SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY EVALUATION IN PARTS OF URI BLOCK, J&K

FINAL REPORT, MARCH 2007

SUBMITTED TO

AGA KHAN PLANNING & BUILDING SERVICES, INDIA

ACADEMY FOR MOUNTAIN ENVIRONICS, ENVIRONICS TRUST

Khasra No. 177, Shokeen Market, Neb Sarai Main IGNOU Road, New Delhi - 110068

environics@gmail.com; telefax: 91-11-29531814, www.environicsindia.org

There was a time when the weather belonged to gods… there was a time when the equation was equally enveloped in mystery, and was forecast in the enigmatic phrases of the astrologer and the oracle and now that it too has passed from the shadow of the occult of the light of knowledge, the people of the civilized earth - the lay clients of the seismologist - would be glad to know whether the time has come yet for a scientific forecast of an impending tremor.

G.K.GILBERT, 1909

CONTENTS

Preface

Earthquakes have always created curiosity in human minds since ancient times, however the scientific methods to predict earthquakes are still a nascent science despite the rapid strides it has been making. The development of this science during the last few decades is largely due to concurrent developments in instrumental geophysics, computational science and modeling, more detailed geological information and an array of space based multi-spectral data collection systems. The huge costs of earthquake damages have also lead policy makers to seek more information and hazard management has become an important element in modern day governance.

The Indian subcontinent has been witnessing varying dimensions and diversity of natural disasters and ironically in the last decade of the millennium, which was the United Nation's International Decade for Disaster Mitigation; we were subject to some major disasters. The first few years of the millennium has already taken a toll that is far higher than all the death and property loss through natural disasters in entire the history of the sub-continent.

An array of disasters like earthquakes, cyclones, floods, tsunami etc have visited the sub-continental region over the last 4-5 years and a lot more efforts are being put to enrich the scientific knowledge as well develop various models to refine our understanding of a particular event and interrelationships among the different events. Scientists believe that the task is still a game of chance, indicating that the prediction of time and space of a particular event is still a far cry. However, it is clear that several areas are far more vulnerable and probabilistic modeling could be helpful in mitigating the damages and a better understanding of the events to enable plan better. We must also understand that the Himalayan environment is in its transitional state and much more understanding is required for improving the reliability. Fortunately with greater globalisation and flow of information, we know the impacts and implications across political borders unlike in the thirties when the Bihar-Nepal Earthquake struck, little was known of the damages immediately by the scientists and administrators of situation across the borders. The Indian Himalayan region has been one of the most vulnerable in terms of its seismicity, landslide and flash floods. The time of such events has been a critical factor as it determines the extent of loss of human lives. This devastating earthquake took place at a time when children were in schools and the maximum number of lives lost was of children thereby completely altering the demographic characteristics of the communities.

To deal with the real world of reconstruction and rehabilitation risk evaluation at local levels become important and hazard micro-zonation offers the tools. The earthquake with an intensity of 7.6 brought devastating consequences to communities in Pakistan Administered Kashmir while the adjoining Uri Tehsil of Baramulla District suffered the worst, where housing stock collapsed in large numbers and human lives were lost pushing the community backwards. The whole transformation in the socio-economic profile of the region is evident after the earthquake, which hovers around their shelter and social infrastructure and demands concerted action. The advances made in the image analysis has obviously given a leverage to apply techniques and methods for mapping and build parameters to enable decision makers in their planning process. Environics Trust, New Delhi in collaboration with RRSSC (ISRO) Kharagpur, Seismology experts from IIT, Roorkee, Ghuman & Gupta, Geotechnical Consultants has undertaken this task so as to enable the Aga Khan Foundation identify safer sites for creation of physical infrastructure in their programme villages.

In one of his recent articles on this earthquake, Prof. Vinod K Gaur, the doyen of geophysical sciences writes,

`Earthquakes in ancient times used to be considered acts of God, through the trauma they exert on innocent populations. Today, we are no longer ignorant of the causes and probable locations of future earthquakes but whilst successive earthquakes come as no surprise to scientists, each one delivers a punishing and unacceptable blow to local communities. There is thus an ironic gulf between what the scientific community knows and what society does with this knowledge.'

