Estimation of Seismic Intensity at Lalitpur, Nepal

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ABSTRACT

An attempt has been made to estimate seismic hazard at rock level in terms of peak horizontal acceleration (PHA) at two sites of Lalitpur district using probabilistic seismic hazard analysis (PSHA). Earthquake data base for the site was prepared merging the various data bases. Magnitude frequency relationship was developed to represent the earthquake recurrences in the region. Then using Young's et al 1997 attenuation relation and with help of CRISS 2007 software peak ground acceleration was estimated and probabilistic spectra for the two sites is obtained. The results show the higher level of seismic risk at the sites which suggest the existing guideline of earthquake resistant design considerations.

Keywords: peak ground acceleration, spectral acceleration, PSHA

1. INTRODUCTION

Lalitpur is one of the three districts of Kathmandu valley. The Kathmandu valley has been reported to have experienced many earthquakes in the past. Records of past destructive earthquakes date back up to 1255 AD (Chitrakar and Pandey, 1986). The significant earthquakes around Nepal (NDGC, 2015) are shown in table 1. The earthquakes on 1255, 1833 and 1934 have badly destroyed the Kathmandu valley (Pant, 2000, Rana 1935). A strong earthquake occurred and damaged eastern side of Nepal in 1988 (ISC, 2015). The recent M7.8 earthquake in Barpak, Gorkha following M7.3 after shock in Dolakha in 2015 severely damaged along 80 kilometer stretch of the Himalayan which lies just north side of Kathmandu valley. The study area falls in the western extremity of the source region that produced the 1934 great earthquake. It is believed that this region has to wait for some 5 hundreds of years before it gets matured to produce great earthquake (M>8.0) again, but we should not ignore the possibility that this region has collected some energy in the last about 80 years (after the 1934 Bihar-Nepal Earthquake) and this energy might be equivalent to one ~M7.0 earthquake at the present.

The recent, Barpak M7.8 earthquake developed 240gal acceleration at Kathmandu. Another very important aspect it has very long duration -56 seconds with period 4 - 5 seconds. Thousands of buildings were damaged, soil is liquefied in many places, ground failure occurred and 8922 people (NDGC, 2015) died and 23000 people injured (Sherchand, 2015). Looking at history recurrence history of major earthquakes (magnitude greater than 7.5) has occurred in the interval of 80-100 years period. It is quite large and show big seismic risk in the region. From similar studies for other places, it had been emphasized by many researchers (Maskey, 2004, Parajuli et al 2008, JICA 2003) which have proved urgent need to revise the seismic risk and make the decision as per updated risk scenario.

Table 1 Significant Nepal earthquakes

Source:https://en.wikipedia.org/wiki/List_of_earthquakes_in_Nepal#cite_note-DPNET-Nepal-2

Date	Place	Latitude	Longitude	Fatalities	Magnitude	Remark
1255	Kathmandu	27.70	85.30	2,200	7.8	
1260	Sagarmatha	27.10	86.80	100	7.1	
1344	Mechi	27.50	87.50	100	7.9	
1408	Bagmati	27.90	86.00	2,500	8.2	
1505	Mustang	29.50	83.00	6,000	8.2	Mw
1681	Koshi	27.60	87.10	4,500	8.0	
1767	Bagmati	28.00	85.50	4,000	7.9	
1833	Gosaikunda	27.90	85.50	6,500	8.0	Ms
1869	Kathmandu	27.70	85.30	750	6.5	M_s
1916	Nepal/Tibet	30.00	81.00	3,500	7.7	M_s
1934	Sagarmatha	26.77	86.76	8,519	8.4	Mw
1966	Nepal/India border	29.55	80.85	80	6.3	M_s
1980	Pithauragarh	29.60	81.09	200	6.5	M_s
1988	Udayapur	26.78	86.62	1,091	6.6	M_s
2011	Sikkim, India	27.33	88.62	111	6.9	M_s
2015	Gorkha	28.15	84.71	8,922	7.8	M_w
2015	Dolakha	27.97	85.96	213	7.3	M_w

