Relative earthquake hazard of Newcastle NSW

by
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Abstract
A model-independent extreme value method used in the original Australian earthquake building code AS2121-1979 has been revived with the extra data to compare earthquake hazard at Newcastle with that at Adelaide, Sydney, Auckland New Zealand and Port Moresby Papua New Guinea, all sites on the Australian Plate. Canadian sites within the North American Plate have also been examined. The results are compared with the relative hazard tabulated in AS1170.4 - 2007 and with published PSHA estimates.

This study shows that Newcastle and Adelaide have very similar hazard. Interestingly Sydney, only 300 km south of Newcastle has much lower hazard, begging the question why? Auckland appears to have a significantly lower hazard than Newcastle but slightly higher than Sydney. The hazard at Vancouver is lower than Newcastle but no Cascadia subduction event has been included here since none has yet been observed. The hazard in Port Moresby PNG is slightly lower than but comparable with that at Newcastle.

Introduction
One of the foundations of AS2121-1979 is the hazard map inset showing zone boundaries as a function of MM Intensity (and an estimate of peak ground velocity) and return period which was the basis for the zoning delineation at two adopted return periods, 500 and 1000 years. The zoning as a function of return period grew out of a proposal by Bubb (1971). The same method for estimating hazard has been resorted to again, to make use of the longer observed history of ground shaking. It was adopted rather than a Probabilistic Seismic Hazard Assessment (PSHA) method to compare earthquake hazard to circumvent the need for extensive and often arbitrary assumptions about source zone boundaries and their recurrence relations, about imported attenuation relationships, about maximum magnitude, focal depth distribution, activity of faults and especially the uncertainties in the assumptions.

This paper was prompted by comments over the last decade, by one widely distributed email regarding the relative hazard of Vancouver with respect to Australian sites, by criticism of the high relative hazard of Australia compared with other intraplate interiors during GSHAP, by the code rating contradiction versus PSHA result of Auckland, and by the revised PSHA outcome for Newcastle (Dhu and Jones, 2002).

The method I have used was introduced by Cornell (1968) and used by Lomnitz (1974) and early Canadian engineers including Milne and Davenport (1969) and others.

The method
Models are frequently utilised to make predictions about future earthquakes even when the underlying physical process is unknown. PSHA can be expected to work reasonably well where the theory of plate tectonics applies such as along plate boundaries where the type of boundary and the rate of the tectonic process can be measured and compared with theory (the sticking point is the questionable independence of one earthquake from another). At sites within the Australian plate, Newcastle, Sydney and Adelaide and near,

but not on, the boundary of the Pacific Plate, Auckland NZ and Vancouver Canada, the earthquakes cannot be explained by plate tectonics per se, an underlying cause is not widely accepted. So which model to use for intraplate hazard assessment?

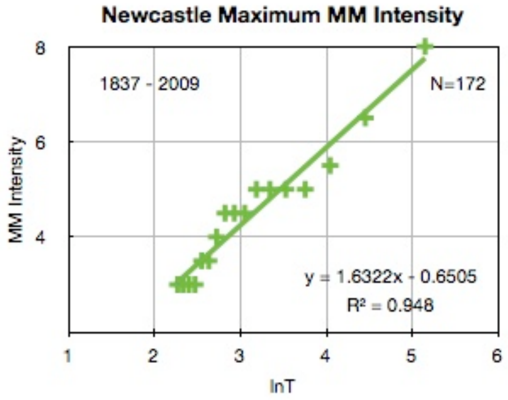
Notions of capacity design for structures and structural systems invoke the idea that for a structure to be a success it must be able to survive the maximum load it is likely to be subjected to rather than a typical load. This suggest the use of extreme value methods which concern the distribution of largest earthquakes and not the frequent small events. If we do not extrapolate the intensity much beyond the observation period then the Type-1 or Gumbel extreme value distribution is suitable even though it supposes there is no upper bound. The set of intensities in order of increasing intensity observed at any site is then plotted according to a ranking formula (j/(N+1)) where j is the jth ranking in N years of observation. Selecting only the largest event in any year filters out foreshocks and aftershocks and some other dependent events like doublets.

Results

The maximum reported intensity for each city in any single event in each year was tabulated, sorted in order of increasing intensity and plotted, the highest intensity ranked j=N, subsequent values at N-1, N-2 etc. for each observation. The line of best fit was computed and interpolated to produce the 10, 100 and 500 year intensity.
Data are summarised in the table below, the decimal intensity is meaningless and only used for visual comparison of the predictions.