Here we hope to bridge this gulf.

March, 2007

The Environics Team

ACKNOWLEDGEMENTS

We sincerely thank Mr Nicholas Mckinlay, CEO, AKF, India and his team for reposing faith in us to undertake this complex task. Ms Surekha Ghogale, CEO - AKPBSI has been a constant source of encouragement and without her active support this effort would really have not come to fruition. We convey our heartfelt thanks. Our sincere thanks goes to the core members; Mr. Feroze Ahmed, Programme Director, AKDN (J&K Project); Mr. Joy Singhal, Mr R.P.Singh, Deputy Manager - Uri; Mr. Amarjeet Singh, Consultant, AKDN - J&K Project; and the consulting team in Uri on various aspects.

We would like to thank Dr. A. Jeyaram, Head – RRSSCK and his team comprising of Dr. Vinu Chandran, Scientist 'SD', Ms Anju, Mr. Rana of the RRSSCK for enabling a digital interface with the region for bringing out set of analytical illustrations; Dr. M.L. Sharma, Associate Professor, D.E.E, IITR for providing inputs on the seismological aspects and bringing in probabalistic modeling for the region, M/s GGGC, Mohali for carrying out site testing in different locations. We acknowledge the feedback and knowledge sharing by a number of professionals in the Wadia Institute of Himalayan Geology, particularly the team which was involved in post-quake analysis.

Apart from our collaborating institutions, there have been several individuals that have extended their support in the whole process. Firstly, the composed people of Uri who have been well receiving and provided every possible help by debating and sharing the post earthquake primary information of their respective places. We would like to put forward our sincere thanks to Lt. Colonel S.D.Nautiyal of 1/9 GR and his dedicated team for letting us accomplish our tasks by permitting our team to visit the remote sites. We would also like to compliment the effort done by the brigade in the region and extend our heartiest best wishes to the team.

The departments/office bearers that deserve special thanks for sparing time and enriching our knowledge base are:

- Dr.Shakil Ahmed Ramsoo, Head (Department of Geology and Geophysics), University of Kashmir
- Mr. Assadullah Khan, Deputy Director (P&S), Department of Agriculture
- Mr. Kasim, Subject Matter Specialist, Department of Agriculture
- Mr. Meher Aftab Kirmani, Assistant Professor, SUKAST, Srinagar
- Mr. Maqbool Bhatt, Quality Control Officer, Department of Agriculture
- Mr. Nisar Ahmed Wani, Research Assistant, Soil Survey Division
- Mr. Kushal Singh, J.D., Department of Geology and Mines, J&K
- Dr. Gulamuddin Bhat, Assistant Geologist, Baramulla
- Mr. Zafar Iqbal, Zonal Education Officer, Salamabad, Uri
- Md. Bhat, Zonal Education Officer, Uri

Our sincere thanks are also to Sarpanchs, Patwari's, Teachers who have been at various stages interacted with us and provided their inputs in their capacities.

We are extremely grateful to Prof V.K.Gaur, a teacher par-excellence and a living inspiration to numerous geoscientists for sharing his recent work and encouraging us to bring in our best efforts.

The Environics Team would like to acknowledge the efforts, support and collaboration of individuals and organisations that we may have inadvertently missed out but have contributed in every which way that this work has been possible.

ACRONYMS

AKF	Aga Khan Foundation
AKDN	Aga Khan Development Network
AKPBSI	Aga Khan Planning and Building Services, India
AME	Academy for Mountain Environics
AOI	Area of Interest
DEE	Department of Earthquake Engineering
DEM	Digital Elevation Model
FSI	Forest Survey of India
GGGC	Ghumman and Gupta Geotechnical Consultants
GIS	Geographical Information System
GR	Gorkha Regiment
GSI	Geological Survey of India
IITR	Indian Institute of Technology, Roorkee
IRS	Indian Resource Satellite
ISZ	Indus Suture Zone
J&K	Jammu and Kashmir
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MMI	Modified Mercalli's Index
MMT	Main Mantle Thrust