2. EARTHQUAKE CATALOGUE

The earthquake catalogue for this area was prepared by combining and consolidating the available information from different sources and covers the period 1255-2014 AD. The earthquake data were collected from different sources, i.e., United States Geological Survey (USGS), Department of Mines and Geology (DMG), International Seismological Centre (ISC). In addition to that, a few more data were collected from the catalogues published by different researchers. Uniformity of data base was prepared using Scordilis, 2006, Pant 2000. Catalogue was completed considering both- Historical Catalogue and Seismicity (1255 – 1910 A.D.) and Instrumental Catalogue and Seismicity (1911-2014 A.D.)

2.1 Declustering

In order to avoid repetition of dependent events such as fore and aftershocks were removed by declustering. Declustering is the method of filtering the overlap events. As the available earthquake data include fore shocks, main shocks and aftershocks, it is difficult to identify main shock or background or dependent events. Hence, after converting reported magnitude (Ms or Mb) and intensity into moment magnitude (Mw), all the dependent events (fore shock and aftershock) were removed by the windowing procedure based on algorithm given by Gardner and Knopoff (1974).

2.2 Catalogue Completeness

The collected earthquake data consists of different magnitude scales and intensities which are finally converted into moment magnitude in order to keep uniformity in completeness by using the empirical relationships given by Johnston, 1996 and Scordilis, 2006. Residual catalogue obtained after declustering the dependent events, containing independent earthquakes is finally prepared. Earthquake catalogue is prepared neglecting magnitude less than M5 because an earthquake with magnitude less than 5 contributes very less in seismic hazard assessment. In this work a total of 1900 unclustered main shocks were collected for the period of 1255 to 2014 A.D. After making completeness of the earthquake data, magnitude frequency relationship was developed for all sources.

2.3 Seismic Source Zone

The first step of seismic analyses is the definition of the earthquake sources that could most probably affect the site of interest at which the seismic hazard will be calculated. In fact, the characterization of seismic source zones depends on the interpretation of the geological, geophysical and seismological data obtained by many tools such as tectonic theory, seismicity, surface geological investigations and subsurface geophysical techniques. The discontinuity in the tectonic boundary of the study area has been divided into a total of 25 quadratic and polygon shaped- areal sources.

2.4 Gutenberg – Richter Coefficients (a, b):

After characterizing the earthquake sources, logarithmic value of the rate of exceedance of earthquakes falling in the particular sources are plotted against the earthquake magnitude in order to find out the Gutenberg-Richter parameters. The slope of the plotted curve represents the “b” value while the rate of earthquake exceeding magnitudes represents the “a” value (Stepp, 1972).

3. PSHA FORMULATION

The Probabilistic Seismic Hazard Assessment (PSHA) refers to the estimation of some measure of the strong earthquake ground motion expected to occur at a selected site. The PSHA is formulated following the procedure mentions in the Cornell 1968, Kramer 1996, Parajuli et al 2008. The seismicity is specified by a recurrence relationship indicating the average rate at which an earthquake of a particular size will be exceeded. The standard Gutenberg–Richter recurrence law is used for this purpose, that is,

$$\lambda_m = 10^{a-bM} = \exp(\alpha - \beta M) \quad (1)$$

Here, λ_m denotes the average return period of the earthquake of magnitude m. If earthquakes lower than a threshold value m_0 are eliminated, then the expression for λ_m is modified as:

$$\lambda_m = \nu \exp[-\beta(m - m_0)] \quad (2)$$

Where, $\nu = \exp(\alpha - \beta m_0), m > m_0$,

$\alpha = 2.303a, \beta = 2.303b$

Similarly, if both the upper and lower limits are incorporated, then λ_m is given by:

$$\lambda_m = \frac{\nu \exp[-\beta(m - m_0)] - \exp[-\beta(m_{\max} - m_0)]}{1 - \exp[-\beta(m_{\max} - m_0)]} \quad (3)$$

