Seismic Hazard Analysis and Zonation
for
Pakistan, Azad Jammu and Kashmir

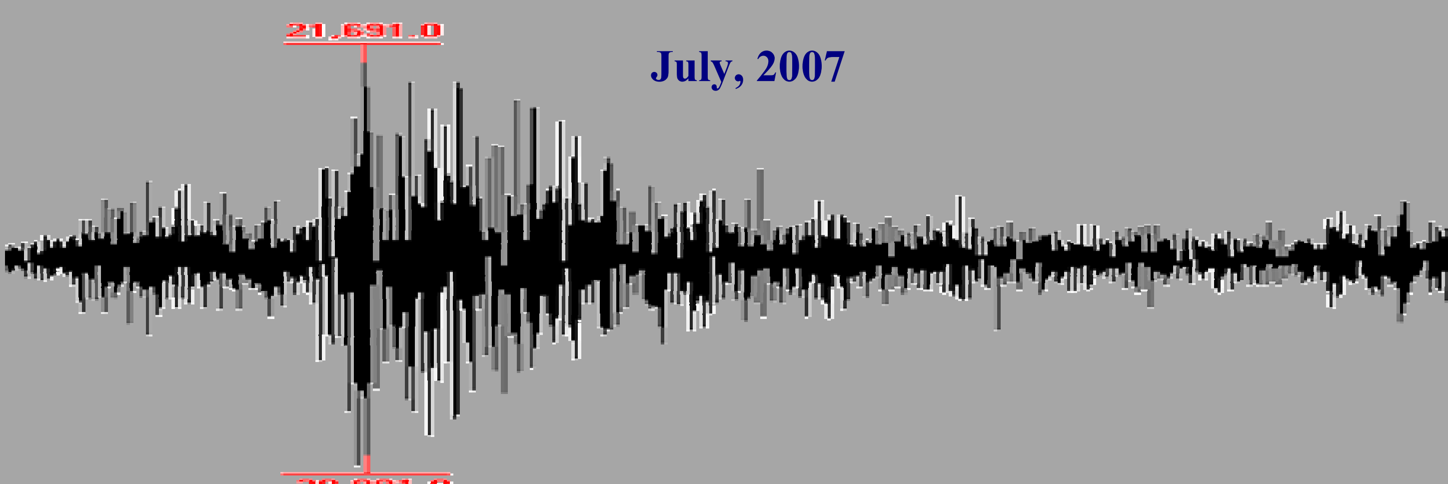
by

Pakistan Meteorological Department

and

NORSAR
Norway

July, 2007



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Preface

The study of strong earthquake ground motions and associated seismic hazard and risk plays an important role for the sustainable development of societies in earthquake prone areas. Using the hazard estimates produced by seismology, risk analysis yields probabilistic estimates of the expected losses of property and lives from earthquakes hazard estimation and vulnerabilities of structures, facilities, and people distributed over the site. Population growth, modern economic developments, real time communication, and industrial interdependence among countries have sharpened the impact of natural disasters. It is now realized that much can be done through studies and knowledge enhancement to mitigate these risks to life and social well being. This is particularly true for the risk due to great earthquakes.

The 8th October, 2005, Muzaffarabad earthquake emphasized the importance of redefining the seismic zonation of Pakistan. The Pakistan Meteorological Department (PMD) has been working in the field of seismic monitoring since 1954 and has the national responsibility for the issuance of earthquakes information to Government and to the public.

The present study is particularly valuable as it contributes to mitigation of earthquake risk as well as post earthquake management of the disasters. The study is in particular concerned with obtaining an estimate of the ground motion parameters at a site for the purpose of earthquake resistant design or seismic safety assessment. This study can also be used to prepare microzonation maps of an area by estimating the strong motion parameters for a closely-spaced grid of sites.

This study is the result of the three-year cooperation between Pakistan Meteorological Department and NORSAR, Norway. This study is conducted by the PMD personnel Mr. Zahid Rafi and Mr. Ameer Hyder Leghari and the NORSAR personnel Dr. Conrad Lindholm, Dr. Hilmar Bungum and Dr. Dominik Lang.

The funding for this study was facilitated by the Norwegian Ministry of Foreign Affairs through the Norwegian Embassy, and Government of Pakistan through bilateral framework for institutional cooperation, which is coordinated by the Planning and Development Division.

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Summary

The study of earthquake ground motions and associated earthquake hazards and risks plays an important role in the sustainable development of countries like Pakistan, where devastating earthquakes have occurred repeatedly. The objective of the present study has been to conduct a seismic hazard investigation that covers all of Pakistan, and the methodology adopted to achieve this was a probabilistic approach. In this study a new version of attenuation and ground acceleration prediction models are used and the parameterization has been based on the most recently updated earthquake catalogues.

The seismicity was modelled through a spatial model and ground motion was computed for 8 frequencies including PGA. Seismic hazard maps in terms of PGA for the annual exceedance rates of 0.02, 0.01 and 0.002 (return periods of 50, 100 and 500 years) for stiff rocks were prepared. These maps are designed to assist in the risk mitigation by providing a general seismic hazard framework. The largest seismic hazard values occur in Quetta region and northern parts of Pakistan. High seismic hazard values are computed in the areas where shallow-to-intermediate seismicity occurs.

PGA values are given for a range of annual exceedance probabilities (Table 1) together with the expected PGA values at 500 years return period of different frequencies (Table 2). The seismic hazard was computed in a one-degree grid and the maps in Figs. 1 to 3 show earthquake hazard in terms of smoothed PGA.

Table 1.Expected Peak Ground Acceleration (PGA) in [m/s^2] for the different cities against annual exceedance probabilities and return periods.

Annual exceedance probability	Return period (years)	Expected PGA (m/s^2) for the cities of									
		Islamabad	Peshawar	Quetta	Karachi	Gwadar	Muzaffarabad	Gilgit	Lahore	Multan	Khuzdar
0.02	50	1.50	1.35	1.91	0.54	0.53	2.04	2.93	0.97	0.71	1.34
0.01	100	2.25	2.40	2.90	0.95	0.88	3.23	4.42	1.69	1.22	2.26
0.005	200	3.33	3.19	3.59	1.28	1.15	4.02	5.28	2.24	1.61	2.96
0.002	500	3.65	3.49	3.85	1.42	1.25	4.31	5.55	2.46	1.78	3.24
0.001	1000	3.71	3.55	3.90	1.45	1.28	4.36	5.60	2.51	1.81	3.30

Table 2. Expected spectral acceleration [m/s^2] for different cities and an annual exceedance probability of 0.002.

Period T [s]	Islamabad	Peshawar	Quetta	Karachi	Gwadar	Muzaffarabad
PGA	3.65	3.49	3.85	1.42	1.25	4.31
0.1	5.07	5.59	14.28	2.86	5.75	7.03
0.2	5.57	6.11	15.75	3.54	6.35	8.06
0.5	3.12	3.32	9.17	2.57	3.48	4.75
1.0	1.42	1.45	4.37	1.08	1.37	2.24
1.5	0.84	0.84	5.56	0.64	0.75	1.31
2.0	0.75	0.75	2.20	0.57	0.65	1.15
2.5	0.45	0.45	1.67	0.34	0.43	0.75

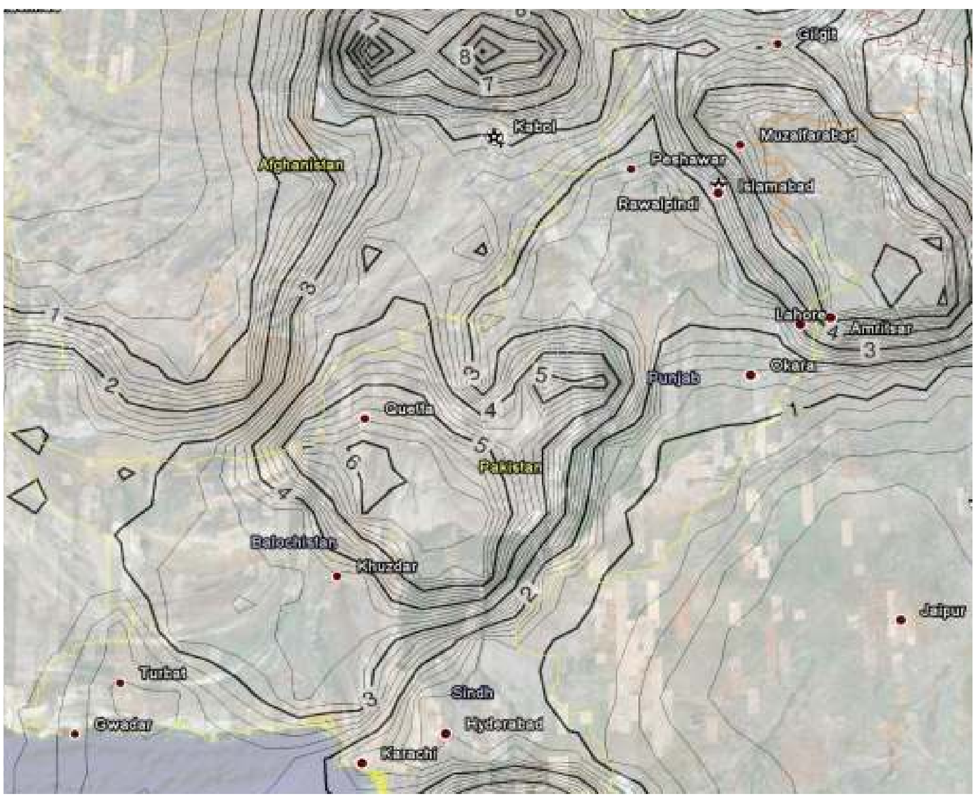


Figure 1.Earthquake hazard for Pakistan and surrounding areas in terms of PGA [m/s^2] for the 0.002 annual exceedance probability (500 years recurrence).

1 Introduction

Pakistan is situated in a highly seismically active region which has experienced many disastrous earthquakes during historical times. The last 100 years alone include the 1945 Makran coast earthquake with magnitude above 8.0, the Mach earthquake in August 1931, M 7.3, the Quetta earthquake in 1935, M 7.4, the Pattan earthquake in 1974, M 6.0, and the recent disastrous Muzaffarabad earthquake in October 2005, M 7.6, which has shaken the entire nation in many ways. Many active faults exist in Northern and Southern areas of Pakistan and more than half of the total population are living with earthquakes and will have to continue doing that.

The October 2005 Muzaffarabad earthquake enhanced the consciousness about the increasing vulnerability that the growing population is confronted with. The increasing population in the earthquake-prone cities is a major reason why the vulnerability due to earthquakes is also increasing. It is globally realized that poorly-constructed buildings and houses are the main reason for the large number of victims due to earthquakes. In recent years several destructive earthquakes occurred in the world, with significant social and academic impact. The observation of strong motion and aftershock sequences as well as the investigation of the destruction from these earthquakes, which include the 1995 Kobe Japan earthquake, the 1999 Chi-Chi Taiwan, China earthquake, the 2001 Gujrat, India earthquake and October, 2005 Muzaffarabad earthquake, among other, provide the disciplines of seismology and earthquake engineering with informative and valuable data, experiences and lessons, and raise a number of important scientific problems. It is believed that the new technologies such as GIS, GPS and remote sensing, among other, have proven to be of significant help in the study of seismic hazard and risk. These efforts have resulted in a significant expansion of knowledge in seismic hazard analysis.

1.1 Scope of the study

The study of strong ground motion, earthquake hazard, and risk plays an important role in modern seismology viz; it is of such great societal importance (e.g., Bilham *et al.,* 2001; Bilham, 2006). Hazard analysis requires characterisation of the seismic sources that can be expected to affect a selected place in terms of location, magnitude, and frequency of occurrence of potentially damaging earthquakes. Using the hazard estimates produced by seismology, risk analysis yields deterministic or probabilistic estimates of the expected losses of properties and lives from earthquakes, which in turn is a convolution of the hazard estimates and vulnerabilities of structures, facilities, and people distributed over the site.

Seismic hazard also has a major impact on the earthquake-resistant design of structures by providing justified estimates of hazard parameters, such as Peak Ground Acceleration (PGA) or response spectrum amplitudes at different natural periods. Traditionally, PGA has been a widely used hazard parameter, partly because it can so easily be read from analogue accelerograms. However, PGA is often found not to be well-correlated with the damage potential of ground motion, which has led to more frequent use of measures (such as Peak Ground Velocity, PGV, or spectral acceleration, SA) that reflect also other wavelengths, or frequencies. By taking into account the entire available databases on seismicity, tectonics, geology and attenuation characteristics of the seismic waves in the area of interest, the seismic hazard analysis is used to provide estimates of the site-specific design ground motion at the site of a structure (Dravinski *et al.*, 1980; Westermo *et al.*, 1980). One important result of our study is the preparation of zoning maps for the generalized applications.

In this study historical data is used which is available only in intensity scales for the ground motion, based on the description of observed damages. Intensity data is still used as an important supplement to the instrumental recordings, not the least because it allows for the use of historical observations.

2 Technical Approach

2.1 Design codes and construction details

The U.S. Army Corps of Engineers have issued a manual under Engineering and Design (U.S. Army Corps of Engineers, 1999) in which several general guidelines are included. While their approach is generally deterministic it contains key concepts that are applicable also to the present study. The seismic assessment has several key steps:

- Establishment of earthquake design criteria. In the present case this means that the definitions of Maximum Design Earthquake (MDE) and Operating Basis Earthquake (OBE) are commonly understood.
- Development of ground motion corresponding to the MDE and OBE levels.

- Establishment of analysis procedures, i.e. procedures applied to reveal how the structure responds to the specified seismic load.
- Development of structural models.
- Prediction of earthquake response of the structure.
- Interpretation and evaluation of the results.

For the present study we will exclusively focus on the second bullet point above, except that we refrain from using the terms MDE or OBE in the following, since these terms are relevant in particular for sensitive structures. The background is however a clear understanding of the MDE and OBE definitions:

- The Operating Basis Earthquake (OBE) is an earthquake or equivalent ground motion that can reasonably be expected to occur within the service life of the project, that is, with a 50% probability of exceedance during the service life. The associated performance requirement is that the project functions with little or no damage, and without interruption of function.
- The Maximum Design Earthquake (MDE) is the maximum earthquake or equivalent level of ground motion for which the structure is designed or evaluated. The associated performance requirement is that the project performs without catastrophic failure although severe damage or loss may be tolerated.

While, in the following, ground motions for different annual exceedance probabilities are provided, it is the responsibility of any contractor to associate the safety levels in terms of MDE and OBE or in accordance with any other defined safety level, e.g., the national building regulations.

As already noted, Peak Ground Acceleration (PGA) is the most commonly-used measure of the ground motion in seismic hazard analyses for many purposes, and it is the simplest way to characterise the damage potentials of an earthquake.

This study is entirely based on a probabilistic computation in which the expected ground motions are evaluated for various levels of exceedance probability. Naturally, the various seismic provisions and guidelines reflect first of all the seismicity level of the study area, where the expectance for the future is based on the past experience. The most detailed seismic code provisions come from regions like Japan and the United States where strong earthquakes hit frequently in regions with complex infrastructure. In such countries the seismic awareness is very high due to the combination of past losses and economic strength that facilitates effective counter measures.

The seismicity of Pakistan is, as already noted, characterised by important historical and recent major earthquakes, with a steadily increasing vulnerability of its northern and south-western regions. Unfortunately, the seismic awareness of these regions is still low.

Seismic design codes have the purpose of providing building guidelines for the reduction of both property and life losses due to the seismic events. These building design codes define standards for the seismic resistant design and construction of new building and for the retrofit of the existing ones. Guidelines are developed based on sound theoretical and physical modelling and on the observed damages caused by major earthquakes. The lessons given by past earthquakes help to promote advances in the development of design methods, the knowledge of materials performance and the enhancement of construction practices.

Basically, a seismic code contains specifications for the seismic hazard, including soil and possible near-fault effects that should be used in seismic design of buildings in the considered region, which in turn is based on a base shear load that the building should resist. In Europe there has been a great effort in launching a set of so-called Eurocodes (EC) which contains complete guidelines for the construction industry including the seismic provisions (EC 8, 2004). Eurocode 8 defines two goals of the anti-seismic design:

- The structure shall be designed to withstand the design seismic action without local or general collapse.
- The structure shall be designed and constructed to withstand a seismic action (seismic load) having a higher probability of occurrence than the design seismic action.

Modern codes, notably the 1997 Uniform Building Code (ICBO, 1997) and the EC-8, 2004, are based on the specification of a base shear that depends on the seismic hazard level of the site, site effects coming from the site geology, near fault effects, weight, fundamental period, lateral forces, and the resisting system of the building. In areas of high seismicity, sufficient ductile detailing to accommodate the inelastic demand (Bachman and Bonneville, 2000) is needed.

The objective of this study is to provide the seismic actions at various annual exceedance probability levels. The building constructors/designers must choose an appropriate risk level/exceedance probability level for the structure for which the design ground motion is associated.

The selection of the appropriate risk level is essentially a question of the consequences of a failure. The risk level is most often specified either as annual exceedance probability or as exceedance probability during the expected lifetime of the structure. The discussion of risk levels is supported through the following connection between return period T_R and lifetime T, where P is annual probability of exceedance (see also Fig. 2.1):

$$T_R = \frac{-T}{\ln(1 - P(Z > z))}$$

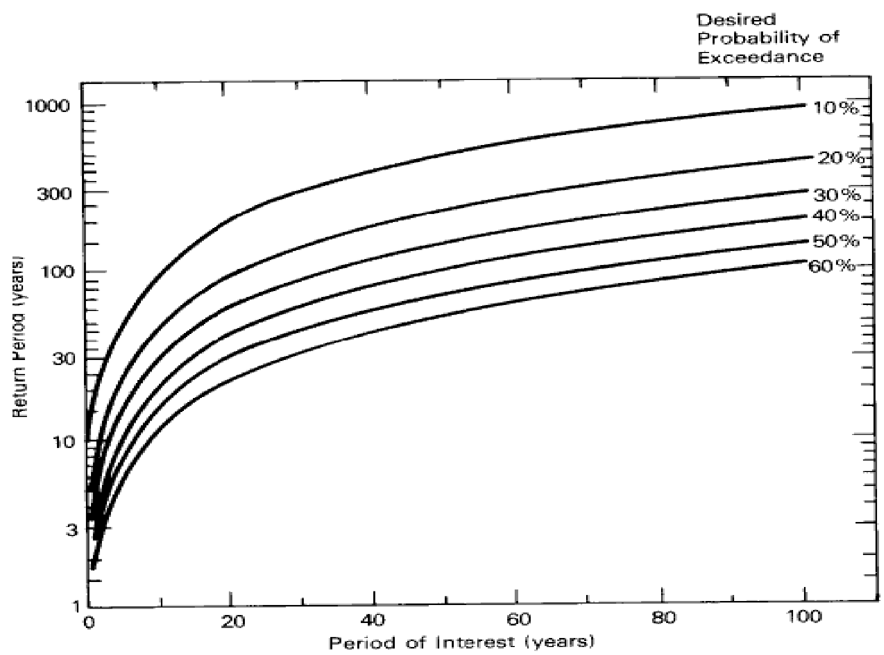


Figure 2.1. Relationship between return periods (inverse of annual exceedance probability), period of interest and desired probability of exceedance during the period of interest (according to Reiter, 1990).

If, for example, the expected lifetime of a structure is T = 200 years, and a 95% non-exceedance probability (5% exceedance probability, P = 0.05) is required, then this safety requirement corresponds to a return period of T_R = 3900 years, or an equivalent $3x10^{-4}$ annual exceedance probability. The curves for various lifetime structures and the corresponding return periods are shown in Fig. 2.1.

2.2 Methodology of probabilistic seismic hazard analysis

It is well known that uncertainties are essential in the definition of all elements that go into seismic hazard analysis, in particular since the uncertainties often drive the results, and increasingly so for low-exceedance probabilities. As might be anticipated this can sometimes lead to difficult choices for decision makers. Rational solutions to dilemmas posed by uncertainty can be based on the utilization of some form of probabilistic seismic hazard analysis. In contrast to the typical deterministic analysis, which (in its simplest form) makes use of discrete single-valued events or models to arrive at the required description of earthquakes hazard, the probabilistic analysis allows the use of multi-valued or continuous model parameters. Of most importance, the probability of different magnitude or intensity earthquakes occurring is included in the analysis. Another advantage of probabilistic seismic hazard analysis is that it results in an estimate of the likelihood of earthquake ground motions or other damage measures occurring at the location of interest. This allows for a more sophisticated incorporation of seismic hazard into seismic risk estimates; probabilistic seismic hazard estimates can be expanded to define seismic risk.

The methodology used in most probabilistic seismic hazard analysis (PSHA) was first defined by Cornell (1968). There are four basic steps for assessment of PSHA:

Step 1 is the definition of earthquake sources. Sources may range from small faults to large seismotectonic provinces with uniform seismicity.

Step 2 is the definition of seismicity recurrence characteristic for the sources, where each source is described by an earthquake probability distribution, or recurrence relationship. A recurrence relationship indicates the chance of an earthquake of a given size to occur anywhere inside the source during a specified period of time. A maximum or upper bound earthquake is chosen for each source, which represents the maximum event to be considered. Because these earthquakes are assumed to occur anywhere within the earthquake source, distances from all possible location within that source to the site must be considered.

Step 3 is the estimation of the earthquake effects which is similar to the deterministic procedure except that in the probabilistic analysis, the range of earthquake sizes considered requires a family of earthquake attenuation or ground motion curves, each relating to a ground motion parameter, such as peak acceleration, to distance for an earthquake of a given size.

Step 4 is the determination of the hazard at the site, which is substantially dissimilar from the procedure used in arriving at the deterministic hazard. In this case the effects of all the earthquakes of different sizes occurring at different locations in different earthquake sources at different probabilities of occurrence are integrated into one curve that shows the probability of exceeding different levels of ground motion level (such as peak acceleration) at the site during a specified period of time. With some assumptions this can be written as:

$$E(Z) = \sum_{i=1}^{N} \alpha_i \int_{m_o}^{m_a} \int_{r=0} f_i(m) f_r(r) P(Z > z \mid m, r) dr dm$$

where E(Z) is the expected number of exceedances of ground motion level z during a specified time period t, α_i is the mean rate of occurrence of earthquakes between lower and upper bound magnitudes (m_o and m_u), f_i (m) is the probability density distribution of magnitude within the source I, $f_i(r)$ is the probability density distribution of epicentral distance between the various locations within source I and the site for which the hazard is being estimated, and P(Z>z | m,r) is the probability that a given earthquake of magnitude m and epicentral distance r will exceed ground motion level z.

It is usually assumed when carrying out the probabilistic seismic hazard analysis that earthquakes are Poisson-distributed and therefore have no memory; implying that each earthquake occurs independently of any other earthquake.

One of the most important of the recent developments within PSHA has been in seismic source modelling. Originally, seismic sources were crudely represented as line sources (Cornell, 1968) and later area zones, which could be narrowed to represent the surface outcrop of faults as in McGuire's (1976) computer program EQRISK. An improved scheme, which included the effects of fault rupture, was proposed by Der Kiureghian and Ang (1977), and in a modified form implemented by McGuire (1978) in his fault modelling program FRISK, written as a supplement to his earlier and very popular EQRISK area source program.

While the standard practice for a long time was to present the results of seismic hazard analyses in terms of a single best-estimate hazard curve, the growing awareness of the importance of parametric variability and the trend to consult expert opinion in matters of scientific doubt, led later to the formulation of Bayesian models of hazard analysis (Mortgat and Shah, 1979) which seek to quantify uncertainty in parameter assignment in probabilistic terms.

In the present work we have applied the CRISIS computer code for seismic hazard assessment (Ordaz *et al.*, 2003). The code accommodates uncertainty in a number of the seismicity model parameters, and has a user-friendly interface. It accepts polygon-dipping areas as well as fault sources, and also facilitates characteristic earthquake recurrence models.

2.3 Probabilistic seismic hazard analysis

2.3.1 Theoretical framework

The model for the occurrence of ground motions at a specific site in excess of a specified level is assumed to be that of a Poisson process. This follows if the occurrence of earthquakes is a Poisson process, and if the probability that any one event will produce site ground motions in excess of a specified level is independent of the occurrence of other events. The probability that a ground motion level is exceeded at a site in unit time is thus expressed as:

$$P(Z > z) = 1 - e^{-\nu(z)}$$

where $\nu(z)$ is the mean number of events per unit time in which Z exceeds z. According to the convention (McGuire, 1976) in probabilistic hazard analysis, the region around a site is partitioned into polygons, which constitute a set of area sources. Basic differences in seismicity and geology may exist between the zones; however, it is assumed that the seismicity within each zone is sufficiently homogeneous to be treated uniformly in the computations. This assumption applies even where non-seismological criteria have been used in the zone definition, e.g., geological structures. With N seismic sources, and seismicity model parameters S_n for each source n, the mean number of events pr. unit time in which ground motion level z is exceeded can be written as:

$$\nu(z) = \sum_{n=1}^{N} \nu_n(z \mid S_n)$$

where

$$v_n(z \mid S_n) = \sum_{i,j} \lambda_n(M_i \mid S_n) \cdot P_n(r_j \mid M_i S_n) \cdot G_n(z \mid r_j M_i S_n)$$

and where $\lambda_n(M_i \mid S_n)$ is the mean number of events per unit time of magnitude M_i ($M_i \in [M_{\min}, M_{\max}]$) in the source n with seismicity parameters S_n. Moreover, $P_n(z \mid M_i S_n)$ is the probability that a significant site–source distance is r_j, ($r_j \in (r_{\min}, r_{\max})$) given an event of magnitude M_i at distance r_j in source n with seismicity parameters S_n. The expression $G_n(z \mid r_j M_i S_n)$ is the probability that the ground motion level z will be exceeded, given an event of magnitude Mi at distance r_j in source n with seismicity parameters S_n. The three functions $\lambda_n(M_i \mid S_n)$, $P_n(z \mid M_i S_n)$ and $G_n(z \mid r_j M_i S_n)$ model the inherent stochastic uncertainty in the frequency of occurrence and location of earthquakes, and in the attenuation of seismic waves.

Given that the mean number of events per unit time for which Z exceeds z is expressed for example as $1/T_R$, where T_R is the return period (inverse of annual exceedance probability), then the number of events in a time period T (e.g. the life time of a certain construction) for which Z exceeds z is given by T/T_R and the probability for Z exceeding z during that life time T is given by:

$$P(Z > z) = 1 - e^{-T/T_N}$$

For a life time T of 50 years and a return period T_R of 475 years (annual probability of exceedance $0.211 \text{x} 10^{-2}$) the probability for Z exceeding z becomes 0.1, corresponding to 90% probability that this size ground motion is not exceeded in 50 years. This is also illustrated in Fig. 2.1.

With several seismic sources, described through particular model parameters, the mean number of events per unit time in which the ground motion level z is exceeded can be expressed specifically, involving functions that model the inherent stochastic uncertainty in the frequency and location of earthquakes, and in the attenuation of the seismic waves.

2.3.2 The earthquake recurrence model

The recurrence rate of earthquakes is assumed to follow the cumulative Gutenberg-Richter relation:

$$\log N(M) = a - bM$$

where N(M) is the number of events per year with magnitude greater or equal than M. This relation appears with few exceptions to hold quite well, indicating a self-similarity of earthquakes.

In seismic hazard analyses a modified and truncated version of this relation is used, involving an engineering threshold magnitude M_{lim}, a limiting upper bound magnitude M_{max} for the source, a slope parameter $\beta = b \times \ln(10)$ that describes the relation between the number of smaller and larger earthquakes, and an activity rate parameter $A=a(M_{lim})$ which describes the number of events on the source with magnitude equal to or greater than M_{lim}. See Fig. 2.2 for two recurrence models.

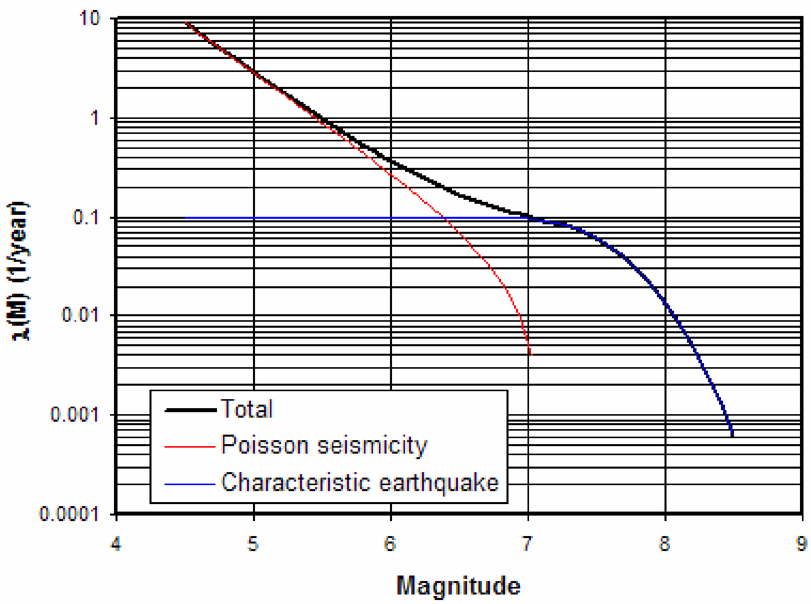


Figure 2.2. Earthquake recurrence functions. The red line indicates the truncated cumulative Gutenberg-Richter relation, while the blue line indicates the truncated characteristic recurrence model used in CRISIS (Ordaz *et al.*, 2003).

The activity rate parameter is liable to vary substantially from one seismic source to another while the b-value is expected to be regionally stable, with variations less than the uncertainty limits. Faults, which may be separately included as seismic sources in addition to area sources, are usually attributed their own b-values, which need to bear no immediate relation to the values obtained from the regional recurrence statistics (Youngs and Coppersmith (1985).

2.3.3 Strong-motion (attenuation) models

There is evidence that the decay rate of ground motions is dependent on the magnitude of the causative earthquake (e.g. Douglas, 2003), and the decay rate also changes systematically with distance. Fourier spectra and response spectra moreover decay differently. Geometrical spreading is dependent on wave type, where in general body waves spread spherically and surface waves cylindrically, while anelastic attenuation is wavelength (frequency) dependent. As hypocentral distance increases, the upgoing ray impinges at a shallower angle on the interfaces, reflecting increasing amount of energy downwards, thereby reducing the energy transmitted to the surface. For moderate and large earthquakes the source can no longer be considered a point source and therefore the size of the fault will mean the decay rate will be less than for smaller events, which is essentially why, for large events, the distance to the causative fault (Joyner-Boore distance) usually is used instead of epicentral or hypocentral distance.

Assuming the occurrence of an event of magnitude Mi at a site-source distance of Rj, the probability of exceedance of ground motion level Z needs to be defined. From studies of strong-motion records, a lognormal distribution is found to be generally consistent with the data, where the mean often have a simple form such as:

$$\ln Z = c1 + c2 \cdot M_i + c3 \cdot \ln R_j + c4 \cdot R_j$$

where Z is the ground motion variable and c1 to c4 are empirically determined constants where c2 reflects magnitude scaling (often in itself magnitude dependent), c3 reflects geometrical spreading and c4 reflects inelastic attenuation. Also found from the recorded data is an estimate of the distribution variance.

One of the most important sources of uncertainty in PSHA is the variability or scatter in the ground motion (attenuation) models, which is an aleatory uncertainty usually expressed through a sigma (σ) value which is often of the order of 0.3 in natural logarithms, corresponding to about 0.7 in base 10 units. This uncertainty, which usually also is both magnitude and frequency dependent, is mostly expressing a basic randomness in nature and therefore cannot be significantly reduced with more data or knowledge. In PSHA we integrate over this uncertainty which thereby is directly influencing (driving) the seismic hazard results.

2.4 Implementation

The earthquake criteria development performed for this study is, as explained in more detail above, based on probabilistic seismic hazard analysis techniques designed to incorporate uncertainties and to quantify the uncertainties in the final hazard characterizations (confidence limits).

The procedure for identifying potential seismic sources in the project region comprises:

- An evaluation of the tectonic history of the region in light of available geological data and information.
- An evaluation of the historical and recent instrumental seismicity data in relation to the project region, emphasizing that these data are the primary empirical basis for conducting seismic hazard analyses.

The present study is building on knowledge and experience within the field of earthquake criteria development for numerous sites in different tectonic environments, thereby ensuring results which are comparable on a larger scale.

2.4.1 Geology

The general approach to this side of the seismic criteria development is to review relevant and available geological information in order to locate and characterize active and potentially active geological structures, i.e. faults and/or segments of faults which may represent a potential seismic source that could influence the seismic hazard at the site. It should be noted however, that the presence of a large fault is not always regarded as a potential earthquake source, since faults are considered potentially active only if they have ruptured fairly recently (which on a geological time scale could be as much as 10,000 years).

2.4.2 Seismology

A seismic hazard analysis should be based on both the geological and seismological history of the region, including recent and historical seismicity, supplemented with paleo-seismological information if available (Kumar et al., 2006). The information called for here includes generally, besides the usual earthquake catalogue, also information which can improve the understanding of the geodynamics of the region, such as earthquake rupture processes, mode of faulting, stress field, source mechanism, etc.

2.4.3 Seismotectonic interpretation

The geological and seismological information is used to define models for the potential earthquake sources that could influence the hazard at the site. The main aspects of the source characterization are: (1) modelling of area sources based on the geologic history of the region in general and on earthquake occurrence statistics (historical and contemporary seismicity catalogues) in particular, and (2) modelling of fault-specific sources with three-dimensional geometry, if such detailed information is available. Note that fault modelling is rarely included in regional hazard studies as the present.

The characterization of each seismic source will be as comprehensive as the data allows and will specifically incorporate the uncertainties in each source characteristic. Maximum earthquake magnitudes are assessed using a combination of physical methods, historical seismicity and empirical evidence from geologically similar regions.

2.4.4 Ground motion (attenuation) models

The present earthquake hazard study requires the availability of earthquake ground motion models for peak ground acceleration and spectral acceleration, for the frequency range of engineering interest. Available models include near field excitation as well as the attenuation with distance, and the scaling with magnitude here is essentially developed for estimating the effects of an earthquake which is not yet been observed in the region considered.

Strong-motion attenuation relationships are important in any seismic hazard model along with seismic source characterization, and it is noteworthy here that the uncertainties in attenuation often are among those which contribute the most to the final results. This is true for any area, and in particular for the Himalaya region, where very few strong-motion observations exist in spite of a high seismicity level.

2.4.5 Computational model

The actual seismic hazard computations for a specific site are based on integrated probabilistic contribution to the ground motion by the fault-specific and area sources modified by the seismic wave attenuation. The uncertainties of some of the input parameters are carried through the computation.

2.4.6 Hazard results and design criteria

The relationship between a range of ground motion levels and the associated annual exceedance probability (hazard curve) is established through median values for each frequency.

An essential element of the present earthquake hazard methodology is that seismic loading criteria may be evaluated in terms of equal-probability (equal hazard) spectra. This means that each frequency is evaluated independently, with its own uncertainty estimate.

The seismic loading criteria are specifically developed for bedrock outcrop (site with no soil). Design response spectra for the required annual exceedance probabilities may then be developed based on the PGA values, and in certain cases accompanied with sets of real time histories (earthquake recordings), appropriately scaled to match the spectra. The latter is done only when specific advanced design analysis is conducted.

3 Geologic Setting

Plate tectonics has been very successful in providing a rational framework to explain large scale geological and tectonic features, both on the boundaries between but also within the tectonic plates. Seismicity and fault plane solutions clearly outline the fault zones and relative motion of the tectonic plates, and new GPS measurements have opened for significant new insights into the dynamics of plate motions. Plate tectonics theory also successfully explains the Himalayan mountain ranges as a result of the collision of the Indian plate with the Eurasian plate, as shown in Fig. 3.1.

The Indian subcontinent has been colliding with the Eurasian subcontinent over the last 30-40 million years (Aitchinson *et al.,* 2007). During this period, continental lithosphere longer than 2000 km has been shortened into the massive mountain ranges and elevated plateaus of central Asia (e.g., Molnar and Topponier, 1975; Bollinger et al., 2004). The earthquake activity as shown in an overview map in Fig. 3.2 clearly demonstrates how the earthquakes concentrate along the plate margins. Even when the details about the map (time period, sources, magnitude type etc.) are not available it shows clearly the regional earthquake distribution.

Even though the Himalayan region is huge and contains large parts that are remote and sparsely populated we still have some overview of the seismicity there for the last 500 years, even with indications of an earthquake deficit at present (e.g., Ambraseys and Bilham, 2003; Bilham and Ambraseys, 2005; Feldl and Bilham, 2006).

As a result of the continent-to-continent collision in the Himalayas, the highest mountains in the world have been created (Fig. 3.1), still being uplifted more rapidly than any other mountain chain.

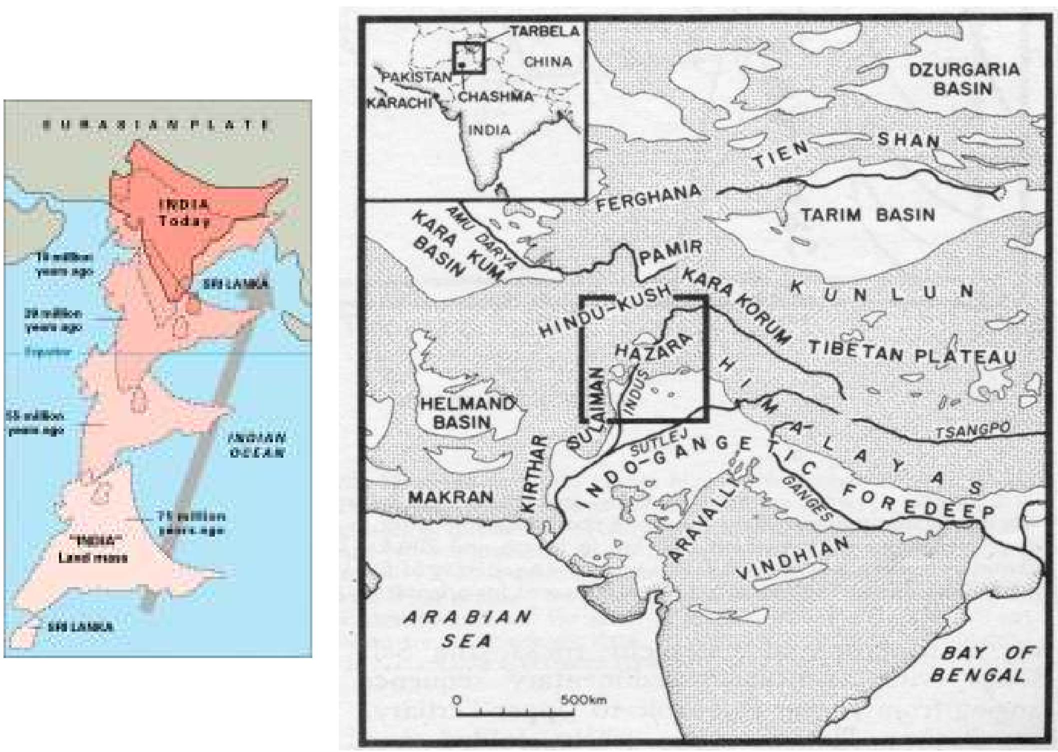


Figure 3.1. The Indian plate colliding with the Eurasian plate.

Some of the greater mountain structures resulting from the collision can be summarized as follows:

- The Himalayas have been formed in the central part.
- The Arakan-Yoma Mountains of Burma.
- The Naga Hills of Assam towards the east.

- To the west, the Baluchistan arc manifested by the Kirther and Sulaiman ranges delineate the continent-continent collision zone.
- The rising mountain ranges of the Tien-Shan Mountains in central Asia.
- The Karakoram Mountains in Pakistan.
- The Hindu Kush Mountains formed at the junction of the Baluchistan arc.
- The Karakorum Mountains and the Pamir ranges (Desio, 1965).

Fig 3.2 shows the regional seismicity and the fault in the Arabian Sea which has generated earthquakes including the 1945 earthquake which generated a tsunami.

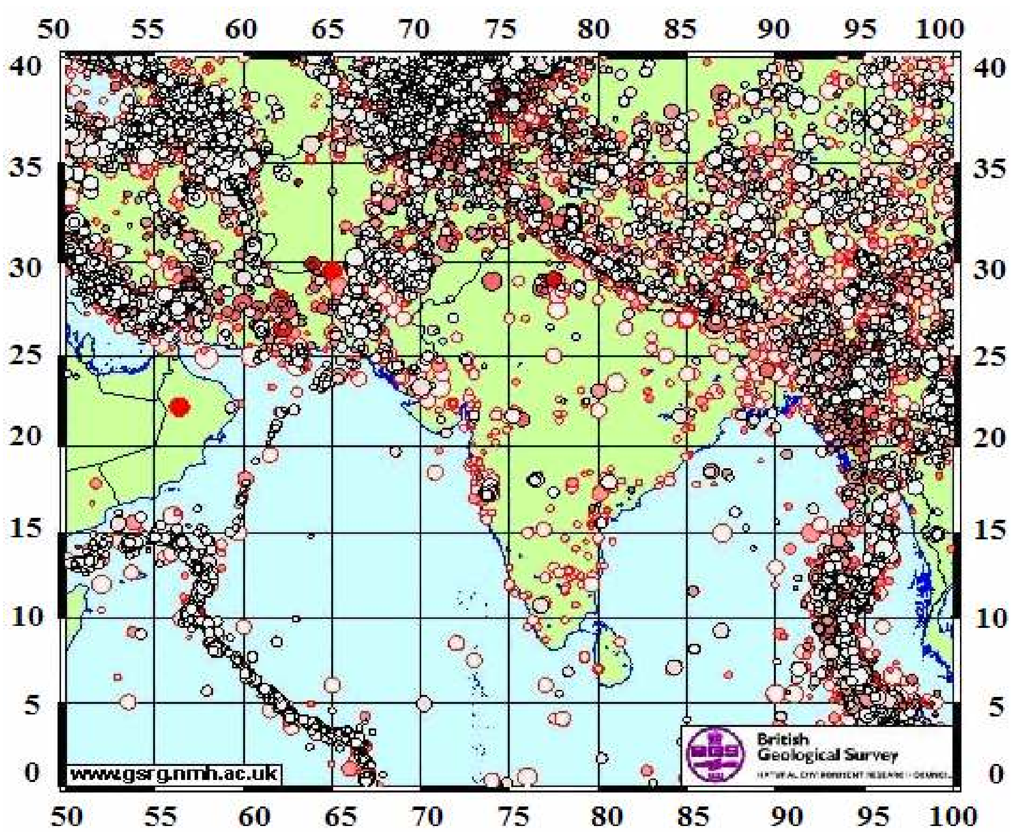


Figure 3.2. The regional seismicity of Southern Asia (above magnitude 3.0) according to the British Geological Survey (BGS).

According to the Figs. 3.1 and 3.3 the mountains, notably HinduKush, Pamir and Karakurom, are characterized by deep and concentrated seismicity through which significant seismic energy is released every year. Seismically, Hindu Kush and Pamir is one of the most active regions in the world (Nowroozi, 1971). The Himalayas and the Baluchistan Arc are the southernmost frontal parts of this collision zone which extends northward through Afghanistan and Tibet into China and Central Asia. Fig 3.3 shows how the Chaman fault meets with the Herat fault and in the Pamir region these structures bend eastward and split into the Karakoram and the Altayan Tagh fault systems. The under-thrusting of the Indian shield beneath the Himalayas and transverse ranges of the Balochistan arc was clearly recognized from fault plane solutions (Fig. 3.3). (Molnar *et al.*, 1973; Shirikovaa, 1974; Tandon and Shirokova, 1975). Left-lateral strike slip motion on the north-south striking Chaman fault has been postulated on the basis of geologic evidence (Wellman, 1966) and this is partly supported by the focal mechanism solution in Fig. 3.4.

The Sulaiman and the Kirthar ranges of Pakistan are aligned in a north-south direction forming the Balochistan Arc (Fig. 3.3). The NW-SE trending mountains of Kashmir, which form the western part of the Himalaya Arc, bend sharply to the south near Nanga Parbat (Meltzer et al., 2001) forming the western Himalayan syntaxis (often called the Hazara syntax). From there, the NE-SW trend of the Balochistan arc is generally maintained along the Sulaiman-Kirther ranges for about 1000 km, before taking another sharp bend towards the west, after which a general east-west trend is maintained along the Makran ranges and the mountains of Southern Iran. The Makran ranges of Iran and Pakistan have been described as an active arc system by Farhoudi and Karig (1977).

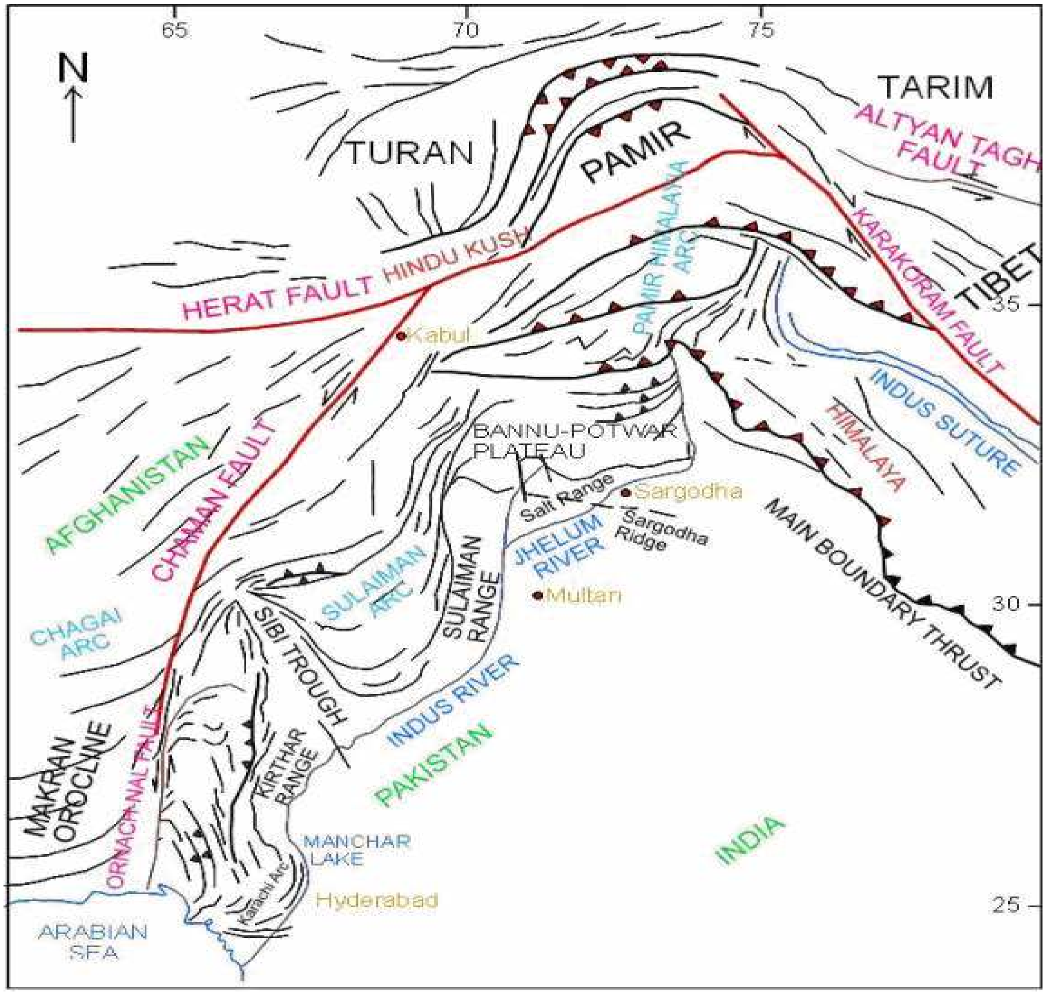


Figure 3.3. Major tectonics in Pakistan (courtesy: Geological Survey of Pakistan).

The structure of the Baluchistan arc, like the Himalaya arc, is dominated by tight folds and over thrusts, mainly from the north-west and west toward the Indian plate with axes directed essentially in a north-south direction, parallel to the general trend of the arc (William, 1976).

At the southern end of the Sulaiman ranges, the mountains swing sharply towards the west, maintain an east-west trend for nearly 300 km, and then take a second sharp bend to the south near the city of Quetta surrounding the Sibi trough (Figs. 3.2 and 3.4). The north-south trend continues along the Kirthur mountains (West, 1936). The Sulaiman and Kirthur mountains ranges are similar in geology, stratigraphy, and structure.