NRSA	National Remote Sensing Agency
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
PR	Predominant Frequency
PSHA	Probabilistic Seismic Hazard Analysis
RQD	Rock Quality Designation
RRSSCK	Regional Remote Sensing Service Centre, Kharagpur
SPSS	Statistical Package for Social Sciences
SR	Site Response
SRT	Salt Range Thrust

Select Glossary

Term	Description
Fault	A planar or gently curved fracture in the Earth's crust across which there has been relative displacement.
Fault plane	The plane that best approximates the fracture surface of a fault
Fold	A planar feature, such as a bedding plane, that has been strongly warped, presumably by deformation
Foliation	Any planar set of minerals or banding of mineral concentrations including cleavage, found in a metamorphic rock.
Formation	The basic unit for the naming of rocks in stratigraphy a set of rocks that are or once were horizontally continuous, that share some distinctive feature of lithology, and are large enough to be mapped.
Fossil	An impression, cast, outline, or track of any animal or plant that is preserved in rock after the original organic material is transformed or removed.
Mass movement	A downhill movement of soil or fractured rock under the force of gravity.
Maturity	A stage in the geomorphic cycle in which maximum relief and well-developed drainage are both present.
Moraine	A glacial deposit of till left at the margin of an ice sheet. See specifically by name, ground moraine, longitudinal moraine, medial moraine, and terminal moraine
Tectonics	The study of the movements and deformation of the crust on a large scale, including epeirogeny, metamorphism, folding, faulting, and plate tectonics.
Thrust fault	A dip-slip fault in which the upper block above the fault plane moves up and over the lower block, so that older strata are placed over younger.
Unconformity	A surface that separates two strata. It represents an interval of time in which deposition stopped,

	erosion removed some sediments and rock, and then deposition resumed (see also Angular unconformity).
Unconsolidated material	Nonlithified sediment that has no mineral cement or matrix binding its grains.
Escarpment	A steep slope or long cliff that results from erosion or faulting and separates two relatively level areas of differing elevations. Long line of cliffs or steep slopes that break the general continuity of the land by separating it into two level or sloping surfaces. Some very high escarpments, or scarps, may form by vertical movement along faults. Often a whole block of land may be forced upward while the adjacent block is downfaulted
Syncline	A concave-upward fold in rock, i.e. the limbs are raised and the center depressed
Anticline	A concave-downward fold, i.e. the limbs are depressed and the center raised
Monocline	A fold in rock connecting two vertically offset, horizontal sections of sedimentary rocks.
Epicenter	The point of occurrence of earthquake
MMI	Modified Mercalli Index, intensity scale used for measuring the intensity of earthquake. The scale quantifies the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale of 1 through 12, with 1 denoting a weak earthquake and 12 one that causes complete destruction.
Peak Ground Acceleration	It is a measure of earthquake acceleration. Unlike the Richter magnitude scale, it is not a measure of the total size of the earthquake, but rather how hard the earth shakes in a given geographic area.

CHAPTER 1.0

SEISMICITY IN THE REGION

This chapter highlights the seismicity in the region and provides a background for understanding the complexity in terms of the tectonic and seismic history of the area and informs why this effort is important.