The CDF (cumulative distribution function) and PDF (probability density function) of the magnitude of earthquake for each source zone can be determined from this recurrence relationship as:

$$f_M(m) = \frac{\beta \exp[-\beta(m - m_{\min})]}{1 - \exp[-\beta(m_{\max} - m_{\min})]} \quad (4)$$

The uncertainties in earthquake location, earthquake size, and ground motion parameter prediction are combined to obtain the probability that the ground motion parameter will be exceeded during a particular time period. This combination is accomplished through the following standard equation (Kramer, 1996, McGuire, 2004).

$$\nu_{y^*} = \sum_{i=1}^{N_s} \nu_{i_{M\,min}} \int\int P[Y > y^* \mid m,r] f_{Mi}(m) f_{Ri}(r) dmdr \quad (5)$$

$$\nu_{y^*} = \sum_{i=1}^{N_s} \sum_{j=1}^{N_r} \sum_{k=1}^{N_m} \nu_{i_{M\,min}} \rho_i P[Y > y^* \mid m,r] P[M = m] P[R = r] \Delta m \Delta r \quad (6)$$

Where, N_s is number of sources in the region, $\nu_{iM\,min} = exp(\alpha - \beta_i m_{min})$ is total rate of exceedences of threshold magnitude (M=5.0 is taken in this study). $P[Y > y^* \mid m,r]$ is conditional probability that chosen acceleration exceeded for a given magnitude (M) and distance (R), and $f_{Mi}(m)$ and $f_{Ri}(r)$ are probability density functions for magnitude and distance respectively. Here, M and m are used as random variable and specific value for magnitude respectively. The first term within the integral considers the prediction uncertainty, the second term considers the uncertainty in earthquake size, and the third term considers the uncertainty in location of the earthquake. The above uncertainties for all source zones are considered by way of the double integration summation. A seismic hazard curve is then constructed by plotting the rate of exceedance of the seismic parameter for different levels of the seismic parameter and calculated by using CRISIS 2007.

4. ATTENUATION EQUATION

Though there are hundreds of attenuation laws developed for various region of the world, no earthquake attenuation relations have been developed for the Himalayan region specially. Because of unavailability of sufficient data, here, instead of developing new equation for the region, attenuation equations among already developed equations for subduction zone Crouse 1991, Fukushima and Tanaka 1990, Molas and Yamazaki 1995, Young et al. 1997, Gregor et al. 2002, Atkinson and Boore 2003, Kanno et al.

2008, Zhao et al. 2006 which supports the tectonics, geology and faulting system were studied. Most of the earthquakes occurring in Nepal are considered to be interface events due to subduction of Indian plate beneath the Eurasian plate. Hence, in this research work attenuation relationship suitable for subduction zone proposed by Youngs et. al. (1997) is used.

From the probability distribution of particular ground motion parameter, the probability that this parameter Y exceeds a certain value, y*, for an earthquake of a given magnitude, m, occurring at a distance, r, is given by:

$$P[Y > y^* \mid m, r] = 1 - F_y(y^*) \qquad (7)$$

Where, $F_Y(y)$ is the value of the cumulative distribution function of Y at m and r. The value of $F_Y(y)$ depends on the probability distribution used to represent Y. In general, ground motion parameters are usually assumed to be log normally distributed (the logarithm of the parameter is normally distributed).

3. RESULTS

Following the procedure explained preceding sections, uniform hazard spectrum (UHS) and PSHA of Tikathali area and Lubhu were estimated and the results are shown in the Figures 1-4. Probabilistic spectra for 10% probability of exceedence in 50 years which 475 years return period (RP) and 2% probability of exceedence in 50 years which 2475 years return period (RP) are obtained using CRISIS software. The obtained results are shown in the respective figures. The results the higher level of seismicity at the two sites. It helps the planner and designers to act or higher level of safety.

