trade (MFAT) development project being undertaken with New Zealand partners Damwatch Services Ltd, and Vietnam partners Water Resources University and Institute of Geophysics (DDCSI 2014). We have developed the earthquake source model using multidisciplinary input to improve the limited spatial and temporal coverage of the historical earthquake catalogue. Specifically, we include geological data defining the location and activity of faults (from unpublished Institute of Geophysics data), along with a new Global Positioning System (GPS) strain rate model developed by the Global Earthquake Model project (GEM; globalquakemodel.org). Collectively the seismicity, GPS and geological datasets cover the spectrum of time periods relevant to seismic hazard application: These three datasets have strengths and weaknesses in terms of spatial coverage, temporal coverage, and data uncertainties, but if used together in a multidisciplinary model they can produce a more complete source model than would otherwise be the case. In the case of this model the GPS data have been used to provide estimates of slip rates and earthquake recurrence intervals for the fault sources, which in most cases have no geologically-based constraints on their activity.

We show a PSH map developed for a grid of sites with 0.1 x 0.1 degree resolution in Figure 3. The map shows the ground motions (in this case PGA) for the 10^4 year return period. The 10^4 year return period is typically considered in the development of design loadings for large dams. Ground conditions assumed in the calculations are those of soft rock, which adequately suits the bedrock conditions of the area. The map shows a pattern of hazard that is strongly influenced by the distribution and activity of the modelled fault sources. The fault sources are shown as red lines, and the location and northwest strike of the fault sources are mimicked by bands of higher hazard. Most obvious on the map is the high hazard along the Red River Fault (north of the map area), due to the relatively short recurrence interval for large earthquakes on the Red River Fault.

Our map shows higher hazard than the pre-existing maps developed from the historical record alone. The modelling of fault sources from the GPS data, and assumption of a larger maximum magnitude in the distributed seismicity model (Mw7.0–8.0) than that used in the pre-existing models (M6.8; the largest historical earthquake) will be causative factors.

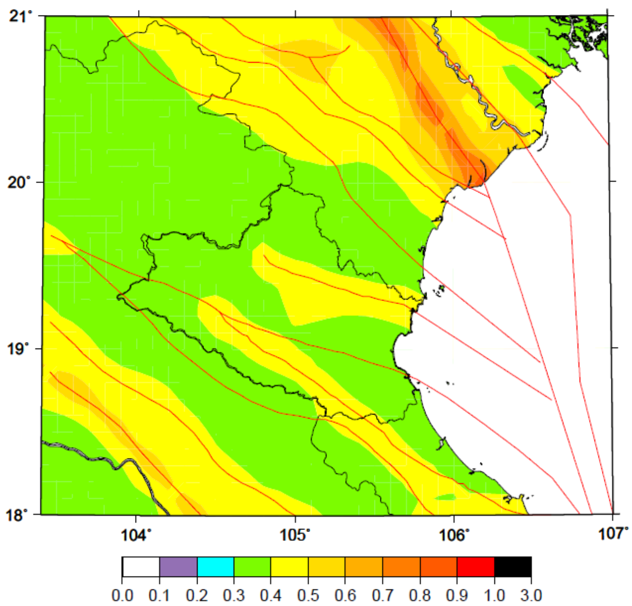

Figure 3. Preliminary seismic hazard map for northern-central Vietnam. The map shows the peak ground acceleration (PGA) in units of g expected for a 10^4 year return period on soft rock site conditions (McVerry et al. 2006). Modelled fault sources are shown as red lines. See the text for further explanation.

4 DIABLO CANYON FRAGILE GEOLOGIC FEATURES

Diablo Canyon nuclear power plant is located in coastal central California (Fig. 4), and is currently the focus of a major seismic hazard re-evaluation. Part of this work is involving the use of fragile geologic features (FGFs) as criteria for validation of the hazard estimates (Stirling 2013). FGFs are marginally-stable rock outcrops and precariously-balanced rocks. Establishing the date at which the feature became fragile, usually resulting from irregular erosive wasting of the outcrop, and estimating the amount of seismic shaking necessary to induce failure, indicates the minimum time elapsed since those shaking conditions were last attained. As such, FGFs hold the potential to provide useful information for evaluating probabilistic seismic hazard (PSH) models at long return periods.