1.1 Plate Tectonics

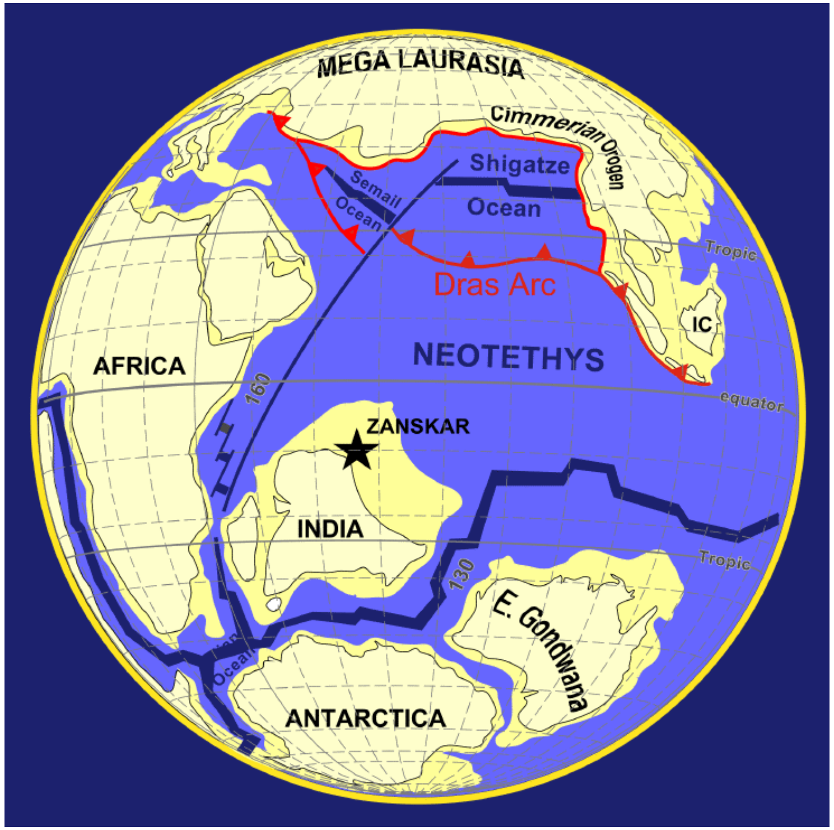
It is now generally accepted that the outer skin of the earth's surface consists of relatively thin, rigid plates or spherical caps. The margins of these plates are seismically active as a consequence of their moving relative to each other. If we take a working figure of 50 kms for the thickness of the plates and estimates of 1000 to 5000 kms for their length and breadth dimensions, we obtain thickness: length/breadth ratios of 1:20 to 1:100. The plates are therefore wafer thin and may be expected to be fragile.

There are two important contrasts – the oceanic and continental parts of the plate are varied in their thickness and their relative ages. The oceanic lithosphere has all formed in the last 200 million years, and the young lithosphere covers more than two-thirds of the earth's surface. On the time scale of Earth's history, we therefore have a process of considerable rapidity. It is found that new oceanic crust is being created at a remarkably fast rate of upto 10 cm per year. This sets a further condition that the velocities of any driving mechanism must be atleast half the spreading rates and this must be consumed at some other part of the globe to accommodate.

As is now well known, earthquakes are the result of a mechanical instability in the earth's upper colder brittle crust where elastic strains steadily created by relative plate movements can accumulate up to about 1 part in 10,000 before fracturing along faults. Earthquakes are thus understood to constitute a periodic phenomenon with a cyclicity determined by the rate of strain accumulation in the region and failure strength of the potential rupture surface(s). In principle, knowledge of this strain rate and the precise strain required to promote failure would permit earthquakes to be forecast. GPS geodesy when compared with geological data on plate motions indicates that the velocity of tectonic plates have changed little over the past 3 million years. We therefore, have a good present-day measure of surface strain accumulation rates. The absence of definitive knowledge about rock failure conditions or the absolute level of strain, however, makes it currently impossible to identify the location and timing of future earthquakes' (Gaur, 2006).

1.2 The Flight of Indian Sub-continent

The Indian Sub-continent is considered to have moved so much that in geological time scales it is almost like a flight in geological time scales.