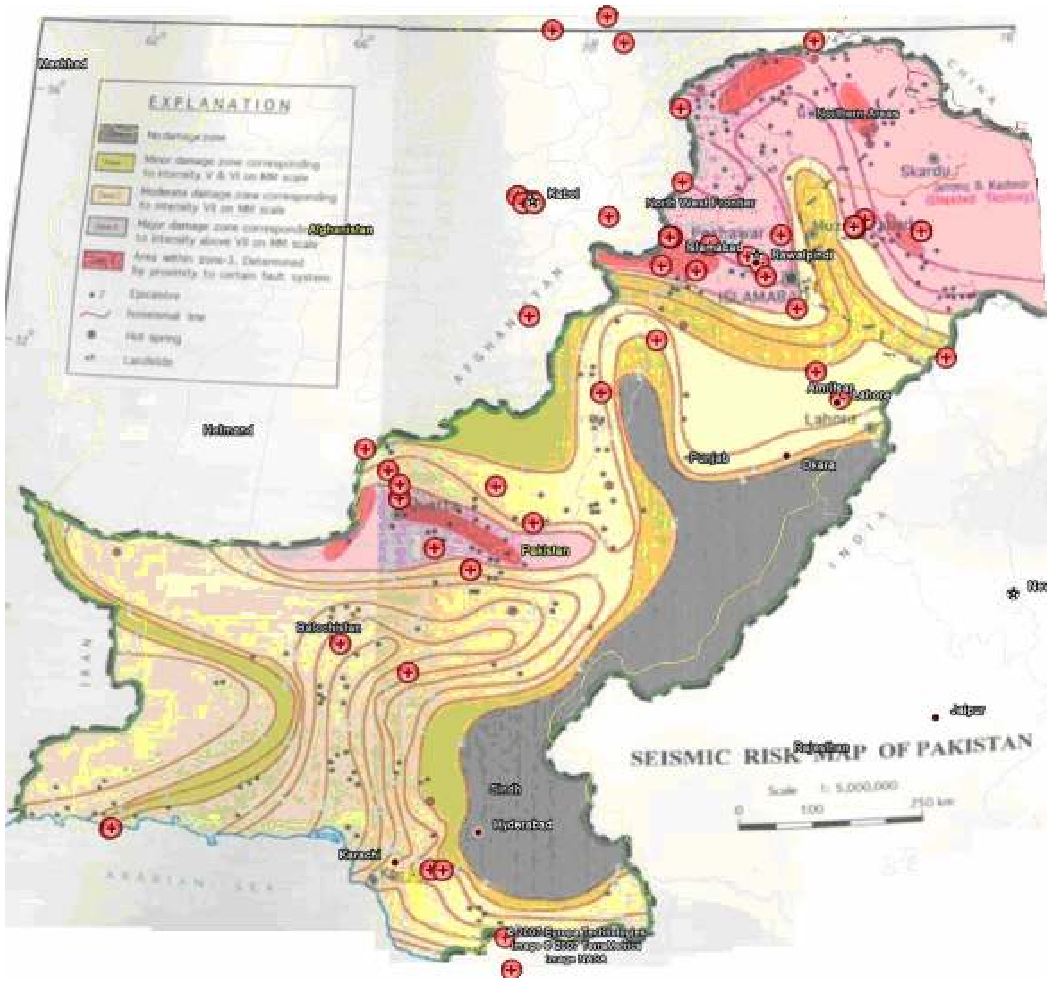


Figure 3.4. Seismic risk map (prepared by Geological Survey of Pakistan) overlaid with historical seismicity.

The structure of the area consists of a complex pattern of folds and thrusts with axes changing from east-west to north-south. The Chaman fault (Fig. 3.3) is a seismically moderately active fault. It starts from Hirat, Afghanistan, in the west and moves to east and causes the seismic activities in Pakistani area. It by-passes the angular configuration of the Quetta and Sulaiman ranges. It connects the Kirther range from west of Quetta. The Chaman fault zone represents the western boundary of the wide deformation zone. While the northern part traverses Afghanistan the central part goes into Pakistan northwest of Quetta before it continues southwards towards the Arabian Sea.

3.1 Seismotectonics of Pakistan

For the study of earthquake hazard in Pakistan, the country was divided into nineteen zones (see Fig. 5.1 later in this report), including some portions of the neighbouring countries of Afghanistan, Tajikistan, Iran and India. The division of the region into these source zones is based on the seismicity, the fault systems and the stress direction analysis. Pakistan is located on the north-west region of the Indian plate that pushes into the Eurasian plate. The direction of horizontal compression has been mapped from the focal mechanism and is shown in Section 5 (Fig. 5.6).

The Hindu Kush region generates regularly very large earthquakes, occurring down to 300 km depth, which are also felt in Pakistan. The compressive stress direction of this region is NNW-SSE, albeit with a somewhat bimodal nature as seen in Fig. 5.6. The direction of crustal stress in Kashmir is NE-SW, perpendicular to the line of plate collision and MBT. In the Hindu Kush region the earthquake mechanism is generally thrust faulting occasionally normal faulting whereas in Kashmir, the earthquakes mainly show thrust fault mechanism with a clear NE-SW compression. Both the Karakoram and Hindu Kush ranges are caused by the collision of the Indian plate into the Eurasian plate the Indian plate collides and under plates the Eurasian plate. The Hindu Kush and the Pamir constitutes one of the most seismically active earthquake zones in the world.

In the Kashmir region we find the important Hazara-Kashmir Syntax (HKS), which was formed due to the change in the Himalayan thrust interface direction from NE in Kashmir to NW along the Indus. The Punjal thrust and the Main Boundary Thrust (MBT) are folded around this syntax and are subject to a 90^o “rotation” from one side to the other. The Panjal thrust, MBT and Muzaffarabad thrust are truncated by the active Jhelum fault (Baig and Lawrence, 1987). Beside other faults in this region, the Jhelum fault acts as an active left lateral oblique reverse fault. The general seismicity pattern of the Jhelum-Ambore zone is low activity of regular earthquakes with magnitudes ≤ 4.0. The historical and instrumental seismic data from this region show no earthquake with a size exceeding magnitude 6.8.

In the western Himalayas (Gilgit Agency), the seismic activity is associated with earthquakes of magnitude 5 and larger, and largely coincides with the surface trace of the Himalayan Main Central Thrust (MCT) rather than with the Himalayan Main Boundary Thrust (MBT) which represents the structural boundary. Many of the earthquakes that occur on the MBT take place at depths of 20 to 40 km and are associated with a shallow northward dipping subsurface extension of the MBT underlying the MCT (the under plating of the Eurasian plate). One section of the eastern Himalaya front thrust was relatively quite during the last decades. This is the source zone of the Kangra earthquake (Ms 8.0) which occurred in 1905 and which extended from Kangra to Dehra Dun, i.e. 76^o E to 78^o E (Middlemiss, 1910).

The second section of presently low seismic activity is near the eastern flanks of the Kashmir syntaxial bend (Fig. 3.2). Note that the north western end of the zone of low activity in Kashmir stops against a zone of high activity which is the area of the destructive Pattan earthquake of December 28, 1974 (M=6.0) and the 8th October, 2005 Muzaffarabad earthquake (Mw 7.6).

The seismicity in the Kirther range is relatively diffuse compared to that in the Suleiman range. In the latter, the seismicity falls on or near a well defined fault scarp which offsets the range against the eastward extending Indus basin. The northern two thirds of the faults have ruptured in the large Much earthquake of August 27, 1931 (West, 1934).

The most remarkable clustering of seismicity Fig. 3.2 occurs in the Quetta transverse range as far as 100 km south of its higher peaks and is located within or beneath the thick young tertiary sediments of the Indus basin.

4 Seismology of the Study Region

The seismicity of the region is directly related to the geo-tectonic processes; however, the quantitative monitoring of the seismicity only goes some 100 years back. With the long term processes in action the short seismicity monitoring time is a serious limitation, but a limitation which we have to accept.

4.1 Earthquake information

The main data bases for earthquake information in this study are:

- PMD, Pakistan Meteorological Department, historical database.
- PDE, United State Geological Survey, database.
- ISC, International Seismological Centre England, database.

- Harvard database.

4.1.1 The USGS historical database

The historical database of USGS was obtained from the Internet. The data in the spatial window was selected ranging from 20^o to 40^{o}N and 58^o to 83^{o}E. This data base comprised 143 events with assigned Ms magnitudes up to 8.6. The seismological events were in chronological order dating from year 765 to 1992. Each earthquake in the data base is detailed according to source, date, time, latitude, longitude, magnitude, intensity, and other seismic-related information.

4.1.2 The PMD historical database

The historical earthquake catalogue was compiled by Pakistan Meteorological Department (Table 4.1). The historical data base comprises of 58 earthquakes from year 25 to 1905. All earthquakes are provided with a short description and estimates of maximum intensity. Important extensions to the original database were made by including data from Quittmeyer and Jacob, (1979; see also Menke and Jacob, 1976). Fig. 4.4 shows these earthquakes.

The main scientific reason for using the two catalogues (PDE and PMD) simultaneously was the definitive compilation of earthquake information and readings. It is a common observation that the same earthquake may have slightly different hypocenters or magnitudes in two different catalogues or an earthquake may be listed in one catalogue and not in the other.

The USGS PDE instrumental database just like the historical database of USGS, the instrumental database of the same (NEIC-PDE) was also obtained from the Internet. The PDE catalogue contains the data from 1973 to February 2007. The data were extracted from the catalogue in the spatial window ranges from 20^o to 40^{o}N and 58^o to 83^{o}E. The portion of this catalogue which was studied consisted of some fourteen thousand earthquakes, having magnitude types such as Mb, ML, Mw, Ms.

4.1.3 The ISC instrumental database

Each earthquake in the data base is detailed according to source, date, time, latitude, longitude, magnitude, and seismic-related information. It is a large database and in a typical mode, the ISC (http://www.isc.ac.uk) receives more than 200,000 recordings from world wide stations. The analysis of these digital records leads to the identification of an average of 10,000 seismic events per month. Out of these almost 4,000 require manual review.

About thirty thousand (29,970) seismic events from the ISC database were analyzed during this study. The region from which these events were extracted from the database was the same as in the previous cases. The data cover the period from 1900 through 2006. These earthquakes from ISC were plotted using the Google Earth software and the map so formed is shown in Fig. 4.1.

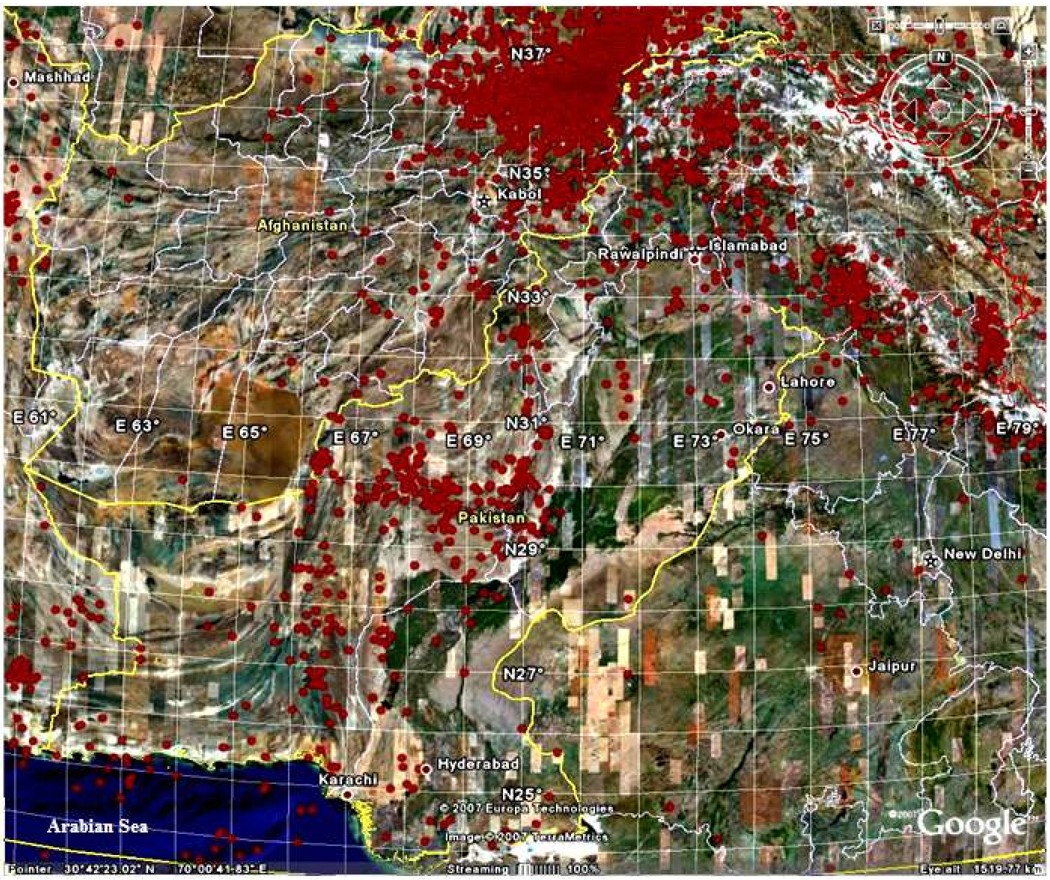


Figure 4.1. Earthquake epicentres shown in red circles (from the ISC-catalogue).

4.1.4 The Harvard instrumental database

The reason for selecting the Harvard catalogue as one of our study tools is that it contains three consistent magnitude types (Mb, Ms and Mw) for each of the events in addition to the standard location (coordinates), depth, time, half duration, moment tensor, scalar moment, and mode of faulting (strike, dip and slip). Altogether 550 seismic events, January 1977 to September 2006, with magnitude equal or greater than 5.0 were analyzed and plotted on the map Fig. 4.2. Due to their magnitude these events are all significant, showing that large parts of Pakistan are quite vulnerable to earthquakes, especially the northern and south-western regions.

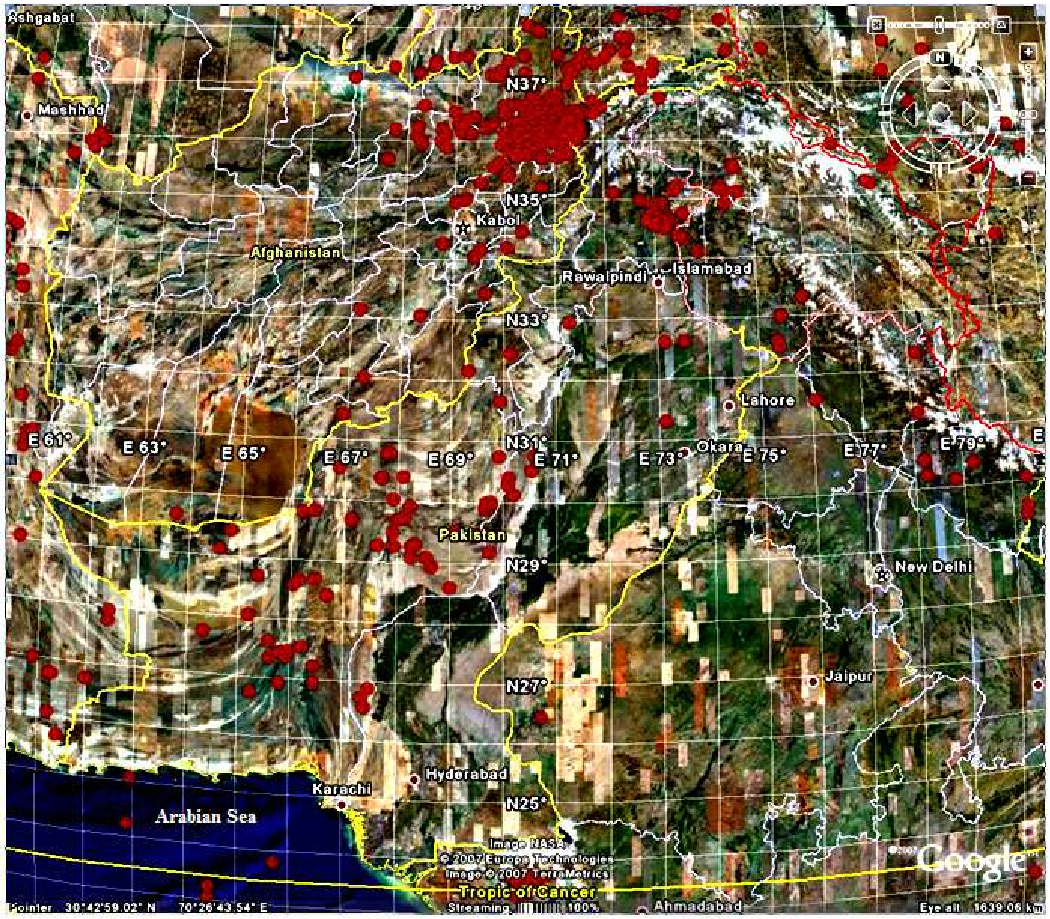


Figure 4.2.Earthquakes with magnitudes M ≥ 5.0 (red circles) according to the Harvard catalogue.

4.1.5 The PMD instrumental database

The PMD data base is comprised of historical and instrumentally recorded earthquakes. Only body wave magnitude Mb is assigned to the recorded earthquakes. The PMD seismic recording network is operational since 1954 but this catalogue contains events since 1905 and previous records were taken from International Seismological Centre. In the 1960’s World Wide Standardized Seismic Network (WWSSN) stations were installed at Peshawar, Islamabad and Quetta. Due to this network PMD recorded teleseismic earthquakes and distant earthquakes records are available in PMD data base.

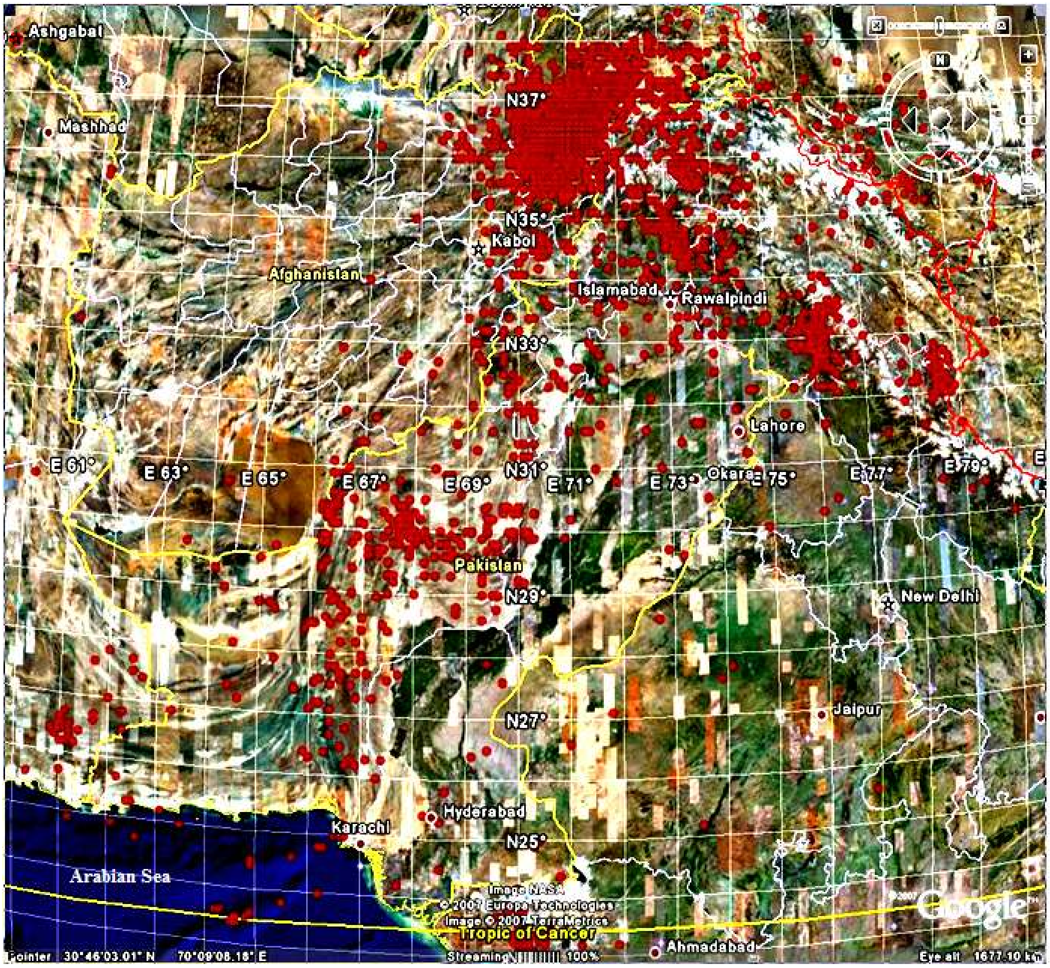


Figure 4.3. Seismicity of the study region according to the PMD-catalogue.

4.1.6 The PDE-NEIC database

PDE catalogue is considered to be the most reliable data base regarding the completeness since 1973. It contains all information for location, date, origin time magnitude of the earthquakes. The data file selected from the PDE data base for the study region contain near fourteen thousand events.

4.2 Seismic zonation

For the study of hazard assessment of Pakistan the study region was divided into 19 seismic zones and this division was based on the seismicity, geology, source mechanism and the stress direction of the region. The region 5, 6 and 7 were further subdivided with respect to depths as these zones have the seismicity for different depths. These zones were analysed at depths 75 km and 210 km as these contributes to the seismic hazard values. The seismicity at all depths is shown in the Fig 4.4. There is clustering of earthquakes in the northwest (Hindukush), northeast (zone 1) and at southwest (Quetta region) of Pakistan, these are the main contributor of seismic hazard.

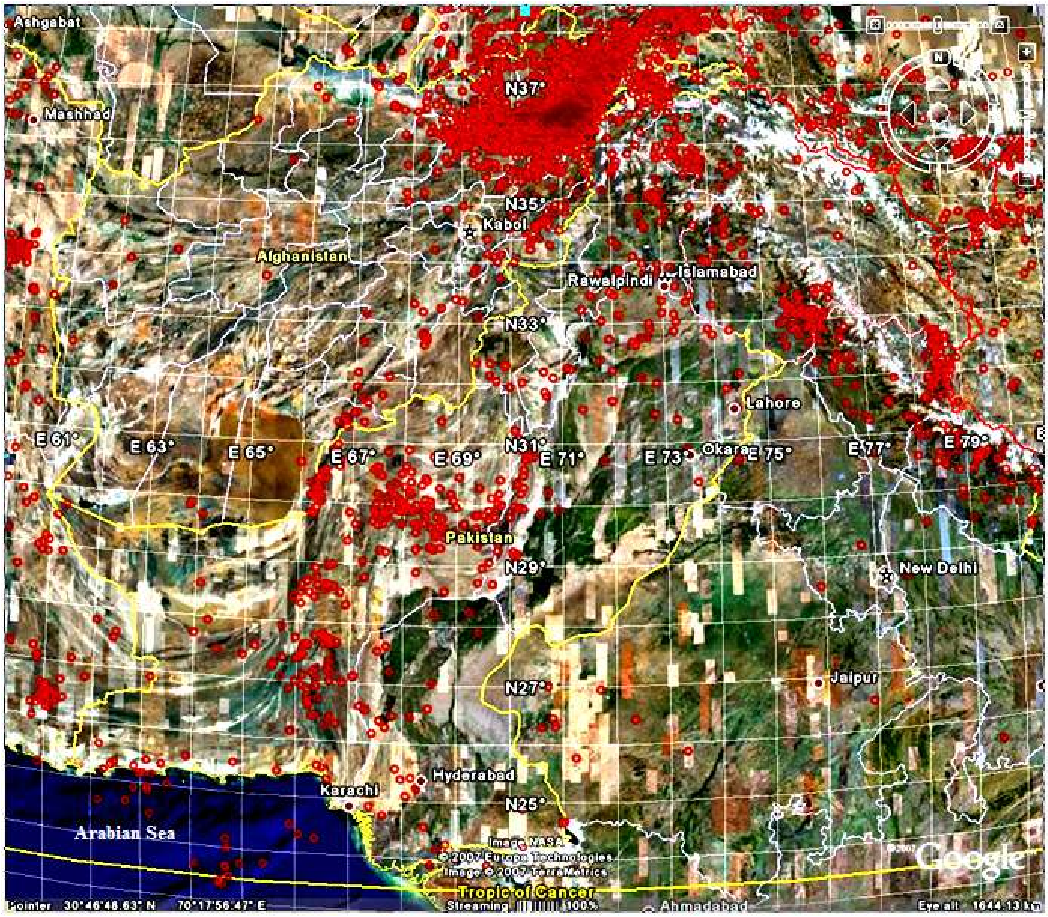


Figure 4.4. Seismicity of the study region according to the PDE-catalogue.

4.2.1 The historical earthquakes

The historical earthquakes from Pakistan are listed in Table 4.1 and shown in Fig. 4.5. Many of these earthquakes have not been closely assessed in terms of magnitude; however, the assigned intensity provides important indirect information on the strength of the earthquake.

The main features that immediately can be extracted from the historical record:

- A concentration of earthquakes in the northern belt from Islamabad/Rawalpindi to Peshawar.

- A concentration of earthquakes in the region around Quetta
- Four earthquakes in the Karachi-Ahmadabad region.
- Regions of low or no historical activity are:
    - South-western Pakistan i.e. Makran, Chagai hills (sparse population)
    - Toba-Kakar Range north of Quetta
    - Punjab

Figure 4.5. The historical earthquakes from the PMD-catalogue before 1905.

Table 4.1. Historical earthquakes as collected by Pakistan Meteorological Department.

Date	Lat (N)	Lon (E)	Intensity	Remarks
25 A.D	33.7	72.9	X	TAXILA EARTTHQUAKE The main centre of Budhist Civilization at that time was turned into ruins. Epicentre of the earthquake was around 33.7 N and 72.9E. Maximum documented Intensity was X.
50 A.D	37.1	69.5	VIII-IX	AIKHANUM EARHQUAKE Epicentre of the earthquake was around 37.1 N, and 69.5E. Maximum documented Intensity was VIII-IX . Caused extensive damage in Afghanistan, Tajikistan and N.W.F.P and was felt upto N.India.
893-894AD	24.8	67.8	VIII-X	DABUL EARTHQUAKE Epicenter of the earthquake was around 24.8 N, and 67.8E. Maximum documented Intensity was VIII-X. An Indian ancient city on the coast of Indian ocean was completely turned into ruins. 1,80,000 people perished.
1052-1053	32.85	69.13	VII-IX	URGUN; Quittmeyer and Jacob, 1979
June 1504	34.5	69.0	VI-VII	QUITTMEYER AND JACOB, 1979
6/7/1505	34.6	68.92	IX-X	PAGHMAN; QUITTMEYER AND JACOB, 1979
6/7/1505	34.6	68.9	VIII-IX	HINDUKUSHEARTHQUAKE Epicenter of the earthquake was around 34.6 N, and 68.9E. Maximum documented Intensity was VIII-IX. It was an immense Earthquake causing famine and extensive damage & loss of life in Afghanistan.
3/1/1519	34.8	71.8	VI-VII	JANDOLVALLEY EARTHQUAKE Jandol valley was severely rocked. Epicentre of the earthquake was around 34.3 N and 71.8E. Maximum documented Intensity wasVI-VII.
May 1668	24.8	67.6	VIII-IX	SAMAJI OR SAMAWANI Town of Samaji or Samawani sank into ground. 80,000 houses destroyed. Epicenter of the earthquake was around 24.8 N and 67.6E. Maximum documented Intensity was VIII-IX.
4/6/1669	33.4	73.2	VI-XI	MANDRA EARTHQUAKE Epicenter of the earthquake was around 33.4 N, and 73.3E. Maximum documented Intensity was VII.
22/6/1669	34	76	VI-VII	KASHMIR EARTHQUAKE.
23/6/1669	33.87	72.25	VIII-IX	ATTOCK EARTHQUAKE
1780	34	76	V-VII	KASHMIR EARTHQUAKE
16/6/1819	23.3	68.9	IX-X	RUNN OF CUTCH It reduced to ruins.2000 people died. Epicenter of the earthquake was around 23.3 N, and 68.9E. Maximum documented Intensity was IX-X.

Date	Lat (N)	Lon (E)	Intensity	Remarks
24/9/1827	31.6	74.4	VIII-IX	LAHORE EARTHQUAKE In this earthquake the fort kolitaran near Lahore was destroyed. About 1000 people perished. A hill shaken down into river Ravi.
6/6/1828	34.1	74.8	X	KASHMIR EARTHQUAKE In this earthquake 1000 people died and 1200 houses destroyed.
1831	31.75	70.35	VIII-IX	DARABAN; QUITTMEYER AND JACOB, 1979
1831	33.5	72.0	IV-VII	HINDUKUSH EARTHQUAKE It was severe earthquake felt from Peshawar to D.G Khan Maximum documented Intensity was VII at Peshawar VI at Srinagar and IV at D.G Khan.
22/01/1832	36.9	70.8	VIII-IX	HINDUKUSH EARTHQUAKE It was severe earthquake Which rocked Afghanistan, Northern and central parts of Pakistan and NW India. Maximum documented Intensity was VIII-IX at Kalifjan, Jurm, Kokcha Valley, and VI at Lahore.
21/2/1832	37.3	70.5	VIII-IX	HINDUKUSH EARTHQUAKE The epicenter of this earthquake was in Badakhshan Province. Earthquake felt at Lahore and NW India.
26.1 1840	34.53	69.17	VI-VIII	KABUL; QUITTMEYER AND JACOB, 1979
19/2/1842	34.3	70.5	VIII-IX	HINDUKUSH EARTHQUAKE Epicenter of the earthquake was near Kabul .Maximum documented Intensity was VIII-IX Alingar valley, Jalalabad and Tijri and VI-VII at Teezeen and VII-VIII at Budheeabad.The earthquake was felt from Kabul to Delhi Over an area of 2,16,000 sq.miles.Jalalabad and Peshawar damaged,.
19/6/1845	23.8	68.8	VII-VIII	RUNN OF CUTCH Documented epicenter of this earthquake was lie between 23.8 N, 68.8 E, and Maximum intensity was VII-VIII .Lakhpat was badly affected.
17/1/1851	32.0	74.0	VI-VIII	PUJAB PLAIN EARTHQUAKE Maximum Documented intensity was VIII and VI-VII at Wazirabad, Ferozpur and Multan, VI at fort Munro.
19/4/1851	25.1	62.3	VII	GAWADAR EARTHQUAKE Epicenter of the earthquake was around 25.1 N, and 62.3E. Maximum documented Intensity was VII at Gwadar.
24/1/1852	34.0	73.5	VIII	MURREE HILLS EARTHQUAKE Epicenter was in Murree hills and Kajnan about 350 people died. Maximum Documented Intensity was VIII.
1862	29.88	69.22	VIII	KOHU VALLEY; QUITTMEYER AND JACOB, 1979.

Date	Lat (N)	Lon (E)	Intensity	Remarks
10/7/1863	34.08	74.82	VI-VII	SRINAGAR, ALSO FELT IN LAHORE
25/7/1864	25.12	62.33	VI-VIII	GWADER
22/1/1865	34.00	71.55	V-VII	PESHAWAR
1867	29.2	68.2	VII	LAHRI EARTHQUAKE. The epicenter of earthquake was around 29.2 N, 68.2 E; Maximum Documented Intensity was VII at Lahri.
10/11/1868	32.5	71.3	VIII	BANNU EARTHQUAKE The epicenter of earthquake was around 32.5N, 71.3 E. Maximum Documented Intensity was VIII at Bannu.
11/8/1868	34.0	71.6	VII-VIII	PESHAWAR EARTHQUAKE The epicenter of earthquake was around 34. 0N,71.6E, near Peshawar. Maximum Documented Intensity was VII-VIII.
24/3/1869	32.92	73.72	V-VII	JEHLUM, QUITTMEYER AND JACOB, 1979
April 1869	34.0	71.55	VII-VIII	PESHAWAR, QUITTMEYER AND JACOB, 1979
20/12/1869	33.6	73.1	VII-VIII	RAWALPINDI EARTHQUKE The epicenter of earthquake was around 33.6N,73.1E. Maximum Documented Intensity was VII-VIII at Rawalpindi-VI at Lawrancepur and Attock. It caused cracks in walls in many houses at Rawalpindi.
April 1871	34.0	76.0	VII-VIII	KASHMIR EARTHQUAKE The epicenter of earthquake was around 34.0N,76.0E, in Kashmir. Maximum Documented Intensity was VII-VIII. It was also felt with Intensity VI at Rawalpindi and Murree.
20/5/1871	36.9	74.3	VII-VIII	GILGIT EARTHQUAKE The epicenter of earthquake was around 36.9N,74.3E,in former Gilgit agency. Maximum Documented Intensity was VII-VIII. Quittmeyer and Jacob, 1979 claim that this event occurred 22 May.with coord. 35.92 and 74.32
15/12/1872	29.2	68.2	IX-X	LEHRI, BALOCHISTAN
18/10/1874	34.5	69.2	IX	KABUL EARTHQUAKE The epicenter of earthquake was around 34.5N,69.2E .Maximum Documented Intensity was IX at Kabul,Jabal-al-saraj and Gulbahar and VIII in Kohistan area of N.W.F.P.
12/12/1875	34.0	71.55	VII-VIII	LAHORE-PESHAWAR EARTHQUAKE The epicenter of earthquake was around 31.6N,74.4E .Maximum Documented Intensity was VII-VIII at Peshawar and Lahore. Note: Coordinates from Quittmeyer and Jacob, 1979

Date	Lat (N)	Lon (E)	Intensity	Remarks
2/5/1878	33.58	71.4	VII-VIII	KOHAT-PESHAWAR EARTHQUAKE The epicenter of earthquake was between Kohat and Peshawar. .Maximum Documented Intensity was VII-VIII at Kohat and Peshawar VI-VII at Attock, Abbotabad, Rawalpindi and Jhelum, V-VI at Bannu, Nowshera, Mardan, Lahore and Simla.
1883	28.08	66.08	VI	KHALAT; QUITTMEYER AND JACOB, 1979
April 1883	34.0	71.55	VI-VII	PESHAWAR, QUITTMEYER AND JACOB, 1979
15/1/1885	34.08	74.82	VI-VII	SRINAGAR; QUITTMEYER AND JACOB, 1979
30/5/1885	34.1	74.8	IX-X	KASHMIR EARTHQUAKE The epicenter of earthquake was around 34.1N,74.8E .Maximum Documented Intensity was IX–X in the epicentral area.VIII-IX at Sopur.Gulmarg,Gingal and Srinagar.VI-VII at Punch,Muzzafarabad area.Extensive damage was about 47 sq.miles between Srinagar,Baramula and Gulmarg.Total felt area was 1,00,000 sq.miles.About 3000 people parished and some villages were completely destroyed.
6/6/1885	34.2	75.0	IX-X	KASHMIR EARTHQUAKE The epicenter of earthquake was around 34.2N,75.0E .Maximium Documented Intensity was IX-X.
28/12/1888	30.2	67.0	VIII-IX	QUETTA EARTHQUAKE The epicenter of earthquake was around 30.2N,67.0E, at Quetta. Maximum Documented Intensity was VIII-IX.
1889	27.7	67.2	VIII	JHALAWAN EARTHQUAKE The epicenter of earthquake was around 27.7N,67.2E at Jhalawan .Maximum Documented Intensity was VIII.
1890	30.4	68.6	VII	LORALAI EARHQUAKE The epicenter of earthquake was around 30.4N, 68.6E .Maximum Documented Intensity was VII at Loralai.
20/12/1892	30.9	66.4	VIII-IX	CHAMAN EARTHQUAKE The epicenter of earthquake was around 30.9N, 66.4E near Chaman. Maximum Documented Intensity was VIII- IX at Chaman and VII at Sanzal. In this earthquake great damage to buildings,bridges,railoads and other structure etc.The earthquake was caused by the movement of Chaman fault on the west bank of Khojak range passing through the north west railway between Shelabagh and Sanzal.At Shelabagh the railway station building was severely damaged.

Date	Lat (N)	Lon (E)	Intensity	Remarks
13/2/1893	30.2	67.0	VIII-IX	QUETTA EARTHQUAKE The epicenter of earthquake was around 30.2N,67.0E .Maximum Documented Intensity was VIII- IX at Quetta.
25/11/1893	34.0	71.55	VI-VII	PESHAWAR-NOWSHERA EARTHQUAKE The epicenter of earthquake was between Peshawar and Nowshera .Maximum Documented Intensity was VI-VII at both places
1900	30.4	67.0	VIII	QUETTA-PASHIN EARTHQUAKE The epicenter of earthquake was around 30.4N, 67.0E .Maximum Documented Intensity was VIII.
20/1/1902	35.9	71.8	VII-VIII	CHITRAL EARTHQUAKE The epicenter of earthquake was around 35.9N, 71.8E near Chitral. Maximum Documented Intensity was VII-VIII.
1902	30.6	66.8	VII	GULISTAN-PASHIN EARTHQUAKE The epicenter of earthquake was around 30.4N, 67.0E .Maximum Documented Intensity was VIII VII.
23/12/1903	29.5	67.6	VII	DADHAR EARTHQUAKE The epicenter of earthquake was around 29.5N, 67.6E. Maximum Documented Intensity was VII.
4/4/1905	32.13	76.28	X	KANGRA EARTHQUIAKE

4.3 The largest earthquakes

4.3.1 The 1905 Kangra earthquake (M 8.0)

The Kangra earthquake with magnitude Ms 8.0 (Gutenberg and Richter) of 4 April 1905 in the north-west Himalaya, near Dehra Dun, was the first of several devastating 20th century earthquakes to occur in northern India. More than 20,000 people were killed near the epicentre area and about 100,000 buildings were destroyed by this earthquake. The felt area was extensive and the intensity ≥VIII was observed in most of the areas. Although this earthquake is not the only severe event known in the western Himalaya, it had the largest death toll and is one of the first to occur in the period of instrumental seismology. It is also one of the four great Himalayan earthquakes to have occurred in the past 200 years.

The magnitude of the Kangra earthquake influenced the estimates of the largest credible earthquake that might occur in the western Himalaya. Moderate earthquakes occur every few decades along the small circle that defines the southern edge of the Tibetan Plateau, but no historical earthquakes have ruptured the surface along the Main Frontal Thrusts bordering the Himalayan foothills (Ambraseys and Bilham, 2000; Kumar and Mahajan, 2001; Kumar et al., 2001; Bilham, 2001). Also the 1905 event produced no frontal rupture.

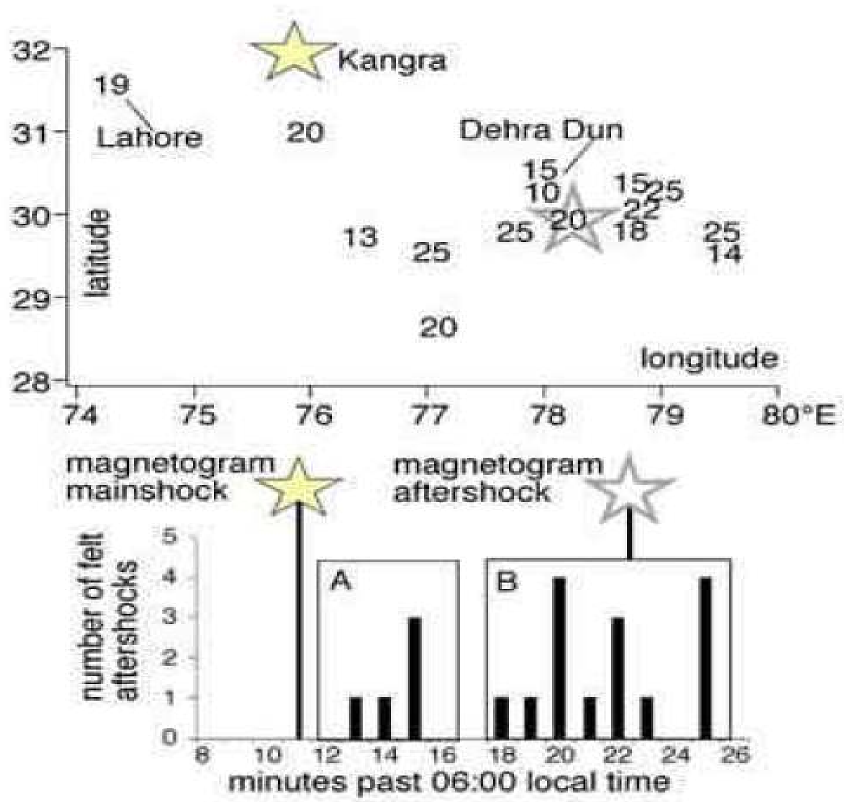


Figure 4.6. Map showing location and felt time in minutes of Kangra aftershocks. Histogram below shows the clustering of these in time relative to main shock and aftershock recorded by magnetometer at Dehradun (Hough *et al.,* 2005).

Though historical records are poor, it appears that the last great earthquake in this region occurred in September 1555. Yet another major earthquake occurred in 1885 near Srinagar. Seeber and Armbruster (1981) found evidence of strain accumulation in the region. Only geodetic data to have been analyzed to assess the rupture parameters for this event are from a levelling line inferred to cross the eastern edge of the rupture zone. Various analyses of these data have been reported but conclusions concerning fault slip and rupture geometry are weakened by considerable uncertainties in defining the northern, southern and western edges of the inferred rupture zone (Chander, 1988). These analyses of the data provide weak constraint for the slip in 1905 earthquake of 5-7.5 m.

It was observed that magnetograms saturated in the first 8 min, but also that a distinct arrival occurred 11.3 min after the main shock. Fig. 4.6 shows the locations of reported aftershocks reported during the 15 min following the main shock. The main location based on reports for two consecutive 8 min windows are calculated to lie 20-100 km SE of Dehradun. However, because the Kangra epicentral region was severely damaged, few people were able to document the timing of aftershocks. The location may be away from main shock epicentre (Hough. *et al.*, 2005).

4.3.2 The 1935 Quetta earthquake

The magnitude 7.7 Quetta earthquake occurred on May 30, 1935. Although Baluchistan in 1935 had one of the lowest population densities on the subcontinent of India, this earthquake occurred where most of the population lived. The depth, reported by Ramanathan and Mukherji (1938) was 10 km. For this reason, and despite the initiation of earthquake-resistant design triggered by the nearby 1931 sequence, the 1935 Quetta earthquake resulted in the largest number of fatalities of any earthquake on the Indian subcontinent.

The Quetta surface-wave magnitude calculated from 25 station magnitudes is 7.7, which corresponds to a seismic moment of 17.0×10^{20} Nm, as estimated by Singh and Gupta (1980). Lawrence *et al.* (1992) and Yeats *et al.* (1997) associated these ruptures with the Ghazaband fault zone, one of a series of large north-south left-lateral strike-slip systems that accommodate plate boundary shear. A temporary seismic network operated in the region in 1978 suggests that microseismicity was at that time concentrated near the ends of the 1935 rupture (Armbruster *et al.*, 1980). Fault-plane solutions in the area confirm left-lateral faulting on this trend, and, in spite of the lack of reported observations of strike-slip offsets at the time, this is the most likely mechanism for the 1935 earthquake.

Most of the damage to rural and urban houses, chiefly of mud brick construction, was enclosed within a narrow zone, with Baleli and Quetta in the north extending in a southwesterly direction into the Harboi Hills, about 160 km long and 25 km broad.). In Quetta about 26,000 people were killed, of which a few thousand bodies were left buried in the ruins of the town. Outside Quetta numbers are even more uncertain, particularly in the Kalat tribal area, where more than 8,000 deaths were recorded. Altogether, the earthquake could have killed about 35,000 people, but reliable figures are lacking.

It appears that the earthquake was associated with the zone of faults that lies along the east edge of the Chiltan range and that this zone extends to the south, passing near the towns of Mastung and Kalat.

4.3.3 The 1945 Makran earthquake

Based on the reported literature (Quittmeyer *et al.*, 1979; Mokhtari *et al.*, 2005; Ramachandran, 2005; Jain *et al.*, 2005) we find that the event occurred off the Makran Coast on 28th November 1945 at 21.56 UTC, with an epicentre location about 90 km SSW of Churi (Balochistan), Pakistan, with coordinates 24.5^{o}N, 63.0^{o}E, and with Mw 8.0, Ms 7.8 and a seismic moment of 10.2 x 10^{20} Nm. A tsunami occurred in the region of Kuch at the southern coast of Makran, Pakistan, reported with wave heights as high as 17 m in some Makran ports and caused great damage to the entire coastal region. The tsunami had a height of about 11-15 m in the Kuch, Indian Gujrat. Also, the height of the tsunami in Mumbai was 2m (Rastogi and Jaswal, 2006). A total of 4000 people are supposed have died as a result of the earthquake and tsunami. These numbers are, however, mostly based on non-scientific sources of more anecdotal nature.

Assessment of the historical records of the tsunami in the Indian Ocean, (Dominey-Howes et al., 2006; Murty and Rafiq, 1991; Murty and Bapat, 1999) shows that essentially there are main tsunamigenic zones in this ocean, which are Sunda subduction zone in the east, and Makran subduction zone in the northwest of Indian Ocean. The Makran subduction zone, with more than 900 km in length, is located off the southern coasts of Iran and Pakistan in the north western Indian Ocean. In this region the Oman oceanic lithosphere slip below the Iranian micro plate at the estimated rate of about 19 mm/year (Vernant Ph. et al., 2004). The last major historical earthquake and tsunami in the Makran subduction zone occurred on 28 November 1945. Data of historical tsunami in thye Indian Ocean basin are collected by some researchers including Murty and Rafiq (1991), Murty aqnda Rafiq (1999), Dominey-Howes et al. (2006), and Rastogi and Jaiswal (2006). According to these catalogues, the total number of tsunami events in the Makran zones is three; including two events are seismic origin, and one of unknown origin. Besides above mentioned three tsunamis in the Makran coast, they have reported that another tsunami has occurred in this region in 1897.

It would have been both interesting and important to model this tsunami numerically, but there are two problems which complicates this at present, firstly that the source parameters are poorly constrained, making it difficult to define a reasonable model for the seabed dislocation, and secondly that the tsunami is poorly mapped, making it difficult to perform back calculations. Also, the possible existence of a subsequent slide cannot be excluded. For the Makran 1945 tsunami, a tsunami modelling is also strongly influenced by large scale depth variations. However, if a 1945 wave height of 12 m can be confirmed for the Makran coast, it is certainly reasonable to assume that a similar event can occur again. There are also some unconfirmed and unsubstantiated claims for the generation of tsunamis during the period 1524 to 1819 in the Arabian Sea.

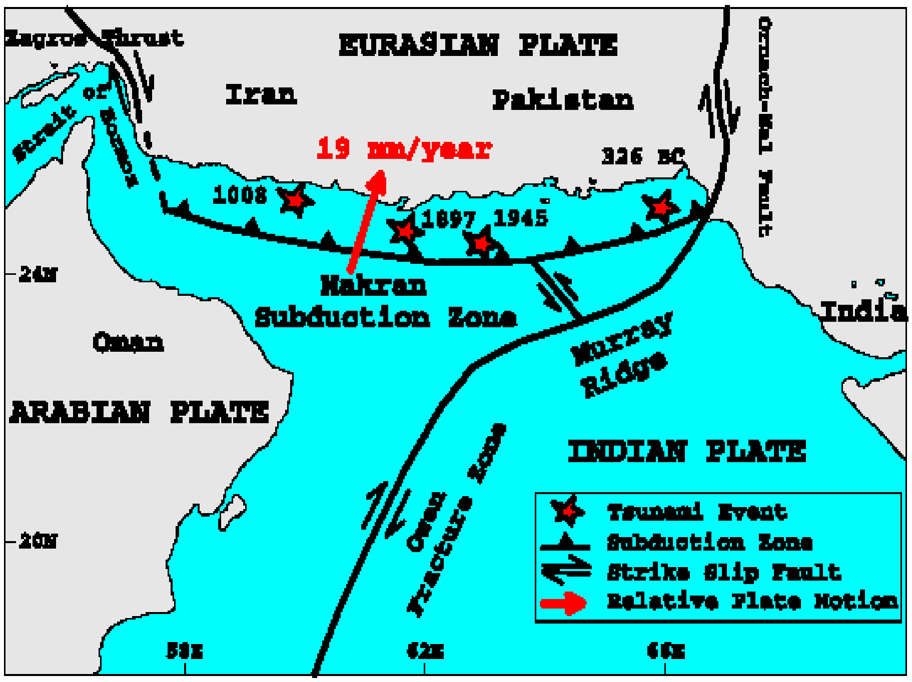


Figure 4.7.Tectonic map of the Arabian, Indian and Eurasian plates showing the location of the Makran zone

4.3.4 The 1974 Pattan earthquake (M 6.0)

This relatively modest yet destructive earthquake occurred on December 28, 1974 near Pattan, and it was followed by many aftershocks. The main shock originated at about 12 km depth and showed an average body wave magnitude of mb 6.0. There is no evidence that the earthquake was associated with surface ruptures. Individual cracks in relatively flat ground running for a few tens of meters were found in the epicentral region.

The shaking of Pattan was very violent, particularly in the upper part of the village where people found it difficult to stand.

Local residence reported ‘deafening’ noises associated with the main shock and some of the largest aftershocks. The shock was felt over an area of 300,000 km^2 and it caused some damage also to the Karakorum Highway along the steep slopes of the Indus gorge.

The main shock of 28 December triggered four SMAC B1-2 accelerographs 139 km away at Tarbela. On the rock the maximum acceleration recorded was about 1.4% g with a predominant period of 0.14s. On alluvium acceleration with frequencies of about 10 Hz reached 3.5% g. At both the base and crest of the earthfill dam of Tarbela, maximum accelerations did not exceed 1.5% g at frequencies of 5 Hz (Ambraseys *et al.*, 1981). This earthquake occurred in the remote and mountainous region of northern Pakistan, resulting in the loss of many lives and damage to property. The focal mechanisms of this and six other moderate magnitude earthquakes since 1976 show consistent reverse motion on a plane dipping towards northeast.

4.3.5 The 2005 Muzaffarabad earthquake (M 7.6)

Geographically, the recent earthquake of 8th October 2005 (Mw 7.6) occurred in the Kashmir region, and the earthquake is already well studied (e.g., Avouac et al., 2006; Pathier et al., 2007; Gahalaut, 2006). The United States Geological Survey (USGS) and European-Mediterranean Seismological Centre (EMSC) have reported the epicentre of this earthquake in the syntaxis, while the Indian Meteorological Department (IMD) has reported it further west. Aftershocks of the earthquake as reported by Pakistan Meteorological Department (PMD) and USGS lie NW of the main shock epicentre in the Indus Kohistan Seismic Zone (IKSZ). The earthquake occurred at the western extremity of the Himalaya, where the arc joins the Karakorum, Pamir, and Hindukush ranges.