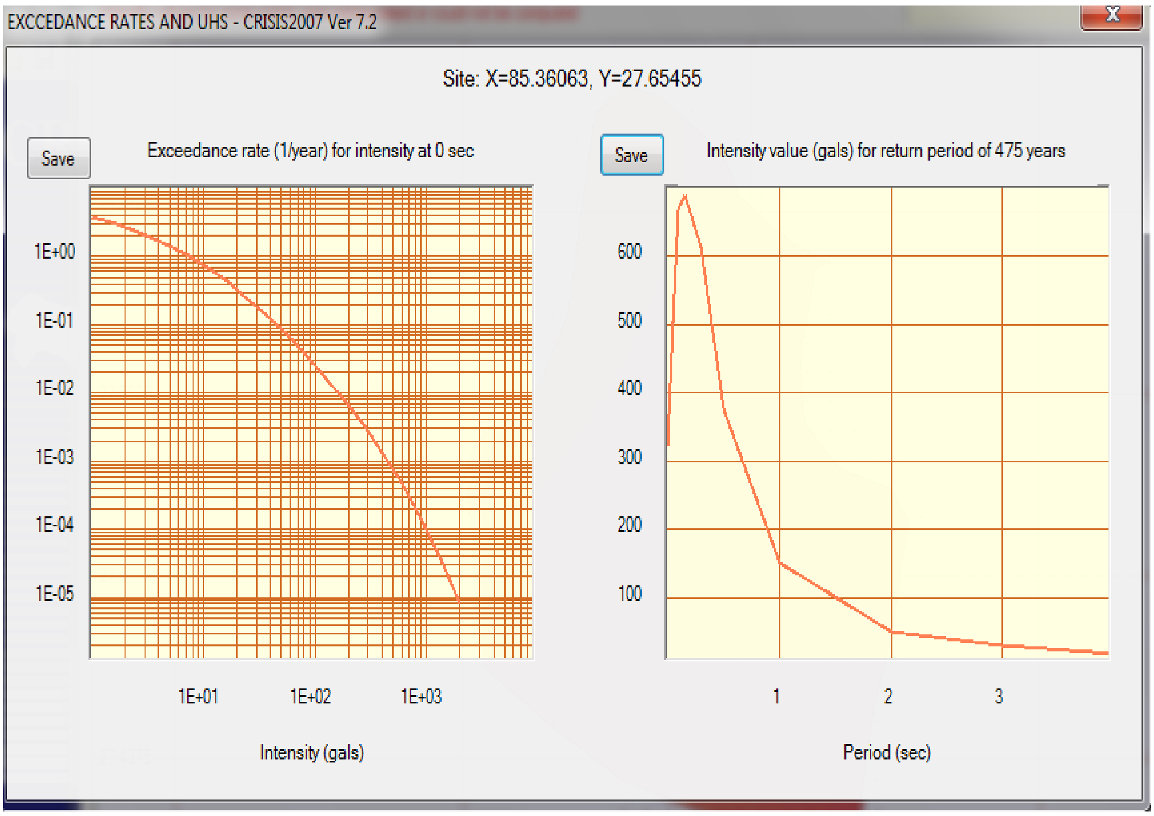

Figure 1: Tikathali PGA of .30g showing Hazard Map and UHS Map, RP=475 yrs

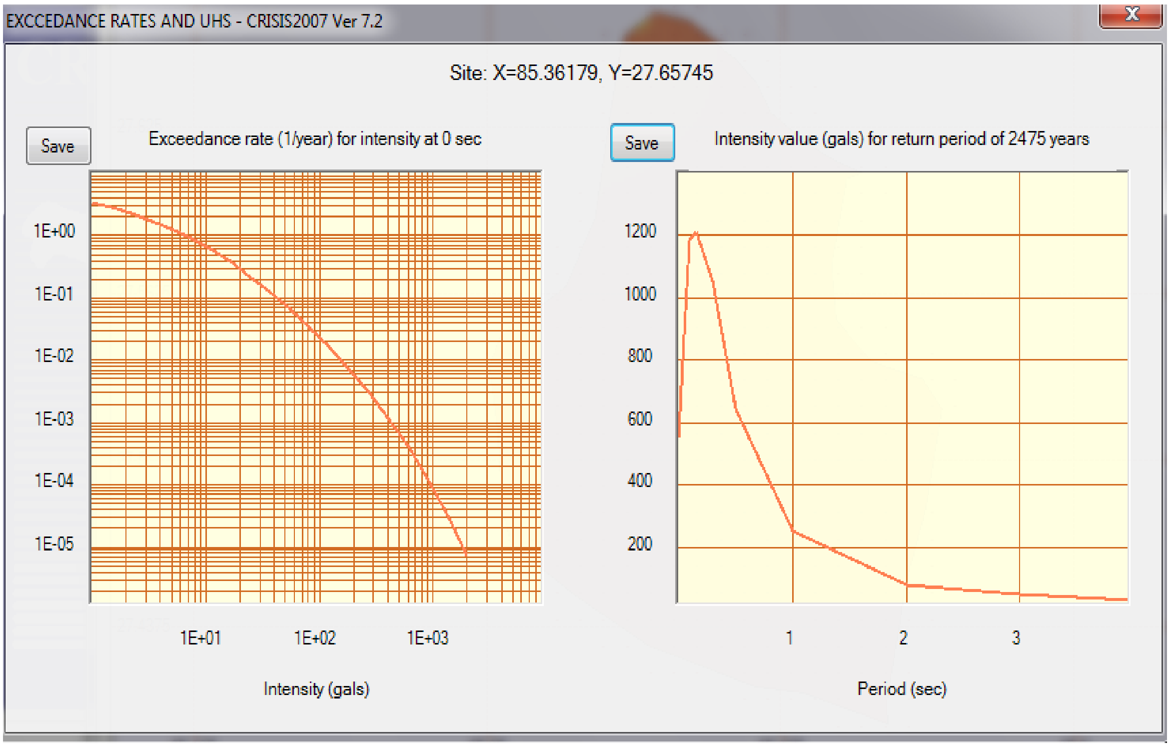