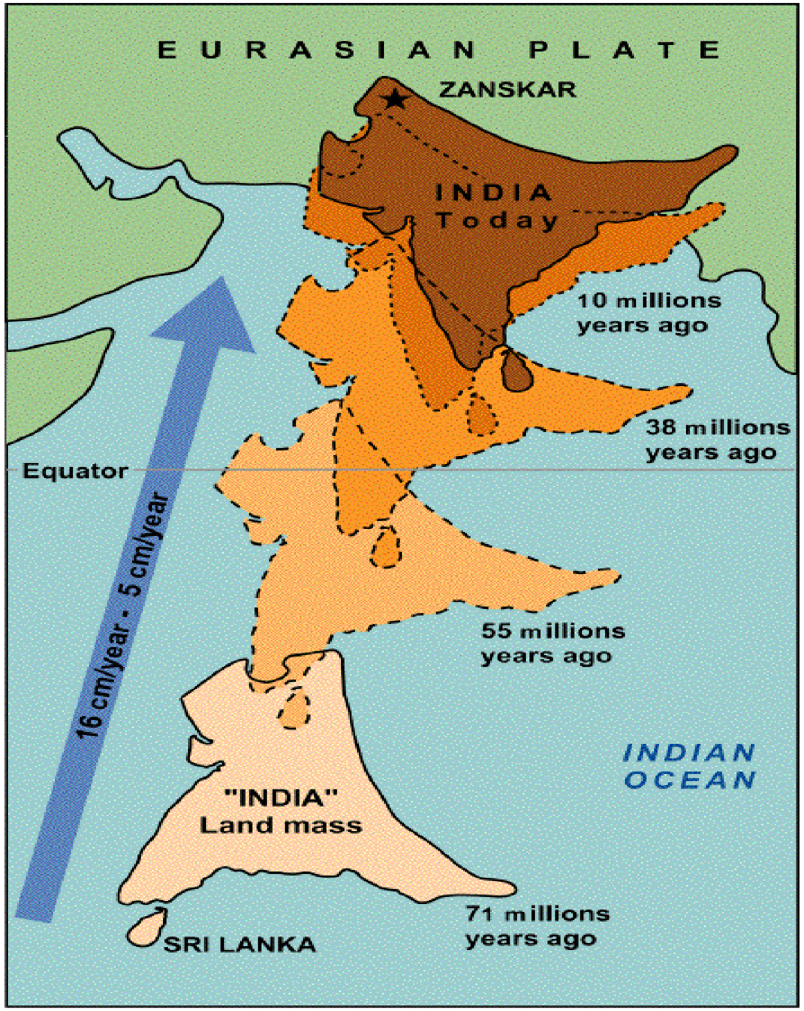


The earth in the Early Permian (~600 million years ago) indicates that at that time, India was part of Gondwana and bordered to the north by the Cimmerian Superterrane. The movement from some where close to the Antarctic to somewhere close to present day Madagascar in the next 500 million years must be considered a slow pace as compared to the dramatic drift over the next 100 million years.

The earth in the Cretaceous (~ 100 million years ago) the Cimmeridian Superterrane has accreted to Mega Laurasia, the oceanic crust of the Neotethys is subducted to the north along the Dras volcanic arc, the Shigatze Ocean opens as a consequence of back-arc spreading, India is separated from Africa and E. Gondwana and the Indian Ocean opens.

These Paleogeographic reconstructions based by Dèzes (1999), on Stampfli and Borel (2002) and Patriat and Achache (1984) and have been adapted from the wikipedia.

The northward drift of India from 71 Ma ago to present time indicates such a long movement such a huge land mass that the orogenic activity at the junction of these plates involving a huge momentum of impact.