City/Return Period (years)	**Max MM Intensity**	**Years of Observation**	10	100	500
Newcastle NSW	VIII 1989	172	3.1	6.9	9.5
Adelaide SA	VIII 1954	126	3.3	7.0	9.5
Sydney NSW	V 1973, 1989	221	2.7	4.7	6.0
Port Moresby	VII, 1979	56	3.9	7.5	10
Auckland NZ	VI 1891	161	2.9	5.0	6.5
Vancouver Canada	VI 1946, 1972	137	1.5	5.8	8.9
Quebec Canada	VIII 1870	346	2.7	6.0	8.4
Ottawa Canada	V 1861, 1914, 1933, 1944	193	3.4	5.0	6.0

This study shows that Newcastle (Fig 1) and Adelaide (Fig 2) have very similar hazard and the two cities should be rated equally in AS1170.4 as they are, Newcastle 0.11g and Adelaide 0.10g. Novocastrians might expect to feel an earthquake every ten years on average and suffer structural damage every 100 years on average. Interestingly Sydney,



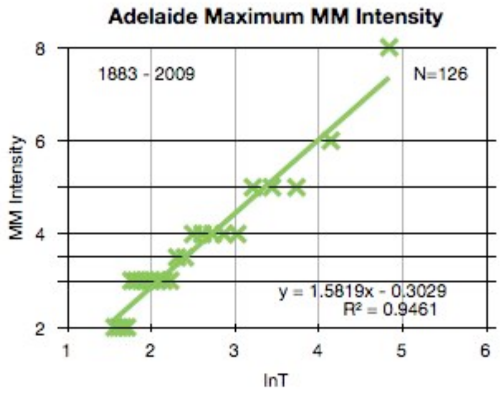


Figure 1 Computed hazard at Newcastle NSW **Figure 2** Earthquake hazard at Adelaide SA

only 160 km south of Newcastle has experienced a very different earthquake history, begging the question why? It has been rated 0.07g in AS1170.4).

Of the three near-plate-boundary cities, Auckland about 200 km above the Pacific-Australian plate boundary on the Australian side (Dowrick & others, 1995), appears to