This earthquake occurred on pre-existing active faults, as shown in Fig. 4.8. The newly deformed area occupies a 90-100 km long northeast trending strip extending from Balakot, Pakistan, southeast through Azad Kashmir. It cuts across the Hazara syntaxis, reactivating the Tanda and Muzaffarabad faults. North of Muzaffarabad the surface rupture coincides approximately with the MBT, on the south-western flank of the syntaxis. The fault offset was 4 m on average and peaks to 7 m northwest of Muzaffarabad. The rupture lasted for 25 s and propagated up dip and bi-laterally with a rupture velocity of about 2 km/s (Philippe *et al.*, 2006). The heavily damaged area north of Muzaffarabad, Kashmir shows the maximum deformation. There are known active faults stretching to the northwest and southeast near the epicentre, which reveal some uplift on the northern side and dextral, right-lateral strike-slip activities (Fujiwara *et al.*, 2006). The known active faults are divided in two fault groups, the Muzaffarabad fault, northwest of Muzaffarabad and the Tanda fault, southeast of Muzaffarabad (Nakata *et al.*, 1991).

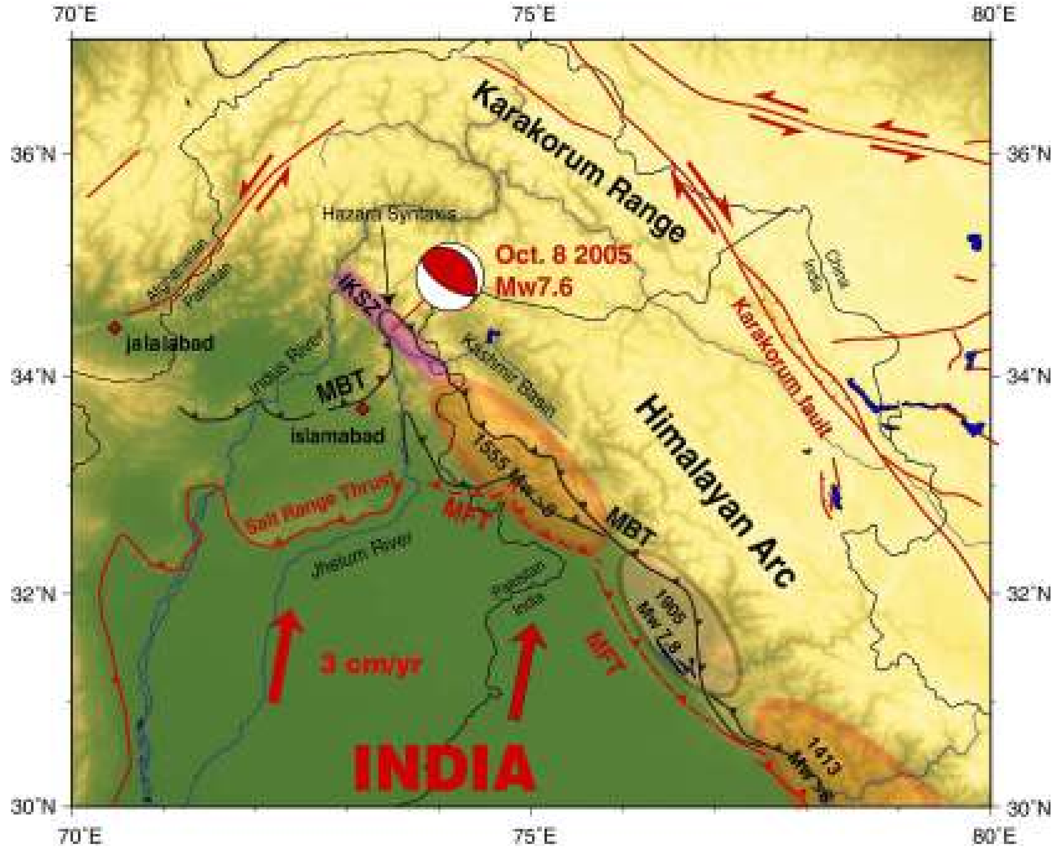


Figure 4.8.The Muzaffarabad earthquake of October 8, 2005 rupture zone seen in the context of other large earthquakes on the Himalaya Main Boundary Thrust (MBT) (after Avouac *et al.*, 2006). Annotation: IKSZ – Indus-Kohistan Seismic Zone.

Seismically, the most active geological structures of this region are considered to be capable of generating large events. However, it is not appropriate to equate the IKSZ with the MBT, because the tectonic histories of these two are quite different. The activity along the IKSZ is much more intense than along the MBT.

5 Seismotectonic Interpretation

5.1 Seismic provinces and area sources

For the study of earthquake hazard in Pakistan, the country was divided into 19 zones, including some portions of the neighboring countries of Afghanistan, Tajikistan, Iran and

India. The division of the region into these source zones is based on the seismicity, the fault systems and the stress direction analysis. The division was also based on the data processing of the whole catalogue regarding the seismicity, depth and the study of research papers. One of the basic principles for the zonation of a region is that the seismicity within a single zone remains uniform and homogeneous, even though this principle clearly is not always fulfilled as judged from the individual catalogues used in the study. The nineteen seismic zones are all having geometric shapes (polygons) and the coordinates of their corners are described below along with a Fig. 5.1.

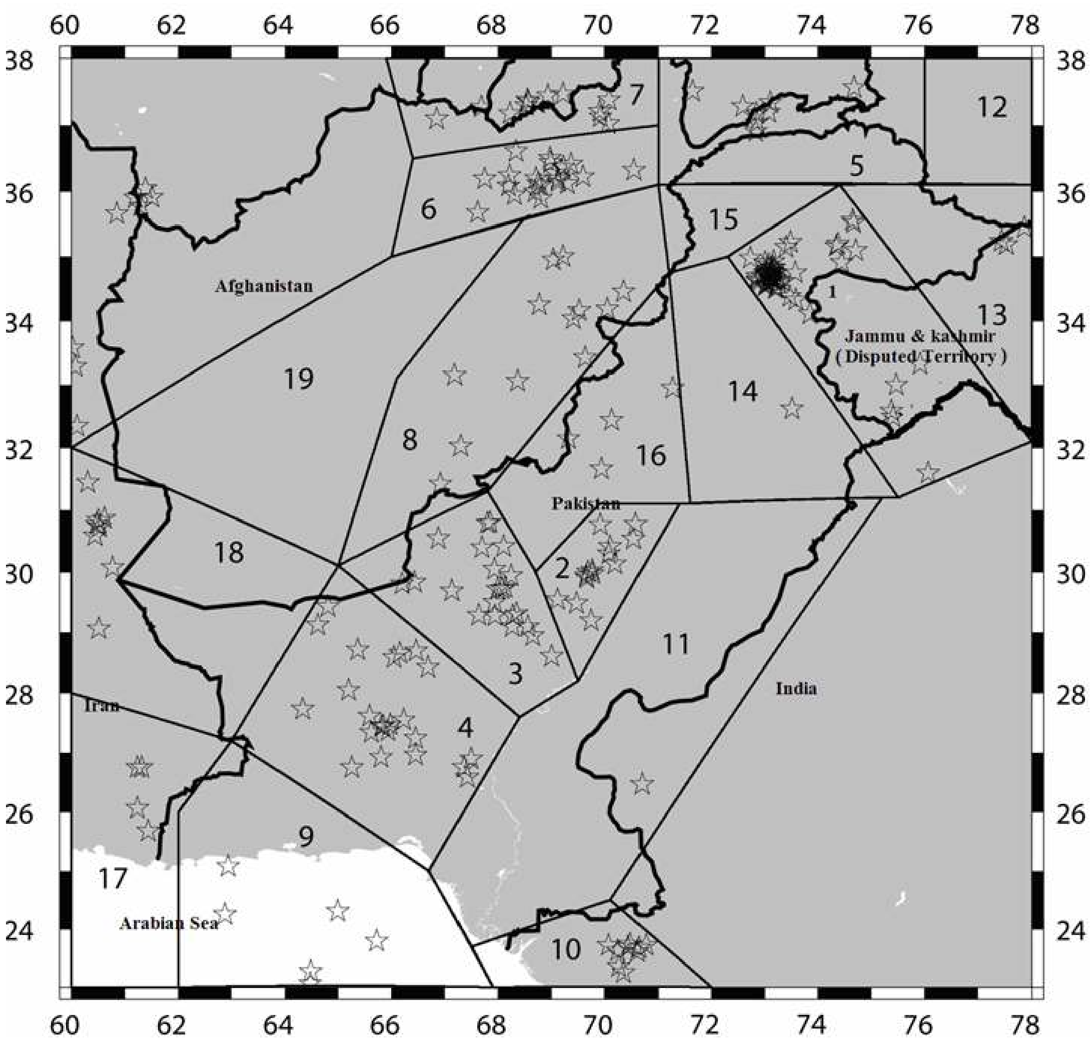


Figure 5.1. Seismic Zones of Pakistan as used in the present study.

5.1.1 Seismic source zones

There are altogether 19 area zones defined for this study, as delineated in the following.

Zone 1; Kohistan-Kashmir

This zone includes mostly the Kashmir areas, some parts of the Gilgit region and the NWFP (North-Western Frontier Province) and some of upper Punjab. The zone has always been very active as it covers the plate boundary of the Eurasian and the Indian plate. The northern region of Punjab is included in this zone as it was always affected by the earthquakes originated from the faults present in the Kashmir region. Some areas of Himachal Pradesh, India are also included in this zone. Lahore, a densely populated city of Pakistan and the capital of Punjab, was destructed in 1905 by the devastating earthquake in Kangra, India, which is also included in this zone. Chilas, Besham and Gilgit city are other important cities of this zone. The coordinates of this zone are:

31.2^o N	75.5 ^{o} E
32.1^o N	78.0 ^{o} E
36.1^o N	74.4 ^{o} E
35.0^o N	72.3 ^{o} E

Zone 2; Northern Baluchistan

Although the name given to this region is the Northern Baluchistan Seismic Zone, it also includes some areas of Punjab. The zone is the region of a large number of earthquakes with magnitudes more than 4.5 in the PDE catalogue. The historical data from PMD does not show any significant activity in this zone, however, one must then remember that the epicenters of the historical catalogue is highly uncertain, and to a large part also reflects on population density. The coordinates of the corners are:

30.0^o N	68.7 ^{o} E
28.2^o N	69.5 ^{o} E
31.1^o N	71.4 ^{o} E
31.1^o N	69.9 ^{o} E

Zone 3; Quetta-Sibi

The geological and the seismological features of this zone are almost similar to those of Zone 2. This zone also contains Quetta which in 1935 was affected by an earthquake of magnitude 7.6. Almost 30,000 people died during this seismic event and the whole city perished. Jacobabad is also a city of Baluchistan in this zone.

30.1^o N	65.0 ^{o} E
27.6^o N	68.4 ^{o} E
28.2^o N	69.5 ^{o} E
30.0^o N	68.7 ^{o} E

31.3° N	67.8 ° E

Zone 4; Southern Baluchistan

Only four earthquakes are found in this zone in the ISC catalogue having M ≥ 6.0. Panjgur, and Sonmiani bay of Baluchistan and Larkana of Sindh are some of the important places in this zone. The Central Brahui range, Siahan range, Kirthur range and the Central Makran mountain ranges run through this zone.

30.1° N	65.0 ° E
27.2° N	63.0 ° E
25.0° N	66.7 ° E
27.6° N	68.4 ° E

Zone 5; Northern Afghanistan-Tajikistan

This zone covers mostly the border area of Pakistan, Afghanistan, Tajikistan and China. The city of Sost, a very important town on the Karakoram Highway and the Kunjarab pass are both located in this zone, as well as a small area of the province of China, Xinjiang. Tashkurgan is a Tajik town in western Xinjiang, China. It is almost on the borders of both Afghanistan and Tajikistan, and close to the borders of Kyrgyzstan and Kazakhstan. Badakhshan in Afghanistan is also in this zone.

36.1° N	71.0 ° E
36.1° N	76.0 ° E
38.0° N	76.0 ° E
38.0° N	71.0 ° E

Zone 6; Hindu Kush

This zone entirely covers the Afghanistan region. Several earthquakes with their epicentres in or around the Hindu Kush ranges have affected the Northern areas of Pakistan. The earthquakes in 1983, 1985 and 1991 in the Hindu Kush had magnitudes 7.4, 7.4 and 6.7, respectively, and it has been reported that more than 300 people died as a result of these events, in the regions of Peshawar, Chitral, Swat and Malakund (the PMD database). A few records of large historic earthquakes have also been found in the PMD data base. Any earthquake in Hindu Kush with magnitude greater or equal to 6 is reported to be felt (although weakly) also in the southern Punjab.

36.5° N	66.4 ° E
35.0° N	66.0 ° E
36.1° N	71.0 ° E

37.0° N	71.0 ° E

Zone 7; North Western Afghanistan-Tajikistan Border Region

This zone covers the area just to the south of Dushanbe, the capital of Tajikistan. In addition to Tajikistan and Afghanistan it also covers some areas of Uzbekistan and Turkmenistan. Being situated near the Hindu Kush region and a few hundred kilometers away from Pakistani region, this is the region of large earthquakes according to the ISC and PDE catalogues. A few records of large earthquakes are found in the PMD historic database, in this zone.

38.0° N	65.9 ° E
36.5° N	66.4 ° E
37.0° N	71.0 ° E
38.0° N	71.0 ° E

Zone 8; Eastern Afghanistan

This zone covers mainly the Afghan territories up to Baghlan in the west, and the border region with Pakistan, in the south east. Kabul, Kandhar, Nuristan and Mazar-Sharif are the major cities of Afghanistan covered in this zone. Many active faults are located in this zone, which have generated significant earthquakes in the past as well as during the recent few decades. The seismicity increases as we go from south to north in this zone and the PMD historic database gives information about a few significant earthquakes in this zone, however according to the PDE catalogue, most of the southern parts of this zone are inactive.

30.1° N	65.0 ° E
31.3° N	67.8 ° E
34.75° N	71.2 ° E
36.1° N	71.0 ° E
35.6° N	68.5 ° E
33.1° N	66.1 ° E

Zone 9; Makran Coast

Tsunamis have also affected the coast of Pakistan. An active subduction zone exists off the Makran coast and the 1945 earthquake originated in this region. The magnitude of this earthquake was 8.2 Ms according to the PMD catalogue and a tsunami was generated by this huge earthquake which struck the Makran coast. As discussed earlier in this report a wave height of 12 m was reported during this tsunami.

From the PMD historical database, only two considerable events in 1851 and 1864 are reported in the Gwadar area. The intensities of these earthquakes were VII.

27.2° N	63.0 ° E
26.0° N	62.0 ° E
23.0° N	62.0 ° E
23.0° N	67.9 ° E
25.0° N	66.7 ° E

Zone 10; Runn of Kuchch

The area under consideration in this zone belongs mostly to India (Runn of Kuch). The zone contains a reasonable number of earthquakes having $M \geq 4.5$ as reported in the PDE catalogue. In the historical data from PMD, there are two major earthquakes in this zone. The seismic activity in this area has always affected also Pakistan.

23.0° N	67.9 ° E
23.0° N	72.0 ° E
24.5° N	70.1 ° E
23.7° N	67.5 ° E

Zone 11; Sindh-Punjab

This is the largest zone with respect to area, but it has the least seismic activity. It covers most parts of Punjab and Sindh including the western areas of India. In the south it covers the coastal areas of Sindh where a few but significant historical earthquakes are found, however there are generally few earthquakes in this zone.

23.7 ° N	67.5 ° E
24.5 ° N	70.1 ° E
31.2 ° N	75.2 ° E
31.1 ° N	71.4 ° E
28.2 ° N	69.5 ° E
27.6 ° N	68.4 ° E
25.0 ° N	66.7 ° E

Zone-12; Pamir-Kunlun

This is a rectangular-shaped zone covering only the Chinese territories near the Pakistani border with China. Kongur Tagh (also referred to as Kongur or Kongur Shan) is the highest peak of the Kunlun Mountains in China.

36.1° N	76.0 ° E
36.1° N	78.0 ° E
38.0° N	78.0 ° E
38.0° N	76.0 ° E

Zone 13; Indian Kashmir

The northern areas of Pakistan, Kashmir, Xinjiang of China and Himachal Pradesh of India are the main areas covered by this zone. It is not a densely populated zone but some seismic activity is present.

32.1° N	78.0 ° E
36.1° N	78.0 ° E
36.1° N	74.4 ° E

Zone 14; Upper Punjab-NWFP

According to the PDE catalogue this zone seems to be very active, especially parts of NWFP. One of the important aspects of this zone is that it includes two provincial capitals: Peshawar and Lahore, the country capital of Islamabad and one densely populated city of India, Amritsar. Malakund and Mardan are other important places in this zone. According to the historical PMD database, there is a belt of uniform seismic activity which exists in this zone. This belt starts near Rawalpindi and ends near Peshawar. In addition to the geological conditions of the area, it is thought that one of the reasons for many earthquake reports from this area is that it has remained densely populated since ancient times.

31.2° N	75.5 ° E
35.0° N	72.3 ° E
34.7° N	71.2 ° E
31.1° N	71.6 ° E

Zone 15; Chitral

This is a very small zone with respect to area. Chitral and Drosh of Pakistan and Asad-abad of Afghanistan are the important cities in this zone.

34.75° N	71.2 ° E
35.0° N	72.3 ° E
36.1° N	74.4 ° E
36.1° N	71.0 ° E

Zone 16; Koh e Sulaiman

Some areas of Baluchistan, western Punjab, and most areas of the NWFP are included in this zone. The seismic activity in this zone is very low as compared to that in the neighboring zones i.e. Zones-2 and 3 in the south and 15 in the north.

30.0° N	68.7° E
31.1° N	69.9 ° E
31.1° N	71.6 ° E

34.7° N	71.2° E
31.3° N	67.8° E

Zone 17; South West Iran

The Harvard and ISC catalogues contain three earthquakes each having M ≥ 6.0 whereas the PMD historic database has no significant reports from this zone.

23.0° N	60.0° E
23.0° N	62.0° E
26.0° N	62.0° E
27.2° N	63.0° E
28.0° N	60.0° E

Zone 18; Western Baluchistan

The old cities of Zahidan of Iran, Nimruz of Afghanistan and the Chaghi hills of Pakistan are all included in this zone. The western parts of Baluchistan are noted to be inactive according to the PMD historic database. The areas of Baluchistan and the border areas with Iran and Afghanistan contain few large earthquakes, according to the ISC catalogue. However, the PDE catalogue provides reports on several events with M ≥ 4.5 in this region.

28.0° N	60.0° E
27.2° N	63.0° E
30.1° N	65.0° E
32.0° N	60.0° E

Zone 19; Central & Southern Afghanistan

According to the PDE catalogue only a few small earthquakes are found in this area with magnitudes near 4.5. No earthquake with M ≥ 6.0 is reported. Except a few areas of Iran, this zone mainly covers the Afghan territories e.g. Lashkargah, Chaghcharan and Negah are the major cities of Afghanistan. The coordinates of the corners of this zone are as below:

32.0° N	60.0° E
30.1° N	65.0° E
33.1° N	66.1° E
35.6° N	68.5° E
35.0° N	66.0° E

5.2 Zones of high seismic activity in Pakistan

It was observed that most of the large earthquakes occurred in the following regions:

- Hindu Kush region.

- Northern areas of Pakistan and Kashmir
- North-western part of Baluchistan and
- The coastal areas of Pakistan (near Makran region)
- The south-eastern corner of Pakistan (Runn of Kutch)

The combination of PMD and international data bases results in a catalogue with different kinds of magnitudes, essentially body wave magnitude (mb) for the smaller events and surface wave (Ms) and moment (Mw) magnitudes for the larger events.

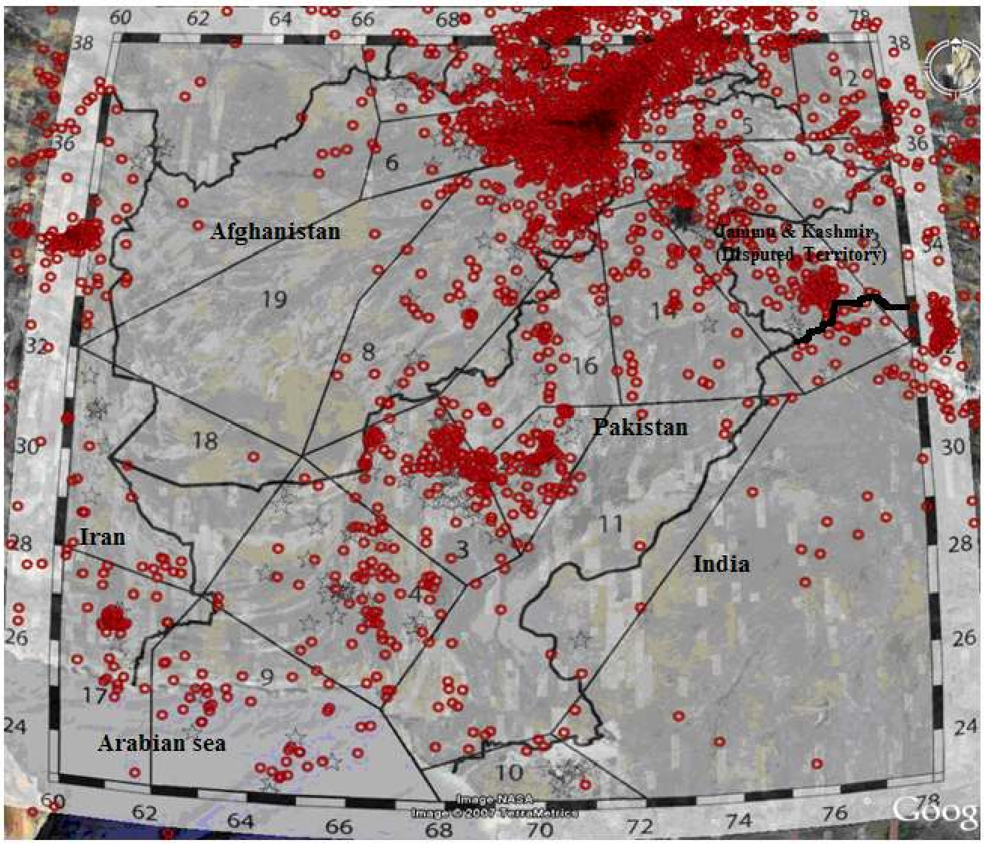
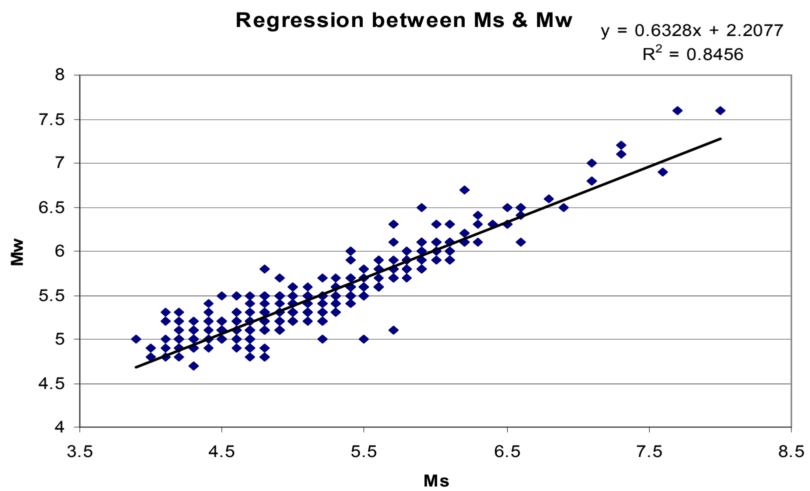


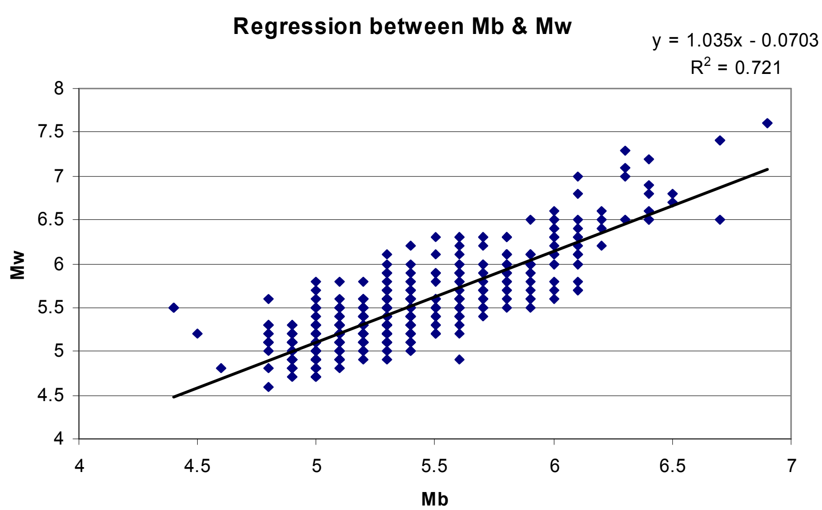
Figure 5.2. Seismicity of the region (map with the 19 zones overlaid in Google Earth).

5.3 Magnitude conversions

The magnitude scale used in this study is moment magnitude (Mw) as defined by Hanks and Kanamori (1977; see also Kanamori, 1977). But the seismological data bases like PDE, ISC and PMD contain body wave and surface wave magnitudes. If for some events Mw are available in catalogue these are only for new events. Mainly because the ground-motion relation used is developed for moment magnitude there is need to convert the magnitudes of all catalogues into Mw, for which purpose we have developed the regressions shown in Fig. 5.3 based on magnitudes from the Harvard catalogue.



(a)



(b)

Figure 5.3.Conversion of (a) surface-wave magnitude (Ms) and (b) body-wave magnitude (mb) into moment magnitude (Mw) based on the Harvard catalogue.

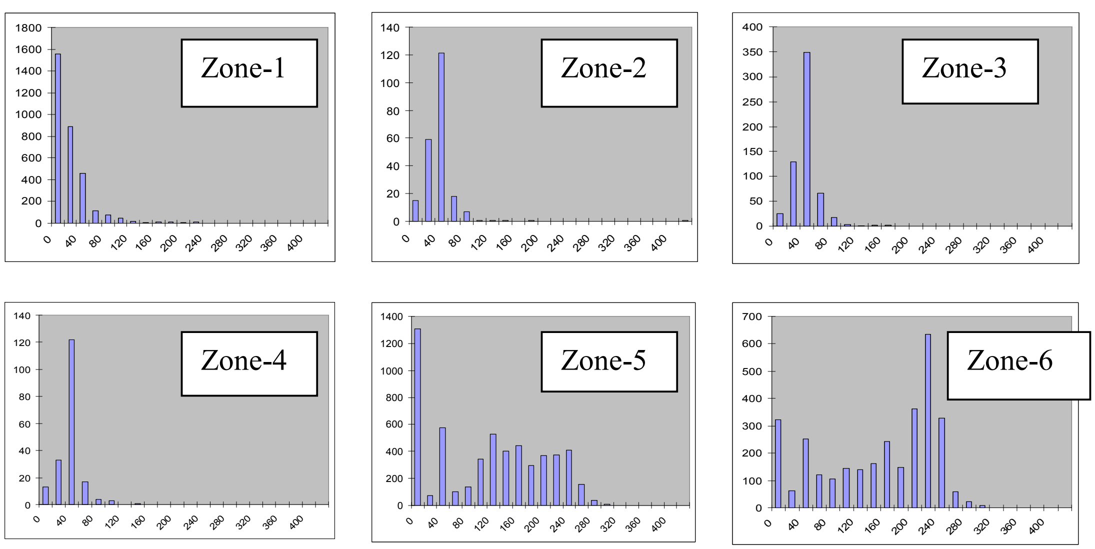
5.4 Maximum magnitude

After having reviewed the historical data it is clearly seen that the Pakistani area has been struck by many large earthquakes in the past. For instance Quetta has been hit for four times (1888, 1893, 1900 and 1935) with VIII to IX intensity earthquakes, and the areas surrounding Peshawar have been hit thrice in a similarly short time period (1868, 1875 and 1878) with VII to VIII intensity earthquakes. Runn of Kuch was hit twice (1819 and 1845) with an intensity VII and X, Hindu Kush region has generated many earthquakes with huge intensity and at last the Kashmir areas are hit four times in the recent history (1828, 1871 and twice in 1885) with intensity IX to X earthquakes. All of these seismic events within the boundaries of Pakistan or near have been devastating, causing famines and extensive damage, such as loss of lives.

5.5 Focal depths

The focal depths of earthquakes vary from the shallow to deep in the whole study area, as shown in Fig. 5-3 for all of the 19 zones defined in this study. It is found that from north to south the depths and mechanism of earthquakes are different in different seismic zones. Generally the seismicity of Pakistan is considered to be shallow and intermediate depths.

This great range of focal depths is a particular challenge with respect to the choice of ground-motion models to be used in the hazard calculations, as discussed in more detail in Section 6.



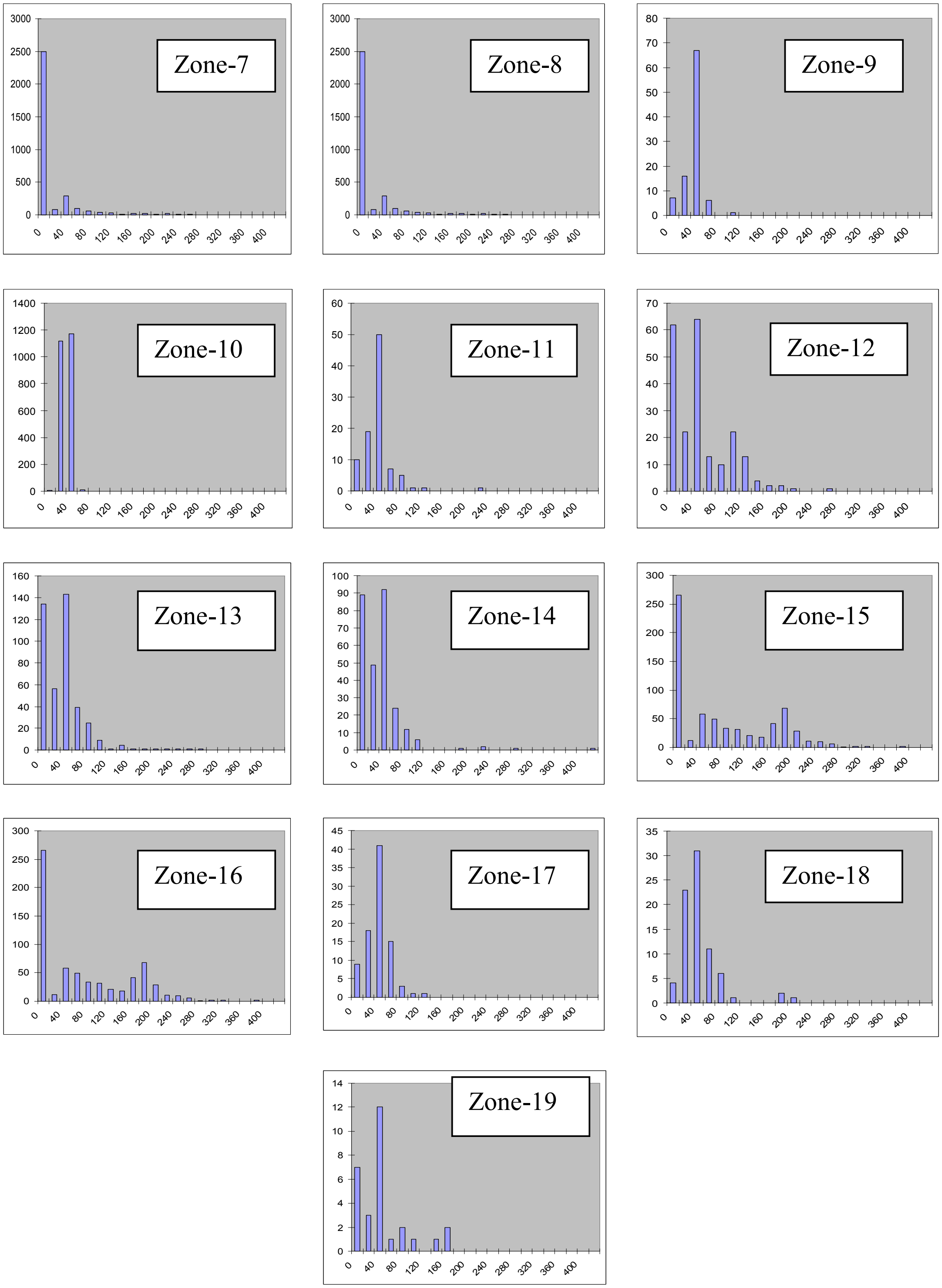


Figure 5.4 (cont.). Number of earthquakes with different depths [km] for the 19 seismic zones of the study area.

In Fig. 5.3 all of the 19 zones have been similarly analysed, because it was necessary to find out the depths of earthquakes occurring in each seismic zone. The histogram analyses clearly demonstrates the deep seismicity in the Hindu Kush region (Zone 5, 6 and 7), and to allow for this we have subdivided them with respect to depths at 75 km and 210 km. To this end the histogram and cumulative distribution in Fig. 5.4 were developed. It is seen that most of the seismicity (80%) is shallow, i.e. below 40 km, while between 40 and 320 km depths nearly 20% of the events occur. In order to accommodate for this the Ambraseys *et al.* (2005) model was modified (see Section 6) to allow for these depths, and used in the CRISIS for the computation of seismic hazard. This is important since the Hindu Kush seismicity is contributing significantly to the hazard also for locations outside of that region.

Admittedly, there are also some other zones with some deep seismicity, notably zones 12, 15 and 16. These zones have, however, lower seismicity and are therefore contributing less to the hazard, and we have therefore not treated these like for the Hindu Kush zones. Since shallow seismicity contributes relatively more to the hazard than deeper events the error made by not allowing for the deeper events in the other zones is moreover on the conservative side, adding to the hazard.

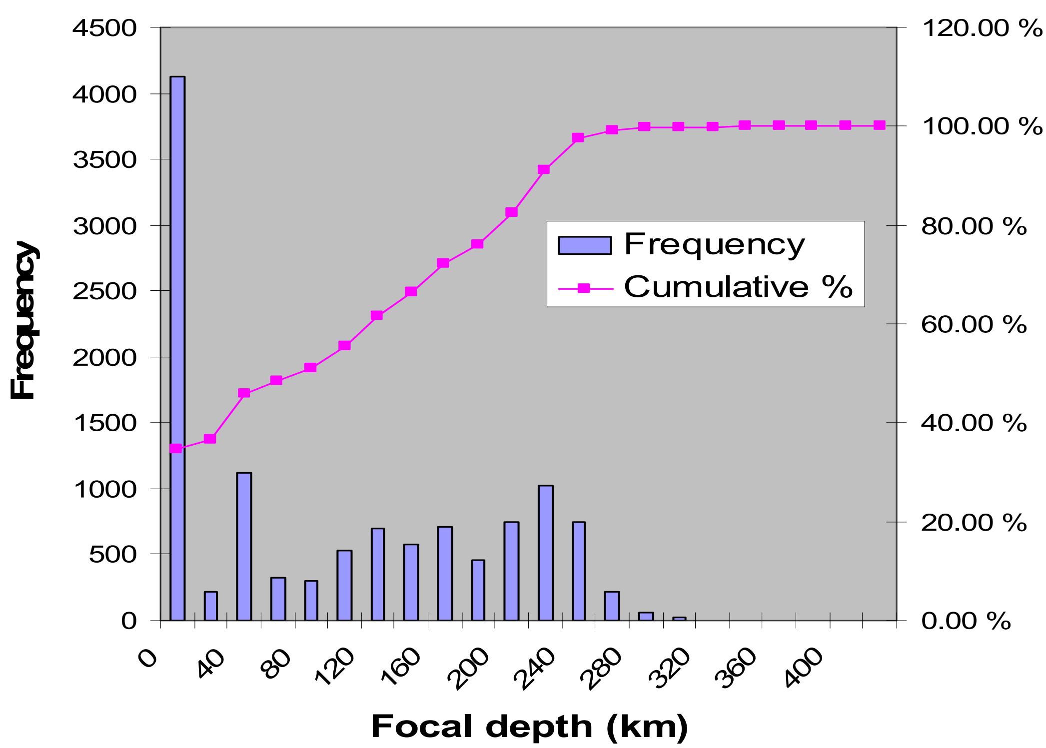


Figure 5.5. Distribution of focal depth for the Hindu Kush region (zones 5, 6 and 7).

5.6 Earthquake focal mechanisms

Much of the northern and southern parts of Pakistan lie in high seismicity areas with a history of large and damaging earthquakes, with Fig. 5.6 showing the Harvard CMT solutions in the Pakistani region between 1977 and 2006.

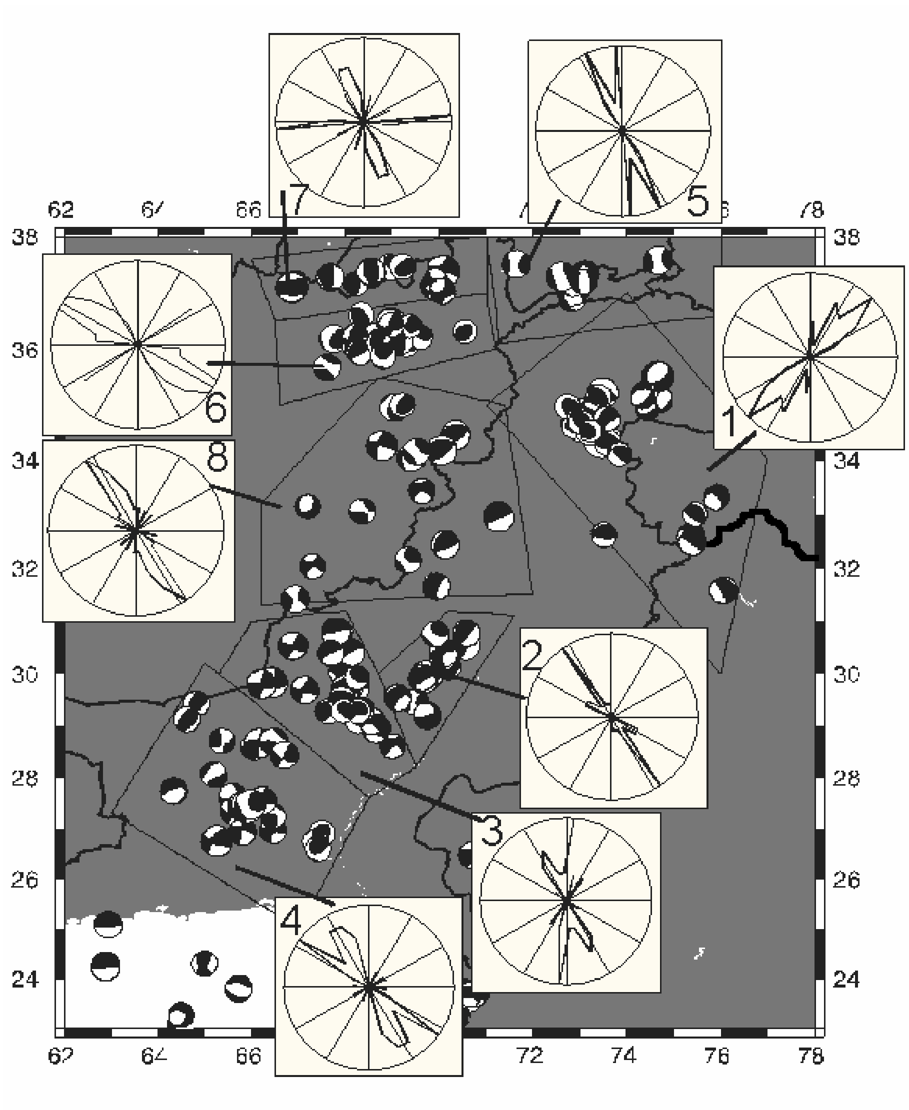


Figure 5.6.Focal mechanisms from the Harvard CMT solutions between 1977 and 2006. Inset are aggregated directions of maximum horizontal compression in the crust as derived from the focal mechanisms following the WSM recommendations (http://www-wsm.physik.uni-karlsruhe.de).

The earthquake focal mechanisms in Fig. 5.6 provide the description of the mode of faulting of each single earthquake and implicitly thereby also reflects on the orientation of the causative stress-tensor. Because of this, the focal mechanism solutions are used to reveal the orientation (not the relative magnitudes) of the stresses in the crust. The inset rose diagrams show the aggregated direction of σ_H in each of the small zones indicated. The σ_H direction was derived by the application of the principles recommended by the World Stress Map project (http://www-wsm.physik.uni-karlsruhe.de). Fig. 5.6 should also be compared with Fig. 5.7, which is from Verma *et al.* (1980).

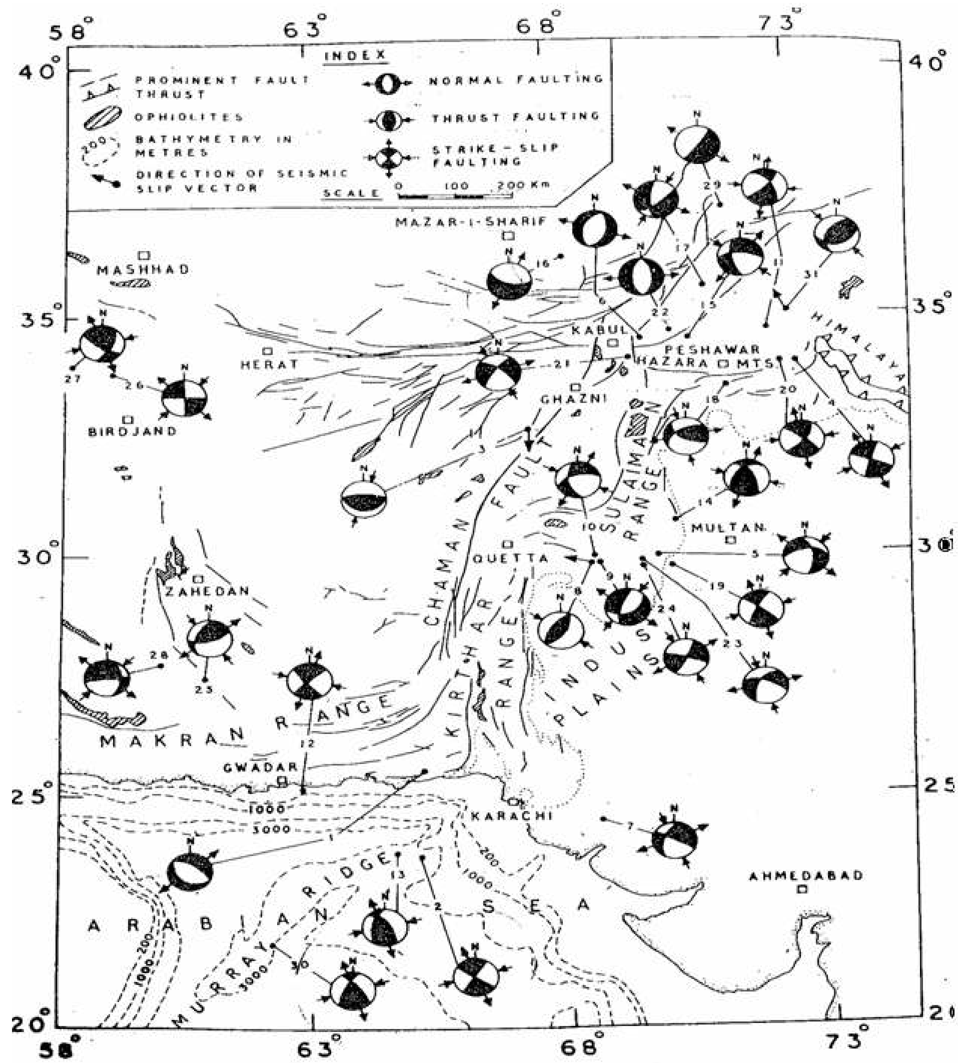


Figure 5.7.Orientation of nodal planes and directions of P and T axes for 31 earthquakes (from Verma *et al.,* 1980).

5.6.1 Source zone stress distributions

In the following we discuss the mode of faulting in some of the more important source zones.

HinduKush and North Afghanistan-Tajikistan border region (Zones 5, 6, 7)

In these zones we find faulting modes ranging from normal faulting in the east to reverse faulting in the west. It also seems that the σ_H direction is subject to a 30 degree rotation from Zone 5 to Zone 6 which is also reflected in a change of faulting mode. Zone 7 is somewhat more difficult to characterize in a clear way. Fig. 3.3 does not provide any help since it does not cover the Hindu Kush region.

The observed prevalent directions of crustal compression surely reflects on the fact that in this corner the major transform faults of Karakoram and Heart and Chaman meet and at the same time the region is pushed from south by the Indian continent.

Kashmir (Zone-1)

The clear NE-SW compression in this zone (about 45 degrees) reflects directly on the continental collision as it is also reflected in the major reverse faults that run perpendicular to the stress direction. It is interesting to compare with Fig. 3.3 where the same picture is seen, however, one may in the Verma et al (1980) paper recognize how the mode of faulting is more inhomogeneous as one translates into the Hazara mountains (western section of Zone 1).

The Baluchistan Arc (Zones 2, 3, 4 and 8)

In perfect agreement with the known regional tectonics we see a 90 degree rotation of the crustal compression from NE-SW in the Kashmir to NW-SE along the Baluchistan Arc. To some extent this is also reflected in Fig. 3.3. This area is the western border of the continent-continent collision and the general stresses are well understood in this tectonic context.

However, along the Baluchistan Arc we observe another interesting feature: While Zones 2, 4 and 8 exhibit a fairy clear NW-SE compression close to 30 degrees, the crustal compression in Zone 3 seem to deviate from the regional trend and show an N-S compression.

It is not accidental that Zone 3 covers the area where the Sulaiman mountain range bends 90 degrees to the NE so that the mountain range runs towards Quetta and the Afghan border. This is also the region of the largest historical earthquakes along the Baluchistan arc.

The Murray Ridge

The earthquake activity off shore Pakistan is generally low, however, since the great 1945 earthquake which caused a devastating tsunami the tectonics of this region is important. It is very interesting to recognize that Verma *et al.* (1980), see Figs. 5.6 and 5.7, could find four focal mechanisms from the region of which three earthquakes indicate NE-SW compression.

6 Ground Motion Models

It is well known from many earlier studies that the uncertainties in the wave attenuation models contribute significantly to the absolute hazard level and to the total uncertainty in the seismic hazard estimates, (e.g. Akkar and Bommer, 2006). The most important factor in this sense is the aleatory uncertainty, since in the hazard computations we integrate directly over the distribution described by the scatter (sigma value) in the ground motion model. The scatter is therefore nearly as important as the mean with respect to contribution to the total hazard.

6.1 General review of models

One complicating factor in the present study is that we need spectral attenuation relations, i.e., spectral relations for a suit of frequencies. Such relations are much fewer than PGA relations, but even for PGA there are few relations for the Himalaya region.

There are spectral relations available for:

- Transcurrent or strike-slip regimes (e.g., Boore *et al.*, 1997), in particular California where strong motion data, including in the near field, are in abundance compared to any other region in the world. Such regions include also important compressional conditions (revealed for example in hidden thrusts), as seen in many of the recent larger earthquakes (such as 1989 Loma Prieta and 1994 Northridge).

- Subduction zones, including Japan, Mexico and Central America (Crouse, 1991; Climent *et al.*, 1994; Dahle *et al.*, 1994; Atkinson and Boore, 1997). Related to this are also relations for back-arc conditions or volcanic chain and shallow crustal events (Schmidt *et al.*, 1997), where there is an important component of compression, but under crustal conditions which are quite different from the Himalayas.
- Extensional regimes, developing global relations based on data from events revealing normal faulting (Spudich *et al.*, 1997). In terms of stress, this is the quite different from what is found in Himalaya, which by the way may not mean that the relations are very different.
- Intraplate regions (e.g., NORSAR and Risk Engineering, 1991; Atkinson and Boore, 1995; Toro *et al.*, 1997), where the conditions are quite different and where relations, because of insufficient empirical data, moreover have to be based more on simulations and theoretical models.
- Compressional tectonics, where little as mentioned is available for the Himalayan region and where the closest we get is the Mediterranean region (Caillot and Bard, 1993; Ambraseys *et al.*, 1996; Ambraseys *et al.*, 2005; Akkar and Bommer, 2007). Tectonic conditions there are admittedly different, but still reasonably close to be good candidates.

The relations discussed above have been studied in detail at NORSAR, finding that there is some times as much difference between relations assumed to cover the same region as there are differences between tectonically different regions. There is usually no such thing as a ‘best relation’.

There are few relations available that have been developed specifically for the Himalayan region or for a region which tectonically is reasonable similar. Notable exceptions here are the PGA relations by Sharma (1998) and Jain *et al.* (2000) together with Khademi et al (2002). These PGA relations are together with the spectral relation of Ambraseys *et al.* (1996) and Ambraseys *et al.* (2005) among the possible relations.

A more recent spectral relation by Sharma and Bungum (2006) has been tested earlier. The testing indicated unreasonable hazard contributions from low and intermediate magnitude earthquakes, and it is not deemed as adequate in the present context.

6.2 Considered models

The following ground motion models have been considered:

- Ambraseys *et al.* (2005), spectral. Based on 595 horizontal records from shallow earthquakes Europe and the Middle East from Mw greater or equal to 5.0 and distance range 0 to 100 km.
- Sharma (1998), PGA only. Based on 41 hard rock records and 25 soil records with distances greater than 50 km. No separation between soil and rock site.
- Jain *et al.* (2000), PGA only. Based on combined SMA and SRR (very simple 3 frequency maximum acceleration measurement device) data. The lowest frequency is 0.4 seconds. Data from magnitude 5.5 to 7.0 and distance range 0 to 322 km.
- Khademi et al (2002), PGA only, Iran. Based on 160 horizontal records in the magnitude range 3.4 to 7.4 in the distance range from 0 to 180 km.
- Akkar and Bommer (2006) which provides spectral ground motion prediction based on 532 strong motion records which largely overlap with the Ambraseys *et al.* (2005) dataset. The disadvantage being that this relation deals with spectral ground velocity rather than with acceleration.