Figure 2: Tikathali PGA of .58g showing Hazard Map and UHS Map, RP=2475 yrs

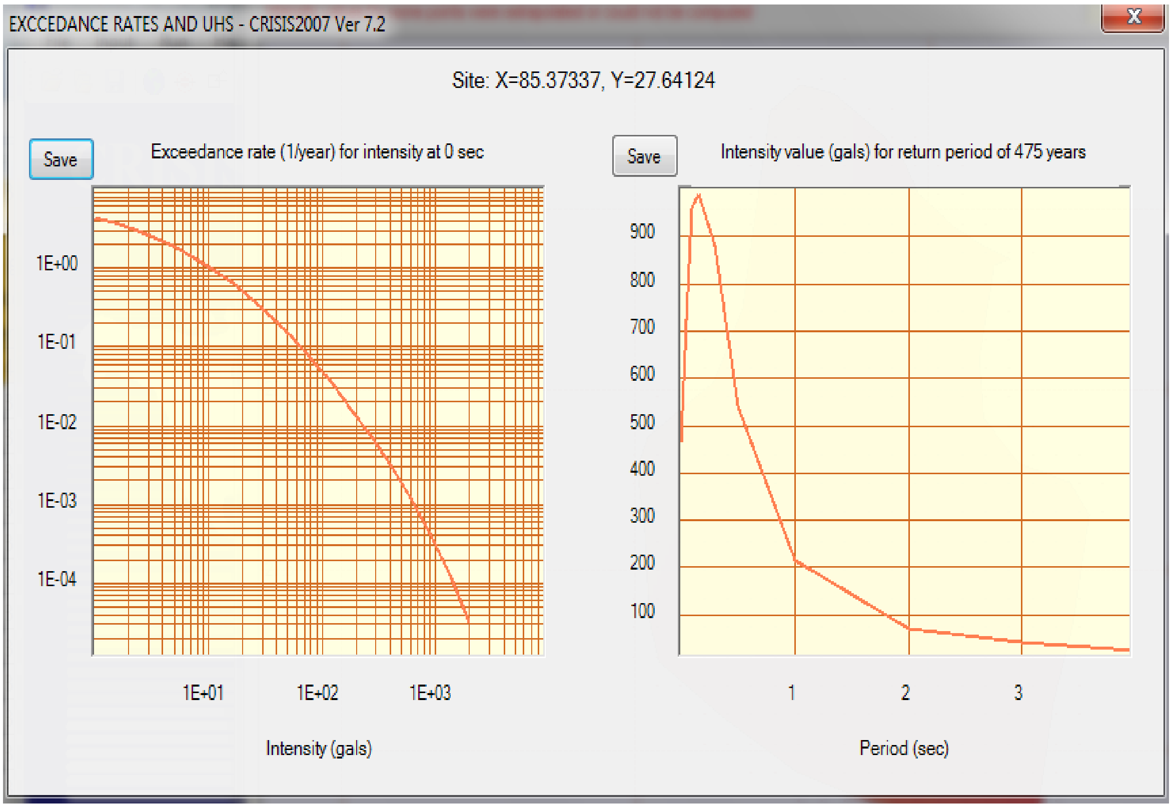

Figure 3: Lubhu PGA. 39g showing Hazard Map and UHS Map, RP=475 years.