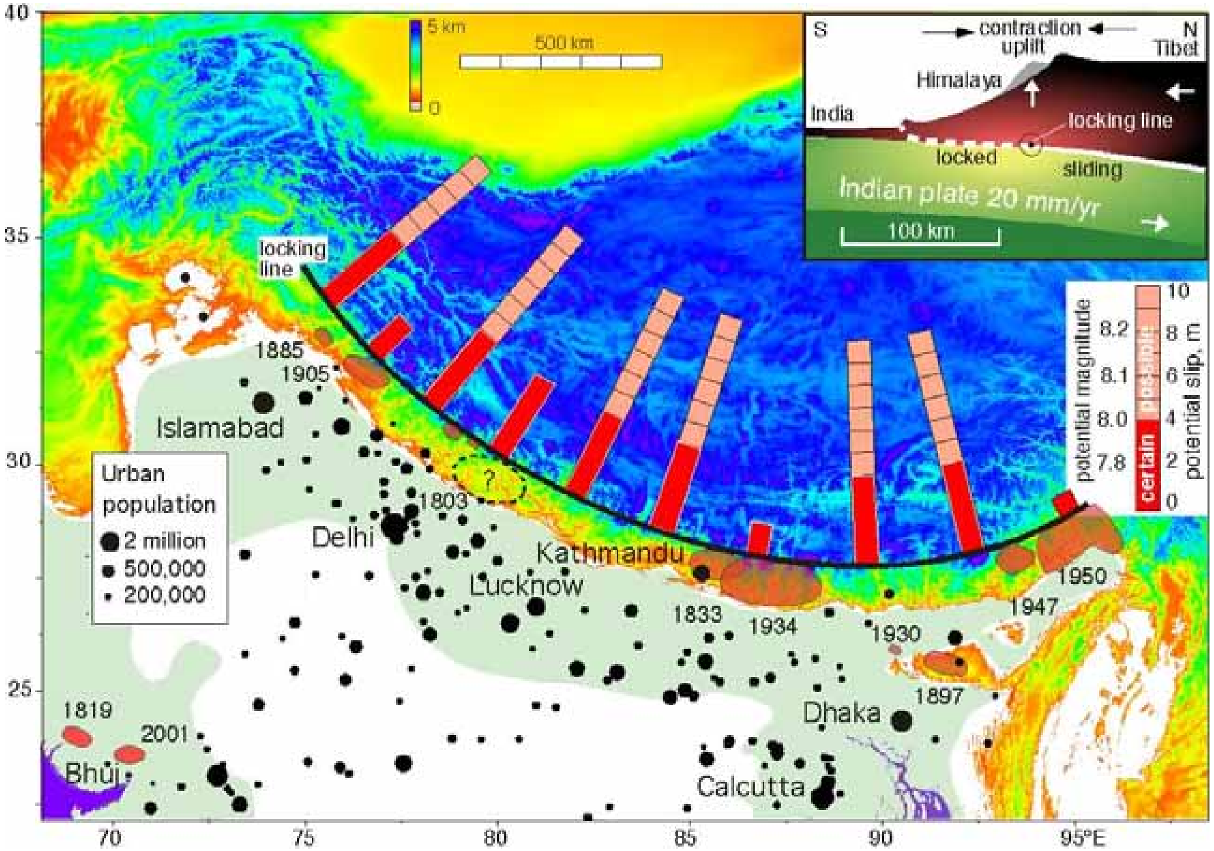


The Collision of the Indian continent with Eurasia is estimated to have occurred at about 55 million years ago and is relentless. Considering the inferred location of the landmass at this period to be around the present day equator, the drift has accelerated and greater must be the impact on the margins. It may be noted that the Indian landmass has simultaneously rotated counter-clockwise (Adapted from USGS).

It is this flight of India of the Indian Sub-continent and its continuous subduction that has given rise to the tallest mountain ranges in the world and continues to be a region that abounds in seismic activity.

1.3 The Danger Zone (Adapted from Roger & Bilham (2005) and Gaur V.K (2006)

Roger and Bilham's (2001) view of the Indo-Asian collision zone shows the estimated slip potential along the Himalaya and urban populations south of the Himalaya (U.N. sources). Shaded areas with dates next to them surround epicenters and zones of rupture of major earthquakes in the Himalaya and the Kutch region, where the 2001 Bhuj earthquake occurred. Red segments along the bars show the slip potential on a scale of 1 to 10 meters, that is, the potential slip that has accumulated since the last recorded great earthquake, or since 1800. The pink portions show possible additional slip permitted by ignorance of the preceding historic record.



Great earthquakes may have occurred in the Kashmir region in the mid 16th century and in Nepal in the 13th century. The bars are not intended to indicate the locus of specific future great earthquakes, but are simply spaced at equal 220-km intervals, the approximate rupture length of the 1934 and 1950 earthquakes. Black circles show population centers in the region; in the Ganges Plain, the region extending ~300 km south and southeast of the Himalaya, the urban population alone exceeds 40 million. The inset is a simplified cross section through the Himalaya indicates the transition between the locked, shallow portions of the fault that rupture in great earthquakes, and the deeper zone where India slides beneath Southern Tibet without earthquakes. Between them, vertical movement, horizontal contraction, and micro earthquake seismicity are currently concentrated.