The Khademi relation is based on data from a presumably compressional regime (not specified regions in Iran), but demonstrate unexpected low attenuation. The predicted accelerations from this relation are extremely high at all magnitudes and distances, indicating also a low scaling with increasing magnitude. This calls for caution.

The Sharma (1998), Jain *et al.* (2000) and Sharma and Bungum (2004) relations have the advantage of being developed from Himalayan data, but unfortunately only the last one is a spectral relation. The Jain *et al.* (2000) relation is largely based on data from SRR (Seismic Response Recorder) sensors, which are low cost (low precision) sensors, and sources are not confined to the Himalayan region. The Sharma (1998) relation is largely replaced by the new Sharma and Bungum (2006) relation, which in tests was demonstrated to be inadequate.

This leaves us essentially with the Ambraseys *et al.* (2005) relation. This relation is based on a large and qualitatively secure dataset. Figs. 6.1 and 6.2 shows in this respect a comparison between the two models for magnitudes 7.0 and 5.0 at different frequencies.

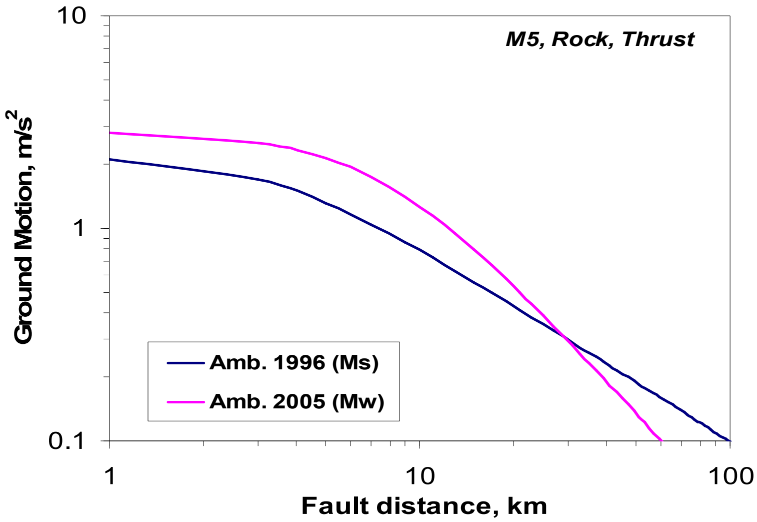


Figure 6.1.Comparison of predicted PGA using the empirical ground motion prediction equations by Ambraseys *et al.* (1996) and Ambraseys *et al.* (2005) for magnitude M 5.0.

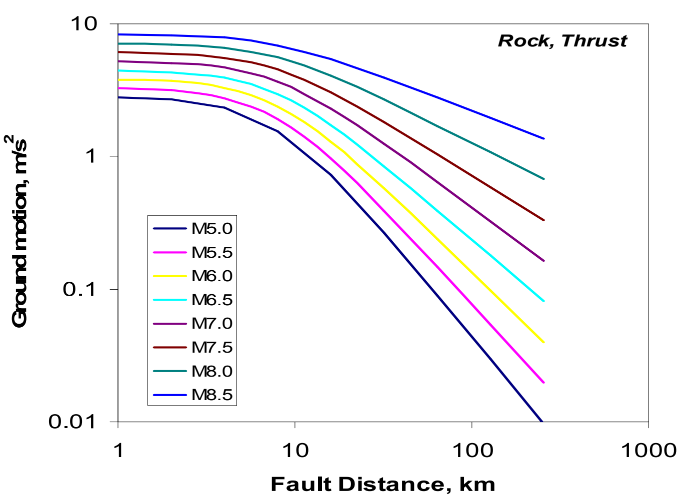


Figure 6.2. PGA predictions for a suite of magnitudes for Ambraseys *et al.* (2005).

The Ambraseys *et al.* (1996) relation was developed for Ms while the Ambraseys *et al.* (2005) was developed for Mw, partly on the same data. Fig. 6.1 compares the two relations for a magnitude 5 event, while Fig. 6.2 shows predicted PGA for a suite of magnitudes. In Fig. 6.3 the predicted spectral acceleration is plotted for two distances and magnitudes.

Ambraseys *et al.* (2005) in particular analyzed the scatter in the data relative to the predictions, and could state that they along with other authors found an increasing scatter with decreasing magnitude as also shown in Fig. 6.4, which also shows that a sigma value around 0.3 is adequate.

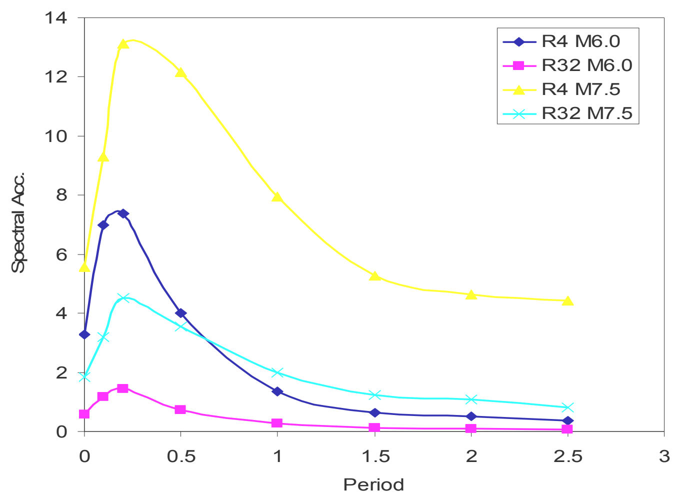


Figure 6.3.Spectral acceleration predictions for two magnitudes (6.0 and 7.5) and two distances (4 and 32 km) from Ambraseys *et al.* (2005).

In conclusion it was decided to use the Ambraseys *et al.* (2005) relation for ground motion modelling in the present study. It is furthermore based on shallow data which we know are the potentially destructive earthquakes. Finally, it is established through a rigorous quality checking that also lends trust to the results.

The σ-values found by Ambraseys for the various magnitudes and frequencies have been applied in the hazard computation model.

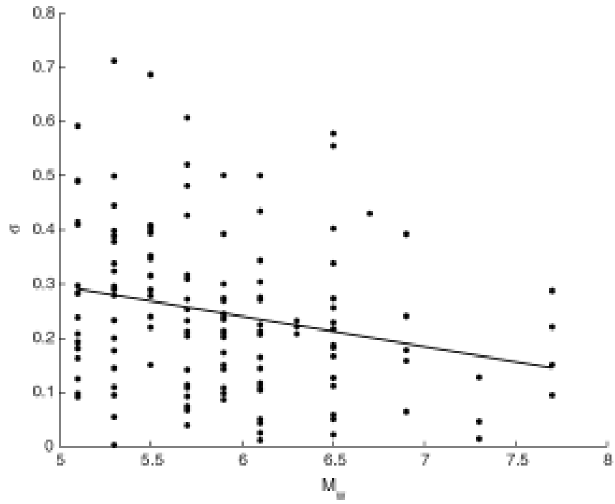


Figure 6.4.Observed dependence of σ on M_w using the binned data for PGA. The fitted line has the equation: $\sigma = 0.5774 - 0.0561 \cdot M_w$ (Ambraseys *et al.,* 2005).

6.2.1 Specifics on the data used by Ambraseys et al. (2005)

The new Ambraseys *et al.* (2005) ground-motion model was as just explained selected for the computation of ground motions, based on more data than what was available for previous similar studies. Also, many of the associated parameters of the strong motion data contained within the data bank were reassessed, leading to an improvement in the reliability of the obtained equations.

The magnitude scale used here is moment magnitude (M_w), defined by Hanks and Kanamori (1977) as:

$$Mw = (2 / 3) \log M_0 - 6$$

where M_0 is the seismic moment in Nm. Only earthquakes with available estimates of M_o were used in this model. The choice of M_W means that only strong motion records from moderate and large earthquakes can be used because Mw is not routinely calculated from smaller earthquakes. Therefore in order to have a good distribution of records at all magnitudes, only records from earthquakes with Mw ≥ 5 were chosen.

In the Ambraseys *et al.* (2005) model, distance to the surface projection of the fault (Joyner and Boore, 1981) d_f (also known as fault distance or Joyner-Boore distance) is used. For earthquakes where the location of the causative fault has not been reported, mainly earthquakes with Mw ≤ 6, epicentral distance d_e was used instead. For small earthquakes d_e and d_f are similar because of small rupture planes of such earthquakes. The distance to the surface projection of the fault is used partly because this has been shown to predict the ground motion quite well and partly because it does not require an estimate of the depth of the earthquake, unlike distance to the rupture or seismogenic (e.g. Campbell and Bozorgnia, 2003). It has also been found (Douglas, 2001) that distance to the rupture does not lead to a reduction in standard deviation associated with ground motion prediction equations.

Records from distances greater than 100 km were excluded for a number of reasons. Firstly, this excludes that are likely to be of low engineering significance due to their large source of site distances. Secondly, it reduces the bias that could be introduced by including records from distance greater than the distance to the first non triggering station. It means that the distribution of records with respect to magnitude and distance is reasonably uniform and reduces the correlation between magnitude and distance. Only earthquakes with published focal mechanism solutions in terms of the trends and plunges of the T, B and P axes have been included.

The method of Frohlich and Apperson (1992) was used to classify earthquakes by style of faulting. In this scheme earthquake with plunges of their T axis greater than 50^o are classified as thrust, those with plunges of their B axis or P axis greater than 60^o are classified as strike-slip or normal and other earthquakes are classified as odd.

In some parts of the world it is a common practice to install strong motion recording instruments in the ground floors or basements of relatively large buildings. There is evidence that such buildings can influence the measure ground motion and therefore such type of data was excluded from analysis. Only records from stations with known site classification in terms of categories proposed by Boore *et al.* (1993) have been used in this model. Therefore four classes were used: very soft soil (L) $V_{s,30} \leq 180$ m/s, soft soil (S) $V_{s,30} \leq 360$ m/s, stiff soil (A) $V_{s,30} \leq 750$ m/s, and rock (R) $V_{s,30} > 750$ m/s.

For only 89 of the stations (out of 338), contributing 161 records (out of 595) measured shear wave velocity profiles existed and therefore the rest of the stations have been classified by using the description of the local site conditions. So the sites with unknown site classifications had to be removed because they could not be handled by the regression method.

All records from instruments that triggered late and hence missed the start of the motion were rejected. The correction technique implemented in the Basic strong motion Accelerogram Processing (BAP) software (Converse and Brady, 1992) was used for the correction of all time histories used in the preparation of attenuation model. This method consists of a correction for the instrument response and high-cut filtering, with a cosine transition from the role-off frequency to cut-off frequency, followed by low-cut bidirectional Butterworth filtering of the acceleration after padding the time histories with zeros. The main problem with filtering strong motion records is the selection of appropriate cut-off frequency for the high-cut and low-cut frequencies. For this a method based on the estimated signal-to-noise ratio of each record was used. After choosing the appropriate cut-off frequency for each component (two horizontal and one vertical) of strong motion record, a single cut-off frequency was chosen for all three components for consistency. The high frequency filtering was accomplished using the commonly chosen roll-off frequency of 23 Hz and a cut-off of 100 Hz for records from digital instruments (e.g. Converse and Brady, 1992). Since most digital instruments have natural frequencies of about 50 Hz and some of those with lower natural frequencies correct for the instrument response automatically, the affect of instrument correction is not large and therefore the requirement to apply a high-cut filter is less than for records from analogue instruments.

A number of strong motion records used by Ambraseys et. al. (1996) for spectral acceleration up to 2s does not seem to be high enough equality to yield accurate SA estimates. Therefore, it is likely that long period (greater than 1s) estimates from the equations of Ambraseys *et al.* (1996) may be affected by noise. Only records within the pass band of the filters (i.e. 1.25 f_l to f_n, where f_l is the low cut-off frequency and f_n is the high roll-off frequency) used were included in the regression analysis at period of interest. For example, a record with low cut-off frequency, f_l of 1 Hz is not used for frequencies less than 1.25 Hz, i.e. for periods greater than 0.8s.

Consequently, the number of records used for the derivation of equations decreases as the period increases. In the Ambraseys *et al.* (2005) model, equations are derived for the prediction of the larger horizontal component of ground motion, also so that the same set of records can be used for deriving mutually consistent equations for the estimation of vertical ground motion. Only records with a vertical component were used. In total, 595 strong motion records were selected. These records came from 135 earthquakes and 338 different stations. The relatively strict criteria were adopted and numbers of selected records (595) were about 50 % more than used by Ambraseys *et al.* (1996). Although the total number of recordings from earthquakes with magnitude greater than 4, have been more than double in the last ten years (Ambraseys et. al., 2005).

The algorithm for the one-stage maximum likelihood method proposed by Joyner and Boore (1993) was used by Ambraseys to derive the equations because it accounts for the correlation between ground motions from the same earthquake. The two stage maximum likelihood method was not used by Ambraseys because it underestimates 'σ' for sets with many singly recorded earthquakes (Spudich *et al.*, 1999). This set was 39 single recorded earthquakes out of 135.

The dependence of coefficient of variation on magnitude was investigated. The variation coefficient σ was plotted against Mw (Fig. 6.4). The fitted line coefficients for PGA and for almost all short periods show that there is a decrease in error with increasing Mw. Therefore the lack of magnitude dependence in σ for longer periods may be due to this and not a characteristic of earthquakes.

The evidence was used in Ambraseys model that decay of ground motions is dependent on the magnitude. Ground motions from large earthquakes decay slower than from small earthquakes and the decay rate of small earthquakes is faster than the commonly used (e.g. Douglas, 2003). To investigate the dependence of decays rate on magnitude, records from ten best recorded earthquakes within the selected set, were used. The PGA data from each of these earthquakes were fitted individually assuming a functional form:

$$\log y = a_1 + a_2 \cdot \log(\sqrt{d^2 + a_3^2})$$

i.e. geometric decay with a far-field decay rate of a_2.

Finally, Ambraseys *et al.* (2005) derived the equations for the estimation of Peak Ground Acceleration and spectral acceleration for 5 % critical damping ratio and for 61 periods between 0.05 s (20 Hz) and 2.5 s (0.4 Hz) using Caltech spacing (Brady *et al.,* 1973).

6.2.2 *Adapting of the selected relation to deep sources*

The earthquakes of the Hindu Kush region occur between depths of 0 to 300 km. This faces us with a problem since the Ambraseys relation is applicable only for shallow earthquakes (the relation was developed from a dataset where the average focal depth was 10.76 km). We can therefore not apply the Ambraseys relation for the deep earthquakes. To solve this problem one option is to adapt the Ambraseys model to deep focus earthquakes.

In Fig. 5.3 the earthquake depth distribution is plotted for all 19 seismic zones, from which it is seen that around 50% of the total earthquakes occurred within a depth range of 0 to 30 km. These earthquakes are upper crust earthquakes for which the Ambraseys relation is applicable (the average focal depth for these earthquakes is 15 km which is relatively close to 10.76 km).

Around 23% of the earthquakes occurred between 30 to 120 km, and the remaining 27% occurred between the depths ranging from 120 to 300 km. The earthquakes were categorised into three classes as described above, and the average depth for the deeper earthquakes were estimated to be 75 and 210 km. The depth distribution mentioned in Fig. 5.3 was used in the hazard computations.

The problem with deeper earthquakes could be met by applying another attenuation relation for the deep zones. The disadvantage of such an approach is that other relations would not necessarily comply with Ambraseys with respect to the spectral ordinates. The advantage of adapting the Ambraseys relations to deep focus earthquakes is that it brings homogeneity to the computing procedure. The original Ambraseys relation is in the following form:

$$\log y = a_1 + a_2 \cdot M_w + (a_3 + a_4 \cdot M_w) \cdot \log\sqrt{d^2 + a_5^2} + a_6 \cdot S_S + a_7 \cdot S_A + a_8 \cdot F_N + a_9 \cdot F_T + a_{10} \cdot F_0$$

In the third term the distance (Joyner-Boore) is given together with a regression parameter a_5. While a_5 is a regression parameter it can also be interpreted as a proxy for focal depth. In the need of a focal depth proxy we have established a_{5proxy} parameters for 75 and 210 km depth using the following relation:

$$a_{5proxy} = (a_5 / 10.76) \cdot 75$$

where 75 is the average depth assigned to the intermediate depth earthquakes and 10.76 is the depth of the earthquakes in the Ambraseys database. For the deep earthquakes the quantity a_{5proxy} is:

$$a_{5\,proxy} = (a_5 / 10.76) \cdot 210$$

where 210 is the average depth assigned to the deep earthquakes. Using the above a_{5proxy} values we established attenuation relations that were used for the deeper activity in the HinduKush region (Zone 5, 6 and 7 in Fig. 5.3)

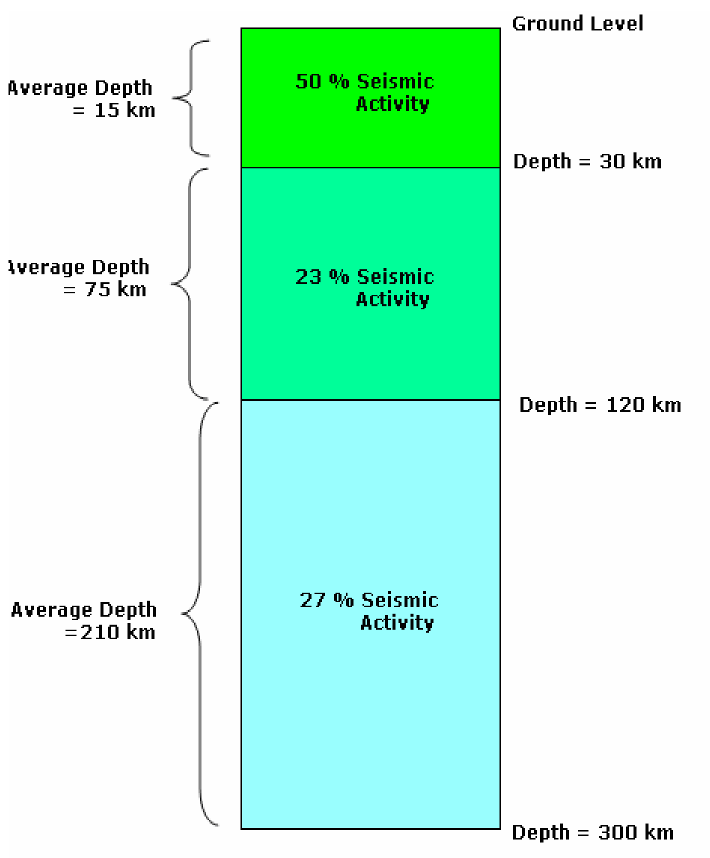


Figure 6.5.Representation of the seismic activity with respect to depth. The hypocentres of almost 50% of earthquakes in the Hindu Kush region and the northern areas of Pakistan lie within a range of 0 to 30 km.

6.2.3 Dependence on the scatter of magnitude

Dependency on the coefficient of variation (α) of magnitude was investigated for better results of PGA. Table 6.1 shows the values of sigma which were calculated from the relations given by Ambraseys *et al.* (2005) for different periods 0.05 s, 0.1 s, 0.2 s and 0.5 s, for periods 1.0 s, 1.5 s, 2.0 s and 2.5 s the sigma values did not change and it remain the same for all magnitudes (4.5 to 8.5). Fig. 6.6 shows that as the magnitude increases the variation becomes less and the maximum variation observed at lower magnitude. Therefore, the lack of magnitude dependence in 'α' for longer periods may be due to this and not a characteristic of the earthquakes. 'α_1' is the derived coefficient for the estimation of horizontal peak ground acceleration and response spectral acceleration for 5% damping.

Table 6.1. Derived coefficients for the estimation peak ground acceleration and response spectral acceleration for 5% damping.

Magnitude Mw	Standard deviation σ			
	T = 0.05 s	T = 0.10 s	T = 0.20 s	T = 0.50 s
4.5	0.92	0.94	0.90	1.02
5.0	0.84	0.85	0.88	0.93
5.5	0.75	0.77	0.79	0.84
6.0	0.67	0.68	0.69	0.75
6.5	0.59	0.59	0.61	0.65
7.0	0.52	0.51	0.52	0.56
7.5	0.44	0.42	0.42	0.47
8.0	0.36	0.34	0.33	0.38
8.5	0.28	0.25	0.24	0.29
Σ_1	$0.708 - 0.069 \cdot Mw$	$0.747 - 0.075 \cdot Mw$	$0.784 - 0.080 \cdot Mw$	$0.798 - 0.079 \cdot Mw$

$$\sigma = \sigma_1 \cdot \ln(10)$$

σ_1 is fixed for 1.0 s 1.5 s, 2.0 s and 2.5 s. So the standard deviation σ for such frequencies is given as:

Magnitude Mw	Standard deviation σ			
	T = 1.00 s	T = 1.50 s	T = 2.00 s	T = 2.50 s
all	0.70	0.672	0.65	0.66

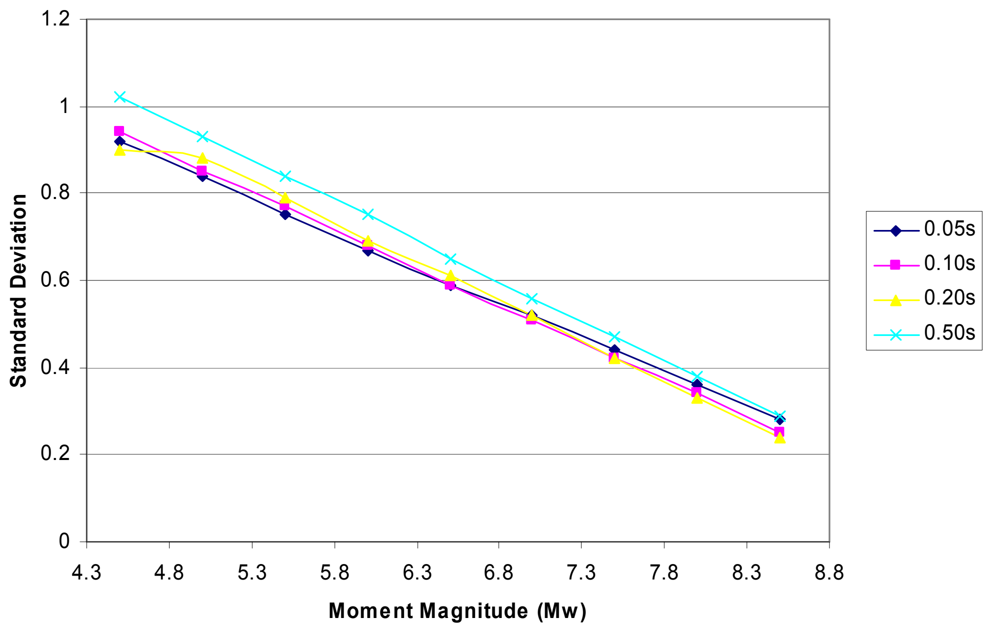


Figure 6.6.Observed dependence of σ (standard deviation) on Mw using the data for PGA values.

7 Seismic Analysis of the Study Area

In this section we establish the basic recurrence parameters for each of the seismic zones, which is the backbone of the source model used in the seismic hazard calculations. Firstly, however, the question of catalogue completeness should be considered.

7.1 Catalogue completeness

A balanced quantification of seismicity of each zone ideally requires a very good catalogue. One important point here is catalogue completeness, since this is important for the calculation of 'a' and b-values for each seismic zone. To this end we have looked in particular at the ISC, PDE and PMD data bases, as shown in Fig. 7.1. We found that the PDE (USGS) catalogue was reasonably complete within the period 1973 to 2007 down to a magnitude of at least 4.5, which is below the lower-bound magnitude of 4.8 used in the hazard calculations. The PMD, PDE and ISC catalogues are appreciably well documented with historical seismic data.

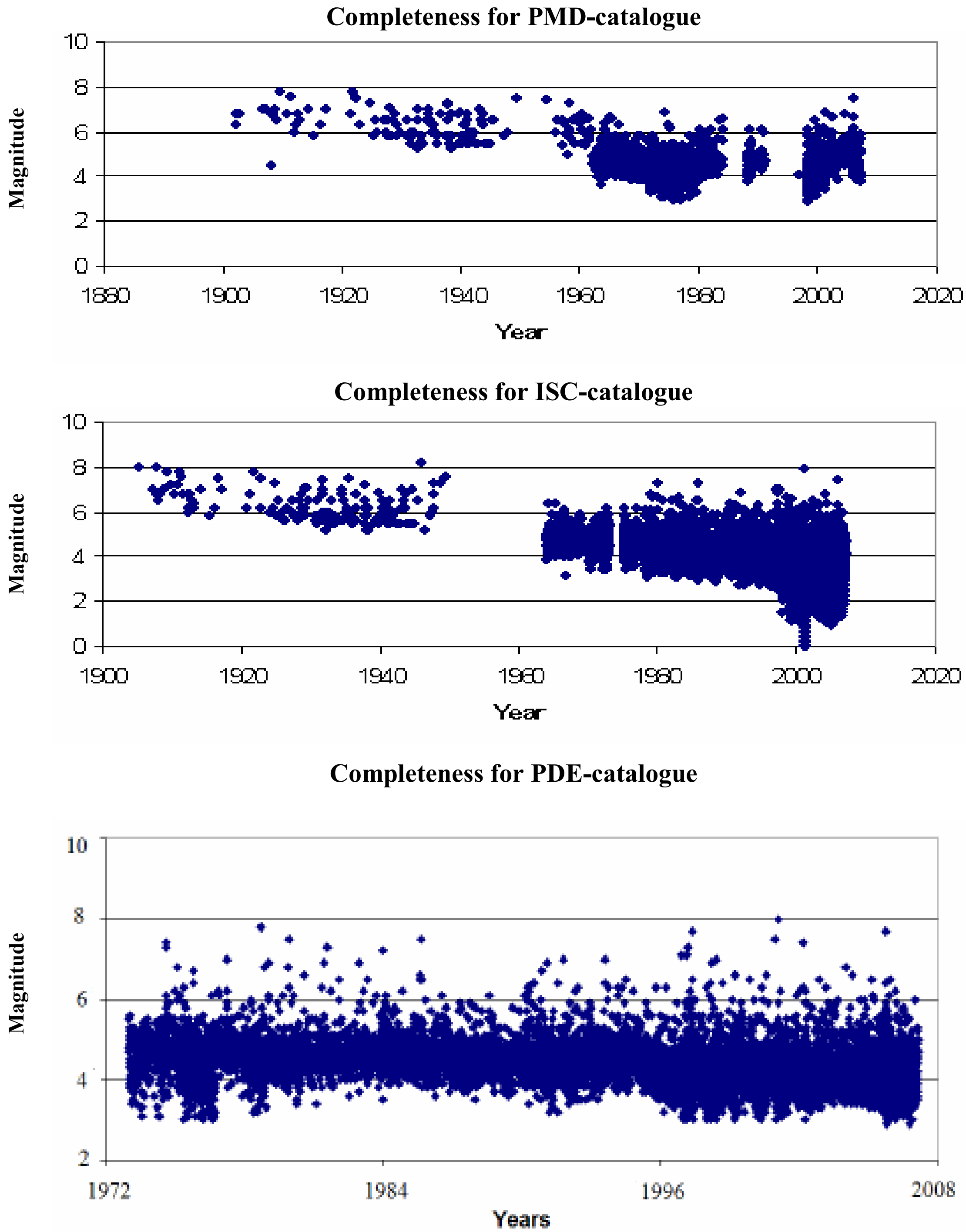


Figure 7.1.The comparison of completeness of the three earthquake catalogues (PMD, PDE and ISC).

7.2 Quantification of earthquake recurrence

The combination of PMD and international data bases results in a catalogue with different kinds of magnitudes, essentially body wave magnitude (mb) for the smaller events and surface wave (M_S) and moment (M_W) magnitudes for the larger events. Since we need to base the hazard estimation on Mw, partly because that is what the ground-notion relations require, this should ideally call for a conversion between the different magnitudes. So we need to convert the different catalogue's magnitudes to moment magnitude (Mw). The PMD catalogue has body-wave magnitudes only and by using the regression relation all the body magnitudes of PMD were converted into moment magnitudes. The Ambraseys *et al.* (2005) model, which is used for the ground motion estimation, works only on Mw magnitudes. The necessary conversion relations were developed in this study as documented in Section 5.3.

7.2.1 Recurrence parameters

The basic input for the seismic hazard analysis is the source model, expressed through the Gutenberg-Richter activity parameters 'a' and 'b' for each of the seismic zones. Using the established catalogue these have been carefully evaluated through regression analyses, also for a Zone 0 that comprises all of the other zones. We used the 19 seismic zones as defined above, a division that was based on the complete seismicity analysis of the whole area. Zones 1, 2, 3 and 7 were the most critical ones in terms of influence on the hazard assessment.

The recurrence calculations are shown in Fig. 7.2 for the PDE catalogue for each of the 19 zones, while the entire region (Zone 0) is shown in Fig. 7.3. In similar ways the results for the ISC catalogue are shown in Figs. 7.4 and 7.5, while the PMD catalogue is shown in Figs. 7.6 and 7.7.

Table 7.1 summarizes the b-values calculated from three considered catalogues, with an average of 0.95 for b and 6.15 for normalised a-values. These values are further used for the modelling of the seismicity. The average b-value (0.95) applies to the whole study area. The b-values as derived from the ISC and PDE catalogues are reasonably close to each other, as seen in Fig. 7.8. The 'a'-values are calculated by using the Gutenberg-Richter relation from the PDE catalogue, due to its completeness. The historical earthquakes were dealt with separately.

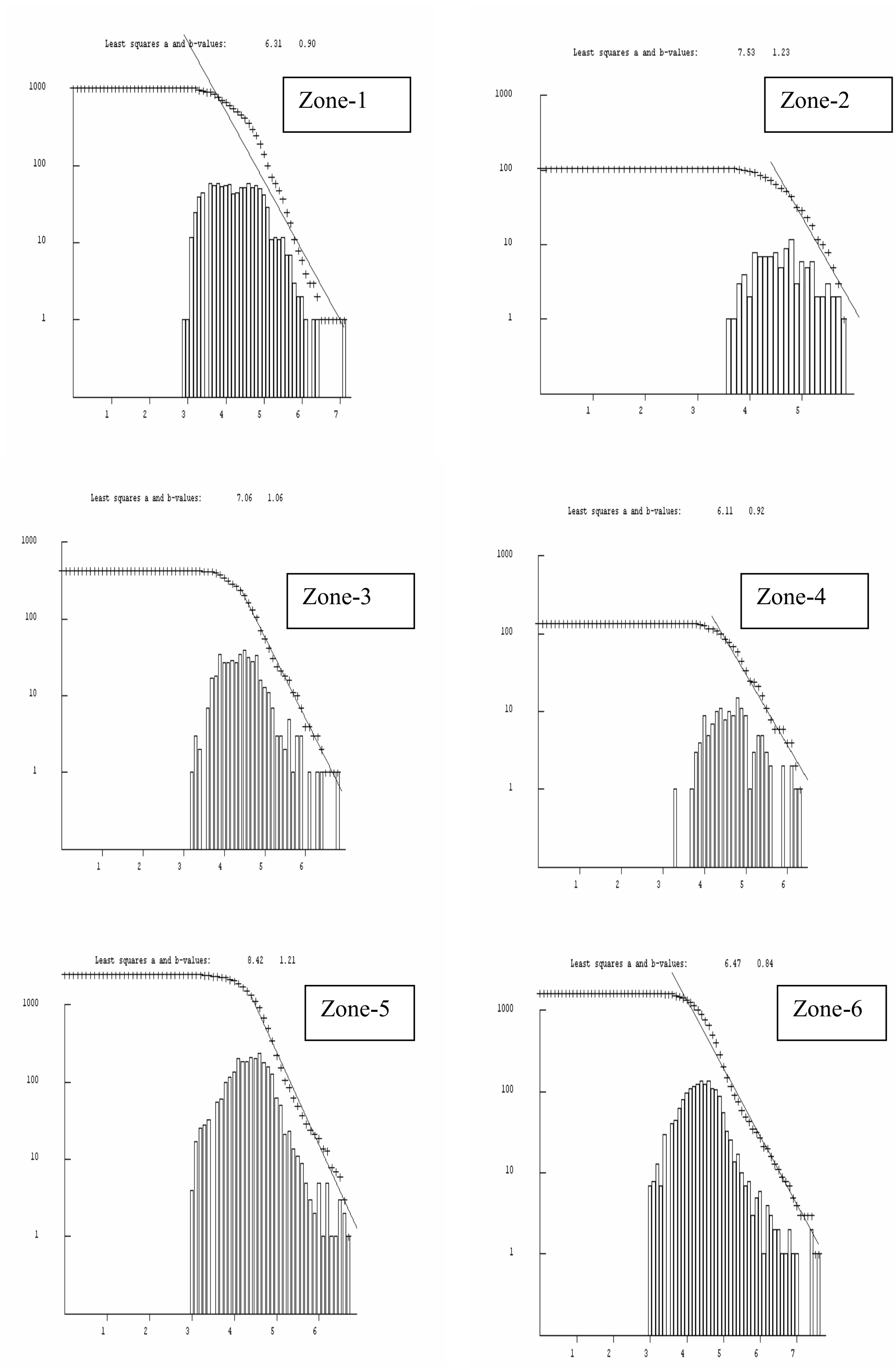


Figure 7.2. b-values from PDE catalogue for the 19 zones of the study region.

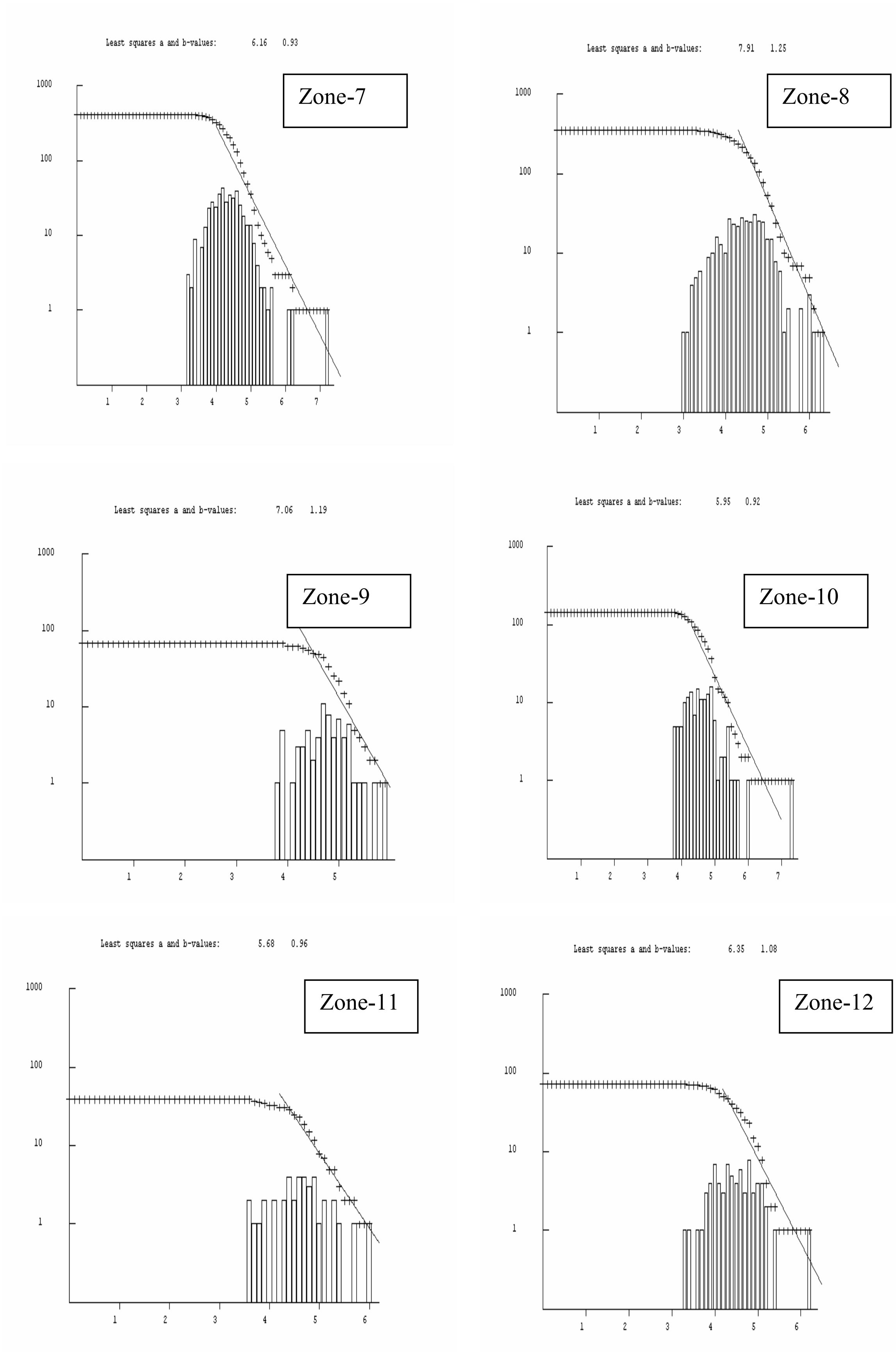


Figure 7.2. (Cont). b-values from PDE catalogue for the 19 zones of the study region.

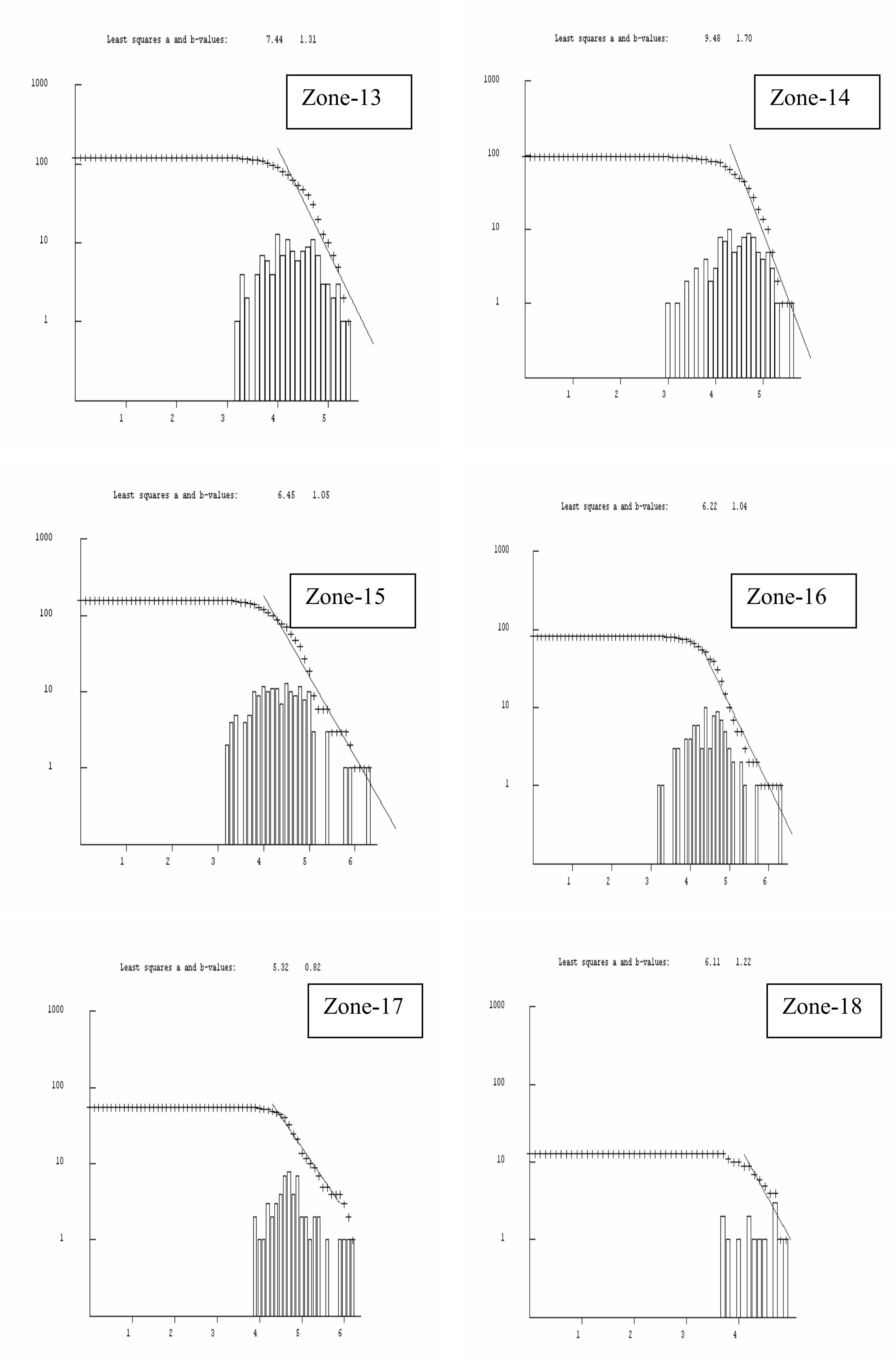


Figure 7.2. (Cont). b-values from PDE catalogue for the 19 zones of the study region.

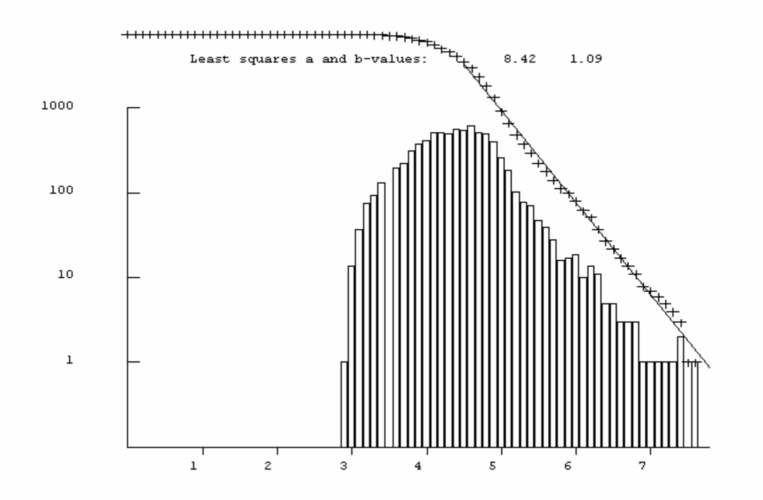


Figure 7.3. b-value for the whole PDE catalogue.