At the request of Pacific Gas and Electric Company, GNS Science has been undertaking reconnaissance of potential FGF sites in the immediate area of the Diablo Canyon Power Plant. The purpose of the reconnaissance is to search for FGFs that might hold potential for providing constraints on seismic hazard at the power plant for long return periods (≥10^4 years). The landforms targeted are paleo-seastacks, which are prominent columns of rock that were once shaped by the sea but are now uplifted well above sea-level and therefore preserved from further marine erosion (Fig. 5). Paleo-seastacks have been inspected at several sites, and fragile geologic features have been documented. These are typically slabs of rock that have become detached from the sides of the seastacks and are unstably perched (Figs. 6-7). Follow up work this year will be in the dating of at least one of the FGFs by cosmogenic methods, and assessment of FGF fragility (threshold ground motions for toppling). This work, combined with New Zealand-based work near the Clyde Dam site will represent the first-ever applications of FGF studies to major commissioned seismic hazard studies.

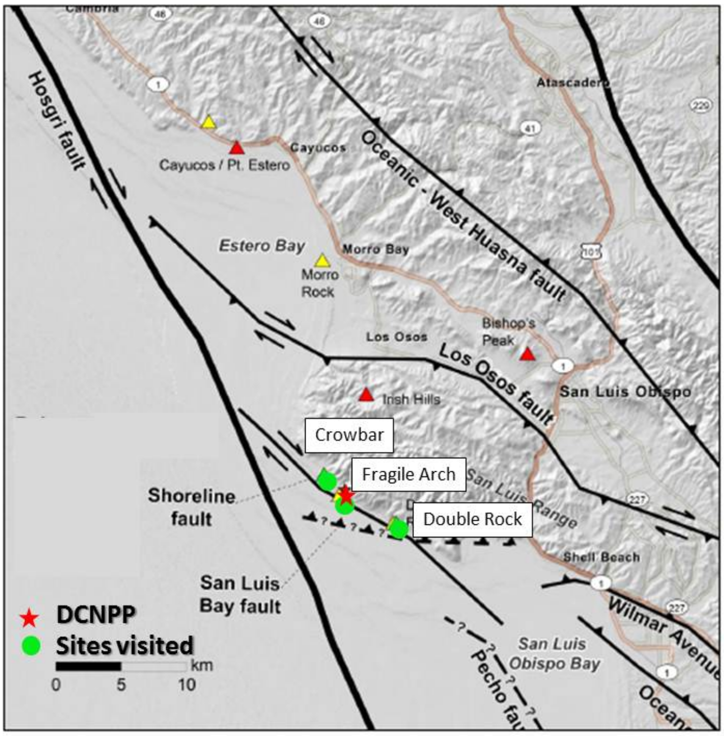

Figure 4. FGF sites visited in the vicinity of the Diablo Canyon Nuclear Power Plant (DCNPP), central California. Local active faults are shown as black lines. Map courtesy of Steve Thompson.

Figure 5. Double Rock west (left) and east (right) paleo-seastacks.

Figure 6. Double Rock east paleo-seastack, showing one FGF (arrowed in main image and shown in profile in the inset). The FGF is approximately 2m tall.

Figure 7. Double Rock west paleo-seastack, showing three FGFs (arrowed in main image and inset). Figures to the lower right of the image give an indication of scale.

5 SUMMARY AND CONCLUSIONS

We have provided a summary of three recent internationally-based seismic hazard studies that have been undertaken by GNS Science. We have briefly described: (1) a NZS1170.5-style Z-factor map for Fiji, which utilises GEM's newly-developed global historical seismicity catalogue and python-based software OpenQuake; (2) a preliminary seismic hazard model for northern Vietnam, utilizing the GEM global geodetic model as well as the more traditional fault and seismicity input datasets, and; (3) the application of fragile geologic features to constraining seismic hazard estimates at the Diablo Canyon nuclear power plant in central California. The three studies illustrate how the adaptation of our New Zealand-based multidisciplinary skills to global problems has become a significant part of our work. International studies of this kind serve to raise the profile of New Zealand Inc, provide intellectually satisfying challenges for New Zealand scientists, and generate offshore income, collaboration and partnerships.

6 ACKNOWLEDGEMENTS

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