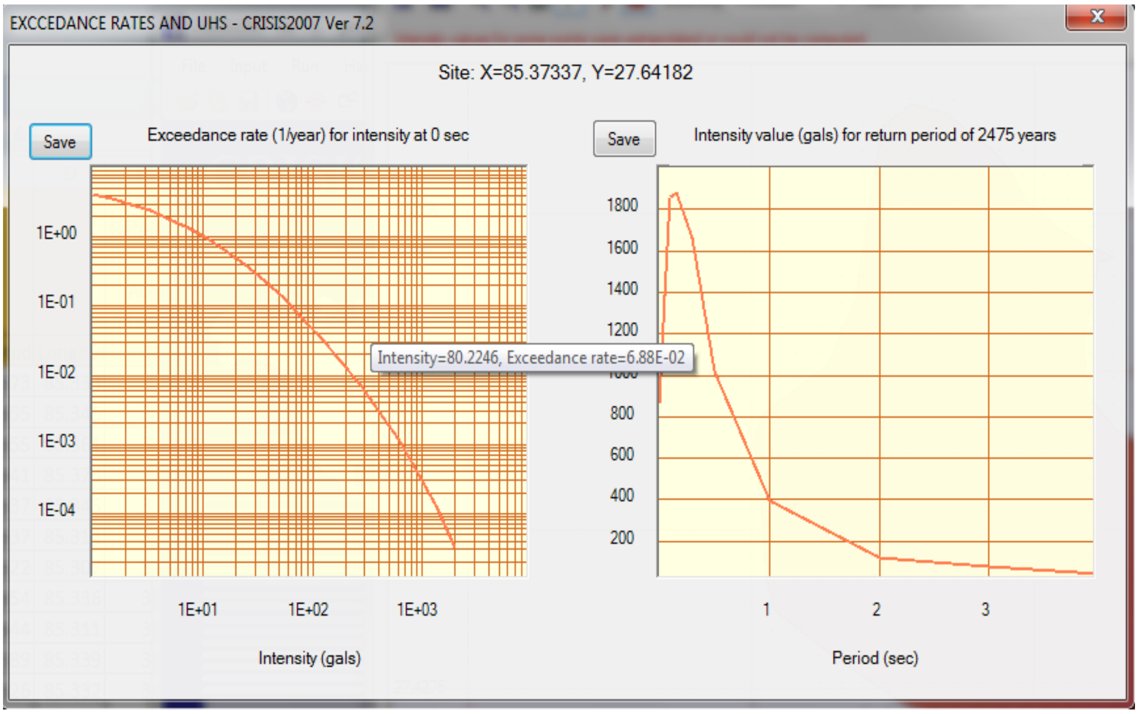

Figure 4: Lubhu PGA. 39g showing Hazard Map and UHS Map, RP=475 years.

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