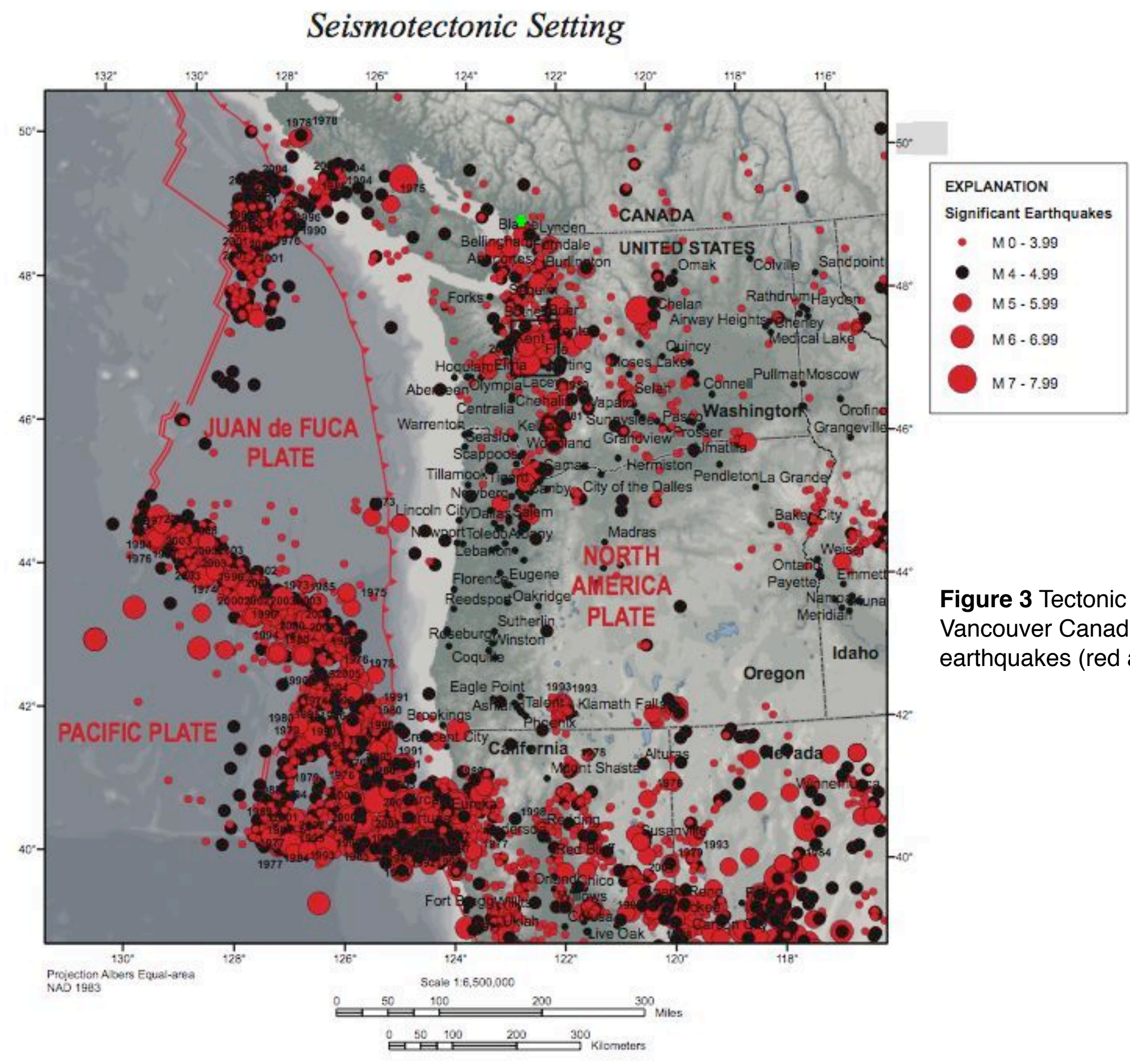


Figure 3 Tectonic Setting of Vancouver Canada (green dot) with earthquakes (red and black dots)

have a significantly lower hazard than Newcastle but slightly higher than Sydney, which belies its zone rating in the NZ Loading Code (0.13g).

The available data for Vancouver is limited, only 5 observations, but the highest intensities have been captured and any more observations will be at lower intensities which will have the effect of reducing the computed 500 year intensity but increasing the 10 year intensity.

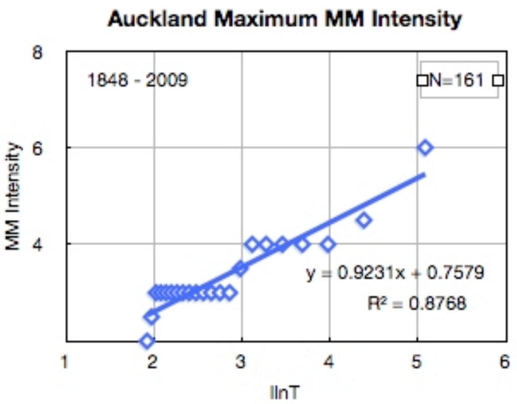


Figure 4 Computed hazard at Auckland NZ

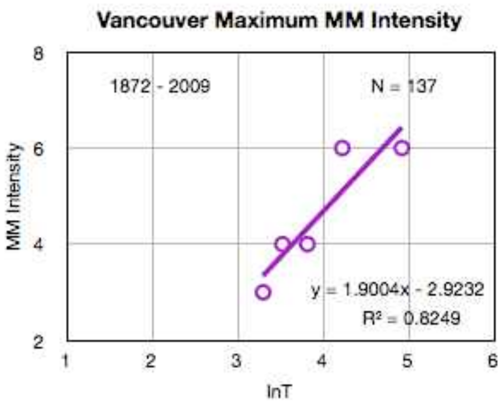
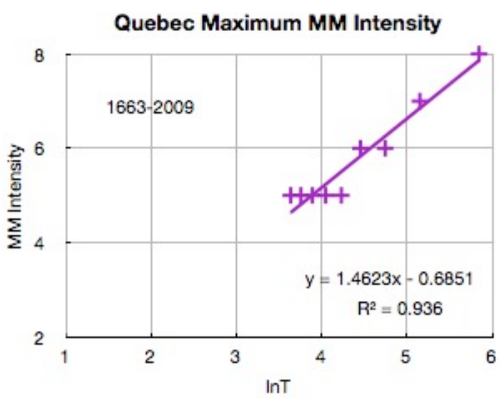