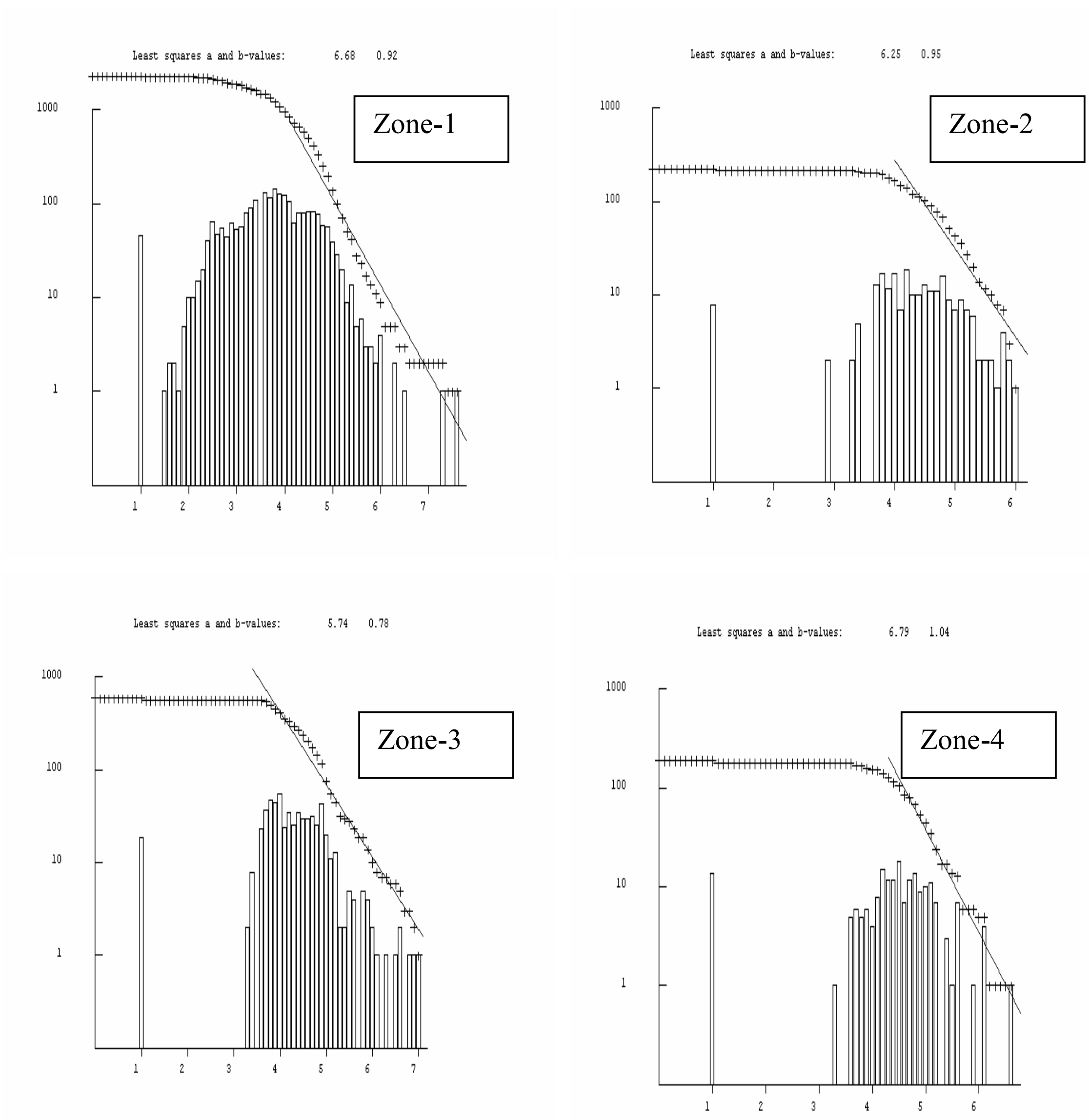


Figure 7.4 (cont). b-values from ISC catalogue for the 19 zones of the study region

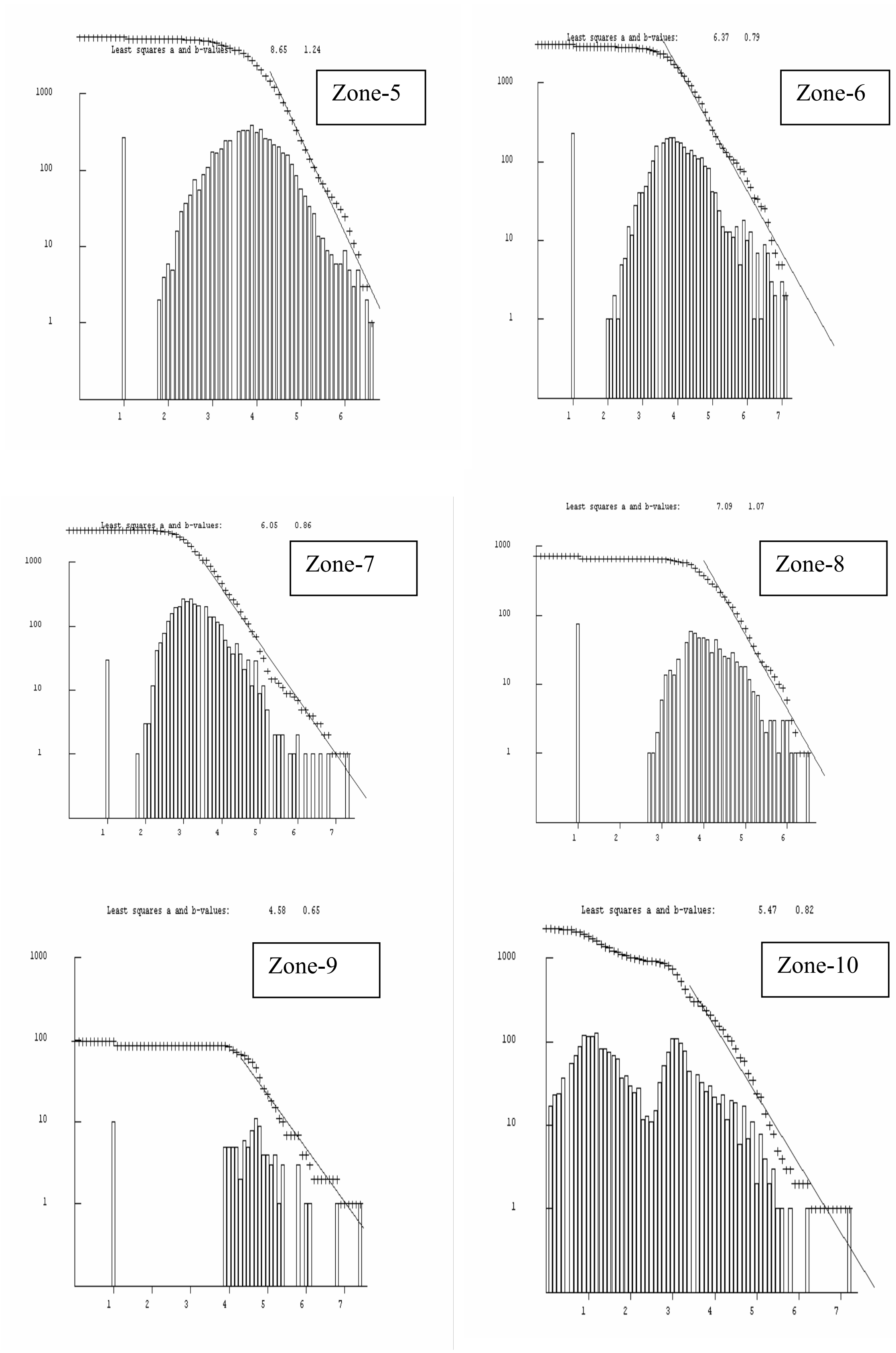


Figure 7.4 (cont). b-values from ISC catalogue for the 19 zones of the study region

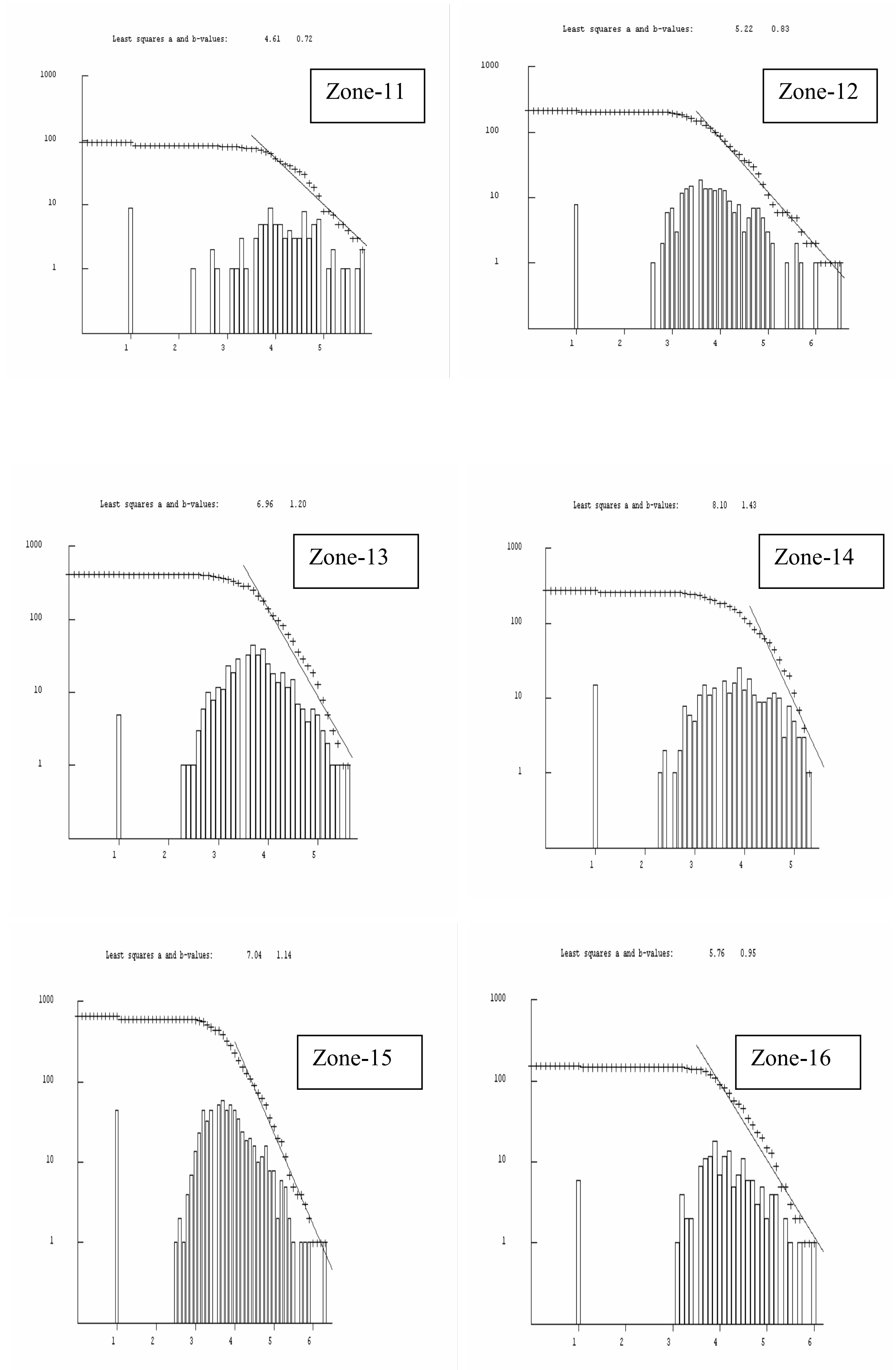


Figure 7.4 (cont). b-values from ISC catalogue for the 19 zones of the study region

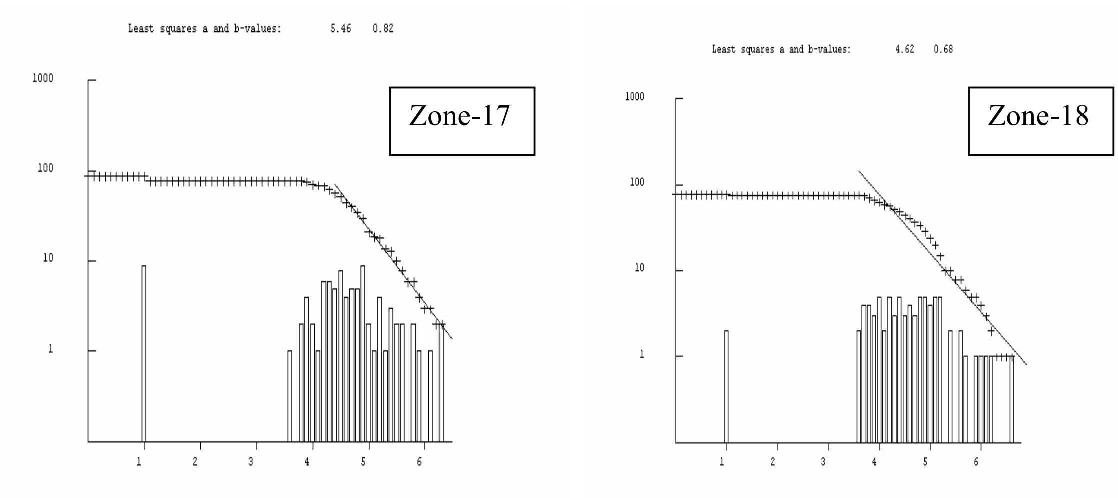


Figure 7.4 (cont). b-values from ISC catalogue for the 19 zones of the study region

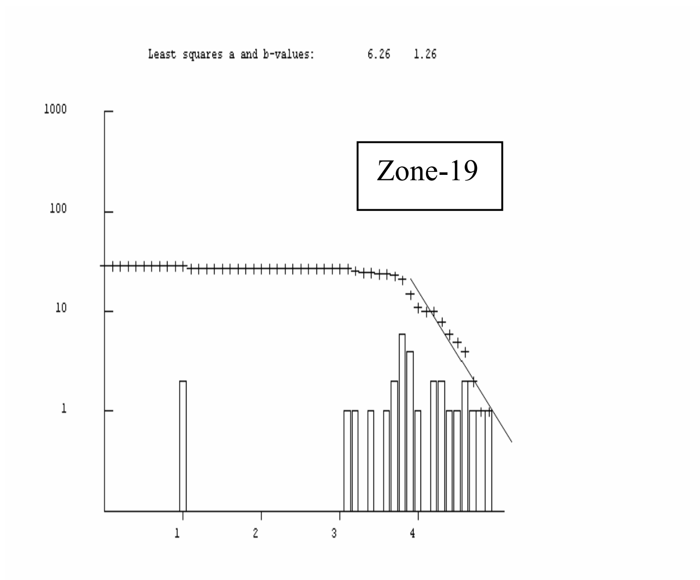


Figure 7.4 (cont). b-values from ISC catalogue for the 19 zones of the study region

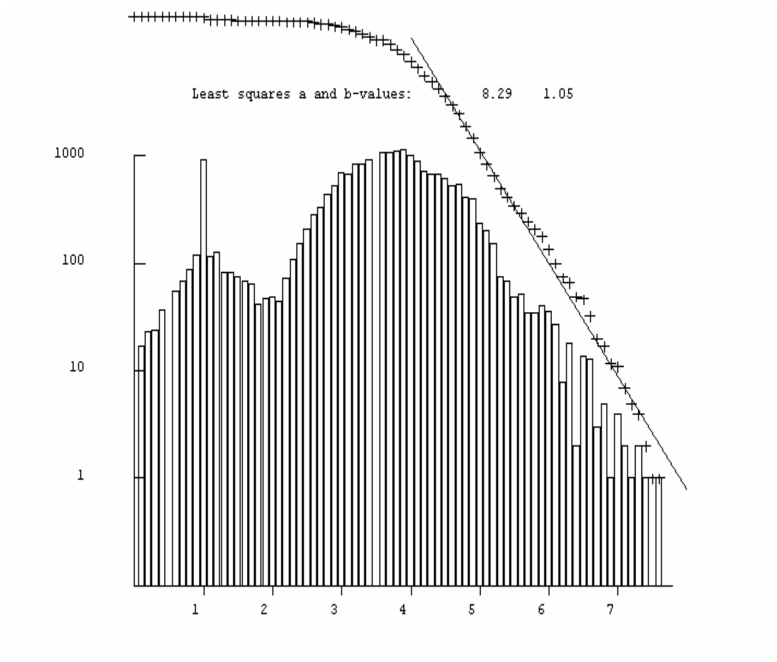


Figure 7.5. b-value for the whole catalogue ISC.

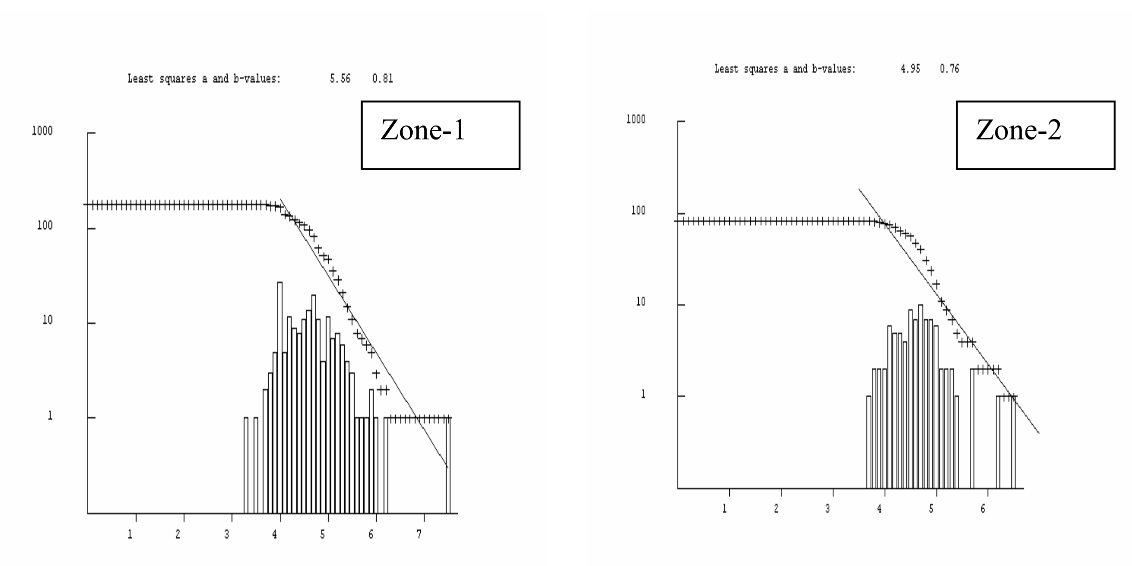


Figure 7.6. b-values from PMD catalogue for the 19 zones of the study region.

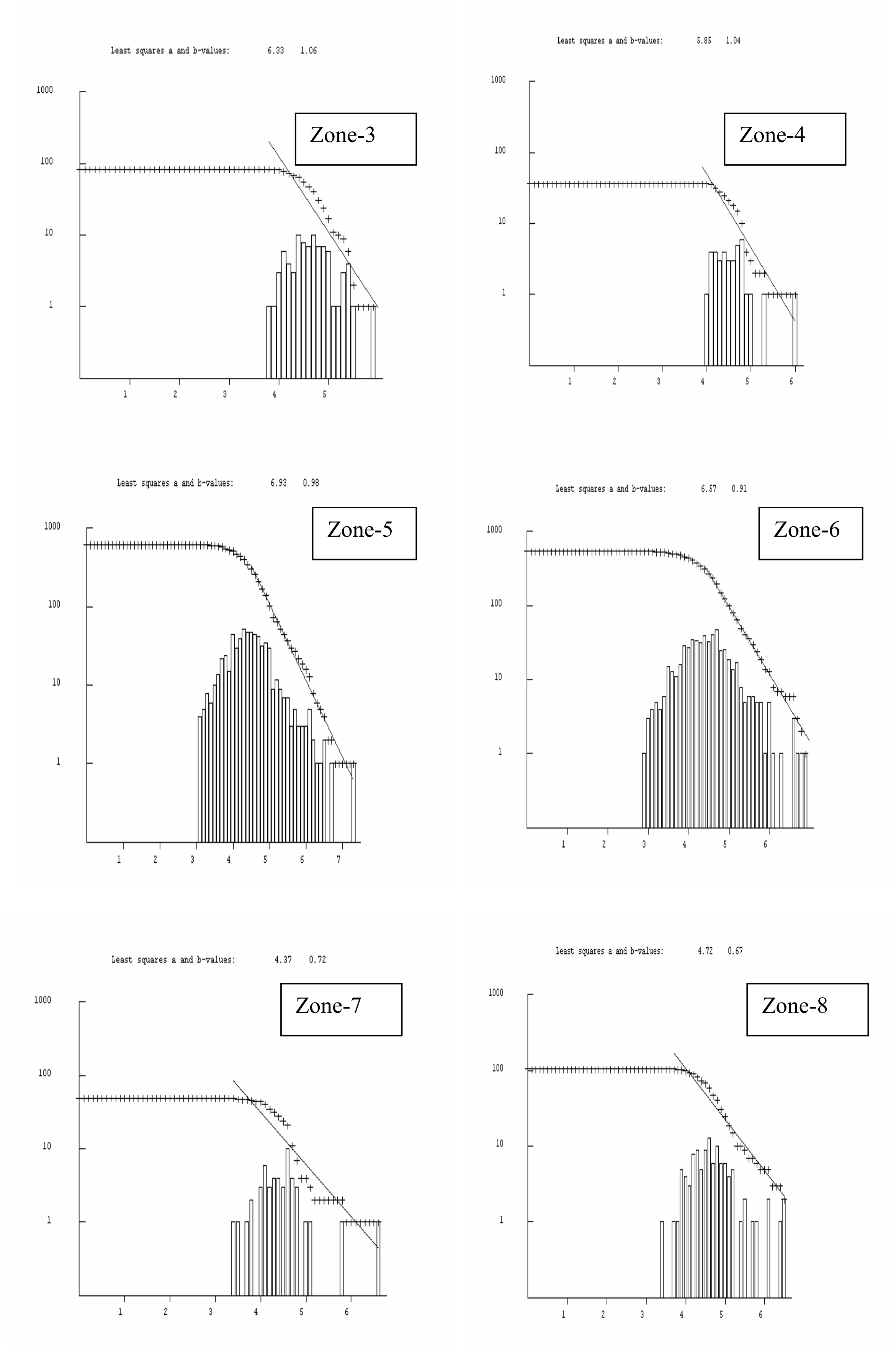


Figure 7.6 (cont.). b-values from PMD catalogue for the 19 zones of the study

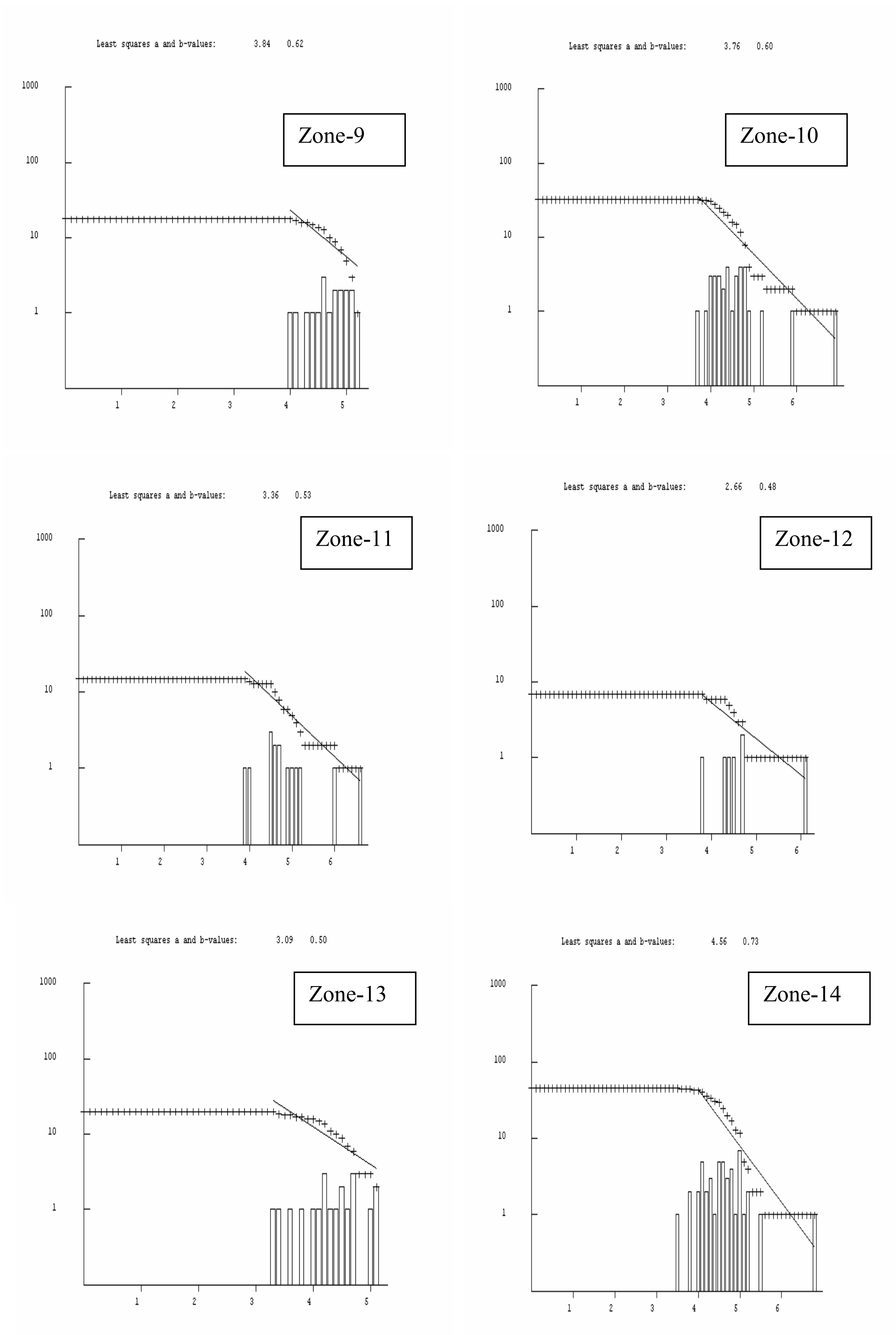


Figure 7.6 (cont.). b-values from PMD catalogue for the 19 zones of the study

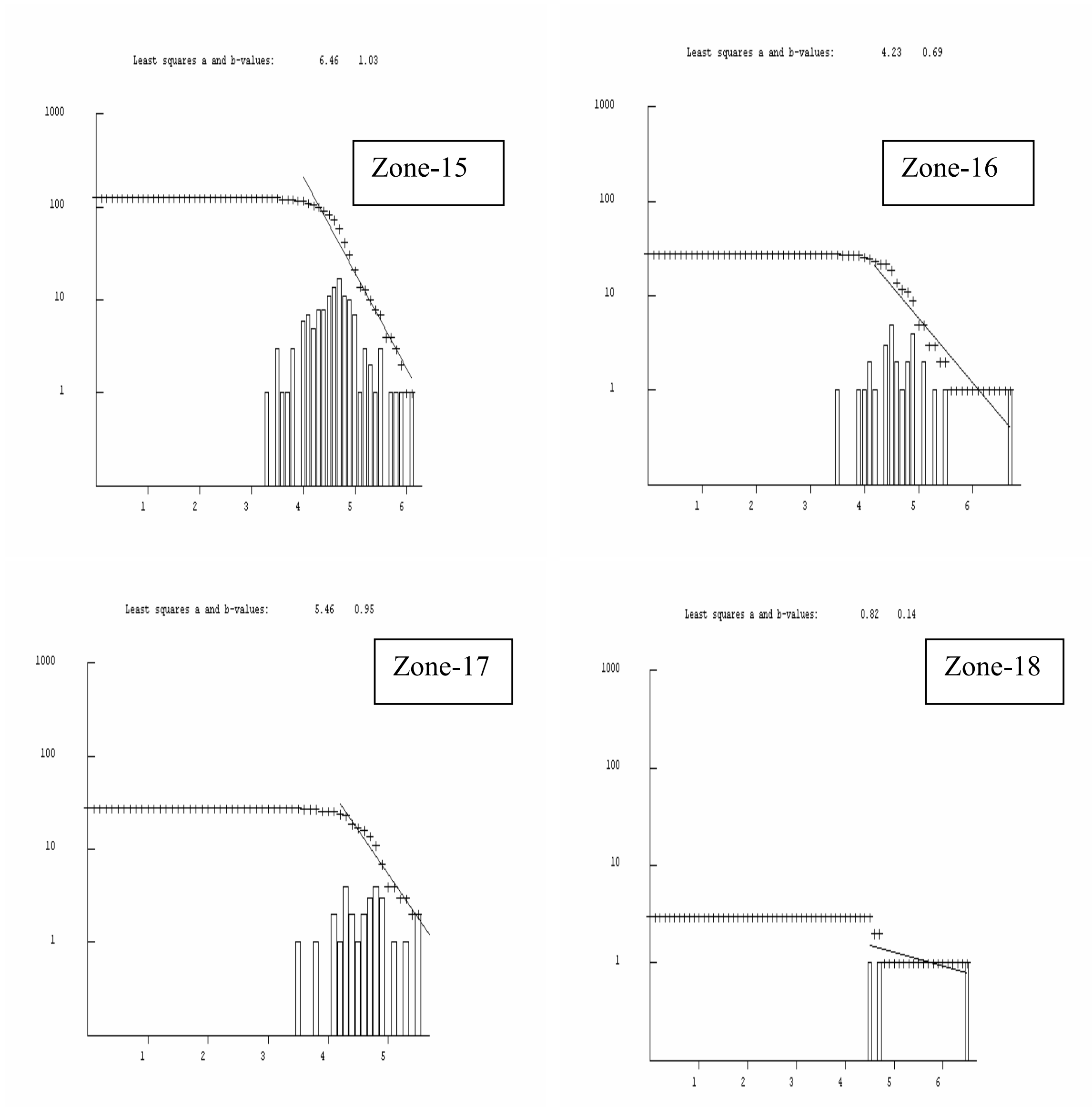


Figure 7.6 (cont.). b-values from PMD catalogue for the 19 zones of the study region.

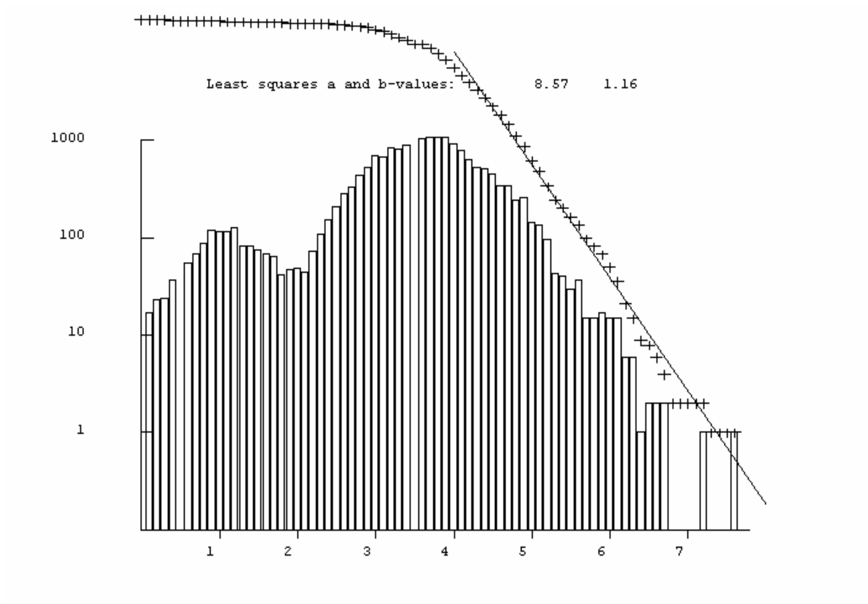


Figure 7.7. b-value for the whole catalogue PMD.

Table 7.1.Summary of a- and b-values. Average normalized a-value for all zones (Zone 0) is 6.15 when the b-value is fixed to 0.95. This corresponds to an average return period of about 1 year for M≥6.5 for the larger area.

Zone	b value for ISC	b value for PMD	b value for PDE	b value Average	a-value from PDE with fixed b-value=0.95 (normalized)
1	0.92 (N=2308)	0.81 (N=181)	0.90 (N=1015)	0.88	6.66 (5.13)
2	0.95 (N=225)	0.76 (N=84)	1.23 (N=106)	0.98	6.07 (4.54)
3	0.78 (N=594)	1.06 (N=470)	1.06 (N=432)	0.97	6.45 (4.92)
4	1.04 (N=193)	1.04 (N=37)	0.92 (N=138)	1.00	6.23 (4.70)
5	1.24 (N=5559)	0.93 (N=627)	1.21 (N=2490)	1.13	7.03 (5.50)
6	0.79 (N=3118)	0.91 (N=545)	0.84 (N=1653)	0.85	7.17 (5.64)
7	0.86 (N=3210)	0.72 (N=49)	0.93 (N=416)	0.84	6.29 (4.76)
8	1.07 (N=738)	0.67 (N=40)	1.25 (N=362)	1.00	6.34 (4.81)
9	0.65 (N=97)	0.62 (N=18)	1.19 (N=69)	0.82	5.86 (4.33)
10	0.82 (N=2298)	0.60 (N=33)	0.92 (N=145)	0.78	6.20 (4.67)
11	0.72 (N=94)	0.53 (N=15)	0.96 (N=39)	0.74	5.62 (4.09)
12	0.82 (N=216)	0.48 (N=7)	1.08 (N=73)	0.79	5.65 (4.12)
13	1.20 (N=418)	0.50 (N=20)	1.31 (N=121)	1.00	5.71 (4.18)
14	1.43 (N=277)	0.73 (N=46)	1.70 (N=96)	1.29	5.74 (4.21)
15	1.14 (N=661)	1.03 (N=127)	1.05 (N=161)	1.07	5.41 (3.88)
16	0.95 (N=156)	0.69 (N=28)	1.04 (N=83)	0.89	5.75 (4.22)
17	0.82 (N=88)	0.95 (N=28)	0.82 (N=56)	0.86	6.00 (4.47)
18	0.68 (N=79)	0.14 (N=3)	1.22 (N=13)	0.95	6.18 (4.65)
19	1.26 (N=29)	0.0 (N=1)	0.0 (N=0)	1.26	4.85 (3.32)
Total average				0.95	6.15 (normalized)

The b-values from the three catalogues are compared in Fig. 7.8, showing (as expected) that seismic data bases of ISC and PDE are reasonably similar, but on the other hand also that the PMD data base is not comparable with ISC and PDE for the seismological data recorded for zones 11 to 19.

The maximum magnitudes (M_{max}) are also essential for the hazard level, so these were determined after the careful analysis of the seismicity catalogues in combination with an analysis of the seismotectonic setting of Pakistan and surrounding areas.

Table 7.2. Seismicity model of the study area.

Zone	λ E/Q per year	Expected value of β	Coefficient of β	Expected value of Max. Magnitude	S.D of Max Magnitude.	Max observed Magnitude	Threshold Magnitude
1	3.71	2.19	0.2	8.0	0.5	7.6	4.8
2	0.95	2.19	0.4	7.0	0.5	6.0	4.8
3	2.3	2.19	0.4	7.8	0.5	7.0	4.8
4	1.38	2.19	0.4	7.2	0.5	6.6	4.8
5	1.84	2.19	0.4	7.5	0.5	6.6	5.2
6	2.5	2.19	0.4	7.8	0.5	7.1	5.2
7	0.33	2.19	0.4	7.8	0.5	7.3	5.2
8	1.8	2.19	0.4	7.5	0.5	6.5	4.8
9	0.58	2.19	0.4	8.2	0.5	7.5	4.8
10	1.28	2.19	0.4	7.8	0.5	7.2	4.8
11	0.33	2.19	0.4	6.8	0.5	5.8	4.8
12	0.36	2.19	0.4	7.5	0.5	6.5	4.8
13	0.42	2.19	0.4	7.0	0.5	5.6	4.8
14	0.45	2.19	0.4	6.8	0.5	5.3	4.8
15	0.21	2.19	0.4	7.0	0.5	6.3	4.8
16	0.46	2.19	0.4	7.0	0.5	6.0	4.8
17	0.81	2.19	0.4	7.0	0.5	6.3	4.8
18	1.23	2.19	0.4	7.0	0.5	6.6	4.8
19	0.06	2.19	0.4	6.8	0.5	4.9	4.8
20	0.83	2.19	0.4	7.5	0.5	6.6	5.2
21	1.15	2.19	0.4	7.5	0.5	7.1	5.2
22	0.15	2.19	0.4	7.5	0.5	7.3	5.2
23	0.97	2.19	0.4	7.5	0.5	6.6	5.2
24	1.35	2.19	0.4	7.5	0.5	7.1	5.2
25	0.17	2.19	0.4	7.5	0.5	7.3	5.2

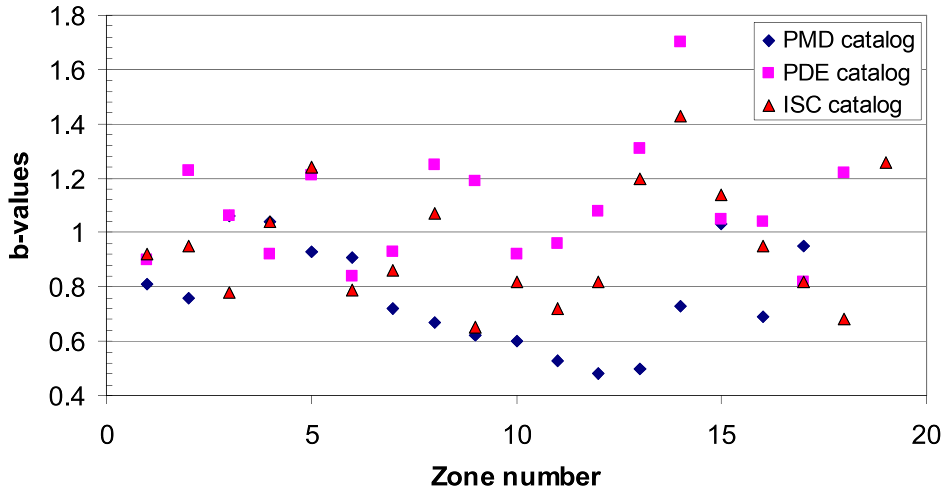


Figure 7.8. Comparison of b-values from catalogues: ISC, PMD and PDE.

7.2.2 Additional parameters for hazard calculations

Total Number of Spectral Ordinates	= 8
Actual Spectral Ordinate	= 1
Structural Period of Actual Spectral Ordinates	= 0.025s = 0.1s = 0.2s = 0.5s = 1.0s = 1.5s = 2.0s = 2.5s
Lower Limit of Intensity Level	= 0.001
Upper Limit of Intensity Level	= 12
Unit for the Calculation of Ground Acceleration	= m/s^2
Number of Levels of Intensity for which Seismic Hazard was Computed	= 12

<u>Control Parameters</u>

Maximum distance	= 300 km
Minimum Triangle Size	= 11 km
Minimum Distance / Triangle Size Ratio	= 3

<u>Return Period</u>

First Return Period	= 50 Years
Second Return Period	= 100 Years
Third Return Period	= 200 Years
Fourth Return Period	= 500 Years
Fifth Return Period	= 1000 Years

8 Seismic Hazard Results

The methodology for the earthquake hazard estimation as conducted in this study is outlined in detail in Section 2. The most useful way of presenting the result are in terms of hazard and intensity maps for different return periods, i.e. for 50, 100 and 500 years, relating estimated ground motion to annual exceedance probabilities which are the inverse of return periods in years.

The results are presented in terms of peak ground acceleration (PGA) and equal probability spectra. All results were computed by using Ambraseys *et al.* (2005) ground-motion model, as a basis and CRISIS 2003-CL, ver, 3.0.2 (Ordaz *et al.*, 2003). All ground motions are computed for hard rocks. For any given site the local soil condition (type and thickness) will modify the ground motions predicted herein.

Hazard curves in terms of PGA values are shown below in Figs. 8.1 to 8.4, for return periods of 50, 100 and 500 years, respectively. The hazard due to tsunami in the Arabian sea, is not related to the ground shaking hazard as shown in the rest of the hazard map shown in fig 8.4. The contours patterns are consistent with the geological and seismotectonic characteristics of the study region. The contours passing through the Kashmir and Northern areas are parallel to the geological structure. Similarly, the contours in the southern Pakistan are parallel to the Suleiman and Kirthur ranges, decreasing with distance from these structures. Thus these maps indicate that the Kashmir, Hazara and Quetta regions have a relatively high seismic potential. A high hazard level in the north-west, north and north-east and south-west of Pakistan reflects of course the fact that many significant earthquakes have taken place there earlier, therefore more damaging earthquakes should also be expected in these regions.

In general, the highest seismic hazard values in Pakistan and surrounding areas are found near the main plate boundaries.

Table 8.1 shows the peak ground acceleration values in m/s^2 for different annual exceedance levels and for different cities, as shown also graphically in Fig. 8.5. Table 8.2 shows the ground acceleration in m/s^2 for different cities of Pakistan on different frequencies for the annual exceedance rate of 0.002, which in this case is shown graphically in Fig. 8.6.

Table 8.1. Expected Peak Ground Acceleration (PGA) in [m/s^2] for the different cities against annual exceedance probabilities and return periods.

Annual exceedance probability	Return period (years)	Expected PGA (m/s^2) for the cities of:									
		Islamabad	Peshawar	Quetta	Karachi	Gwadar	Muzaffarabad	Gilgit	Lahore	Multan	Khuzdar
0.02	50	1.50	1.35	1.91	0.54	0.53	2.04	2.93	0.97	0.71	1.34
0.01	100	2.25	2.40	2.90	0.95	0.88	3.23	4.42	1.69	1.22	2.26
0.005	200	3.33	3.19	3.59	1.28	1.15	4.02	5.28	2.24	1.61	2.96
0.002	500	3.65	3.49	3.85	1.42	1.25	4.31	5.55	2.46	1.78	3.24
0.001	1000	3.71	3.55	3.90	1.45	1.28	4.36	5.60	2.51	1.81	3.30

Table 8.2. Expected spectral acceleration [m/s^2] for different cities for an annual exceedance rate of 0.002.

Period T (s)	Islamabad	Peshawar	Quetta	Karachi	Gwadar	Muzaffara-bad
PGA	3.65	3.49	3.85	1.42	1.25	4.31
0.1	5.07	5.59	14.28	2.86	5.75	7.03
0.2	5.57	6.11	15.75	3.54	6.35	8.06
0.5	3.12	3.32	9.17	2.57	3.48	4.75
1.0	1.42	1.45	4.37	1.08	1.37	2.24
1.5	0.84	0.84	5.56	0.64	0.75	1.31
2.0	0.75	0.75	2.20	0.57	0.65	1.15
2.5	0.45	0.45	1.67	0.34	0.43	0.75

All of the derived expected ground acceleration values for the complete grid (one degree spacing) are listed in the Appendix. For each location eight different values are given (for PGA and the seven periods as listed in Table 8.2).

Figure 8.1. Earthquake hazard for Pakistan in terms of PGA [m/s^2] for the 0.02 annual exceedance probabilities (50 year recurrence).

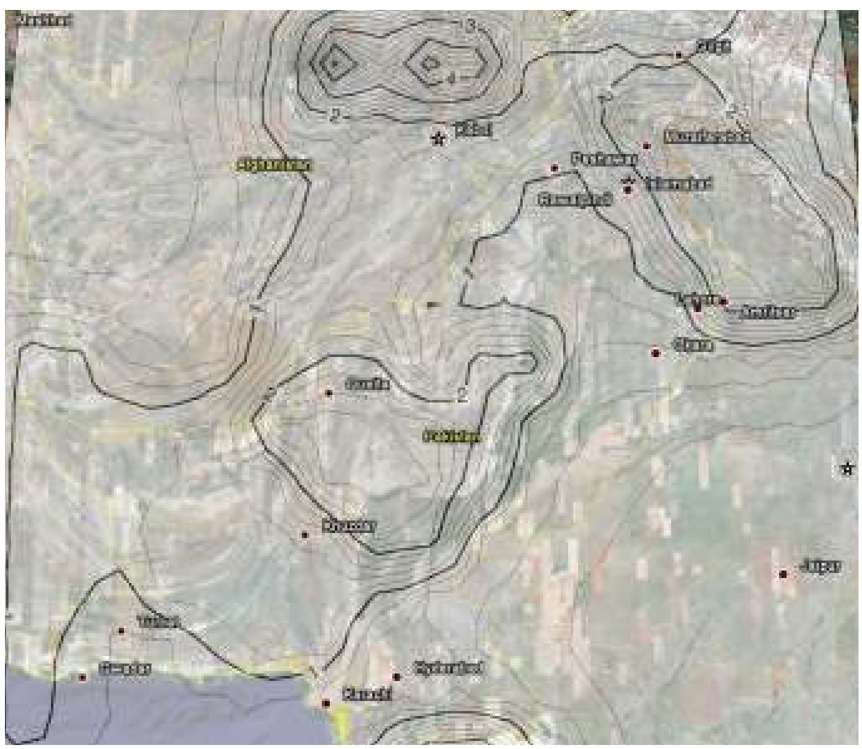


Figure 8.2. Earthquake hazard for Pakistan in terms of PGA [m/s^2] for the 0.01 annual exceedance probabilities (100 year recurrence).

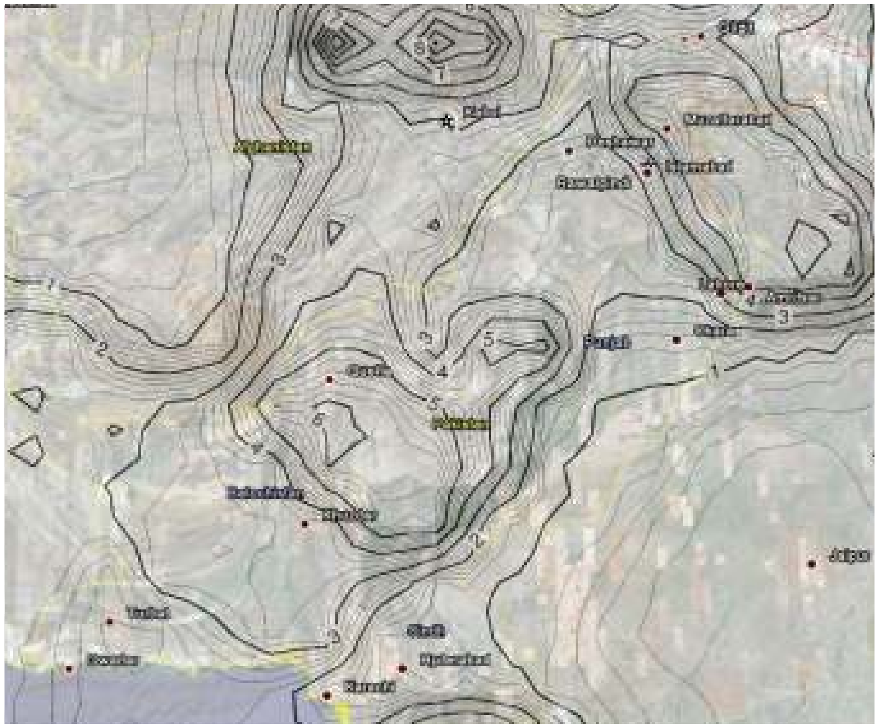


Figure 8.3. Earthquake hazard for Pakistan in terms of PGA [m/s^2] for the 0.002 annual exceedance probabilities (500 year recurrence).

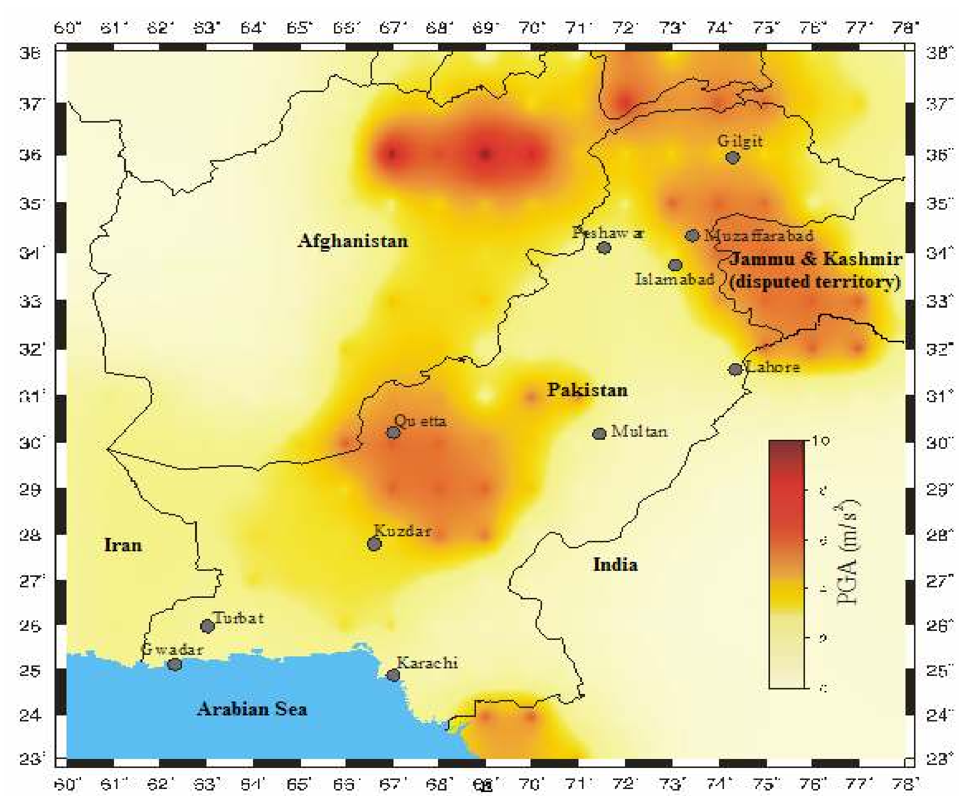


Figure 8.4. Seismic hazard map of Pakistan prepared for PGA for 500 years return period.

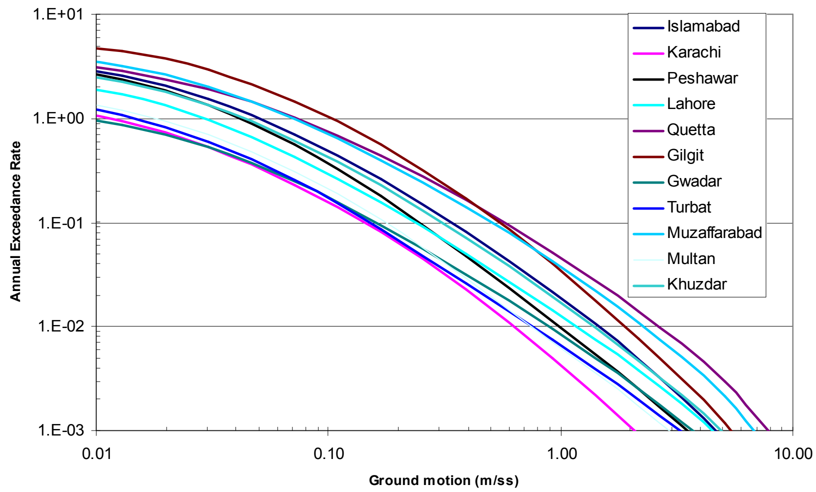


Figure 8.5. PGA hazard curves for different cities of Pakistan (500 years).

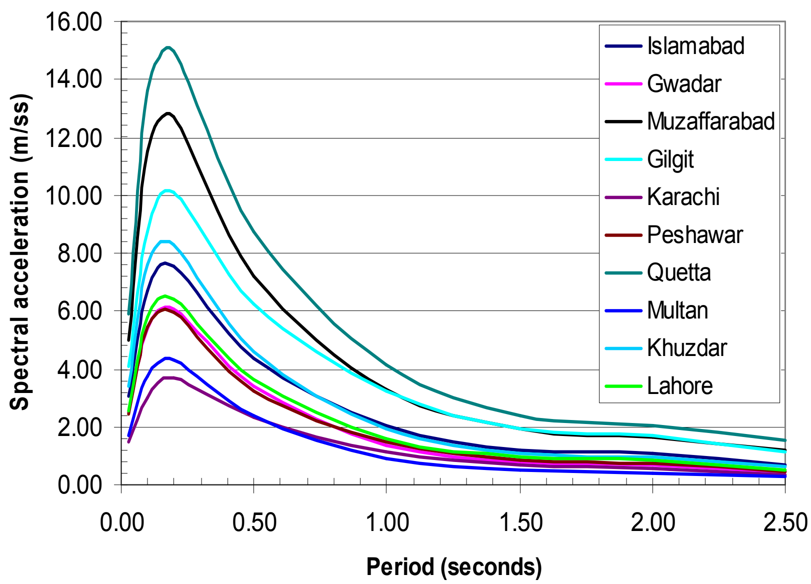


Figure 8.6. Hazard spectrum for different cities of Pakistan.

8.1 Deaggregation results

Probabilistic seismic hazard assessment (PSHA) integrates ground motion contributions from all the seismic sources. PSHA is the preferred way of computing seismic hazard, because of the consistent way of uncertainties are carried out through computation. However, it is sometimes difficult to reveal the relative contribution in the distance-magnitude space for the computed hazard. Deaggregation of the hazard results has therefore become important for an improved understanding of the results.

Fig. 8.7 shows the deaggregation results for Islamabad, Peshawar, Karachi, Gwadar, Quetta and Muzaffarabad. The deaggregation is done for ground motion levels that are close to the 500 years PGA levels. The aim of deaggregation is to visualize the relative contributions to the hazard in the magnitude-distance space.

The deaggregation results for ground acceleration levels at 3.65 m/s^2 for Islamabad, 3.49 m/s^2 for Peshawar,1.42 m/s^2 for Karachi, 1.25 m/s^2 for Gwadar, 3.85 m/s^2 for Quetta and 4.31 m/s^2 for Muzaffarabad corresponds to the return period of 500 years.

The result in Figs. 8.8 to 8.13 even more clearly exhibits the great importance of near field earthquakes, for different magnitude levels. It should be kept in mind here that lower-frequency ground motions from large earthquakes indeed can propagate damagingly over quite long distances, as often evidenced historically.

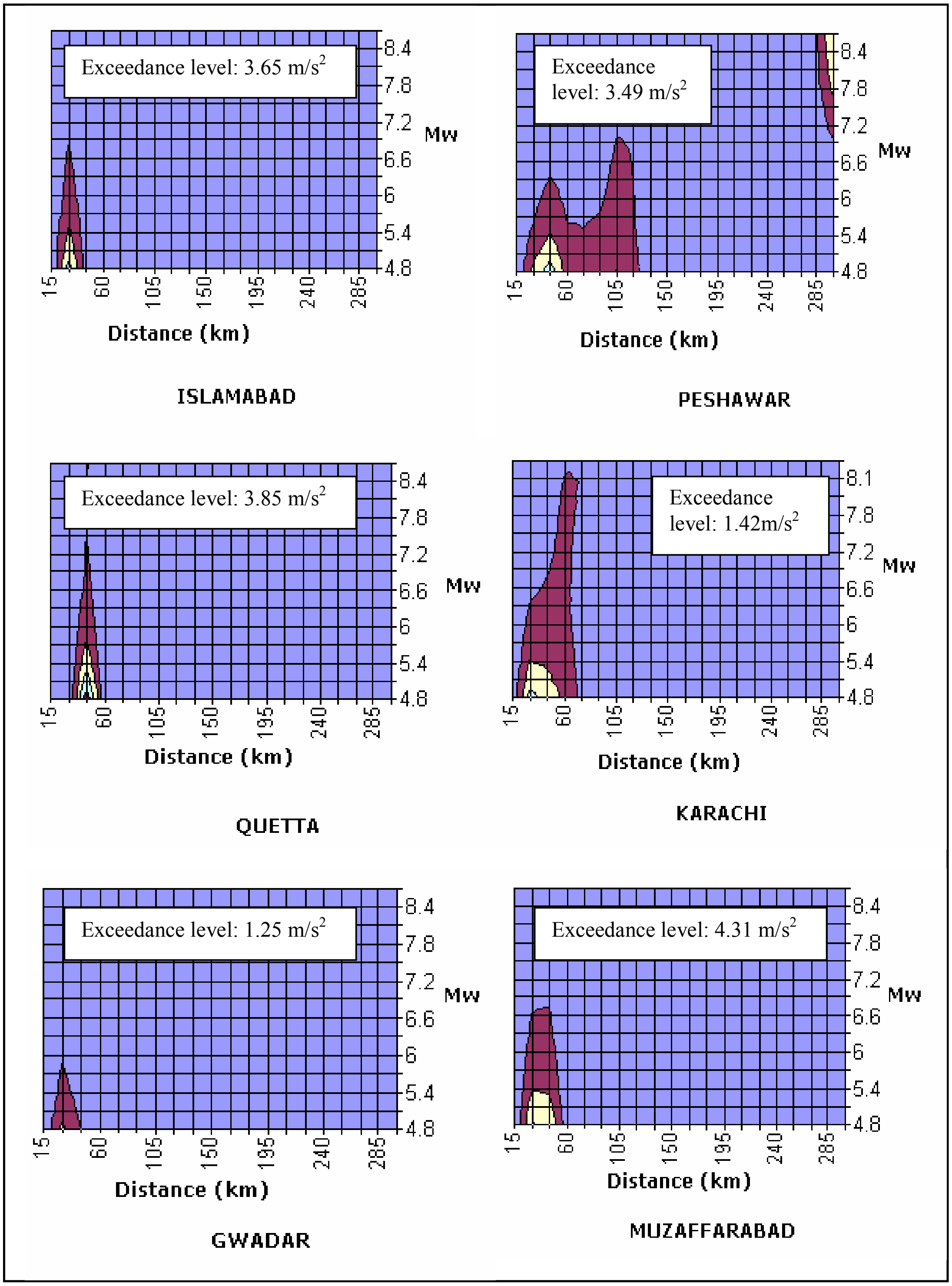


Figure 8.7. Deaggregation results for different cities at Peak Ground Acceleration.