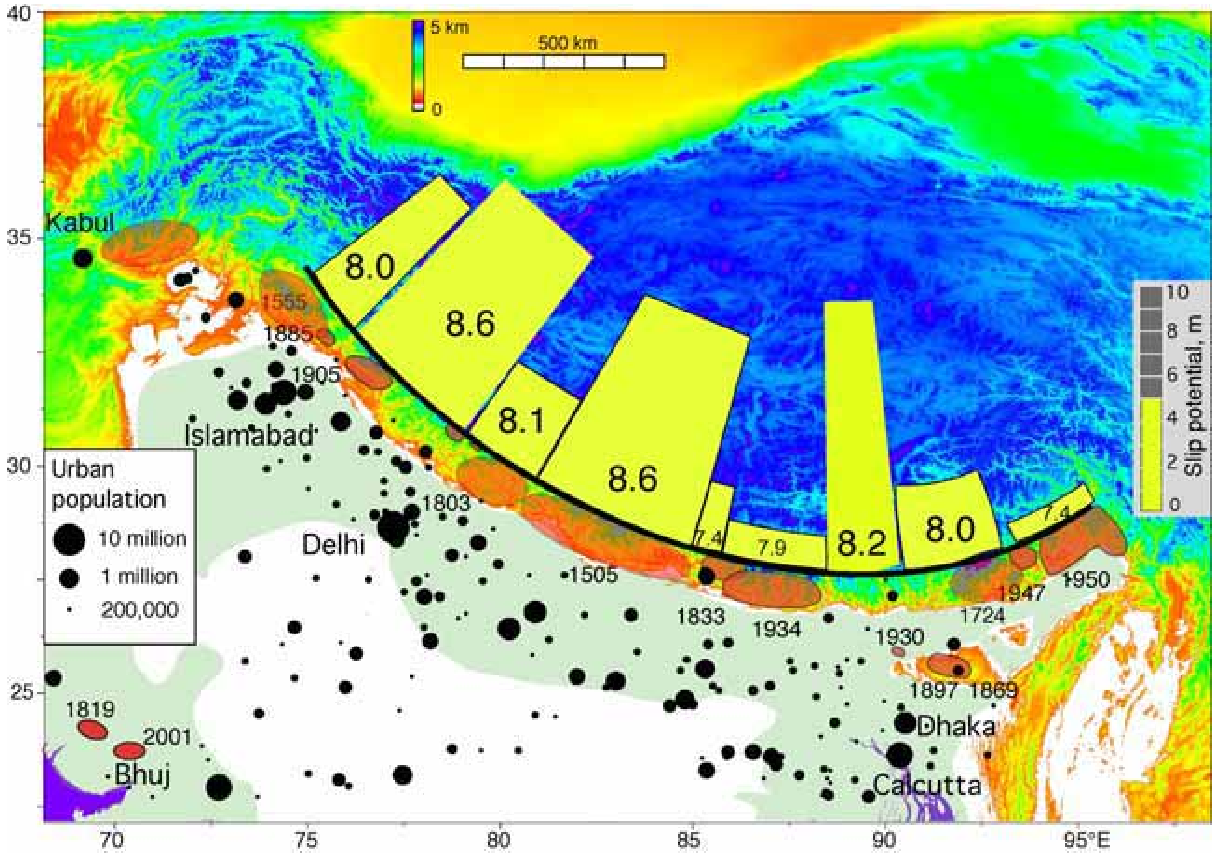
In 2001 Bilham et al estimated the present-day slip potential of the Himalaya by assuming that the currently observed convergence rate had prevailed for 200 years, and by calculating the accumulated slip that would be released at various points along the arc since the last earthquake at each of those points, should an earthquake occur there today (Bilham et al., 2001). The extension of the historical record to 1500, and geological evidence for surface rupture in a large earthquake in 1400 (Wesnowsky et al 1999, Kumar et al, 2001) permits a revised estimate of this slip potential. Its accuracy depends on the following assumptions: that we know of all significant earthquakes since 1500, that present geodetic convergence rates have prevailed for the past 500 years, and that no slow earthquakes have released slip during or after large earthquakes.

In the 2001 analysis Bilham et al made no attempt to estimate the along-strike rupture length of potential future ruptures. Despite the different along-arc lengths of segments shown, the segment estimates do not necessarily represent the segment size of future earthquakes. Each trapezoidal figure represents the slip developed since the previous known earthquake at that location. We have no way of knowing whether a future earthquake will rupture the same area. Using the slip and rupture area of each of these regions we can estimate the magnitude of an earthquake should it occur today.