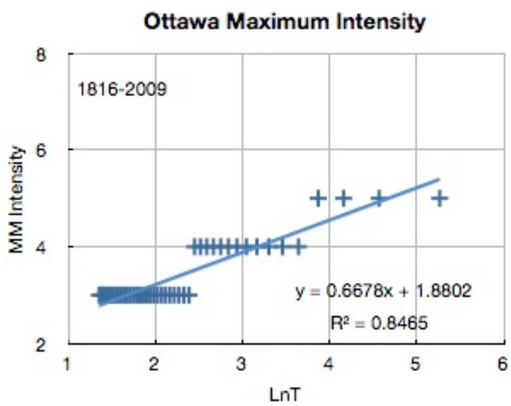
Figure 5 Earthquake hazard at Vancouver Canada

The hazard at Vancouver, within 100 km of the edge of the small, slowly moving Juan de Fuca Plate indenting the North American Plate, is according to our study lower than that for Newcastle but there may be missing (low) intensities. The hazard computed on the Natural Resources Canada website for Vancouver, 0.25g for the 500 yr event, does not compare with the 0.11g for Newcastle in AS1170.4 (perhaps the factor of 2 is due to the future Cascadia subduction event).

Quebec was founded in 1608 and the first damaging earthquake struck in 1663. Lamontagne (2009) notes that Gouin (2001) rated the downed chimneys as MMI VI but he rated it intensity VIII so there is a wide difference in the interpretation. Only the damaging earthquakes are mentioned by Lamontagne, MMV or greater, but he mentions that an earthquake is felt there every 10 years or so and if we include this observation as MMIII, the line of best fit and computed 10, 100 and 500 year intensities hardly change.

Based on its earthquake hazard and population. the seismic risk of the Ottawa-Gatineau region ranks third in Canadian urban areas (Lamontagne





Figures 6, 7 Earthquake hazard at Quebec and Ottawa, Canada and others, 2008). The hazard in Ottawa however is low, very similar to that at Sydney based on the table above and Sydney has the highest assessed earthquake risk of any city in Australia (Walker, pers., comm.). The intensity database for Ottawa is not the same as our other samples, it is the intensity computed using the database of known earthquakes, magnitude and distance with an attenuation relationship and some checking of the important historical events. It is interesting because it includes many low intensities from small local earthquakes and they have little impact on predicted intensities. Reports of such events have no doubt been missed in the compilation for all the other cities.

Port Moresby capital of Papua New Guinea is about 100 km west of the Solomon Sea Plate boundary and, like Auckland, is within the Australian Plate. The hazard in Port Moresby is higher than but comparable with that at Newcastle so the loading code coefficient should be similar. The available written history for Port Moresby is very short and awaits a dedicated researcher.

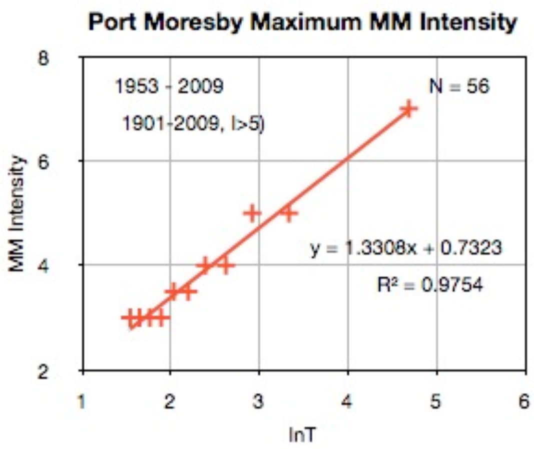


Figure 8 Earthquake hazard at Port Moresby, PNG

Discussion

PSHA is a subjective art with many assumptions hidden behind fancy graphs and figures. Here is an alternative, older, out-of-fashion methodology, computing relative hazard at different places using an identical methodology with no model assumptions. It is especially useful where there is no strong motion data, no attenuation relationship, a poorly defined focal depth range and an uncertain maximum magnitude.

In intraplate Australia the method gives a quick and straight-forward assessment of the relative hazard of different sites with a similar historical longevity incorporating mechanism, attenuation and site effects without challenging assumptions. This method can also be usefully employed to compare the hazard at sites throughout the world, regardless of the tectonic environment provided the intensity scale is compatible. It may raise interesting questions, such as why do Sydney and Newcastle only 160 km apart and both in the same geological structure, the Sydney Basin, have such different earthquake stories? Why does a near plate boundary site such as Auckland appear to have a lower earthquake strike rate than a mid-plate site like Newcastle? Vancouver in Canada like Auckland does not have a remarkable record of past earthquake shaking yet is rated twice as hazardous as Auckland New Zealand which is presumably justified on the evidence of paleoseismology studies. More work needs to be done.

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