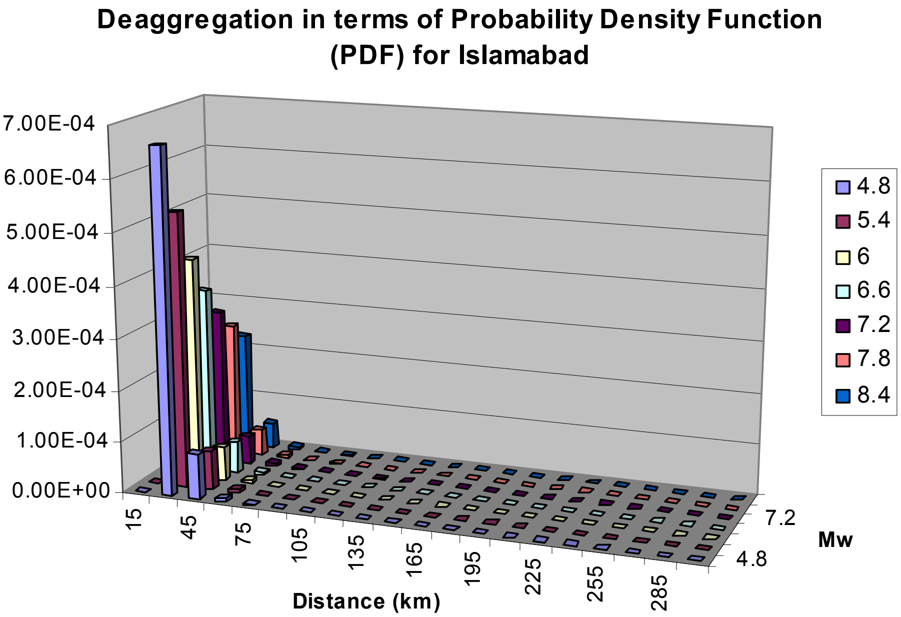


Figure 8.8.Probability Density Function (PDF) of Peak Ground Acceleration (PGA) for ground motion level at 2.27 m/s^2 for Islamabad.

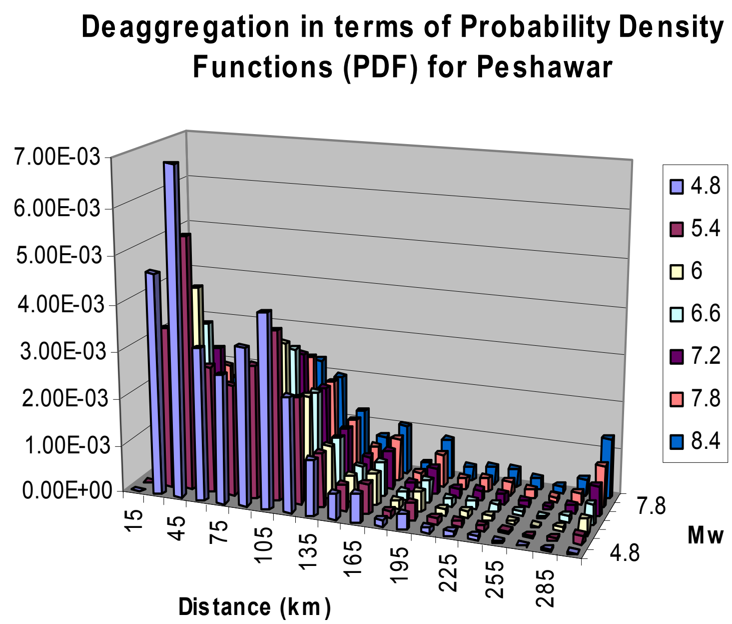


Figure 8.9. Probability Density Function (PDF) of Peak Ground Acceleration (PGA) for ground motion level at 2.49 m/s^2 for Peshawar.

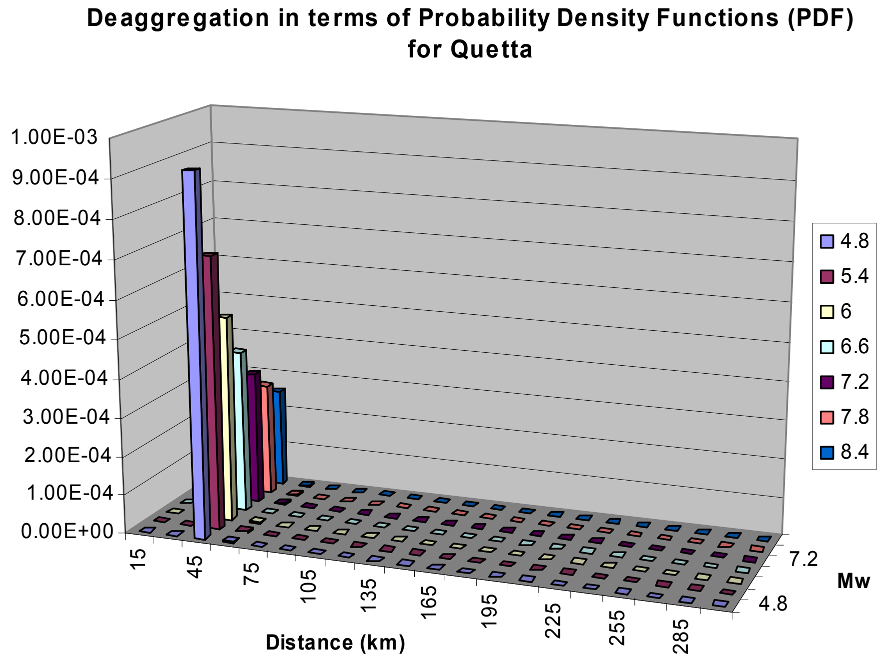


Figure 8.10. Probability Density Function (PDF) of Peak Ground Acceleration (PGA) for ground motion level at 6.14 m/s^2 for Quetta.

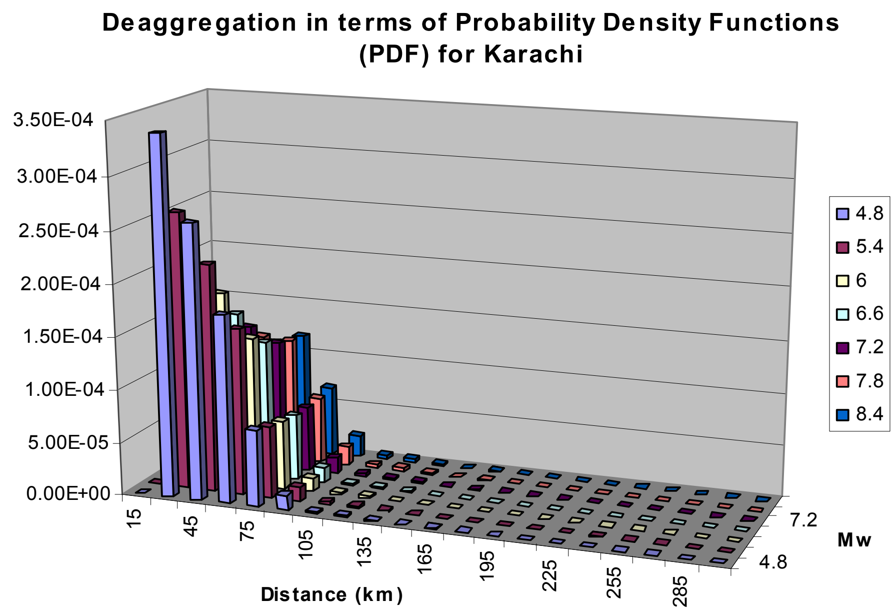


Figure 8.11. Probability Density Function (PDF) of Peak Ground Acceleration (PGA) for ground motion level at 1.40 m/s^2 for Karachi.

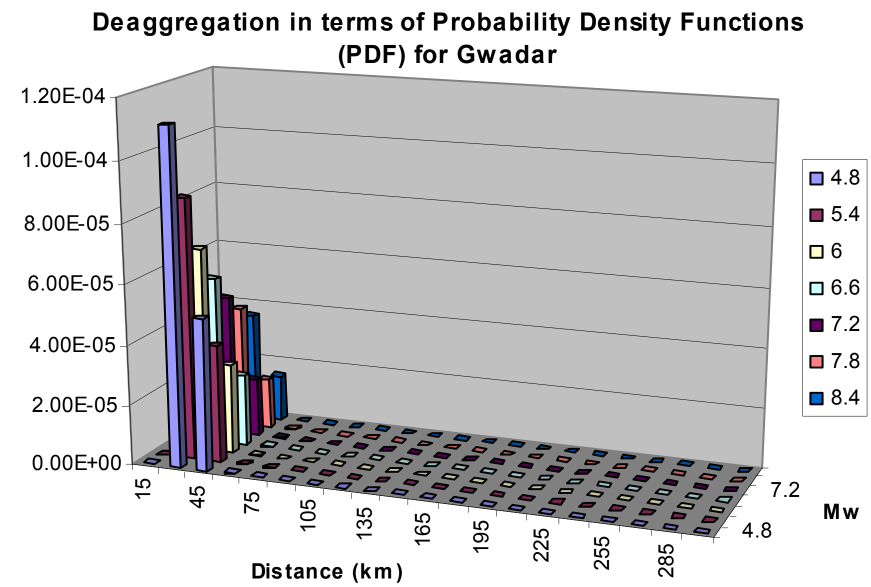


Figure 8.12. Probability Density Function (PDF) of Peak Ground Acceleration (PGA) for ground motion level at 5.75 m/s^2 for Gwadar.

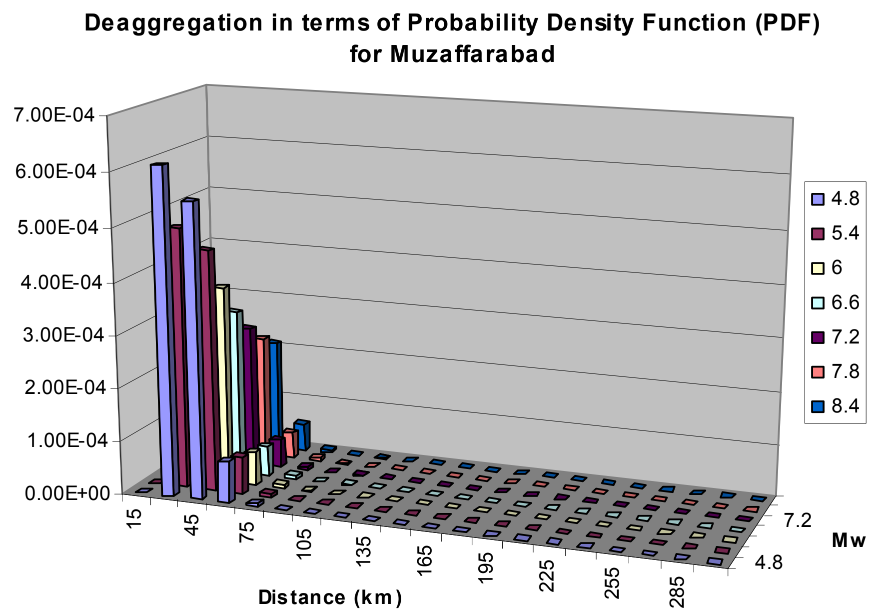


Figure 8.13. Probability Density Function (PDF) of Peak Ground Acceleration (PGA) for ground motion level at 3.25 m/s^2 for Muzaffarabad.

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10 Glossary

Accelerogram - Time history of accelerations.

Active fault - (1) A fault that has had sufficiently recent displacements so that, in the opinion of the user of the term, further displacements in the foreseeable future are considered likely. (2) A fault that on the basis of historical, seismological, or geological evidence has a high probability of producing an earthquake. (3) A fault that may produce an earthquake within a specified exposure time, given the assumptions adopted for a specific seismic-risk analysis.

Attenuation - The reduction in amplitude of a wave with time or distance travelled, most often used for the decrease in amplitude of ground motion with increase in distance from the source. This attenuation is due to two mechanisms, one is the distribution of energy over a larger volume as the distance increases, the other is the loss of energy due to internal damping. The latter effect is frequency dependent and gives higher attenuation of the high frequency motion.

Attenuation law - A description of the behaviour of a characteristic of earthquake ground motion as a function of the distance from the source of energy.

b-value - A parameter indicating the relative frequency of earthquakes of different sizes. It is the slope of a straight line indicating absolute or relative frequency (plotted logarithmically) versus earthquake magnitude (or meizoseismal intensity), often shown to be stable over a wide range of magnitudes. The B-value indicates the slope of the curve of the Gutenberg-Richter recurrence relationship.

Body waves - A seismic wave that travels through the interior of an elastic material. These waves consist of compressional waves (P-waves) and shear waves (S-waves). Near the source most of the energy carried is in the form of body waves.

Capable fault - A fault along which it is mechanically feasible for sudden slip to occur. Evaluation of capability is based on geologic and/or seismic evidence. Capable is used for faults where it is possible, but not certain, that earthquakes can occur, often used synonymously with potentially active faults.

Continental plate - A large rigid part of the earth's crust and upper mantle (lithosphere) which moves relative to the other continental plates. The speed of movement may be up to 15-20 cm/year. Scandinavia belongs to the Eurasian continental plate.

Crust - The outer major layer of the earth, separated from the underlying mantle by the Moho discontinuity, and characterized by P-wave velocity less than 8 km/s. The thickness of the crust in the Norwegian Continental Shelf in the range 15-25 km.

Damping - Loss of energy in wave motion due to transfer into heat by frictional forces. In engineering often expressed relative to the critical damping, $C_{cr} = 2(KM)^{1/2}$, where K and M are stiffness and mass of the vibrating system, respectively.

Design acceleration - A specification of the ground acceleration at a site in terms of a single value such as the peak or rms; used for the earthquake-resistant design of a structure (or as a base for deriving a design spectrum). See *Design time history*.

Design earthquake - (1) A specification of a seismic ground motion at a site; used for the earthquake-resistant design of a structure. (2) An earthquake event used the earthquake-resistant design of structures, which may or may not be equivalent to the maximum earthquake prescribed for the installation.

Design event (Design seismic event) - A specification of one or more earthquake source parameters, and of the location of energy release with respect to the site of interest; used for the earthquake-resistant design of structures.

Design ground motion - Description of ground shaking (e.g., time history, response spectrum) at a given site used for the earthquake-resistant design of structures; in modern hazard studies usually the result of contributions from all seismic sources surrounding the site and not corresponding to any specific design earthquake. See *Design earthquake*.

Design spectrum - A set of curves for design purposes that gives acceleration, velocity or displacement (usually absolute acceleration, relative velocity, and relative displacement of the vibrating mass) as a function of period of vibration and damping.

Deterministic hazard assessment - An assessment that specifies single-valued parameters such as maximum earthquake magnitude or peak ground acceleration without consideration of likelihood.

Duration - A qualitative or quantitative description of the length of time during which ground motion at a site shows certain characteristics (perceptibility, violent shaking, etc.).

Earthquake - A sudden motion or vibration in the earth caused by the abrupt release of energy in the earth's lithosphere; shaking of the ground by different types of waves generated by tectonic movements or volcanic activity. By far the largest number of destructive earthquakes are caused by tectonic movements. An earthquake is initiated when the accumulated tectonic stresses at any one point in the ground become greater than the strength at this point. Release of stress at one point may increase the stresses nearby, and result in a progressive rupture which may propagate for several hundred kilometres. The rupture will almost invariably occur along old zones of weakness (faults), and the wave motion may range from violent at some locations to imperceptible at others.

Earthquake cycle - For a particular fault, fault segment, or region, a period of time that encompasses an episode of strain accumulation and its subsequent seismic relief.

Epicentre - The point on the earth's surface that is directly above the focus (hypocenter) of an earthquake.

Equal hazard spectrum - Specifies ground motion (usually pseudo-relative velocity) as a function of natural period and damping level for a given probability of occurrence. The term is sometimes used synonymously with design spectrum or response spectrum.

Deterministic hazard assessment - An assessment that specifies single-valued parameters such as maximum earthquake magnitude or peak ground acceleration without consideration of likelihood.

Fault - A fracture or a zone of fractures along which displacement has occurred parallel to the fracture. Earthquakes are caused by a sudden rupture along a fault or fault system; the ruptured area may be up to several thousand square kilometres. Relative movements across a fault may typically be tens of centimetres for magnitude 6.0-6.5 earthquakes, several meters for magnitude 7-8 earthquakes.

Fault slip rate - The rate of slip on a fault averaged over a time period involving several large earthquakes. The term does not necessarily imply fault creep.

Geologic hazard – A geologic process (e.g., land sliding, soil liquefaction, active faulting) that during an earthquake or other natural events may produce adverse effects n structures.

Hypocenter - The point where the earthquake started, also called focus. Hypocenter depths are typically 30 km and less for shallow earthquakes, several hundreds of kilometres for earthquakes occurring in subduction zones. Most earthquakes in Fennoscandia originate at depths between 10 and 30 km.

Intensity (of an earthquake) - A qualitative or quantitative measure of the severity of ground shaking at a given site (e.g., MSK intensity, Modified Mercalli intensity, Rossi-Forel intensity, Housner Spectral intensity, Arias intensity, peak acceleration, etc.) based on effects of the earthquake such as how the earthquake was felt, damage to structures, how people reacted, soil or rock slides, etc.

Interplate earthquake - An earthquake along a tectonic late boundary. Most earthquakes are caused by the relative plate movements along plate margins, i.e., between plates.

Intraplate earthquake - An earthquake within a tectonic plate. Scandinavia belongs to the Eurasian plate and is well removed from the nearest plate boundary.

Isoseismal - Contour lines drawn to separate one level of seismic intensity from another.

Logic tree - A formalized decision flow path in which decisions are made sequentially at a series of *nodes***,** each of which generates *branches* flowing to subsequent nodes.

Macroseismic - Ground shaking which gives noticeable effects. See *Intensity*.

Magnitude - A measure of earthquake size at its source. Magnitude was defined by C. Richter in 1935 as: "The logarithm to the trace amplitude in 0.001 mm on a standard Wood-Anderson seismometer located 100 km from the epicentre" The Wood-Anderson instrument measures the responses in the period range near 1 sec. Other magnitude scales have later been devised based on the responses measured in other period ranges, and on maximum amplitudes of specific wave forms Some of the more commonly used magnitude scales are:

1. M_L= local magnitude, similar to the original Richter magnitude. Usually determined from shear wave response in the period range near 1 sec. at relatively close distances from the epicentre (< 600 km).
2. m_b= body wave magnitude is based on the largest amplitude of body waves, usually the compressional component with period near 1 sec.
3. M_S= surface wave magnitude is measured in the period range near 20 sec.
4. M_W=moment magnitude is based on the seismic moment and be computed directly from source parameters or from long period components in the earthquake record. Symbol M is also used for this magnitude.

Magnitude scales are also based on other earthquake parameters such as felt area, length of rupture and surface displacement, and area within different intensity zones.

A large number of empiric relations between magnitude and other earthquake parameters such as energy, fault movement, fault area, intensity, maximum acceleration, etc., are available. Such relations may differ considerably from one seismic region to another.

Maximum credible, expectable, expected, probable - These terms are used to specify the largest value of a variable, for example, the magnitude of an earthquake that might reasonable be expected to occur. In the view of the Earthquake Engineering

Research Institute, U.S (EERI) Committee on Seismic Risk (cf. *Earthquake Spectra*, Vol. 1, pp. 33-40), these are misleading terms and their use is discouraged.

Maximum credible earthquake - The maximum earthquake that is capable of occurring in a given area or on a given fault during the current tectonic regime; the largest earthquake that can be reasonably expected to occur (USGS); the earthquake that would cause the most severe vibratory ground motion capable of being at the site under the current known tectonic framework (US Bureau of Reclamation). "Credibility" is in the eyes of the user of the term.

Maximum earthquake - The maximum earthquake that is thought, in the judgment of the user, to be appropriate for consideration in the location and design of a specific facility.

Maximum possible - The largest value possible for a variable. This follows from an explicit assumption that larger values are not possible, or implicitly from assumptions that related variables or functions are limited in range. The maximum possible value may be expressed deterministically or probabilistically.

Maximum probable earthquake - The maximum earthquake that, in the judgment of the user, is likely to occur in a given area or on a given fault during a specific time period in the future.

Mean (average) recurrence interval - The mean (average) time between earthquakes or faulting events with specific characteristics (e.g., magnitude ε5) in a specified region or in a specific fault zone.

Mean (average) return period - The mean (average) time between occurrences of ground motion with specified characteristics (e.g., peak horizontal acceleration >0.1 g) at a site. Equal to the inverse of the annual probability of exceedance.

Moho - Mohorovicic discontinuity, a sharp discontinuity in seismic velocities separating the earth's crust from the underlying mantle, also called the crust-mantle boundary. P wave speeds are typically 6.7-7.2 km/s in the lower crust and 7.6-8.6 km/s at the top of the upper mantle.

Neotectonics - (1) The study of post-Miocene structures and structural history of the earth's crust. (2) The study of recent deformation of the crust, generally Neogene (post-Oligocene). (3) Tectonic processes now active, taken over the geologic time span during which they have been acting in the presently observed sense, and the resulting structures.

P wave - A seismic body wave with particle motion in the direction of propagation, also called compressional wave even though the motion alternates between extension and compressions.

Potentially active fault - A term used by different people in different ways, but sometimes referring to a fault that has had displacements on it within the late Quaternary period.

Pseudo acceleration (PSA) - See Response spectrum.

Pseudo velocity (PSV) - See Response spectrum.

Response spectrum - Describe the maximum response of single-degree-of-freedom systems (linear oscillator) to given ground motions (e.g., an earthquake accelerogram) as a function of the period and the damping of the system. The responses may be pseudo acceleration, pseudo velocity or relative displacement. Pseudo acceleration and pseudo velocity values may be expressed in an approximate way from the relative displacement through the relation: where $PSA/\omega^2 = (PSV)/\omega = RD$ is pseudo acceleration, PSV is pseudo velocity and RD relative displacement, respectively, and ω is circular frequency. By using the pseudo values, all three responses can be plotted together in a logarithmic, tripartite nomogram.

Return period - Same as recurrence interval, average time period between earthquakes of a given size in a particular region, cycle time.

S wave - A seismic body wave with particle motion perpendicular to the direction of propagation, also called shear wave. The passage of an S-wave involves a pure shear of the medium.

Secondary effects - Nontectonic surface processes that are directly related to earthquake shaking or to tsunamis.

Seismic activity rate - The mean number per unit time of earthquakes with specific characteristics (e.g., magnitude ε5) originating on a selected fault or in a selected area.

Seismic design load effects - The actions (axial forces, shears, or bending moments) and deformations induced in a structural system due to a specified representation (time history, response spectrum, or base shear) of seismic design motion.

Seismic design loading - The prescribed representation (time history, response spectrum, or equivalent static base shear) of seismic ground motion to be used for the design of a structure.

Seismic event - The abrupt release of energy in the earth's lithosphere, causing an earthquake.

Seismic hazard - Any physical phenomenon or effect (e.g., ground shaking, ground failure, landsliding, liquefaction) associated with an earthquake that may produce adverse effects on human activities, representing the earthquake's potential danger. Specifically, the probability of occurrence over a given time period in a given location of an earthquake with a given level of severity. Seismic exposure may be used synonymously with seismic hazard.

Seismic moment - The area of a fault rupture multiplied by the average slip over the rupture area and multiplied by the shear modulus (rigidity) of the affected rocks. Seismic moment can be determined directly from the long period asymptote of path corrected far field displacement spectra. Dimension dyne-cm or N-m.

Seismic moment rate - The long term rate at which seismic moment is being generated.

Seismic risk - The probability that social or economic consequences of earthquakes will equal or exceed specified values at a site, at several sites, or in an area, during a specified exposure time; the likelihood of human and property loss that can result from the hazards of an earthquake. Often expressed as hazard times vulnerability.

Seismic zone - A generally large area within which seismic design requirements for structures are constant. Some times used synonymously with *Seismogenic zone*.

Seismic zoning (zonation) - The process of determining seismic hazard at many sites for the purpose of delineating seismic zones. Some times used synonymously with *Seismotectonic zoning*.

Seismicity - The occurrence of earthquakes in space and time.

Seismogenic structure - A geologic structure that is capable of producing an earthquake.

Seismogenic zone (province) - A planar representation of a three-dimensional domain in the earth's lithosphere in which earthquakes are inferred to be of similar tectonic origin; may also represent a fault. See *Seismotectonic zone*.

Seismotectonic zone (province) - A seismogenic zone in which the tectonic processes causing earthquakes have been reasonably well identified; usually these zones are fault zones. In seismic hazard analyses often used to describe a region (area) within which the active geologic and seismic processes are considered to be relatively uniform.

Seismotectonic - The study of the tectonic component represented by seismic activity a subfield of active tectonics concentrating on the seismicity, both instrumental and historical, and dealing with geological and other geophysical aspects of seismicity.

Strain - Change in the shape or volume of a body as a result of stress.

Stress - Force per unit area.

Stress drop - The sudden reduction in stress across the fault plane during rupture. Intraplate earthquakes have in general higher stress drop than interpolate earthquakes. Typical values are 1-10 MPa (10-100 bars).

Surface waves - Seismic waves travelling along the surface of the earth or along layers in the earth's crust, with a speed less than that of S waves. The two most common types are Raleigh waves and Love waves.

Tectonics - A branch of geology dealing with the broad architecture of the outer part of the earth, that is, the regional assembling of structural or deformational features, a study of their mutual relations, origin, and historical evolution.

Vulnerability - (1) The degree of loss to a given element at risk, or set of such elements, resulting from an earthquake of a given magnitude or intensity, usually expressed on a scale from 0 (no loss) to 10 (total loss). (2) Degree of damage caused by various levels of loading. The vulnerability may be calculated in a probabilistic or deterministic way for a single structure or groups of structures.

11 Appendix

Expected Ground Acceleration in [m/s^2]for different return periods and locations. For each location eight values are given, for PGA and for periods of 0.025, 0.1, 0.2, 0.5, 1.0, 1.5, 2.0 and 2.5 s.

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
60	23	0.25	0.42	0.69	1.27	1.97
60	23	0.52	0.88	1.46	2.78	4.4
60	23	0.68	1.12	1.79	3.21	4.92
60	23	0.39	0.62	0.97	1.67	2.48
60	23	0.12	0.2	0.32	0.57	0.85
60	23	0.06	0.11	0.17	0.3	0.45
60	23	0.05	0.09	0.14	0.25	0.37
60	23	0.04	0.06	0.09	0.16	0.25
61	23	0.42	0.69	1.11	2	2.92
61	23	0.87	1.46	2.42	4.45	6.59
61	23	1.1	1.79	2.82	4.98	7.12
61	23	0.59	0.96	1.47	2.53	3.69
61	23	0.18	0.3	0.49	0.87	1.3
61	23	0.09	0.16	0.25	0.45	0.68
61	23	0.08	0.13	0.21	0.38	0.58
61	23	0.05	0.09	0.14	0.25	0.39
62	23	0.35	0.59	0.96	1.73	2.6
62	23	0.72	1.23	2.04	3.76	5.76
62	23	0.95	1.54	2.45	4.32	6.36
62	23	0.53	0.86	1.34	2.36	3.48
62	23	0.17	0.29	0.47	0.88	1.38
62	23	0.09	0.15	0.25	0.48	0.76
62	23	0.07	0.13	0.21	0.41	0.66
62	23	0.05	0.08	0.14	0.27	0.43
63	23	0.28	0.47	0.78	1.43	2.23
63	23	0.56	0.97	1.59	2.99	4.71
63	23	0.76	1.24	2.01	3.58	5.46
63	23	0.45	0.74	1.19	2.16	3.27
63	23	0.15	0.26	0.46	0.91	1.49
63	23	0.08	0.15	0.25	0.52	0.88
63	23	0.07	0.12	0.22	0.46	0.77
63	23	0.05	0.08	0.14	0.28	0.49
64	23	0.28	0.48	0.79	1.44	2.22
64	23	0.56	0.98	1.61	2.99	4.67
64	23	0.75	1.25	2.04	3.6	5.44
64	23	0.44	0.75	1.22	2.21	3.3
64	23	0.15	0.27	0.47	0.96	1.57
64	23	0.08	0.15	0.26	0.55	0.94
64	23	0.07	0.13	0.23	0.49	0.83
64	23	0.04	0.08	0.14	0.3	0.52
65	23	0.28	0.48	0.8	1.45	2.24
65	23	0.56	0.98	1.61	3.01	4.71
65	23	0.74	1.26	2.05	3.61	5.47
65	23	0.44	0.75	1.22	2.23	3.34
65	23	0.14	0.27	0.48	0.97	1.59
65	23	0.08	0.15	0.27	0.56	0.95
65	23	0.06	0.12	0.23	0.5	0.85
65	23	0.04	0.08	0.15	0.31	0.52

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
66	23	0.29	0.5	0.81	1.45	2.24
66	23	0.59	1	1.63	3.01	4.71
66	23	0.79	1.29	2.07	3.62	5.47
66	23	0.48	0.79	1.26	2.24	3.34
66	23	0.17	0.29	0.51	0.99	1.6
66	23	0.09	0.17	0.29	0.58	0.96
66	23	0.08	0.14	0.25	0.52	0.85
66	23	0.05	0.09	0.16	0.31	0.53
67	23	0.37	0.57	0.88	1.51	2.25
67	23	0.72	1.14	1.75	3.08	4.71
67	23	0.98	1.49	2.26	3.76	5.5
67	23	0.61	0.97	1.44	2.41	3.48
67	23	0.22	0.38	0.63	1.16	1.79
67	23	0.12	0.22	0.37	0.68	1.08
67	23	0.11	0.19	0.32	0.61	0.97
67	23	0.07	0.12	0.2	0.38	0.6
68	23	1.05	1.7	2.64	4.45	6.04
68	23	2.25	3.69	5.82	9.63	14.11
68	23	2.65	4.23	6.41	10.63	15.59
68	23	1.42	2.29	3.52	6.09	8.95
68	23	0.49	0.83	1.36	2.6	4.24
68	23	0.25	0.44	0.75	1.48	2.48
68	23	0.21	0.37	0.64	1.27	2.15
68	23	0.14	0.25	0.43	0.89	1.61
69	23	1.18	1.85	2.77	4.55	6.1
69	23	2.52	3.97	6.01	9.73	14
69	23	2.99	4.62	6.75	10.93	15.74
69	23	1.65	2.56	3.85	6.47	9.43
69	23	0.59	0.99	1.6	3	4.8
69	23	0.31	0.53	0.9	1.73	2.86
69	23	0.26	0.46	0.76	1.49	2.49
69	23	0.18	0.31	0.52	1.07	1.89
70	23	1.18	1.85	2.76	4.54	6.09
70	23	2.52	3.97	6	9.7	13.95
70	23	2.99	4.62	6.75	10.92	15.7
70	23	1.65	2.57	3.85	6.46	9.42
70	23	0.59	0.99	1.6	3	4.8
70	23	0.31	0.54	0.9	1.73	2.87
70	23	0.26	0.46	0.76	1.49	2.49
70	23	0.18	0.31	0.53	1.07	1.89
71	23	1.15	1.83	2.76	4.56	6.11
71	23	2.47	3.95	6.03	9.78	14.11
71	23	2.9	4.56	6.73	10.96	15.85
71	23	1.54	2.46	3.74	6.38	9.35
71	23	0.52	0.89	1.46	2.81	4.58
71	23	0.27	0.47	0.8	1.59	2.7
71	23	0.22	0.4	0.68	1.36	2.33
71	23	0.15	0.27	0.47	0.98	1.79
72	23	0.43	0.71	1.12	1.98	2.9
72	23	0.89	1.45	2.35	4.23	6.28
72	23	1.14	1.83	2.83	4.91	7.08
72	23	0.66	1.07	1.63	2.8	4.12
72	23	0.22	0.39	0.64	1.19	1.86
72	23	0.12	0.21	0.36	0.68	1.08
72	23	0.1	0.18	0.31	0.59	0.94
72	23	0.07	0.12	0.2	0.38	0.62
73	23	0.1	0.15	0.23	0.39	0.51

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
73	23	0.19	0.29	0.44	0.69	0.96
73	23	0.27	0.43	0.63	1.01	1.32
73	23	0.18	0.28	0.45	0.74	1.04
73	23	0.05	0.1	0.17	0.34	0.52
73	23	0.03	0.06	0.1	0.21	0.32
73	23	0.03	0.05	0.09	0.19	0.29
73	23	0.02	0.03	0.06	0.11	0.17
60	24	0.42	0.69	1.1	2	2.92
60	24	0.87	1.46	2.41	4.46	6.62
60	24	1.11	1.79	2.81	4.98	7.13
60	24	0.6	0.96	1.46	2.51	3.67
60	24	0.19	0.31	0.48	0.85	1.25
60	24	0.1	0.16	0.25	0.44	0.65
60	24	0.08	0.13	0.21	0.36	0.54
60	24	0.05	0.09	0.14	0.24	0.37
61	24	0.68	1.11	1.73	2.92	4.2
61	24	1.45	2.41	3.83	6.6	9.51
61	24	1.77	2.81	4.33	7.12	10.14
61	24	0.94	1.45	2.23	3.68	5.34
61	24	0.28	0.47	0.73	1.27	1.89
61	24	0.14	0.23	0.37	0.66	1
61	24	0.12	0.19	0.31	0.55	0.84
61	24	0.08	0.13	0.21	0.37	0.57
62	24	0.57	0.95	1.49	2.6	3.76
62	24	1.2	2.02	3.23	5.75	8.27
62	24	1.5	2.42	3.74	6.35	9.1
62	24	0.82	1.3	2.02	3.44	5.12
62	24	0.26	0.44	0.72	1.32	2.07
62	24	0.14	0.23	0.38	0.72	1.16
62	24	0.11	0.19	0.32	0.61	1
62	24	0.08	0.13	0.21	0.41	0.67
63	24	0.45	0.75	1.22	2.21	3.26
63	24	0.93	1.55	2.55	4.69	6.88
63	24	1.19	1.95	3.06	5.43	7.9
63	24	0.68	1.12	1.78	3.17	4.83
63	24	0.23	0.41	0.69	1.38	2.31
63	24	0.12	0.22	0.39	0.79	1.36
63	24	0.1	0.19	0.33	0.69	1.2
63	24	0.07	0.12	0.21	0.45	0.8
64	24	0.46	0.77	1.23	2.24	3.31
64	24	0.94	1.57	2.58	4.72	6.97
64	24	1.19	1.98	3.1	5.47	8
64	24	0.69	1.14	1.84	3.26	4.97
64	24	0.23	0.42	0.73	1.46	2.43
64	24	0.13	0.23	0.41	0.85	1.45
64	24	0.11	0.2	0.36	0.75	1.28
64	24	0.07	0.13	0.23	0.48	0.84
65	24	0.45	0.76	1.22	2.22	3.29
65	24	0.93	1.56	2.56	4.69	6.94
65	24	1.18	1.96	3.08	5.44	7.96
65	24	0.67	1.13	1.81	3.23	4.93
65	24	0.23	0.41	0.71	1.43	2.4
65	24	0.12	0.22	0.4	0.83	1.42
65	24	0.1	0.19	0.35	0.73	1.26
65	24	0.07	0.12	0.22	0.47	0.83
66	24	0.45	0.75	1.21	2.2	3.22
66	24	0.93	1.55	2.54	4.65	6.79

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
66	24	1.19	1.95	3.05	5.39	7.82
66	24	0.69	1.13	1.79	3.16	4.79
66	24	0.24	0.42	0.71	1.4	2.32
66	24	0.13	0.23	0.4	0.81	1.38
66	24	0.11	0.2	0.35	0.71	1.21
66	24	0.07	0.13	0.22	0.46	0.8
67	24	0.48	0.77	1.2	2.15	3.2
67	24	0.96	1.56	2.49	4.58	6.82
67	24	1.26	1.97	3.03	5.28	7.74
67	24	0.77	1.2	1.83	3.13	4.68
67	24	0.28	0.47	0.77	1.43	2.28
67	24	0.16	0.26	0.44	0.84	1.36
67	24	0.13	0.23	0.39	0.74	1.2
67	24	0.09	0.15	0.24	0.47	0.78
68	24	0.79	1.15	1.62	2.49	3.34
68	24	1.62	2.4	3.34	5.16	6.79
68	24	2.09	2.96	4.17	6.28	8.36
68	24	1.19	1.77	2.57	4.01	5.6
68	24	0.43	0.71	1.14	2.06	3.16
68	24	0.24	0.4	0.65	1.21	1.88
68	24	0.2	0.35	0.57	1.06	1.64
68	24	0.13	0.23	0.38	0.72	1.17
69	24	1.65	2.6	3.87	6	7.77
69	24	3.6	5.77	8.45	14.01	20.53
69	24	4.1	6.31	9.27	15.45	22.72
69	24	2.18	3.38	5.23	8.73	12.87
69	24	0.73	1.23	2.04	3.94	6.4
69	24	0.38	0.66	1.12	2.27	3.92
69	24	0.31	0.55	0.95	1.96	3.46
69	24	0.21	0.38	0.67	1.47	2.74
70	24	1.79	2.73	4	6.07	7.83
70	24	3.9	5.98	8.62	13.98	20.15
70	24	4.47	6.66	9.64	15.74	22.81
70	24	2.36	3.64	5.55	9.23	13.57
70	24	0.79	1.34	2.25	4.39	7.15
70	24	0.41	0.71	1.24	2.55	4.45
70	24	0.34	0.6	1.04	2.19	3.92
70	24	0.23	0.42	0.76	1.7	3.21
71	24	0.71	1.03	1.4	2.1	2.74
71	24	1.44	2.11	2.83	4.12	5.4
71	24	1.89	2.66	3.62	5.38	6.94
71	24	1.11	1.63	2.35	3.58	4.91
71	24	0.41	0.67	1.08	1.93	2.93
71	24	0.22	0.39	0.62	1.14	1.75
71	24	0.19	0.33	0.54	1	1.53
71	24	0.13	0.22	0.36	0.68	1.09
72	24	0.25	0.38	0.52	0.77	1
72	24	0.49	0.7	0.98	1.38	1.77
72	24	0.7	1.01	1.35	1.99	2.49
72	24	0.47	0.7	1.01	1.51	2.03
72	24	0.17	0.29	0.47	0.82	1.18
72	24	0.1	0.17	0.28	0.5	0.73
72	24	0.09	0.15	0.25	0.45	0.66
72	24	0.06	0.09	0.15	0.27	0.4
73	24	0.09	0.14	0.21	0.35	0.47
73	24	0.17	0.26	0.4	0.63	0.88
73	24	0.25	0.39	0.57	0.93	1.21

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
73	24	0.16	0.26	0.41	0.68	0.97
73	24	0.05	0.09	0.16	0.31	0.48
73	24	0.03	0.05	0.1	0.19	0.3
73	24	0.02	0.05	0.09	0.18	0.27
73	24	0.02	0.03	0.05	0.1	0.16
60	25	0.43	0.69	1.11	2	2.91
60	25	0.88	1.47	2.41	4.45	6.59
60	25	1.13	1.8	2.82	4.97	7.11
60	25	0.62	0.98	1.47	2.51	3.65
60	25	0.2	0.32	0.5	0.86	1.26
60	25	0.1	0.17	0.26	0.45	0.66
60	25	0.09	0.14	0.22	0.37	0.55
60	25	0.06	0.09	0.14	0.25	0.37
61	25	0.69	1.11	1.74	2.93	4.2
61	25	1.47	2.43	3.85	6.62	9.51
61	25	1.8	2.83	4.35	7.14	10.16
61	25	0.96	1.47	2.25	3.7	5.34
61	25	0.3	0.48	0.75	1.29	1.92
61	25	0.16	0.25	0.39	0.68	1.02
61	25	0.13	0.21	0.32	0.57	0.86
61	25	0.09	0.14	0.22	0.38	0.59
62	25	0.59	0.96	1.49	2.6	3.77
62	25	1.22	2.03	3.23	5.75	8.28
62	25	1.53	2.44	3.75	6.35	9.12
62	25	0.86	1.33	2.06	3.48	5.15
62	25	0.28	0.47	0.75	1.37	2.13
62	25	0.15	0.25	0.41	0.75	1.21
62	25	0.13	0.21	0.34	0.65	1.05
62	25	0.08	0.14	0.22	0.43	0.7
63	25	0.47	0.77	1.23	2.22	3.26
63	25	0.95	1.58	2.57	4.69	6.87
63	25	1.23	1.98	3.09	5.43	7.9
63	25	0.73	1.16	1.83	3.21	4.88
63	25	0.26	0.44	0.73	1.44	2.38
63	25	0.14	0.24	0.41	0.83	1.41
63	25	0.12	0.21	0.36	0.73	1.25
63	25	0.08	0.13	0.23	0.47	0.83
64	25	0.47	0.78	1.24	2.23	3.29
64	25	0.96	1.59	2.59	4.71	6.92
64	25	1.24	2.01	3.12	5.47	7.96
64	25	0.74	1.19	1.87	3.28	4.96
64	25	0.26	0.46	0.77	1.5	2.47
64	25	0.15	0.25	0.44	0.88	1.48
64	25	0.12	0.22	0.38	0.77	1.31
64	25	0.08	0.14	0.24	0.49	0.86
65	25	0.48	0.78	1.24	2.23	3.29
65	25	0.97	1.6	2.58	4.7	6.92
65	25	1.26	2.01	3.11	5.45	7.95
65	25	0.75	1.2	1.86	3.25	4.92
65	25	0.27	0.46	0.77	1.48	2.43
65	25	0.15	0.26	0.44	0.87	1.45
65	25	0.13	0.22	0.38	0.76	1.29
65	25	0.08	0.14	0.24	0.48	0.84
66	25	0.51	0.8	1.24	2.19	3.22
66	25	1.03	1.64	2.59	4.66	6.84
66	25	1.33	2.07	3.14	5.39	7.83
66	25	0.79	1.22	1.86	3.17	4.73

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
66	25	0.28	0.47	0.76	1.41	2.25
66	25	0.16	0.26	0.43	0.81	1.34
66	25	0.13	0.23	0.37	0.71	1.18
66	25	0.09	0.14	0.24	0.45	0.77
67	25	0.42	0.61	0.89	1.4	1.95
67	25	0.83	1.23	1.78	2.86	4.06
67	25	1.1	1.6	2.3	3.54	4.91
67	25	0.68	1.02	1.44	2.27	3.09
67	25	0.25	0.41	0.63	1.08	1.57
67	25	0.15	0.23	0.37	0.64	0.95
67	25	0.13	0.21	0.33	0.57	0.85
67	25	0.08	0.13	0.2	0.34	0.51
68	25	0.36	0.52	0.75	1.18	1.67
68	25	0.69	1.02	1.46	2.35	3.49
68	25	0.97	1.36	1.91	2.96	4.11
68	25	0.65	0.95	1.31	1.99	2.66
68	25	0.26	0.42	0.62	1.03	1.43
68	25	0.16	0.24	0.38	0.62	0.89
68	25	0.14	0.22	0.34	0.56	0.8
68	25	0.08	0.13	0.2	0.32	0.45
69	25	0.4	0.57	0.81	1.25	1.73
69	25	0.76	1.11	1.56	2.48	3.59
69	25	1.06	1.49	2.08	3.14	4.28
69	25	0.71	1.03	1.42	2.17	2.85
69	25	0.29	0.46	0.69	1.13	1.58
69	25	0.17	0.27	0.42	0.69	0.98
69	25	0.15	0.24	0.38	0.62	0.9
69	25	0.09	0.15	0.22	0.37	0.51
70	25	0.42	0.6	0.85	1.31	1.8
70	25	0.8	1.16	1.64	2.59	3.69
70	25	1.1	1.56	2.2	3.29	4.46
70	25	0.72	1.06	1.47	2.27	2.98
70	25	0.28	0.46	0.7	1.17	1.66
70	25	0.17	0.27	0.42	0.71	1.02
70	25	0.14	0.24	0.38	0.63	0.93
70	25	0.09	0.15	0.23	0.38	0.55
71	25	0.27	0.4	0.53	0.77	0.99
71	25	0.52	0.73	1	1.37	1.73
71	25	0.75	1.05	1.37	1.97	2.44
71	25	0.52	0.76	1.06	1.53	2.03
71	25	0.21	0.34	0.52	0.88	1.22
71	25	0.12	0.2	0.32	0.54	0.77
71	25	0.11	0.18	0.29	0.49	0.7
71	25	0.07	0.11	0.17	0.28	0.4
72	25	0.17	0.25	0.36	0.52	0.67
72	25	0.31	0.46	0.64	0.97	1.2
72	25	0.46	0.66	0.95	1.32	1.69
72	25	0.32	0.49	0.7	1.07	1.39
72	25	0.12	0.2	0.33	0.56	0.82
72	25	0.07	0.12	0.2	0.36	0.51
72	25	0.06	0.11	0.19	0.33	0.47
72	25	0.04	0.07	0.11	0.18	0.25
73	25	0.06	0.1	0.16	0.26	0.37
73	25	0.12	0.19	0.29	0.48	0.66
73	25	0.18	0.29	0.43	0.69	0.96
73	25	0.12	0.2	0.32	0.53	0.75
73	25	0.04	0.07	0.12	0.24	0.38

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
73	25	0.02	0.04	0.08	0.15	0.23
73	25	0.02	0.04	0.07	0.14	0.21
73	25	0.01	0.02	0.04	0.08	0.12
60	26	0.43	0.69	1.11	2	2.92
60	26	0.88	1.47	2.41	4.46	6.62
60	26	1.13	1.8	2.82	4.98	7.13
60	26	0.62	0.98	1.47	2.51	3.66
60	26	0.2	0.32	0.5	0.86	1.26
60	26	0.11	0.17	0.26	0.45	0.66
60	26	0.09	0.14	0.22	0.37	0.55
60	26	0.06	0.09	0.14	0.25	0.37
61	26	0.69	1.11	1.74	2.93	4.22
61	26	1.46	2.42	3.85	6.62	9.55
61	26	1.79	2.82	4.34	7.14	10.18
61	26	0.96	1.47	2.24	3.7	5.36
61	26	0.31	0.49	0.75	1.28	1.9
61	26	0.16	0.25	0.39	0.67	1.01
61	26	0.13	0.21	0.32	0.56	0.85
61	26	0.09	0.14	0.22	0.38	0.58
62	26	0.61	0.99	1.55	2.68	3.87
62	26	1.28	2.12	3.38	5.96	8.57
62	26	1.6	2.53	3.89	6.54	9.37
62	26	0.89	1.37	2.1	3.52	5.18
62	26	0.3	0.48	0.75	1.34	2.06
62	26	0.16	0.25	0.41	0.73	1.15
62	26	0.13	0.21	0.34	0.63	0.99
62	26	0.09	0.14	0.22	0.41	0.67
63	26	0.47	0.76	1.19	2.14	3.14
63	26	0.95	1.55	2.5	4.52	6.62
63	26	1.24	1.95	3.02	5.29	7.66
63	26	0.74	1.15	1.77	3.09	4.68
63	26	0.27	0.44	0.71	1.35	2.22
63	26	0.15	0.24	0.4	0.77	1.31
63	26	0.13	0.21	0.34	0.68	1.15
63	26	0.08	0.13	0.22	0.44	0.77
64	26	0.5	0.78	1.22	2.16	3.18
64	26	1	1.6	2.54	4.55	6.7
64	26	1.31	2.03	3.08	5.32	7.72
64	26	0.79	1.21	1.84	3.16	4.74
64	26	0.29	0.47	0.76	1.42	2.29
64	26	0.16	0.26	0.43	0.82	1.36
64	26	0.14	0.23	0.37	0.72	1.2
64	26	0.09	0.14	0.24	0.46	0.79
65	26	0.67	1.07	1.66	2.82	4.09
65	26	1.39	2.28	3.57	6.2	8.93
65	26	1.74	2.72	4.15	6.89	9.87
65	26	0.99	1.51	2.3	3.85	5.64
65	26	0.35	0.56	0.89	1.59	2.46
65	26	0.19	0.3	0.49	0.89	1.41
65	26	0.16	0.26	0.42	0.77	1.22
65	26	0.1	0.17	0.27	0.5	0.82
66	26	0.84	1.34	2.1	3.45	5
66	26	1.79	2.91	4.62	7.7	11.15
66	26	2.18	3.37	5.19	8.34	11.94
66	26	1.15	1.79	2.7	4.53	6.45
66	26	0.39	0.62	0.98	1.71	2.57
66	26	0.2	0.33	0.52	0.93	1.42

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
66	26	0.17	0.27	0.44	0.79	1.22
66	26	0.11	0.18	0.29	0.53	0.84
67	26	0.79	1.28	2.04	3.37	4.88
67	26	1.68	2.8	4.53	7.57	10.93
67	26	2.03	3.22	5.05	8.16	11.71
67	26	1.08	1.68	2.56	4.31	6.18
67	26	0.37	0.58	0.91	1.56	2.35
67	26	0.19	0.31	0.48	0.84	1.28
67	26	0.16	0.26	0.41	0.71	1.09
67	26	0.1	0.17	0.26	0.47	0.74
68	26	0.34	0.5	0.7	1.12	1.6
68	26	0.67	0.98	1.4	2.27	3.41
68	26	0.93	1.3	1.82	2.85	4.01
68	26	0.59	0.86	1.19	1.78	2.41
68	26	0.23	0.36	0.52	0.85	1.17
68	26	0.13	0.21	0.31	0.5	0.69
68	26	0.12	0.18	0.27	0.45	0.62
68	26	0.07	0.11	0.16	0.26	0.36
69	26	0.3	0.44	0.64	1.04	1.53
69	26	0.57	0.85	1.27	2.14	3.3
69	26	0.79	1.15	1.63	2.62	3.82
69	26	0.53	0.77	1.09	1.64	2.24
69	26	0.21	0.33	0.49	0.78	1.09
69	26	0.12	0.19	0.29	0.47	0.65
69	26	0.11	0.17	0.26	0.43	0.59
69	26	0.07	0.1	0.15	0.23	0.32
70	26	0.25	0.39	0.59	1	1.5
70	26	0.49	0.77	1.19	2.09	3.26
70	26	0.68	1.03	1.52	2.53	3.75
70	26	0.44	0.66	0.97	1.52	2.13
70	26	0.16	0.26	0.41	0.67	0.96
70	26	0.09	0.15	0.23	0.4	0.56
70	26	0.08	0.13	0.21	0.36	0.51
70	26	0.05	0.08	0.12	0.2	0.28
71	26	0.18	0.3	0.48	0.87	1.36
71	26	0.36	0.58	0.95	1.83	2.98
71	26	0.5	0.79	1.24	2.19	3.39
71	26	0.32	0.5	0.76	1.28	1.85
71	26	0.11	0.19	0.3	0.52	0.76
71	26	0.06	0.1	0.17	0.3	0.44
71	26	0.05	0.09	0.15	0.27	0.4
71	26	0.03	0.06	0.09	0.15	0.22
72	26	0.09	0.14	0.2	0.31	0.42
72	26	0.17	0.26	0.39	0.58	0.78
72	26	0.25	0.39	0.54	0.85	1.09
72	26	0.17	0.25	0.39	0.6	0.83
72	26	0.05	0.09	0.15	0.26	0.4
72	26	0.03	0.05	0.09	0.16	0.24
72	26	0.03	0.05	0.08	0.15	0.22
72	26	0.02	0.03	0.05	0.08	0.12
73	26	0.02	0.04	0.07	0.11	0.15
73	26	0.04	0.08	0.13	0.2	0.28
73	26	0.07	0.12	0.19	0.31	0.42
73	26	0.04	0.08	0.12	0.2	0.28
73	26	0.01	0.02	0.04	0.07	0.1
73	26	0.01	0.01	0.02	0.04	0.06
73	26	0.01	0.01	0.02	0.03	0.05

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
73	26	0	0.01	0.01	0.02	0.03
74	26	0	0.01	0.02	0.04	0.07
74	26	0	0.02	0.04	0.08	0.12
74	26	0	0.03	0.07	0.13	0.19
74	26	0	0.02	0.04	0.08	0.13
74	26	0	0.01	0.01	0.02	0.04
74	26	0	0	0.01	0.01	0.02
74	26	0	0	0.01	0.01	0.02
74	26	0	0	0	0.01	0.01
60	27	0.42	0.69	1.1	2	2.92
60	27	0.88	1.46	2.41	4.46	6.62
60	27	1.13	1.8	2.81	4.98	7.13
60	27	0.62	0.97	1.46	2.49	3.66
60	27	0.2	0.32	0.49	0.84	1.24
60	27	0.11	0.17	0.25	0.43	0.64
60	27	0.09	0.14	0.21	0.36	0.53
60	27	0.06	0.09	0.14	0.24	0.36
61	27	0.69	1.11	1.73	2.9	4.13
61	27	1.46	2.42	3.84	6.56	9.34
61	27	1.79	2.81	4.33	7.08	10.03
61	27	0.95	1.45	2.21	3.62	5.24
61	27	0.3	0.48	0.72	1.23	1.81
61	27	0.16	0.24	0.37	0.64	0.95
61	27	0.13	0.2	0.31	0.53	0.79
61	27	0.09	0.14	0.21	0.36	0.55
62	27	0.7	1.12	1.75	2.97	4.29
62	27	1.48	2.44	3.88	6.7	9.71
62	27	1.82	2.85	4.38	7.22	10.32
62	27	0.98	1.5	2.27	3.77	5.45
62	27	0.33	0.51	0.78	1.34	1.98
62	27	0.17	0.27	0.41	0.71	1.06
62	27	0.14	0.22	0.34	0.6	0.9
62	27	0.09	0.15	0.23	0.4	0.61
63	27	0.6	0.92	1.37	2.29	3.25
63	27	1.24	1.94	2.93	5	7.04
63	27	1.57	2.38	3.5	5.71	8.01
63	27	0.9	1.33	1.96	3.19	4.59
63	27	0.31	0.49	0.75	1.31	1.98
63	27	0.17	0.26	0.41	0.72	1.12
63	27	0.14	0.22	0.35	0.62	0.96
63	27	0.09	0.15	0.23	0.41	0.66
64	27	0.83	1.33	2.09	3.4	4.88
64	27	1.76	2.89	4.61	7.6	10.87
64	27	2.14	3.34	5.17	8.26	11.78
64	27	1.14	1.77	2.67	4.45	6.32
64	27	0.39	0.61	0.96	1.68	2.54
64	27	0.2	0.32	0.51	0.91	1.41
64	27	0.17	0.27	0.43	0.77	1.2
64	27	0.11	0.18	0.28	0.53	0.84
65	27	0.85	1.34	2.09	3.39	4.86
65	27	1.81	2.91	4.61	7.58	10.87
65	27	2.2	3.38	5.17	8.24	11.72
65	27	1.19	1.81	2.69	4.42	6.26
65	27	0.41	0.64	0.99	1.68	2.5
65	27	0.22	0.34	0.53	0.92	1.38
65	27	0.18	0.29	0.45	0.78	1.18
65	27	0.12	0.19	0.29	0.52	0.81

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
66	27	0.86	1.34	2.09	3.44	5
66	27	1.81	2.91	4.61	7.7	11.18
66	27	2.21	3.38	5.17	8.32	11.93
66	27	1.21	1.83	2.71	4.48	6.39
66	27	0.44	0.67	1.02	1.71	2.52
66	27	0.23	0.37	0.55	0.94	1.39
66	27	0.2	0.31	0.48	0.81	1.2
66	27	0.13	0.2	0.3	0.53	0.8
67	27	0.86	1.34	2.08	3.42	4.95
67	27	1.81	2.9	4.59	7.64	11.07
67	27	2.21	3.37	5.15	8.27	11.85
67	27	1.21	1.83	2.7	4.46	6.34
67	27	0.44	0.67	1.03	1.72	2.52
67	27	0.23	0.37	0.56	0.95	1.4
67	27	0.2	0.31	0.48	0.81	1.21
67	27	0.13	0.2	0.31	0.53	0.81
68	27	0.63	0.98	1.5	2.56	3.69
68	27	1.29	2.05	3.23	5.72	8.27
68	27	1.64	2.5	3.75	6.25	8.92
68	27	0.98	1.43	2.11	3.39	4.85
68	27	0.36	0.56	0.85	1.4	2.04
68	27	0.2	0.31	0.47	0.79	1.16
68	27	0.17	0.27	0.41	0.69	1.01
68	27	0.11	0.17	0.26	0.44	0.65
69	27	0.36	0.52	0.73	1.16	1.65
69	27	0.69	1.01	1.44	2.32	3.49
69	27	0.97	1.35	1.89	2.94	4.11
69	27	0.63	0.92	1.26	1.91	2.58
69	27	0.25	0.39	0.57	0.95	1.31
69	27	0.15	0.23	0.34	0.56	0.79
69	27	0.13	0.2	0.3	0.5	0.71
69	27	0.08	0.12	0.18	0.29	0.42
70	27	0.27	0.41	0.6	1.01	1.5
70	27	0.52	0.8	1.21	2.1	3.25
70	27	0.72	1.08	1.56	2.57	3.76
70	27	0.47	0.69	1	1.55	2.16
70	27	0.17	0.27	0.41	0.68	0.97
70	27	0.1	0.16	0.24	0.4	0.56
70	27	0.08	0.14	0.21	0.35	0.51
70	27	0.05	0.08	0.13	0.21	0.29
71	27	0.2	0.32	0.51	0.93	1.44
71	27	0.39	0.64	1.05	2	3.18
71	27	0.54	0.86	1.34	2.37	3.62
71	27	0.33	0.51	0.77	1.3	1.89
71	27	0.11	0.18	0.28	0.48	0.7
71	27	0.06	0.1	0.15	0.26	0.39
71	27	0.05	0.08	0.13	0.23	0.34
71	27	0.03	0.05	0.08	0.14	0.2
72	27	0.09	0.17	0.28	0.55	0.9
72	27	0.19	0.34	0.59	1.18	1.98
72	27	0.26	0.46	0.77	1.46	2.33
72	27	0.15	0.25	0.42	0.77	1.18
72	27	0.04	0.08	0.13	0.23	0.36
72	27	0.02	0.04	0.07	0.12	0.18
72	27	0.02	0.03	0.05	0.1	0.15
72	27	0.01	0.02	0.04	0.07	0.1
73	27	0.05	0.08	0.11	0.18	0.23

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
73	27	0.09	0.15	0.22	0.34	0.46
73	27	0.13	0.21	0.32	0.49	0.66
73	27	0.08	0.13	0.2	0.32	0.44
73	27	0.02	0.04	0.06	0.11	0.16
73	27	0.01	0.02	0.04	0.06	0.09
73	27	0.01	0.02	0.03	0.05	0.08
73	27	0.01	0.01	0.02	0.04	0.05
74	27	0.02	0.04	0.06	0.09	0.13
74	27	0.04	0.07	0.11	0.18	0.24
74	27	0.06	0.1	0.17	0.26	0.37
74	27	0.03	0.06	0.1	0.18	0.25
74	27	0.01	0.02	0.03	0.06	0.09
74	27	0.01	0.01	0.02	0.03	0.05
74	27	0	0.01	0.01	0.03	0.04
74	27	0	0.01	0.01	0.02	0.03
75	27	0	0	0.01	0.03	0.04
75	27	0	0	0.02	0.05	0.08
75	27	0	0	0.03	0.08	0.12
75	27	0	0	0.02	0.05	0.08
75	27	0	0	0.01	0.01	0.02
75	27	0	0	0	0.01	0.01
75	27	0	0	0	0.01	0.01
75	27	0	0	0	0.01	0.01
60	28	0.43	0.7	1.11	2	2.87
60	28	0.89	1.48	2.43	4.46	6.51
60	28	1.14	1.81	2.83	4.99	7.05
60	28	0.62	0.97	1.46	2.48	3.58
60	28	0.2	0.32	0.49	0.83	1.22
60	28	0.11	0.17	0.25	0.43	0.63
60	28	0.09	0.14	0.21	0.35	0.52
60	28	0.06	0.09	0.14	0.24	0.36
61	28	0.7	1.12	1.76	2.97	4.28
61	28	1.49	2.46	3.92	6.73	9.7
61	28	1.82	2.86	4.42	7.25	10.33
61	28	0.96	1.47	2.24	3.71	5.39
61	28	0.3	0.48	0.73	1.24	1.83
61	28	0.16	0.24	0.37	0.64	0.95
61	28	0.13	0.2	0.31	0.53	0.78
61	28	0.09	0.14	0.21	0.36	0.55
62	28	0.71	1.14	1.78	2.98	4.28
62	28	1.51	2.48	3.95	6.75	9.7
62	28	1.85	2.89	4.44	7.27	10.35
62	28	1	1.51	2.27	3.73	5.39
62	28	0.33	0.51	0.76	1.28	1.88
62	28	0.17	0.26	0.4	0.67	0.99
62	28	0.14	0.22	0.33	0.56	0.82
62	28	0.09	0.15	0.22	0.38	0.57
63	28	0.72	1.15	1.78	2.98	4.28
63	28	1.53	2.49	3.94	6.73	9.69
63	28	1.89	2.91	4.45	7.26	10.34
63	28	1.03	1.54	2.31	3.78	5.43
63	28	0.35	0.53	0.81	1.35	1.97
63	28	0.18	0.28	0.43	0.71	1.05
63	28	0.15	0.24	0.36	0.6	0.88
63	28	0.1	0.16	0.24	0.4	0.61
64	28	0.83	1.32	2.07	3.39	4.9
64	28	1.78	2.88	4.6	7.62	10.96

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
64	28	2.16	3.34	5.14	8.24	11.78
64	28	1.15	1.76	2.63	4.38	6.24
64	28	0.4	0.61	0.94	1.59	2.37
64	28	0.21	0.32	0.49	0.85	1.28
64	28	0.17	0.27	0.42	0.72	1.08
64	28	0.11	0.18	0.28	0.49	0.76
65	28	0.86	1.34	2.08	3.39	4.88
65	28	1.82	2.91	4.61	7.6	10.92
65	28	2.21	3.38	5.16	8.25	11.76
65	28	1.22	1.83	2.69	4.42	6.26
65	28	0.44	0.67	1.02	1.69	2.49
65	28	0.24	0.37	0.55	0.93	1.37
65	28	0.2	0.31	0.47	0.79	1.18
65	28	0.13	0.2	0.3	0.53	0.8
66	28	0.88	1.35	2.08	3.38	4.85
66	28	1.84	2.91	4.58	7.56	10.86
66	28	2.26	3.41	5.14	8.21	11.68
66	28	1.29	1.9	2.75	4.44	6.24
66	28	0.49	0.74	1.11	1.81	2.62
66	28	0.27	0.42	0.61	1.02	1.48
66	28	0.23	0.36	0.53	0.89	1.29
66	28	0.15	0.22	0.34	0.57	0.85
67	28	0.94	1.42	2.14	3.46	4.96
67	28	1.94	3.01	4.66	7.67	11.06
67	28	2.41	3.57	5.28	8.37	11.88
67	28	1.41	2.07	2.95	4.7	6.54
67	28	0.55	0.85	1.26	2.09	3
67	28	0.31	0.48	0.71	1.19	1.74
67	28	0.26	0.42	0.62	1.05	1.52
67	28	0.17	0.26	0.4	0.68	1.02
68	28	1.56	2.46	3.63	5.72	7.4
68	28	3.4	5.46	7.99	13.2	19.3
68	28	3.89	5.98	8.73	14.4	21.03
68	28	2.08	3.18	4.84	7.99	11.62
68	28	0.73	1.17	1.87	3.47	5.53
68	28	0.38	0.63	1.02	1.97	3.29
68	28	0.32	0.53	0.87	1.7	2.88
68	28	0.21	0.36	0.6	1.24	2.21
69	28	1.38	2.27	3.42	5.6	7.33
69	28	3.01	5.06	7.56	12.83	19.15
69	28	3.46	5.51	8.18	13.8	20.49
69	28	1.83	2.88	4.48	7.61	11.22
69	28	0.63	1.03	1.66	3.13	5.06
69	28	0.33	0.54	0.89	1.76	2.97
69	28	0.27	0.46	0.76	1.51	2.59
69	28	0.18	0.3	0.52	1.09	1.97
70	28	0.42	0.59	0.82	1.27	1.75
70	28	0.83	1.17	1.62	2.54	3.63
70	28	1.13	1.56	2.16	3.22	4.37
70	28	0.73	1.04	1.42	2.14	2.82
70	28	0.28	0.44	0.64	1.05	1.47
70	28	0.16	0.25	0.38	0.62	0.9
70	28	0.14	0.22	0.34	0.55	0.8
70	28	0.09	0.14	0.21	0.34	0.48
71	28	0.26	0.39	0.58	0.98	1.48
71	28	0.51	0.77	1.18	2.07	3.23
71	28	0.71	1.05	1.52	2.51	3.72

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
71	28	0.45	0.66	0.96	1.49	2.08
71	28	0.16	0.25	0.39	0.63	0.9
71	28	0.09	0.15	0.22	0.37	0.52
71	28	0.08	0.13	0.19	0.32	0.46
71	28	0.05	0.08	0.12	0.19	0.27
72	28	0.17	0.29	0.47	0.9	1.42
72	28	0.34	0.58	0.99	1.97	3.17
72	28	0.47	0.77	1.25	2.31	3.58
72	28	0.28	0.45	0.69	1.2	1.79
72	28	0.09	0.15	0.23	0.4	0.59
72	28	0.05	0.08	0.12	0.21	0.31
72	28	0.04	0.07	0.1	0.18	0.26
72	28	0.03	0.04	0.07	0.11	0.17
73	28	0.08	0.13	0.21	0.37	0.53
73	28	0.16	0.27	0.44	0.76	1.1
73	28	0.22	0.38	0.59	1	1.41
73	28	0.13	0.22	0.34	0.56	0.81
73	28	0.04	0.07	0.1	0.18	0.26
73	28	0.02	0.03	0.06	0.1	0.14
73	28	0.02	0.03	0.05	0.08	0.12
73	28	0.01	0.02	0.03	0.06	0.08
74	28	0.04	0.06	0.09	0.15	0.2
74	28	0.08	0.12	0.19	0.29	0.4
74	28	0.11	0.18	0.27	0.43	0.57
74	28	0.07	0.11	0.18	0.28	0.4
74	28	0.02	0.03	0.05	0.09	0.14
74	28	0.01	0.02	0.03	0.05	0.08
74	28	0.01	0.02	0.03	0.05	0.07
74	28	0.01	0.01	0.02	0.03	0.04
75	28	0.01	0.03	0.05	0.08	0.11
75	28	0.03	0.05	0.09	0.15	0.21
75	28	0.04	0.08	0.14	0.23	0.32
75	28	0.02	0.05	0.09	0.16	0.22
75	28	0.01	0.02	0.03	0.05	0.07
75	28	0	0.01	0.02	0.03	0.04
75	28	0	0.01	0.01	0.02	0.04
75	28	0	0.01	0.01	0.02	0.03
60	29	0.44	0.71	1.14	2.05	2.96
60	29	0.91	1.51	2.49	4.6	6.7
60	29	1.16	1.85	2.89	5.12	7.24
60	29	0.63	0.99	1.49	2.53	3.68
60	29	0.2	0.32	0.5	0.84	1.24
60	29	0.11	0.17	0.26	0.43	0.64
60	29	0.09	0.14	0.21	0.36	0.53
60	29	0.06	0.09	0.14	0.24	0.36
61	29	0.7	1.13	1.78	3	4.33
61	29	1.5	2.48	3.95	6.79	9.82
61	29	1.83	2.88	4.45	7.31	10.44
61	29	0.96	1.47	2.24	3.74	5.44
61	29	0.3	0.48	0.72	1.23	1.82
61	29	0.16	0.24	0.37	0.63	0.93
61	29	0.13	0.2	0.3	0.52	0.77
61	29	0.09	0.13	0.21	0.36	0.55
62	29	0.71	1.14	1.78	2.98	4.27
62	29	1.51	2.49	3.96	6.75	9.67
62	29	1.85	2.89	4.45	7.27	10.34
62	29	0.99	1.49	2.25	3.71	5.37

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
62	29	0.32	0.5	0.74	1.25	1.83
62	29	0.17	0.25	0.38	0.64	0.94
62	29	0.14	0.21	0.32	0.53	0.78
62	29	0.09	0.14	0.21	0.37	0.55
63	29	0.71	1.13	1.77	2.98	4.28
63	29	1.51	2.47	3.93	6.74	9.7
63	29	1.85	2.88	4.43	7.26	10.34
63	29	1	1.51	2.26	3.72	5.39
63	29	0.34	0.51	0.77	1.28	1.86
63	29	0.18	0.27	0.4	0.67	0.98
63	29	0.15	0.22	0.34	0.56	0.81
63	29	0.1	0.15	0.22	0.38	0.57
64	29	0.75	1.17	1.81	3.01	4.33
64	29	1.58	2.54	3.99	6.79	9.78
64	29	1.95	2.98	4.52	7.34	10.44
64	29	1.08	1.6	2.37	3.85	5.52
64	29	0.38	0.58	0.87	1.42	2.06
64	29	0.2	0.31	0.46	0.77	1.11
64	29	0.17	0.26	0.4	0.65	0.95
64	29	0.11	0.17	0.25	0.43	0.64
65	29	0.88	1.36	2.09	3.42	4.95
65	29	1.84	2.93	4.62	7.66	11.06
65	29	2.25	3.42	5.18	8.3	11.85
65	29	1.26	1.88	2.76	4.5	6.36
65	29	0.47	0.71	1.08	1.79	2.62
65	29	0.25	0.4	0.59	1	1.47
65	29	0.22	0.34	0.51	0.86	1.27
65	29	0.14	0.22	0.33	0.57	0.85
66	29	1.01	1.5	2.22	3.52	4.99
66	29	2.09	3.17	4.81	7.73	11
66	29	2.58	3.78	5.49	8.57	12.02
66	29	1.51	2.21	3.13	4.95	6.82
66	29	0.59	0.92	1.37	2.3	3.33
66	29	0.33	0.52	0.78	1.32	1.95
66	29	0.29	0.45	0.68	1.15	1.7
66	29	0.18	0.29	0.44	0.77	1.18
67	29	1.75	2.67	3.92	6.01	7.77
67	29	3.81	5.88	8.53	13.93	20.2
67	29	4.37	6.51	9.44	15.42	22.37
67	29	2.35	3.56	5.36	8.84	12.9
67	29	0.86	1.38	2.2	4.09	6.52
67	29	0.46	0.75	1.23	2.36	4
67	29	0.39	0.64	1.05	2.04	3.53
67	29	0.26	0.43	0.73	1.53	2.78
68	29	1.8	2.71	3.94	5.99	7.7
68	29	3.89	5.93	8.54	13.82	19.91
68	29	4.5	6.61	9.52	15.4	22.16
68	29	2.45	3.68	5.48	8.95	12.96
68	29	0.91	1.46	2.33	4.33	6.88
68	29	0.49	0.8	1.31	2.54	4.26
68	29	0.41	0.68	1.12	2.19	3.76
68	29	0.28	0.47	0.79	1.66	3
69	29	1.71	2.61	3.85	5.98	7.82
69	29	3.72	5.78	8.45	13.96	20.42
69	29	4.26	6.37	9.25	15.15	22
69	29	2.28	3.44	5.18	8.52	12.43
69	29	0.8	1.28	2.02	3.7	5.85

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
69	29	0.42	0.69	1.11	2.1	3.52
69	29	0.36	0.58	0.94	1.81	3.08
69	29	0.24	0.39	0.65	1.33	2.37
70	29	1.09	1.71	2.57	4.13	5.64
70	29	2.37	3.79	5.84	9.43	13.54
70	29	2.76	4.26	6.27	10.01	14.24
70	29	1.46	2.21	3.2	5.18	7.05
70	29	0.51	0.78	1.15	1.89	2.71
70	29	0.27	0.42	0.62	1.03	1.49
70	29	0.23	0.35	0.53	0.88	1.28
70	29	0.15	0.23	0.34	0.58	0.86
71	29	0.34	0.48	0.68	1.07	1.56
71	29	0.66	0.95	1.35	2.18	3.36
71	29	0.94	1.28	1.76	2.75	3.93
71	29	0.6	0.84	1.15	1.7	2.29
71	29	0.22	0.34	0.49	0.77	1.07
71	29	0.13	0.19	0.28	0.45	0.62
71	29	0.11	0.17	0.25	0.4	0.55
71	29	0.07	0.11	0.15	0.24	0.33
72	29	0.22	0.34	0.52	0.93	1.45
72	29	0.44	0.68	1.07	2.02	3.23
72	29	0.61	0.91	1.38	2.39	3.66
72	29	0.39	0.56	0.81	1.31	1.88
72	29	0.13	0.2	0.3	0.48	0.68
72	29	0.07	0.11	0.17	0.27	0.38
72	29	0.06	0.1	0.14	0.23	0.32
72	29	0.04	0.06	0.09	0.14	0.2
73	29	0.14	0.25	0.44	0.88	1.41
73	29	0.29	0.52	0.93	1.94	3.18
73	29	0.4	0.68	1.16	2.27	3.56
73	29	0.23	0.38	0.61	1.12	1.72
73	29	0.07	0.12	0.19	0.34	0.52
73	29	0.04	0.06	0.1	0.17	0.26
73	29	0.03	0.05	0.08	0.14	0.21
73	29	0.02	0.04	0.05	0.09	0.14
74	29	0.07	0.11	0.18	0.27	0.38
74	29	0.14	0.22	0.35	0.55	0.76
74	29	0.2	0.32	0.48	0.77	1.05
74	29	0.12	0.19	0.29	0.47	0.64
74	29	0.04	0.06	0.09	0.16	0.22
74	29	0.02	0.03	0.05	0.09	0.13
74	29	0.02	0.03	0.04	0.07	0.11
74	29	0.01	0.02	0.03	0.05	0.07
75	29	0.04	0.06	0.09	0.14	0.19
75	29	0.07	0.11	0.17	0.26	0.36
75	29	0.11	0.18	0.26	0.41	0.52
75	29	0.07	0.11	0.17	0.27	0.37
75	29	0.02	0.03	0.05	0.09	0.13
75	29	0.01	0.02	0.03	0.05	0.08
75	29	0.01	0.02	0.03	0.05	0.07
75	29	0.01	0.01	0.02	0.03	0.04
76	29	0.02	0.03	0.05	0.08	0.11
76	29	0.03	0.06	0.09	0.15	0.21
76	29	0.05	0.09	0.14	0.23	0.32
76	29	0.03	0.06	0.09	0.16	0.22
76	29	0.01	0.02	0.03	0.05	0.08
76	29	0.01	0.01	0.02	0.03	0.05

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
76	29	0	0.01	0.01	0.03	0.04
76	29	0	0.01	0.01	0.02	0.03
60	30	0.43	0.71	1.14	2.05	2.96
60	30	0.91	1.51	2.49	4.6	6.71
60	30	1.15	1.85	2.89	5.12	7.24
60	30	0.63	0.98	1.49	2.53	3.68
60	30	0.2	0.32	0.49	0.84	1.24
60	30	0.1	0.17	0.25	0.43	0.63
60	30	0.09	0.14	0.21	0.35	0.52
60	30	0.06	0.09	0.14	0.24	0.36
61	30	0.7	1.13	1.78	3	4.33
61	30	1.5	2.48	3.95	6.79	9.82
61	30	1.82	2.87	4.45	7.31	10.43
61	30	0.95	1.47	2.24	3.73	5.43
61	30	0.29	0.47	0.72	1.23	1.81
61	30	0.15	0.23	0.36	0.62	0.93
61	30	0.12	0.19	0.29	0.51	0.76
61	30	0.08	0.13	0.2	0.36	0.55
62	30	0.7	1.13	1.77	2.97	4.26
62	30	1.5	2.48	3.95	6.74	9.65
62	30	1.84	2.88	4.44	7.26	10.32
62	30	0.97	1.48	2.24	3.7	5.36
62	30	0.31	0.48	0.73	1.23	1.81
62	30	0.16	0.24	0.37	0.63	0.93
62	30	0.13	0.2	0.31	0.52	0.77
62	30	0.09	0.14	0.21	0.36	0.55
63	30	0.71	1.13	1.77	2.96	4.22
63	30	1.51	2.48	3.94	6.7	9.57
63	30	1.84	2.88	4.44	7.23	10.26
63	30	0.98	1.49	2.25	3.69	5.34
63	30	0.32	0.5	0.75	1.26	1.84
63	30	0.17	0.26	0.39	0.65	0.96
63	30	0.14	0.21	0.32	0.54	0.8
63	30	0.09	0.14	0.22	0.37	0.56
64	30	0.71	1.14	1.78	3.01	4.36
64	30	1.51	2.48	3.96	6.81	9.88
64	30	1.84	2.89	4.45	7.33	10.49
64	30	1.01	1.53	2.3	3.8	5.5
64	30	0.35	0.54	0.81	1.36	1.99
64	30	0.18	0.29	0.43	0.73	1.07
64	30	0.16	0.24	0.37	0.62	0.91
64	30	0.1	0.16	0.24	0.41	0.61
65	30	0.97	1.51	2.31	3.76	5.33
65	30	2.06	3.25	5.12	8.27	11.9
65	30	2.48	3.78	5.67	9.09	12.99
65	30	1.37	2.08	3.06	5.1	7.24
65	30	0.5	0.78	1.21	2.1	3.18
65	30	0.27	0.43	0.66	1.18	1.81
65	30	0.23	0.37	0.57	1.01	1.56
65	30	0.15	0.24	0.37	0.68	1.1
66	30	1.77	2.7	3.94	6.01	7.75
66	30	3.86	5.94	8.58	13.94	20.13
66	30	4.43	6.58	9.52	15.52	22.46
66	30	2.35	3.57	5.4	8.89	12.98
66	30	0.83	1.34	2.17	4.1	6.6
66	30	0.44	0.72	1.2	2.36	4.05
66	30	0.37	0.61	1.01	2.03	3.56

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
66	30	0.25	0.42	0.72	1.54	2.85
67	30	1.82	2.74	4.02	6.14	7.99
67	30	3.92	6	8.71	14.28	20.76
67	30	4.52	6.68	9.66	15.75	22.79
67	30	2.47	3.73	5.58	9.17	13.37
67	30	0.92	1.48	2.36	4.37	6.92
67	30	0.49	0.81	1.33	2.56	4.28
67	30	0.42	0.69	1.14	2.2	3.78
67	30	0.28	0.47	0.8	1.67	3.01
68	30	1.8	2.7	3.91	5.93	7.6
68	30	3.89	5.92	8.48	13.63	19.52
68	30	4.48	6.59	9.47	15.29	21.96
68	30	2.42	3.64	5.42	8.85	12.82
68	30	0.89	1.43	2.29	4.26	6.8
68	30	0.48	0.78	1.28	2.49	4.2
68	30	0.4	0.66	1.1	2.14	3.7
68	30	0.27	0.46	0.77	1.63	2.96
69	30	1.65	2.47	3.39	5.13	6.3
69	30	3.67	5.6	7.63	11.49	15.66
69	30	4.13	6.06	8.38	12.89	17.85
69	30	2.13	3.07	4.41	6.67	8.93
69	30	0.73	1.11	1.65	2.76	4
69	30	0.39	0.59	0.9	1.53	2.27
69	30	0.32	0.5	0.76	1.31	1.94
69	30	0.21	0.33	0.52	0.91	1.42
70	30	1.37	2.02	2.73	3.97	5.22
70	30	3.03	4.48	6.14	8.85	11.67
70	30	3.49	5.15	6.87	10.07	13.45
70	30	1.79	2.57	3.56	5.42	7.09
70	30	0.59	0.89	1.28	2.08	2.94
70	30	0.31	0.46	0.68	1.12	1.6
70	30	0.25	0.39	0.57	0.95	1.36
70	30	0.17	0.26	0.39	0.65	0.96
71	30	0.53	0.74	1.02	1.5	2.01
71	30	1.09	1.52	2.11	3.18	4.33
71	30	1.41	1.98	2.67	3.91	5.21
71	30	0.85	1.17	1.57	2.32	3.02
71	30	0.3	0.44	0.63	0.99	1.33
71	30	0.17	0.24	0.35	0.55	0.76
71	30	0.14	0.21	0.3	0.48	0.66
71	30	0.09	0.13	0.19	0.3	0.42
72	30	0.26	0.38	0.56	0.94	1.45
72	30	0.52	0.76	1.14	2.03	3.21
72	30	0.72	1.03	1.49	2.45	3.68
72	30	0.45	0.64	0.9	1.39	1.94
72	30	0.16	0.23	0.34	0.53	0.74
72	30	0.09	0.13	0.19	0.29	0.41
72	30	0.07	0.11	0.16	0.25	0.35
72	30	0.05	0.07	0.1	0.16	0.22
73	30	0.2	0.32	0.5	0.92	1.44
73	30	0.4	0.64	1.04	2	3.21
73	30	0.55	0.85	1.32	2.36	3.64
73	30	0.33	0.51	0.75	1.26	1.85
73	30	0.11	0.17	0.26	0.44	0.63
73	30	0.06	0.09	0.14	0.23	0.34
73	30	0.05	0.08	0.12	0.2	0.29
73	30	0.03	0.05	0.08	0.13	0.18

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
74	30	0.17	0.28	0.46	0.87	1.39
74	30	0.34	0.56	0.93	1.87	3.07
74	30	0.48	0.76	1.21	2.22	3.46
74	30	0.3	0.47	0.72	1.23	1.82
74	30	0.1	0.16	0.26	0.46	0.68
74	30	0.05	0.09	0.14	0.25	0.38
74	30	0.05	0.08	0.12	0.22	0.33
74	30	0.03	0.05	0.08	0.13	0.2
75	30	0.17	0.23	0.33	0.49	0.64
75	30	0.31	0.45	0.61	0.93	1.16
75	30	0.46	0.64	0.9	1.26	1.62
75	30	0.31	0.46	0.65	1	1.3
75	30	0.11	0.18	0.29	0.5	0.72
75	30	0.07	0.11	0.18	0.31	0.46
75	30	0.06	0.1	0.16	0.28	0.42
75	30	0.04	0.06	0.09	0.16	0.22
76	30	0.16	0.23	0.33	0.49	0.64
76	30	0.29	0.43	0.6	0.92	1.16
76	30	0.44	0.62	0.88	1.25	1.62
76	30	0.3	0.45	0.65	1.01	1.32
76	30	0.11	0.18	0.29	0.51	0.75
76	30	0.07	0.11	0.18	0.32	0.47
76	30	0.06	0.1	0.16	0.29	0.44
76	30	0.04	0.06	0.09	0.16	0.23
77	30	0.15	0.22	0.31	0.47	0.62
77	30	0.27	0.41	0.57	0.88	1.12
77	30	0.41	0.59	0.83	1.2	1.55
77	30	0.29	0.44	0.63	0.98	1.28
77	30	0.11	0.18	0.29	0.5	0.74
77	30	0.06	0.11	0.18	0.32	0.47
77	30	0.06	0.1	0.17	0.29	0.44
77	30	0.04	0.06	0.09	0.16	0.23
78	30	0.09	0.14	0.2	0.33	0.45
78	30	0.17	0.25	0.38	0.59	0.82
78	30	0.25	0.38	0.54	0.87	1.13
78	30	0.18	0.27	0.41	0.66	0.94
78	30	0.06	0.1	0.17	0.31	0.48
78	30	0.03	0.06	0.1	0.2	0.3
78	30	0.03	0.05	0.09	0.18	0.28
78	30	0.02	0.03	0.06	0.1	0.15
60	31	0.42	0.7	1.13	2.05	2.96
60	31	0.89	1.5	2.49	4.6	6.71
60	31	1.12	1.82	2.88	5.12	7.24
60	31	0.59	0.95	1.46	2.52	3.67
60	31	0.18	0.3	0.47	0.81	1.21
60	31	0.09	0.15	0.24	0.41	0.61
60	31	0.08	0.12	0.19	0.34	0.5
60	31	0.05	0.08	0.13	0.23	0.35
61	31	0.68	1.12	1.77	3	4.33
61	31	1.46	2.47	3.94	6.79	9.81
61	31	1.77	2.84	4.43	7.3	10.42
61	31	0.91	1.42	2.21	3.71	5.42
61	31	0.27	0.44	0.68	1.19	1.78
61	31	0.13	0.22	0.34	0.59	0.9
61	31	0.11	0.18	0.27	0.48	0.73
61	31	0.08	0.12	0.19	0.34	0.53
62	31	0.62	1.05	1.7	2.93	4.23

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
62	31	1.32	2.33	3.82	6.67	9.61
62	31	1.6	2.66	4.24	7.13	10.22
62	31	0.83	1.32	2.08	3.56	5.27
62	31	0.25	0.41	0.64	1.12	1.68
62	31	0.13	0.2	0.32	0.56	0.84
62	31	0.1	0.17	0.26	0.45	0.69
62	31	0.07	0.11	0.18	0.32	0.49
63	31	0.36	0.54	0.78	1.23	1.69
63	31	0.73	1.11	1.64	2.63	3.63
63	31	0.97	1.42	2.07	3.19	4.39
63	31	0.56	0.82	1.16	1.79	2.43
63	31	0.19	0.28	0.42	0.68	0.96
63	31	0.1	0.16	0.23	0.37	0.52
63	31	0.09	0.13	0.2	0.32	0.45
63	31	0.06	0.09	0.13	0.21	0.29
64	31	0.28	0.4	0.54	0.79	1.05
64	31	0.55	0.77	1.05	1.53	2.03
64	31	0.78	1.08	1.42	2.06	2.71
64	31	0.51	0.72	1	1.41	1.84
64	31	0.2	0.3	0.44	0.69	0.96
64	31	0.11	0.18	0.26	0.42	0.57
64	31	0.1	0.15	0.23	0.37	0.51
64	31	0.06	0.09	0.14	0.22	0.3
65	31	0.45	0.61	0.83	1.19	1.54
65	31	0.88	1.19	1.6	2.34	3.03
65	31	1.18	1.61	2.19	3.05	3.93
65	31	0.78	1.09	1.47	2.18	2.78
65	31	0.31	0.48	0.71	1.15	1.6
65	31	0.18	0.28	0.43	0.69	0.98
65	31	0.16	0.25	0.38	0.61	0.88
65	31	0.1	0.15	0.23	0.37	0.53
66	31	1.02	1.56	2.35	3.83	5.42
66	31	2.14	3.32	5.14	8.42	12.23
66	31	2.61	3.91	5.77	9.23	13.18
66	31	1.48	2.23	3.24	5.28	7.42
66	31	0.56	0.89	1.35	2.33	3.48
66	31	0.31	0.49	0.76	1.33	2.02
66	31	0.26	0.42	0.65	1.16	1.76
66	31	0.17	0.27	0.43	0.78	1.24
67	31	1.34	2.07	3.03	4.97	6.54
67	31	2.87	4.46	6.59	10.74	15.53
67	31	3.39	5.15	7.38	11.87	17
67	31	1.89	2.84	4.2	6.91	9.97
67	31	0.71	1.12	1.76	3.14	4.86
67	31	0.39	0.62	0.98	1.8	2.88
67	31	0.33	0.53	0.84	1.56	2.49
67	31	0.21	0.35	0.57	1.11	1.87
68	31	1.29	2.03	2.97	4.84	6.29
68	31	2.77	4.43	6.56	10.53	15.07
68	31	3.25	5.03	7.24	11.68	16.78
68	31	1.78	2.69	3.98	6.57	9.45
68	31	0.66	1.04	1.61	2.9	4.54
68	31	0.36	0.57	0.9	1.65	2.67
68	31	0.31	0.49	0.77	1.43	2.3
68	31	0.2	0.32	0.52	0.99	1.73
69	31	0.69	1.02	1.51	2.5	3.56
69	31	1.41	2.11	3.23	5.59	8.04

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
69	31	1.81	2.63	3.8	6.12	8.64
69	31	1.12	1.58	2.21	3.4	4.7
69	31	0.45	0.66	0.97	1.52	2.13
69	31	0.25	0.38	0.55	0.89	1.23
69	31	0.22	0.33	0.49	0.78	1.1
69	31	0.14	0.21	0.3	0.48	0.67
70	31	1.34	2.25	3.38	5.55	7.24
70	31	2.98	5.17	7.78	13.36	20.11
70	31	3.33	5.42	8.05	13.59	20.19
70	31	1.66	2.61	4	6.59	9.28
70	31	0.53	0.83	1.25	2.1	3.06
70	31	0.27	0.42	0.63	1.08	1.61
70	31	0.23	0.35	0.53	0.9	1.36
70	31	0.15	0.23	0.35	0.61	0.94
71	31	1.33	2.27	3.32	5.36	6.87
71	31	3.01	5.23	7.65	12.64	18.47
71	31	3.28	5.46	7.99	13.21	19.33
71	31	1.54	2.52	3.87	6.39	8.88
71	31	0.45	0.72	1.11	1.94	2.89
71	31	0.22	0.34	0.53	0.95	1.47
71	31	0.17	0.27	0.43	0.77	1.2
71	31	0.12	0.19	0.3	0.55	0.88
72	31	0.36	0.53	0.78	1.28	1.85
72	31	0.72	1.09	1.64	2.78	4.11
72	31	0.97	1.41	2.05	3.3	4.72
72	31	0.56	0.81	1.15	1.78	2.46
72	31	0.18	0.27	0.41	0.64	0.9
72	31	0.1	0.15	0.22	0.34	0.48
72	31	0.08	0.12	0.18	0.29	0.41
72	31	0.06	0.08	0.12	0.19	0.27
73	31	0.33	0.5	0.74	1.22	1.77
73	31	0.66	1.02	1.54	2.64	3.91
73	31	0.89	1.31	1.93	3.13	4.49
73	31	0.53	0.78	1.12	1.74	2.42
73	31	0.19	0.28	0.42	0.68	0.98
73	31	0.1	0.16	0.24	0.39	0.55
73	31	0.09	0.14	0.21	0.34	0.49
73	31	0.06	0.09	0.13	0.2	0.29
74	31	0.36	0.53	0.77	1.24	1.76
74	31	0.7	1.07	1.58	2.62	3.83
74	31	0.96	1.39	2.01	3.17	4.45
74	31	0.59	0.87	1.23	1.9	2.59
74	31	0.21	0.33	0.5	0.85	1.19
74	31	0.12	0.19	0.29	0.49	0.71
74	31	0.1	0.17	0.26	0.44	0.63
74	31	0.07	0.1	0.16	0.26	0.37
75	31	0.43	0.6	0.85	1.28	1.73
75	31	0.84	1.19	1.66	2.55	3.51
75	31	1.13	1.59	2.22	3.25	4.35
75	31	0.72	1.04	1.45	2.22	2.94
75	31	0.27	0.43	0.66	1.11	1.6
75	31	0.15	0.25	0.39	0.67	0.99
75	31	0.13	0.22	0.35	0.6	0.89
75	31	0.09	0.14	0.21	0.36	0.53
76	31	0.45	0.61	0.84	1.18	1.51
76	31	0.89	1.2	1.59	2.27	2.8
76	31	1.19	1.63	2.22	3.04	3.85

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
76	31	0.77	1.1	1.52	2.29	2.97
76	31	0.29	0.47	0.73	1.24	1.82
76	31	0.17	0.28	0.44	0.76	1.13
76	31	0.15	0.24	0.39	0.68	1.02
76	31	0.09	0.15	0.24	0.42	0.62
77	31	0.31	0.44	0.59	0.87	1.09
77	31	0.59	0.83	1.1	1.54	1.98
77	31	0.86	1.16	1.54	2.22	2.72
77	31	0.57	0.84	1.15	1.72	2.29
77	31	0.22	0.36	0.56	0.97	1.38
77	31	0.13	0.21	0.34	0.59	0.87
77	31	0.11	0.19	0.3	0.53	0.79
77	31	0.07	0.12	0.18	0.31	0.46
78	31	0.21	0.3	0.42	0.61	0.81
78	31	0.4	0.56	0.77	1.12	1.42
78	31	0.57	0.81	1.1	1.57	2.06
78	31	0.4	0.58	0.84	1.24	1.65
78	31	0.15	0.24	0.39	0.66	0.98
78	31	0.09	0.15	0.23	0.42	0.61
78	31	0.08	0.13	0.21	0.39	0.56
78	31	0.05	0.08	0.12	0.21	0.31
60	32	0.21	0.36	0.59	1.1	1.72
60	32	0.43	0.74	1.24	2.41	3.84
60	32	0.58	0.96	1.54	2.8	4.32
60	32	0.33	0.53	0.83	1.45	2.18
60	32	0.1	0.17	0.27	0.48	0.72
60	32	0.05	0.09	0.14	0.25	0.37
60	32	0.04	0.08	0.12	0.21	0.31
60	32	0.03	0.05	0.08	0.14	0.21
61	32	0.23	0.34	0.49	0.75	1.03
61	32	0.46	0.68	1	1.54	2.12
61	32	0.62	0.94	1.31	2.02	2.73
61	32	0.37	0.54	0.78	1.2	1.62
61	32	0.11	0.18	0.27	0.45	0.64
61	32	0.06	0.1	0.15	0.25	0.36
61	32	0.05	0.08	0.13	0.21	0.3
61	32	0.04	0.06	0.09	0.14	0.2
62	32	0.18	0.26	0.37	0.57	0.8
62	32	0.36	0.51	0.72	1.15	1.65
62	32	0.5	0.72	1.01	1.53	2.09
62	32	0.31	0.46	0.64	0.98	1.3
62	32	0.1	0.16	0.24	0.39	0.54
62	32	0.06	0.09	0.14	0.22	0.3
62	32	0.05	0.08	0.12	0.19	0.26
62	32	0.03	0.05	0.08	0.12	0.17
63	32	0.16	0.23	0.32	0.51	0.74
63	32	0.3	0.44	0.63	1.01	1.52
63	32	0.44	0.62	0.87	1.36	1.91
63	32	0.28	0.42	0.57	0.87	1.18
63	32	0.1	0.15	0.22	0.36	0.5
63	32	0.06	0.09	0.13	0.21	0.28
63	32	0.05	0.08	0.11	0.18	0.25
63	32	0.03	0.05	0.07	0.11	0.15
64	32	0.18	0.26	0.37	0.58	0.81
64	32	0.34	0.5	0.71	1.13	1.64
64	32	0.49	0.7	0.99	1.5	2.06
64	32	0.33	0.48	0.68	1.03	1.38

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
64	32	0.12	0.19	0.29	0.47	0.66
64	32	0.07	0.11	0.17	0.28	0.4
64	32	0.06	0.1	0.15	0.25	0.36
64	32	0.04	0.06	0.09	0.15	0.2
65	32	0.31	0.43	0.58	0.85	1.13
65	32	0.58	0.82	1.11	1.62	2.15
65	32	0.83	1.14	1.51	2.2	2.87
65	32	0.56	0.8	1.09	1.56	2.06
65	32	0.22	0.35	0.51	0.82	1.14
65	32	0.13	0.21	0.31	0.5	0.69
65	32	0.12	0.18	0.27	0.45	0.62
65	32	0.07	0.11	0.16	0.26	0.36
66	32	0.9	1.44	2.27	3.77	5.4
66	32	1.91	3.13	5.06	8.38	12.26
66	32	2.29	3.59	5.54	9.06	13.14
66	32	1.24	1.92	2.91	4.94	7.08
66	32	0.44	0.7	1.09	1.9	2.89
66	32	0.23	0.38	0.59	1.04	1.62
66	32	0.2	0.32	0.5	0.89	1.39
66	32	0.13	0.21	0.33	0.6	0.96
67	32	0.98	1.52	2.33	3.87	5.51
67	32	2.07	3.27	5.13	8.54	12.54
67	32	2.51	3.81	5.71	9.27	13.38
67	32	1.4	2.12	3.13	5.21	7.44
67	32	0.52	0.81	1.24	2.15	3.21
67	32	0.28	0.45	0.69	1.21	1.83
67	32	0.24	0.38	0.59	1.04	1.59
67	32	0.16	0.25	0.39	0.7	1.1
68	32	0.97	1.54	2.41	4.12	5.83
68	32	2.06	3.35	5.38	9.15	13.68
68	32	2.47	3.85	5.88	9.77	14.35
68	32	1.37	2.1	3.16	5.39	7.81
68	32	0.5	0.79	1.21	2.11	3.18
68	32	0.27	0.43	0.67	1.17	1.8
68	32	0.23	0.37	0.57	1.01	1.56
68	32	0.15	0.24	0.37	0.67	1.07
69	32	0.65	0.99	1.49	2.5	3.55
69	32	1.34	2.08	3.22	5.61	8.03
69	32	1.7	2.54	3.75	6.14	8.65
69	32	1.01	1.45	2.09	3.29	4.63
69	32	0.38	0.57	0.85	1.35	1.92
69	32	0.21	0.32	0.47	0.76	1.09
69	32	0.18	0.28	0.41	0.66	0.95
69	32	0.12	0.18	0.26	0.42	0.6
70	32	0.59	0.91	1.41	2.45	3.52
70	32	1.21	1.95	3.1	5.56	8
70	32	1.53	2.34	3.56	6	8.54
70	32	0.89	1.3	1.89	3.07	4.42
70	32	0.32	0.48	0.71	1.14	1.62
70	32	0.18	0.26	0.39	0.62	0.88
70	32	0.15	0.23	0.33	0.54	0.76
70	32	0.1	0.14	0.21	0.34	0.49
71	32	0.55	0.88	1.39	2.44	3.51
71	32	1.15	1.91	3.07	5.56	7.99
71	32	1.45	2.27	3.51	5.99	8.53
71	32	0.8	1.2	1.8	2.99	4.35
71	32	0.26	0.41	0.61	1.01	1.45

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
71	32	0.14	0.21	0.32	0.52	0.76
71	32	0.12	0.18	0.27	0.44	0.63
71	32	0.08	0.12	0.18	0.29	0.43
72	32	0.5	0.79	1.24	2.21	3.16
72	32	1.04	1.7	2.73	5.03	7.26
72	32	1.31	2.05	3.14	5.43	7.71
72	32	0.73	1.11	1.63	2.69	3.87
72	32	0.25	0.38	0.56	0.93	1.32
72	32	0.13	0.2	0.3	0.49	0.7
72	32	0.11	0.17	0.26	0.42	0.6
72	32	0.07	0.11	0.16	0.26	0.38
73	32	0.52	0.82	1.27	2.22	3.16
73	32	1.08	1.74	2.76	5.03	7.25
73	32	1.37	2.12	3.2	5.44	7.71
73	32	0.8	1.19	1.74	2.8	3.96
73	32	0.28	0.44	0.66	1.09	1.53
73	32	0.16	0.24	0.37	0.61	0.87
73	32	0.13	0.21	0.32	0.53	0.77
73	32	0.09	0.13	0.2	0.32	0.46
74	32	0.63	0.94	1.38	2.29	3.23
74	32	1.27	1.93	2.93	5.09	7.27
74	32	1.64	2.41	3.48	5.62	7.86
74	32	1.01	1.45	2.08	3.19	4.38
74	32	0.39	0.59	0.91	1.46	2.1
74	32	0.22	0.34	0.52	0.87	1.24
74	32	0.19	0.3	0.46	0.77	1.11
74	32	0.12	0.18	0.28	0.47	0.67
75	32	1.6	2.51	3.7	5.8	7.49
75	32	3.53	5.66	8.27	13.67	19.98
75	32	3.97	6.1	8.91	14.69	21.46
75	32	2.07	3.16	4.81	7.91	11.46
75	32	0.69	1.12	1.78	3.3	5.27
75	32	0.36	0.59	0.97	1.87	3.15
75	32	0.3	0.5	0.83	1.62	2.76
75	32	0.2	0.33	0.56	1.15	2.07
76	32	1.79	2.71	3.95	6.01	7.75
76	32	3.94	6.03	8.7	14.13	20.39
76	32	4.47	6.61	9.53	15.45	22.27
76	32	2.34	3.53	5.31	8.67	12.56
76	32	0.78	1.27	2.05	3.89	6.3
76	32	0.4	0.68	1.13	2.24	3.87
76	32	0.33	0.57	0.96	1.94	3.41
76	32	0.23	0.39	0.67	1.45	2.68
77	32	1.73	2.68	3.96	6.1	7.95
77	32	3.83	6	8.79	14.56	21.33
77	32	4.29	6.5	9.5	15.68	22.91
77	32	2.2	3.38	5.19	8.59	12.57
77	32	0.7	1.15	1.87	3.56	5.8
77	32	0.35	0.6	1	2.01	3.49
77	32	0.29	0.5	0.85	1.74	3.07
77	32	0.2	0.34	0.59	1.27	2.37
78	32	0.59	0.9	1.28	2.03	2.73
78	32	1.22	1.87	2.71	4.28	5.8
78	32	1.54	2.32	3.28	5.18	6.88
78	32	0.9	1.32	1.93	3.02	4.19
78	32	0.31	0.5	0.79	1.39	2.12
78	32	0.17	0.28	0.45	0.81	1.26

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
78	32	0.14	0.24	0.4	0.71	1.11
78	32	0.09	0.15	0.25	0.46	0.72
60	33	0.07	0.1	0.15	0.22	0.29
60	33	0.13	0.2	0.28	0.42	0.54
60	33	0.19	0.29	0.42	0.6	0.8
60	33	0.12	0.19	0.28	0.43	0.56
60	33	0.04	0.06	0.1	0.17	0.23
60	33	0.02	0.04	0.06	0.1	0.14
60	33	0.02	0.03	0.05	0.09	0.12
60	33	0.01	0.02	0.03	0.05	0.08
61	33	0.08	0.12	0.17	0.25	0.33
61	33	0.16	0.23	0.33	0.48	0.62
61	33	0.23	0.34	0.48	0.7	0.93
61	33	0.15	0.22	0.32	0.49	0.63
61	33	0.05	0.07	0.11	0.19	0.27
61	33	0.03	0.04	0.07	0.11	0.16
61	33	0.02	0.04	0.06	0.1	0.14
61	33	0.02	0.03	0.04	0.06	0.09
62	33	0.08	0.13	0.19	0.31	0.46
62	33	0.16	0.24	0.37	0.61	0.9
62	33	0.23	0.36	0.52	0.84	1.22
62	33	0.15	0.23	0.34	0.54	0.75
62	33	0.05	0.08	0.12	0.2	0.29
62	33	0.03	0.04	0.07	0.12	0.17
62	33	0.02	0.04	0.06	0.1	0.15
62	33	0.02	0.03	0.04	0.06	0.09
63	33	0.08	0.12	0.2	0.38	0.62
63	33	0.15	0.24	0.4	0.78	1.32
63	33	0.22	0.35	0.55	1.01	1.62
63	33	0.14	0.22	0.34	0.58	0.87
63	33	0.04	0.07	0.11	0.2	0.3
63	33	0.02	0.04	0.06	0.11	0.17
63	33	0.02	0.03	0.05	0.1	0.14
63	33	0.01	0.02	0.04	0.06	0.09
64	33	0.12	0.19	0.29	0.49	0.72
64	33	0.23	0.37	0.56	0.96	1.48
64	33	0.34	0.52	0.77	1.27	1.85
64	33	0.22	0.34	0.5	0.81	1.14
64	33	0.07	0.12	0.19	0.33	0.48
64	33	0.04	0.07	0.11	0.19	0.28
64	33	0.04	0.06	0.1	0.17	0.25
64	33	0.02	0.04	0.06	0.1	0.15
65	33	0.21	0.3	0.43	0.65	0.9
65	33	0.4	0.57	0.82	1.27	1.77
65	33	0.56	0.82	1.13	1.69	2.3
65	33	0.38	0.54	0.77	1.16	1.55
65	33	0.13	0.21	0.32	0.54	0.76
65	33	0.08	0.12	0.19	0.32	0.45
65	33	0.07	0.11	0.17	0.28	0.41
65	33	0.04	0.07	0.1	0.17	0.24
66	33	0.54	0.85	1.27	2.12	2.88
66	33	1.12	1.79	2.73	4.6	6.3
66	33	1.42	2.21	3.24	5.31	7.2
66	33	0.82	1.22	1.8	2.88	4.04
66	33	0.28	0.45	0.69	1.19	1.76
66	33	0.15	0.25	0.39	0.66	0.99
66	33	0.13	0.21	0.33	0.57	0.85

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
66	33	0.09	0.14	0.21	0.37	0.58
67	33	0.97	1.54	2.41	4.13	5.9
67	33	2.06	3.33	5.34	9.17	13.79
67	33	2.47	3.85	5.87	9.77	14.38
67	33	1.36	2.09	3.17	5.44	7.94
67	33	0.49	0.78	1.21	2.11	3.17
67	33	0.26	0.43	0.66	1.16	1.77
67	33	0.23	0.37	0.57	1	1.53
67	33	0.14	0.23	0.36	0.66	1.06
68	33	0.97	1.5	2.29	3.64	5.16
68	33	2.06	3.25	5.09	8.03	11.33
68	33	2.47	3.77	5.63	8.89	12.57
68	33	1.33	2.03	2.99	4.93	6.95
68	33	0.47	0.73	1.13	1.97	3
68	33	0.25	0.39	0.61	1.09	1.68
68	33	0.21	0.33	0.52	0.92	1.43
68	33	0.14	0.22	0.35	0.64	1.03
69	33	0.96	1.56	2.45	4.08	5.67
69	33	2.06	3.41	5.5	9.12	13.36
69	33	2.45	3.88	5.95	9.79	14.26
69	33	1.3	2.03	3.07	5.25	7.47
69	33	0.44	0.7	1.1	1.94	2.98
69	33	0.23	0.37	0.58	1.04	1.64
69	33	0.19	0.31	0.49	0.88	1.4
69	33	0.13	0.21	0.33	0.61	1
70	33	0.62	0.96	1.47	2.5	3.58
70	33	1.29	2.05	3.19	5.61	8.09
70	33	1.63	2.48	3.71	6.13	8.68
70	33	0.94	1.37	2.01	3.24	4.63
70	33	0.33	0.5	0.75	1.24	1.78
70	33	0.18	0.27	0.41	0.68	0.98
70	33	0.15	0.23	0.35	0.58	0.84
70	33	0.1	0.15	0.23	0.38	0.56
71	33	0.56	0.9	1.39	2.43	3.49
71	33	1.18	1.92	3.07	5.53	7.96
71	33	1.48	2.3	3.52	5.97	8.49
71	33	0.84	1.25	1.85	3.03	4.37
71	33	0.29	0.45	0.66	1.1	1.57
71	33	0.16	0.24	0.36	0.59	0.85
71	33	0.13	0.21	0.31	0.51	0.73
71	33	0.09	0.13	0.19	0.32	0.47
72	33	0.53	0.82	1.27	2.21	3.18
72	33	1.09	1.74	2.76	5.01	7.28
72	33	1.39	2.12	3.2	5.44	7.73
72	33	0.82	1.21	1.75	2.81	3.98
72	33	0.3	0.46	0.67	1.09	1.54
72	33	0.17	0.25	0.38	0.61	0.88
72	33	0.14	0.22	0.33	0.54	0.77
72	33	0.09	0.13	0.2	0.32	0.46
73	33	0.61	0.92	1.36	2.27	3.22
73	33	1.24	1.89	2.88	5.07	7.3
73	33	1.6	2.35	3.42	5.57	7.83
73	33	0.99	1.42	2.03	3.12	4.31
73	33	0.39	0.59	0.89	1.42	2.02
73	33	0.22	0.34	0.51	0.84	1.19
73	33	0.19	0.3	0.45	0.75	1.07
73	33	0.12	0.18	0.27	0.45	0.63

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
74	33	1.3	2.04	2.98	4.87	6.35
74	33	2.81	4.47	6.64	10.75	15.49
74	33	3.27	5.04	7.26	11.71	16.83
74	33	1.78	2.68	3.96	6.48	9.27
74	33	0.64	1.02	1.58	2.83	4.4
74	33	0.35	0.56	0.89	1.63	2.62
74	33	0.3	0.48	0.77	1.43	2.29
74	33	0.19	0.31	0.5	0.96	1.66
75	33	1.8	2.69	3.88	5.87	7.51
75	33	3.94	5.97	8.53	13.68	19.55
75	33	4.49	6.58	9.41	15.11	21.63
75	33	2.39	3.55	5.27	8.52	12.24
75	33	0.84	1.35	2.15	4	6.41
75	33	0.45	0.74	1.21	2.34	3.96
75	33	0.38	0.63	1.04	2.03	3.5
75	33	0.25	0.42	0.72	1.5	2.73
76	33	1.81	2.72	3.94	5.99	7.72
76	33	3.96	6.02	8.67	14.04	20.21
76	33	4.51	6.63	9.52	15.38	22.1
76	33	2.4	3.59	5.35	8.69	12.54
76	33	0.84	1.36	2.17	4.03	6.45
76	33	0.45	0.74	1.21	2.35	3.98
76	33	0.37	0.63	1.04	2.04	3.51
76	33	0.25	0.42	0.72	1.51	2.74
77	33	1.64	2.58	3.86	6.06	7.96
77	33	3.6	5.79	8.6	14.52	21.58
77	33	4.05	6.23	9.19	15.36	22.65
77	33	2.12	3.26	5.01	8.32	12.19
77	33	0.71	1.15	1.83	3.39	5.4
77	33	0.37	0.61	1	1.92	3.23
77	33	0.31	0.52	0.86	1.67	2.83
77	33	0.2	0.34	0.57	1.18	2.12
78	33	0.52	0.77	1.14	1.86	2.65
78	33	1.04	1.56	2.33	3.97	5.83
78	33	1.36	2.01	2.89	4.63	6.49
78	33	0.85	1.24	1.78	2.78	3.81
78	33	0.32	0.5	0.78	1.3	1.89
78	33	0.18	0.29	0.45	0.77	1.13
78	33	0.15	0.25	0.4	0.68	1.01
78	33	0.1	0.16	0.24	0.42	0.62
60	34	0.02	0.03	0.05	0.09	0.12
60	34	0.03	0.06	0.1	0.17	0.23
60	34	0.05	0.1	0.16	0.25	0.36
60	34	0.03	0.06	0.1	0.18	0.25
60	34	0.01	0.02	0.03	0.06	0.09
60	34	0.01	0.01	0.02	0.04	0.06
60	34	0	0.01	0.02	0.03	0.05
60	34	0	0.01	0.01	0.02	0.03
61	34	0.02	0.04	0.06	0.1	0.14
61	34	0.04	0.07	0.11	0.19	0.25
61	34	0.06	0.11	0.17	0.28	0.39
61	34	0.04	0.07	0.11	0.19	0.27
61	34	0.01	0.02	0.04	0.07	0.1
61	34	0.01	0.01	0.02	0.04	0.06
61	34	0.01	0.01	0.02	0.03	0.05
61	34	0	0.01	0.01	0.02	0.03
62	34	0.01	0.03	0.05	0.08	0.12

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
62	34	0.02	0.05	0.09	0.17	0.23
62	34	0.03	0.07	0.13	0.24	0.35
62	34	0.01	0.04	0.08	0.15	0.22
62	34	0.01	0.01	0.02	0.05	0.07
62	34	0	0.01	0.01	0.03	0.04
62	34	0	0.01	0.01	0.02	0.03
62	34	0	0	0.01	0.02	0.02
63	34	0.02	0.04	0.07	0.13	0.19
63	34	0.03	0.08	0.14	0.25	0.38
63	34	0.05	0.11	0.2	0.37	0.52
63	34	0.03	0.06	0.11	0.22	0.32
63	34	0.01	0.02	0.03	0.07	0.1
63	34	0	0.01	0.02	0.04	0.06
63	34	0	0.01	0.02	0.03	0.05
63	34	0	0.01	0.01	0.02	0.03
64	34	0.07	0.12	0.18	0.32	0.48
64	34	0.14	0.22	0.35	0.62	0.94
64	34	0.2	0.33	0.5	0.85	1.25
64	34	0.13	0.21	0.33	0.55	0.79
64	34	0.04	0.07	0.12	0.21	0.32
64	34	0.02	0.04	0.07	0.12	0.19
64	34	0.02	0.03	0.06	0.11	0.17
64	34	0.01	0.02	0.04	0.07	0.1
65	34	0.26	0.38	0.51	0.76	1.02
65	34	0.49	0.69	0.97	1.43	1.92
65	34	0.7	0.99	1.32	1.91	2.54
65	34	0.51	0.73	1.01	1.44	1.88
65	34	0.21	0.33	0.49	0.79	1.09
65	34	0.13	0.2	0.3	0.49	0.67
65	34	0.11	0.18	0.27	0.45	0.62
65	34	0.07	0.11	0.16	0.25	0.34
66	34	0.45	0.59	0.78	1.09	1.37
66	34	0.83	1.1	1.41	1.97	2.56
66	34	1.15	1.51	1.98	2.69	3.36
66	34	0.88	1.17	1.53	2.17	2.68
66	34	0.41	0.6	0.87	1.31	1.78
66	34	0.25	0.38	0.53	0.83	1.12
66	34	0.23	0.34	0.49	0.76	1.04
66	34	0.13	0.19	0.27	0.42	0.56
67	34	0.79	1.18	1.76	2.86	4.05
67	34	1.59	2.42	3.77	6.35	8.94
67	34	2.02	2.96	4.36	7	9.89
67	34	1.31	1.85	2.58	3.98	5.53
67	34	0.59	0.87	1.25	1.99	2.81
67	34	0.35	0.52	0.75	1.19	1.68
67	34	0.31	0.47	0.67	1.07	1.51
67	34	0.19	0.27	0.4	0.64	0.92
68	34	1.03	1.56	2.34	3.75	5.27
68	34	2.14	3.35	5.21	8.29	11.79
68	34	2.61	3.9	5.74	9.13	12.97
68	34	1.57	2.26	3.21	5.09	7.12
68	34	0.68	1.02	1.46	2.37	3.44
68	34	0.41	0.59	0.86	1.4	2.01
68	34	0.36	0.53	0.77	1.24	1.79
68	34	0.21	0.31	0.46	0.77	1.17
69	34	1.01	1.52	2.26	3.5	4.87
69	34	2.12	3.26	4.99	7.68	10.59

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
69	34	2.56	3.81	5.57	8.63	12
69	34	1.49	2.16	3.06	4.85	6.75
69	34	0.61	0.93	1.35	2.22	3.25
69	34	0.36	0.53	0.78	1.29	1.88
69	34	0.31	0.47	0.69	1.14	1.66
69	34	0.19	0.28	0.42	0.72	1.11
70	34	0.97	1.48	2.25	3.51	4.92
70	34	2.06	3.22	5	7.73	10.71
70	34	2.45	3.73	5.55	8.64	12.09
70	34	1.37	2.03	2.95	4.78	6.7
70	34	0.53	0.8	1.2	2.01	3
70	34	0.29	0.45	0.67	1.14	1.71
70	34	0.25	0.39	0.59	0.99	1.49
70	34	0.16	0.24	0.37	0.65	1.01
71	34	0.66	0.99	1.49	2.49	3.55
71	34	1.35	2.07	3.2	5.59	8.03
71	34	1.71	2.53	3.74	6.11	8.63
71	34	1.05	1.49	2.13	3.32	4.65
71	34	0.42	0.62	0.92	1.45	2.04
71	34	0.24	0.36	0.52	0.84	1.18
71	34	0.21	0.32	0.47	0.75	1.05
71	34	0.13	0.19	0.28	0.45	0.63
72	34	0.6	0.89	1.31	2.18	3
72	34	1.2	1.84	2.81	4.87	6.82
72	34	1.55	2.28	3.32	5.38	7.41
72	34	0.97	1.37	1.93	2.94	4
72	34	0.38	0.56	0.83	1.31	1.84
72	34	0.21	0.33	0.48	0.77	1.08
72	34	0.19	0.29	0.43	0.69	0.97
72	34	0.12	0.17	0.25	0.41	0.58
73	34	1	1.46	2.12	3.25	4.48
73	34	2.11	3.11	4.55	7.03	9.61
73	34	2.56	3.71	5.32	8.06	11.03
73	34	1.45	2.13	3.01	4.75	6.62
73	34	0.54	0.84	1.29	2.24	3.39
73	34	0.3	0.47	0.74	1.31	2
73	34	0.26	0.41	0.64	1.15	1.76
73	34	0.17	0.26	0.41	0.76	1.22
74	34	1.78	2.68	3.86	5.86	7.49
74	34	3.9	5.94	8.5	13.65	19.52
74	34	4.45	6.54	9.37	15.07	21.6
74	34	2.36	3.52	5.24	8.47	12.19
74	34	0.83	1.32	2.11	3.94	6.32
74	34	0.44	0.72	1.18	2.29	3.9
74	34	0.37	0.61	1.01	1.99	3.44
74	34	0.25	0.41	0.7	1.47	2.69
75	34	1.81	2.7	3.89	5.88	7.51
75	34	3.96	5.99	8.56	13.71	19.57
75	34	4.51	6.6	9.44	15.15	21.66
75	34	2.41	3.58	5.29	8.53	12.23
75	34	0.86	1.37	2.18	4.03	6.46
75	34	0.46	0.75	1.23	2.36	3.99
75	34	0.39	0.64	1.06	2.05	3.53
75	34	0.26	0.43	0.73	1.52	2.75
76	34	1.71	2.62	3.82	5.87	7.55
76	34	3.76	5.87	8.48	13.8	19.95
76	34	4.24	6.37	9.22	15.04	21.78

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
76	34	2.22	3.35	5.04	8.21	11.87
76	34	0.77	1.22	1.93	3.57	5.71
76	34	0.41	0.66	1.07	2.05	3.47
76	34	0.34	0.56	0.92	1.79	3.05
76	34	0.22	0.37	0.62	1.28	2.3
77	34	0.73	1.09	1.61	2.63	3.71
77	34	1.48	2.26	3.43	5.83	8.32
77	34	1.89	2.78	4.03	6.44	9.01
77	34	1.15	1.66	2.38	3.67	5.09
77	34	0.45	0.69	1.04	1.71	2.44
77	34	0.25	0.4	0.6	1.01	1.44
77	34	0.22	0.35	0.53	0.9	1.29
77	34	0.14	0.21	0.32	0.55	0.8
78	34	0.44	0.67	1.02	1.74	2.54
78	34	0.88	1.37	2.13	3.8	5.74
78	34	1.16	1.74	2.59	4.33	6.23
78	34	0.72	1.07	1.54	2.45	3.39
78	34	0.27	0.43	0.65	1.08	1.52
78	34	0.15	0.24	0.38	0.62	0.91
78	34	0.13	0.21	0.33	0.56	0.81
78	34	0.08	0.13	0.2	0.33	0.47
60	35	0	0	0	0	0
60	35	0	0	0	0	0
60	35	0	0	0	0	0
60	35	0	0	0	0	0
60	35	0	0	0	0	0
60	35	0	0	0	0	0
60	35	0	0	0	0	0
60	35	0	0	0	0	0
61	35	0	0	0	0.02	0.03
61	35	0	0	0	0.03	0.05
61	35	0	0	0.01	0.04	0.08
61	35	0	0	0	0.03	0.05
61	35	0	0	0	0.01	0.02
61	35	0	0	0	0	0.01
61	35	0	0	0	0	0.01
61	35	0	0	0	0	0.01
62	35	0	0	0.01	0.03	0.05
62	35	0	0	0.03	0.06	0.1
62	35	0	0.01	0.04	0.1	0.16
62	35	0	0	0.02	0.06	0.1
62	35	0	0	0.01	0.02	0.03
62	35	0	0	0	0.01	0.02
62	35	0	0	0	0.01	0.01
62	35	0	0	0	0.01	0.01
63	35	0	0.01	0.03	0.06	0.08
63	35	0	0.03	0.06	0.11	0.17
63	35	0	0.04	0.09	0.17	0.24
63	35	0	0.02	0.05	0.1	0.16
63	35	0	0.01	0.02	0.03	0.05
63	35	0	0	0.01	0.02	0.03
63	35	0	0	0.01	0.01	0.02
63	35	0	0	0.01	0.01	0.02
64	35	0.15	0.22	0.31	0.47	0.61
64	35	0.27	0.41	0.57	0.87	1.1
64	35	0.41	0.58	0.83	1.19	1.51
64	35	0.29	0.44	0.63	0.98	1.26

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
64	35	0.11	0.19	0.3	0.51	0.73
64	35	0.07	0.11	0.19	0.32	0.47
64	35	0.06	0.1	0.17	0.3	0.44
64	35	0.04	0.06	0.09	0.16	0.22
65	35	0.42	0.55	0.71	0.98	1.17
65	35	0.76	1.01	1.27	1.7	2.13
65	35	1.08	1.4	1.8	2.4	2.85
65	35	0.84	1.12	1.46	2.07	2.53
65	35	0.4	0.58	0.85	1.29	1.75
65	35	0.24	0.37	0.53	0.83	1.12
65	35	0.22	0.34	0.49	0.76	1.04
65	35	0.13	0.19	0.27	0.42	0.56
66	35	1.06	1.48	2.08	3.07	4.11
66	35	2.11	2.96	4.11	6.05	7.8
66	35	2.69	3.77	5.26	7.7	10.28
66	35	1.8	2.54	3.5	5.37	7.52
66	35	0.83	1.26	1.88	3.2	4.78
66	35	0.49	0.75	1.14	1.93	2.97
66	35	0.44	0.67	1.01	1.72	2.63
66	35	0.27	0.42	0.65	1.17	1.88
67	35	1.16	1.54	2.04	2.87	3.7
67	35	2.26	2.94	3.83	5.38	6.74
67	35	2.96	3.92	5.19	7.18	9.19
67	35	2.14	2.85	3.8	5.55	7.43
67	35	1.05	1.56	2.29	3.73	5.41
67	35	0.63	0.96	1.4	2.32	3.42
67	35	0.56	0.85	1.25	2.06	3.05
67	35	0.36	0.54	0.82	1.42	2.16
68	35	1.16	1.62	2.29	3.82	5.49
68	35	2.22	3.23	4.69	8.15	12.49
68	35	2.93	4.02	5.58	8.97	12.84
68	35	2.07	2.81	3.82	5.76	7.98
68	35	1.04	1.51	2.17	3.37	4.7
68	35	0.63	0.93	1.32	2.08	2.93
68	35	0.56	0.83	1.19	1.88	2.65
68	35	0.34	0.51	0.73	1.2	1.74
69	35	1.22	1.78	2.59	4.25	5.82
69	35	2.43	3.72	5.62	9.37	13.79
69	35	3.07	4.38	6.28	10.12	14.52
69	35	2.02	2.8	3.84	5.88	8.16
69	35	1	1.42	2.03	3.19	4.47
69	35	0.59	0.87	1.23	1.94	2.76
69	35	0.53	0.77	1.11	1.75	2.48
69	35	0.32	0.47	0.67	1.1	1.62
70	35	1.14	1.72	2.54	4.16	5.73
70	35	2.32	3.64	5.6	9.23	13.47
70	35	2.88	4.24	6.16	9.98	14.37
70	35	1.82	2.57	3.6	5.62	7.86
70	35	0.84	1.23	1.76	2.82	4
70	35	0.5	0.73	1.06	1.69	2.42
70	35	0.44	0.65	0.95	1.51	2.15
70	35	0.27	0.39	0.57	0.94	1.42
71	35	1.03	1.6	2.44	4.09	5.7
71	35	2.11	3.42	5.47	9.17	13.54
71	35	2.61	3.95	5.91	9.77	14.28
71	35	1.62	2.31	3.31	5.31	7.5
71	35	0.72	1.06	1.51	2.43	3.47

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
71	35	0.43	0.62	0.9	1.44	2.05
71	35	0.38	0.55	0.8	1.29	1.83
71	35	0.22	0.33	0.48	0.78	1.17
72	35	0.86	1.25	1.84	2.98	4.26
72	35	1.73	2.59	3.95	6.63	9.57
72	35	2.19	3.16	4.56	7.26	10.27
72	35	1.41	1.95	2.7	4.13	5.68
72	35	0.63	0.93	1.3	2.03	2.81
72	35	0.38	0.55	0.78	1.22	1.68
72	35	0.34	0.49	0.7	1.1	1.52
72	35	0.2	0.28	0.41	0.64	0.91
73	35	1.75	2.66	3.86	5.9	7.57
73	35	3.86	5.94	8.55	13.83	19.89
73	35	4.35	6.48	9.34	15.17	21.88
73	35	2.27	3.41	5.11	8.35	12.1
73	35	0.81	1.26	1.96	3.64	5.87
73	35	0.44	0.69	1.09	2.07	3.56
73	35	0.38	0.59	0.94	1.81	3.12
73	35	0.24	0.38	0.63	1.31	2.41
74	35	1.8	2.7	3.92	5.96	7.68
74	35	3.92	5.98	8.63	13.99	20.17
74	35	4.48	6.58	9.47	15.31	22.02
74	35	2.4	3.57	5.3	8.62	12.44
74	35	0.89	1.39	2.17	4	6.39
74	35	0.48	0.77	1.23	2.33	3.94
74	35	0.41	0.66	1.06	2.03	3.48
74	35	0.27	0.43	0.72	1.49	2.71
75	35	1.74	2.64	3.82	5.82	7.44
75	35	3.84	5.91	8.46	13.59	19.46
75	35	4.34	6.44	9.26	14.97	21.53
75	35	2.29	3.41	5.09	8.25	11.89
75	35	0.83	1.3	2.01	3.71	5.92
75	35	0.45	0.71	1.13	2.13	3.62
75	35	0.39	0.61	0.98	1.86	3.19
75	35	0.25	0.4	0.66	1.34	2.43
76	35	0.78	1.14	1.66	2.67	3.76
76	35	1.57	2.34	3.5	5.87	8.39
76	35	2.02	2.9	4.15	6.54	9.13
76	35	1.27	1.79	2.51	3.82	5.24
76	35	0.53	0.8	1.17	1.89	2.66
76	35	0.31	0.47	0.69	1.12	1.59
76	35	0.27	0.42	0.61	1.01	1.42
76	35	0.17	0.25	0.37	0.61	0.88
77	35	0.65	1	1.51	2.54	3.63
77	35	1.33	2.09	3.27	5.75	8.25
77	35	1.68	2.53	3.77	6.22	8.82
77	35	1.02	1.47	2.12	3.33	4.68
77	35	0.4	0.6	0.9	1.42	2.01
77	35	0.23	0.35	0.51	0.83	1.16
77	35	0.2	0.3	0.46	0.73	1.04
77	35	0.12	0.18	0.27	0.44	0.62
78	35	0.41	0.63	0.97	1.7	2.52
78	35	0.81	1.3	2.06	3.75	5.72
78	35	1.07	1.63	2.48	4.25	6.18
78	35	0.64	0.98	1.41	2.29	3.23
78	35	0.23	0.37	0.56	0.93	1.32
78	35	0.13	0.21	0.32	0.53	0.75

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
78	35	0.11	0.18	0.28	0.47	0.67
78	35	0.07	0.11	0.17	0.27	0.39
63	36	0	0	0	0.02	0.03
63	36	0	0	0	0.03	0.05
63	36	0	0	0.01	0.04	0.08
63	36	0	0	0	0.03	0.05
63	36	0	0	0	0.01	0.02
63	36	0	0	0	0	0.01
63	36	0	0	0	0	0.01
63	36	0	0	0	0	0.01
64	36	0.14	0.21	0.31	0.47	0.6
64	36	0.26	0.41	0.56	0.86	1.09
64	36	0.4	0.57	0.82	1.18	1.5
64	36	0.28	0.44	0.62	0.98	1.25
64	36	0.11	0.19	0.3	0.51	0.73
64	36	0.07	0.11	0.19	0.32	0.47
64	36	0.06	0.1	0.17	0.3	0.44
64	36	0.04	0.06	0.09	0.16	0.22
65	36	0.47	0.62	0.8	1.07	1.27
65	36	0.88	1.12	1.4	1.88	2.29
65	36	1.21	1.57	2.03	2.59	3.07
65	36	0.97	1.27	1.65	2.29	2.76
65	36	0.47	0.69	0.99	1.49	2.02
65	36	0.29	0.44	0.62	0.96	1.27
65	36	0.27	0.4	0.57	0.89	1.18
65	36	0.16	0.22	0.32	0.48	0.64
66	36	1.03	1.34	1.73	2.41	3.03
66	36	1.96	2.54	3.2	4.34	5.42
66	36	2.63	3.41	4.42	6.04	7.53
66	36	1.91	2.57	3.38	4.85	6.33
66	36	0.95	1.4	2.06	3.3	4.7
66	36	0.57	0.87	1.26	2.06	2.97
66	36	0.51	0.77	1.13	1.84	2.66
66	36	0.32	0.49	0.73	1.24	1.84
67	36	3.4	5.21	6.89	9.95	13.15
67	36	6.99	10.65	16.23	28.33	43.17
67	36	8.14	12.27	18.5	31.83	47.98
67	36	5.17	7.82	11.82	20.41	30.86
67	36	2.25	3.62	5.79	10.59	16.72
67	36	1.28	2.11	3.51	6.85	11.28
67	36	1.11	1.85	3.12	6.24	10.55
67	36	0.77	1.34	2.37	5.25	9.52
68	36	2.6	3.56	4.88	6.55	8.1
68	36	5.33	7.03	9.26	13.35	17.6
68	36	6.51	8.89	12.14	18.34	25.06
68	36	4.2	6.03	8.63	13.86	19.84
68	36	2.04	3.24	5.12	9.63	15.53
68	36	1.2	1.91	3.14	6.23	10.7
68	36	1.05	1.67	2.74	5.55	9.96
68	36	0.72	1.22	2.1	4.8	9.15
69	36	3.58	5.38	7.06	10.1	13.25
69	36	7.44	11.26	17.07	29.56	44.78
69	36	8.54	12.98	19.74	34.34	52.2
69	36	5.3	8.05	12.22	21.24	32.25
69	36	2.29	3.68	5.92	10.98	17.53
69	36	1.3	2.14	3.62	7.19	11.94
69	36	1.13	1.88	3.24	6.67	11.36

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
69	36	0.77	1.35	2.43	5.59	10.05
70	36	3.09	4.7	6.25	8.7	11.18
70	36	6.53	9.69	14.38	24.22	35.93
70	36	7.42	11.21	16.93	29.19	44.08
70	36	4.49	6.78	10.11	17.15	25.58
70	36	1.91	3.05	4.9	8.98	14.18
70	36	1.08	1.76	2.92	5.79	9.33
70	36	0.93	1.54	2.58	5.32	8.73
70	36	0.63	1.07	1.92	4.29	7.47
71	36	1.45	2.03	2.76	4.12	5.45
71	36	2.93	4.1	5.66	8.42	11.37
71	36	3.7	5.14	6.88	10.11	13.53
71	36	2.44	3.33	4.55	6.81	9.21
71	36	1.14	1.7	2.5	4.11	6.03
71	36	0.67	1.02	1.5	2.51	3.74
71	36	0.59	0.9	1.33	2.21	3.31
71	36	0.38	0.59	0.89	1.58	2.47
72	36	1.23	1.73	2.42	3.66	5.01
72	36	2.49	3.58	5.14	7.81	10.71
72	36	3.11	4.36	6.02	9.02	12.24
72	36	2.01	2.75	3.72	5.54	7.44
72	36	0.94	1.33	1.9	2.97	4.15
72	36	0.55	0.8	1.14	1.78	2.51
72	36	0.49	0.71	1.02	1.59	2.23
72	36	0.3	0.44	0.63	1.03	1.51
73	36	1.23	1.76	2.48	3.78	5.17
73	36	2.51	3.66	5.3	8.07	11.09
73	36	3.12	4.44	6.15	9.29	12.69
73	36	1.99	2.75	3.76	5.67	7.66
73	36	0.9	1.29	1.86	2.95	4.17
73	36	0.52	0.76	1.1	1.76	2.51
73	36	0.46	0.68	0.98	1.56	2.22
73	36	0.29	0.42	0.62	1.03	1.53
74	36	1.34	1.9	2.63	3.98	5.36
74	36	2.78	3.96	5.57	8.39	11.43
74	36	3.42	4.83	6.57	9.8	13.25
74	36	2.12	2.93	4.03	6.13	8.41
74	36	0.92	1.35	1.97	3.25	4.75
74	36	0.53	0.79	1.16	1.93	2.89
74	36	0.46	0.69	1.03	1.7	2.54
74	36	0.29	0.45	0.67	1.17	1.83
75	36	1.2	1.72	2.42	3.65	4.97
75	36	2.46	3.56	5.14	7.68	10.41
75	36	3.07	4.36	6.03	9.02	12.22
75	36	1.94	2.7	3.71	5.62	7.61
75	36	0.84	1.24	1.8	2.93	4.21
75	36	0.48	0.72	1.06	1.74	2.53
75	36	0.43	0.63	0.94	1.53	2.22
75	36	0.27	0.41	0.61	1.03	1.57
76	36	0.94	1.33	1.88	2.91	4.03
76	36	1.88	2.74	3.95	6.29	8.78
76	36	2.4	3.37	4.74	7.2	9.83
76	36	1.5	2.12	2.88	4.32	5.84
76	36	0.63	0.95	1.35	2.16	3.02
76	36	0.37	0.55	0.8	1.27	1.8
76	36	0.32	0.48	0.7	1.13	1.59
76	36	0.2	0.3	0.44	0.72	1.05

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
77	36	0.74	1.12	1.67	2.75	3.89
77	36	1.52	2.37	3.64	6.14	8.69
77	36	1.91	2.84	4.2	6.75	9.47
77	36	1.14	1.64	2.34	3.68	5.18
77	36	0.45	0.67	0.99	1.58	2.26
77	36	0.25	0.39	0.56	0.92	1.3
77	36	0.22	0.34	0.5	0.8	1.14
77	36	0.14	0.21	0.3	0.5	0.72
78	36	0.45	0.71	1.09	1.89	2.73
78	36	0.93	1.48	2.34	4.14	6.1
78	36	1.2	1.84	2.78	4.73	6.71
78	36	0.7	1.06	1.55	2.52	3.59
78	36	0.25	0.4	0.59	1	1.44
78	36	0.14	0.22	0.33	0.55	0.81
78	36	0.12	0.19	0.28	0.48	0.7
78	36	0.08	0.12	0.18	0.3	0.45
64	37	0.09	0.14	0.21	0.33	0.45
64	37	0.16	0.25	0.39	0.59	0.81
64	37	0.24	0.38	0.55	0.88	1.12
64	37	0.17	0.28	0.43	0.68	0.95
64	37	0.06	0.11	0.18	0.33	0.49
64	37	0.04	0.07	0.11	0.21	0.31
64	37	0.03	0.06	0.1	0.19	0.29
64	37	0.02	0.04	0.06	0.1	0.15
65	37	0.4	0.52	0.67	0.94	1.11
65	37	0.71	0.96	1.2	1.59	1.98
65	37	1.02	1.31	1.68	2.28	2.67
65	37	0.8	1.07	1.39	1.94	2.4
65	37	0.38	0.56	0.81	1.23	1.65
65	37	0.23	0.36	0.51	0.79	1.06
65	37	0.21	0.32	0.47	0.73	1
65	37	0.12	0.18	0.25	0.4	0.52
66	37	0.68	0.92	1.15	1.55	1.94
66	37	1.25	1.64	2.14	2.81	3.44
66	37	1.75	2.31	2.88	3.86	4.81
66	37	1.33	1.79	2.35	3.19	4.02
66	37	0.67	1	1.4	2.19	2.96
66	37	0.42	0.61	0.89	1.37	1.88
66	37	0.38	0.56	0.81	1.25	1.72
66	37	0.22	0.33	0.47	0.74	1.04
67	37	1.2	1.68	2.37	3.78	5.29
67	37	2.31	3.28	4.67	7.45	10.63
67	37	3.04	4.21	5.85	9.12	12.76
67	37	2.17	2.99	4.12	6.39	8.99
67	37	1.08	1.6	2.36	3.88	5.69
67	37	0.65	0.98	1.44	2.4	3.6
67	37	0.58	0.87	1.29	2.14	3.24
67	37	0.36	0.55	0.83	1.46	2.27
68	37	1.32	1.8	2.43	3.52	4.67
68	37	2.57	3.49	4.73	6.72	8.68
68	37	3.35	4.54	6.06	8.76	11.58
68	37	2.4	3.23	4.35	6.53	8.95
68	37	1.23	1.82	2.65	4.34	6.41
68	37	0.75	1.11	1.63	2.72	4.06
68	37	0.67	1	1.46	2.43	3.65
68	37	0.42	0.63	0.95	1.67	2.67
69	37	1.51	2.15	3.07	4.95	6.39

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
69	37	2.94	4.23	6.09	9.88	14.23
69	37	3.8	5.31	7.48	11.77	16.58
69	37	2.67	3.71	5.17	8.12	11.41
69	37	1.35	2.02	2.98	4.96	7.41
69	37	0.82	1.22	1.81	3.1	4.68
69	37	0.72	1.09	1.62	2.77	4.23
69	37	0.46	0.7	1.08	1.95	3.2
70	37	1.42	1.9	2.51	3.53	4.57
70	37	2.76	3.62	4.76	6.46	8.06
70	37	3.63	4.87	6.32	8.82	11.35
70	37	2.58	3.48	4.69	6.99	9.48
70	37	1.31	1.97	2.9	4.83	7.22
70	37	0.79	1.19	1.78	3.03	4.57
70	37	0.7	1.07	1.58	2.69	4.07
70	37	0.46	0.7	1.08	1.94	3.18
71	37	1.52	2.08	2.72	3.83	4.96
71	37	3.03	4.07	5.39	7.25	9.08
71	37	3.91	5.32	6.87	9.64	12.46
71	37	2.62	3.56	4.82	7.15	9.62
71	37	1.25	1.87	2.76	4.59	6.83
71	37	0.74	1.12	1.66	2.83	4.26
71	37	0.65	0.99	1.47	2.49	3.77
71	37	0.43	0.66	1.01	1.82	2.95
72	37	2.16	3.37	5.2	7.52	9.96
72	37	4.53	7.13	11.01	19.56	30.22
72	37	5.26	7.99	12.15	21.15	32.17
72	37	3.17	4.84	7.19	12.08	17.89
72	37	1.34	2.05	3.09	5.28	7.76
72	37	0.76	1.16	1.77	3.12	4.81
72	37	0.66	1.01	1.56	2.78	4.35
72	37	0.42	0.66	1.04	1.98	3.28
73	37	1.75	2.49	3.41	5.14	6.32
73	37	3.6	5.28	7.06	10.38	13.89
73	37	4.41	6.2	8.48	12.85	17.6
73	37	2.68	3.78	5.31	8.11	11.16
73	37	1.17	1.73	2.57	4.3	6.38
73	37	0.67	1	1.49	2.54	3.88
73	37	0.58	0.87	1.3	2.2	3.41
73	37	0.38	0.58	0.89	1.63	2.64
74	37	1.84	2.75	4.06	6.14	7.9
74	37	3.8	5.79	8.48	14.06	20.61
74	37	4.58	6.71	9.73	15.92	23.09
74	37	2.8	4.1	5.94	9.5	13.56
74	37	1.19	1.8	2.69	4.57	6.77
74	37	0.67	1.02	1.54	2.69	4.14
74	37	0.58	0.89	1.35	2.35	3.69
74	37	0.38	0.59	0.92	1.72	2.81
75	37	2.02	2.91	4.11	5.93	7.35
75	37	4.24	6.2	8.55	13.09	18.05
75	37	5.02	7.14	10.12	16.04	22.73
75	37	2.89	4.23	6.07	9.5	13.33
75	37	1.17	1.79	2.72	4.72	7.12
75	37	0.65	1	1.54	2.76	4.36
75	37	0.56	0.86	1.33	2.39	3.84
75	37	0.37	0.59	0.93	1.81	3.06
76	37	1.32	1.92	2.66	3.99	5.33
76	37	2.74	3.98	5.63	8.29	11.12

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
76	37	3.37	4.87	6.64	9.91	13.41
76	37	2.06	2.89	4.03	6.2	8.49
76	37	0.83	1.25	1.85	3.11	4.59
76	37	0.47	0.71	1.07	1.81	2.74
76	37	0.41	0.62	0.93	1.58	2.37
76	37	0.26	0.41	0.63	1.12	1.77
77	37	0.93	1.43	2.21	3.6	5.18
77	37	1.94	3.08	4.87	7.97	11.49
77	37	2.37	3.6	5.43	8.72	12.49
77	37	1.36	2.01	2.94	4.83	6.87
77	37	0.52	0.79	1.19	2.01	2.99
77	37	0.29	0.45	0.67	1.14	1.71
77	37	0.25	0.39	0.58	0.99	1.48
77	37	0.16	0.24	0.37	0.65	1.01
78	37	0.56	0.91	1.42	2.49	3.6
78	37	1.17	1.92	3.07	5.53	7.97
78	37	1.47	2.32	3.57	6.08	8.72
78	37	0.85	1.3	1.95	3.27	4.81
78	37	0.31	0.48	0.74	1.28	1.92
78	37	0.17	0.27	0.41	0.71	1.07
78	37	0.14	0.23	0.35	0.61	0.92
78	37	0.09	0.14	0.22	0.39	0.62
64	38	0.05	0.09	0.14	0.24	0.34
64	38	0.09	0.16	0.26	0.44	0.61
64	38	0.14	0.24	0.39	0.63	0.91
64	38	0.09	0.17	0.27	0.48	0.69
64	38	0.03	0.06	0.1	0.2	0.33
64	38	0.02	0.03	0.06	0.13	0.2
64	38	0.01	0.03	0.05	0.11	0.19
64	38	0.01	0.02	0.03	0.07	0.11
65	38	0.23	0.33	0.46	0.65	0.84
65	38	0.43	0.6	0.84	1.17	1.45
65	38	0.61	0.89	1.16	1.63	2.1
65	38	0.45	0.66	0.95	1.34	1.73
65	38	0.19	0.3	0.47	0.77	1.08
65	38	0.11	0.19	0.29	0.49	0.68
65	38	0.1	0.17	0.27	0.45	0.63
65	38	0.06	0.1	0.15	0.24	0.34
66	38	0.51	0.75	1.12	1.92	2.78
66	38	0.96	1.45	2.18	3.9	5.81
66	38	1.3	1.9	2.81	4.71	6.8
66	38	0.94	1.35	1.93	3.07	4.36
66	38	0.42	0.64	0.97	1.59	2.33
66	38	0.25	0.39	0.58	0.97	1.42
66	38	0.22	0.35	0.52	0.88	1.29
66	38	0.13	0.2	0.31	0.52	0.78
67	38	0.71	1.03	1.49	2.38	3.32
67	38	1.36	1.99	2.94	4.91	6.71
67	38	1.8	2.59	3.71	5.88	8.2
67	38	1.28	1.81	2.54	3.91	5.44
67	38	0.6	0.91	1.33	2.18	3.2
67	38	0.37	0.55	0.81	1.34	1.95
67	38	0.33	0.5	0.73	1.21	1.76
67	38	0.19	0.29	0.44	0.74	1.12
68	38	0.77	1.12	1.64	2.8	4.27
68	38	1.46	2.08	3.22	5.77	8.77
68	38	1.95	2.79	4.02	6.7	10.08

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
68	38	1.45	2.02	2.84	4.46	6.42
68	38	0.73	1.08	1.55	2.51	3.6
68	38	0.45	0.66	0.96	1.54	2.2
68	38	0.41	0.6	0.87	1.4	2
68	38	0.23	0.34	0.5	0.82	1.25
69	38	0.78	1.08	1.48	2.23	3.04
69	38	1.46	2.05	2.86	4.45	6.03
69	38	1.97	2.7	3.68	5.53	7.52
69	38	1.45	1.99	2.67	3.91	5.23
69	38	0.73	1.07	1.53	2.42	3.43
69	38	0.45	0.66	0.96	1.5	2.12
69	38	0.41	0.6	0.87	1.37	1.93
69	38	0.24	0.35	0.5	0.81	1.2
70	38	0.8	1.16	1.71	2.93	4.46
70	38	1.51	2.15	3.37	6.05	9.16
70	38	2.02	2.9	4.17	7	10.52
70	38	1.49	2.08	2.93	4.61	6.67
70	38	0.74	1.1	1.58	2.57	3.7
70	38	0.45	0.67	0.97	1.57	2.26
70	38	0.41	0.6	0.88	1.42	2.05
70	38	0.24	0.35	0.52	0.85	1.31
71	38	0.93	1.24	1.66	2.38	3.05
71	38	1.79	2.46	3.26	4.73	5.97
71	38	2.36	3.16	4.23	6.03	7.7
71	38	1.61	2.22	2.92	4.2	5.52
71	38	0.77	1.12	1.59	2.52	3.52
71	38	0.46	0.68	0.98	1.54	2.16
71	38	0.42	0.61	0.88	1.38	1.94
71	38	0.25	0.37	0.54	0.87	1.28
72	38	1.39	2.25	3.39	5.52	7.04
72	38	2.83	4.81	7.23	12.15	17.99
72	38	3.47	5.44	8.12	13.82	20.65
72	38	2.14	3.21	4.8	7.83	11.29
72	38	0.92	1.38	2.06	3.51	5.24
72	38	0.52	0.78	1.17	2.01	3.11
72	38	0.45	0.68	1.03	1.77	2.75
72	38	0.28	0.44	0.67	1.22	2
73	38	1.15	1.63	2.27	3.27	4.3
73	38	2.35	3.31	4.67	6.64	8.52
73	38	2.94	4.15	5.71	8.24	10.88
73	38	1.88	2.62	3.57	5.38	7.27
73	38	0.82	1.2	1.74	2.85	4.13
73	38	0.47	0.7	1.03	1.68	2.47
73	38	0.42	0.62	0.91	1.48	2.14
73	38	0.26	0.4	0.59	1.01	1.56
74	38	1.28	1.98	2.91	4.76	6.16
74	38	2.59	4.12	6.19	9.91	14.16
74	38	3.22	4.88	7.09	11.52	16.63
74	38	2.02	2.94	4.27	6.85	9.71
74	38	0.87	1.29	1.91	3.22	4.78
74	38	0.49	0.74	1.1	1.86	2.84
74	38	0.43	0.64	0.96	1.63	2.49
74	38	0.27	0.42	0.63	1.13	1.82
75	38	1.26	1.89	2.66	4.01	5.34
75	38	2.59	3.92	5.66	8.23	10.93
75	38	3.18	4.74	6.61	10.04	13.77
75	38	1.96	2.81	3.98	6.21	8.59

Long (E)	Lat (N)	50 Years	100 Years	200 Years	500 Years	1000 Years
75	38	0.81	1.21	1.8	3.04	4.53
75	38	0.46	0.69	1.04	1.76	2.68
75	38	0.4	0.6	0.9	1.54	2.31
75	38	0.26	0.39	0.6	1.08	1.73
76	38	0.96	1.4	2.03	3.07	4.15
76	38	1.95	2.9	4.24	6.46	8.58
76	38	2.45	3.55	5.14	7.67	10.37
76	38	1.51	2.18	3.04	4.7	6.46
76	38	0.61	0.93	1.37	2.26	3.32
76	38	0.35	0.53	0.79	1.32	1.93
76	38	0.3	0.46	0.69	1.15	1.69
76	38	0.2	0.3	0.45	0.77	1.19
77	38	0.62	0.95	1.46	2.5	3.59
77	38	1.26	1.98	3.12	5.55	7.95
77	38	1.62	2.43	3.66	6.11	8.72
77	38	1.01	1.45	2.09	3.37	4.83
77	38	0.4	0.6	0.9	1.47	2.12
77	38	0.23	0.35	0.51	0.84	1.23
77	38	0.2	0.3	0.45	0.74	1.08
77	38	0.12	0.19	0.28	0.47	0.69
78	38	0.38	0.6	0.94	1.68	2.53
78	38	0.75	1.22	1.97	3.64	5.64
78	38	1	1.55	2.39	4.18	6.19
78	38	0.61	0.93	1.38	2.3	3.36
78	38	0.22	0.35	0.54	0.94	1.38
78	38	0.12	0.2	0.31	0.52	0.78
78	38	0.11	0.17	0.27	0.46	0.68
78	38	0.07	0.11	0.17	0.28	0.43