We know less about earthquakes in the eastern Himalaya than those in the west, and it is possible that we have underestimated seismic slip potential there. The 1897 earthquake reduced stresses in the region, but only for a 120 km long segment of eastern

Bhutan. We know with certainty of no large earthquakes in western Bhutan with the exception of the 1713 earthquake that damaged several monasteries. The along-strike extent of this earthquake is unknown (Ambraseys and Jackson, 2003).

The huge number of vulnerable population is clear from the map which indicated Urban population and slip potential in the Himalaya, based on elapsed time since the last major earthquake in various sectors along the arc since 1400 and the GPS-derived convergence rate across the Himalaya. The height of each trapezoid is proportional to the current slip potential in meters, and the numbers refer to the potential size of earthquake should the same segment length slip as is currently believed to have occurred in the last earthquake. The slip potential in



the eastern Himalaya is tentative since the effects of the 1897 Shillong earthquake are uncertain and we know of no great historical earthquakes in Bhutan with the exception of a possible event in 1713.

1.5 The Importance of the Current Effort

The consequences of the western Himalaya slipping in its entirety between 1400 and 1555 is that a 1200 km length of the Himalaya has matured sufficiently to experience two or more M>>8 ruptures. The total length, and the presence of relatively modest earthquakes in the intervening 500 years, suggests that the western Himalaya may be in a stress state somewhat similar to the Andaman plate boundary prior to 2004. ***`Although we have no historical examples of simultaneous rupture of contiguous segments of the Himalaya, we would, given the recent M=9 earthquake on India's Andaman boundary, be foolish to ignore the possibility that a similar great earthquake in the Himalaya' (Bilham et al, 2005)***.

The importance of the current effort can be captured in the following statement of Prof Gaur, `If the warning offered by the three disastrous earthquakes in India in the past 6 years is unheeded by city planners, politicians and architects, the disastrous impact of a future earthquake could be far more grievous than any we have yet seen. Three inexorably growing trends of our social dynamic conspire to force this conclusion: increased populations (10 to 100 times larger than that exposed to previous Indian earthquakes), increased vulnerability (the building stock is taller, and far less well-constructed than ever before), and the demographic pattern of high population density in regions expected to experience abnormally high ground shaking intensity (thick sediments near river valleys like the Ganges and Brahmaputra systems, and ancient lakes like those in the Kathmandu and Kashmir valleys). Given that several Mw>8 earthquakes are anticipated along the Himalaya, the populations at risk exceed 50 million people. A crash programme to ensure and, wherever desirable, enforce incorporation of earthquake resistant design and construction practices using all possible means, and retrofitting of all community buildings and support systems has the promise of safeguarding a large proportion of those potentially at risk and preventing trillions of dollars of economic damage that a future earthquake in the region may otherwise exact.'

In terms of the process, another doyen in the field, Prof Khattri has this to say `A way to do this efficiently is to have a compliment of large-scale national seismic zoning map and small-scale microzoning maps of important localities. A few questions that need to be addressed are noted next. How can we profitably weave into the fabric of seismic zoning at all scales, new evidences from diverse fields such as GPS, palaeo-seismology, etc. as noted above, in preparing a state-of-the-art zoning map? What should be the smallest size of an area for attempting micro zoning? This also relates to the question as to how fine a scale the knowledge of geological properties needs to be for the stated end-objective of micro zoning. For geology can be studied from microscopic to megascopic scales. Moreover, often the boundaries of geological units are not sharp. How can one exploit the formalism of fuzzy logic to our advantage in defining the zones, etc. in such situations?' He further points out that `A matter of grave concern is the use of the current building codes devised on the basis of flawed national seismic zone map, that are becoming a means to create unsafe buildings in large sectors of the country. Hence, there is an urgency to produce scientifically correct national seismic zoning maps, both in the large and the micro scales (i.e. micro-zoning maps for large cities and other significant units) on the basis of which appropriate building codes can be defined. All future construction and retrofitting activity may be done on such a properly defined basis. There is also dire need to promote wider implementation of earthquake-resistant building codes and ways to achieve this need to be discussed. A possibility is to introduce incentives to those who follow the codes for new constructions as well as for those who do retrofitting.'

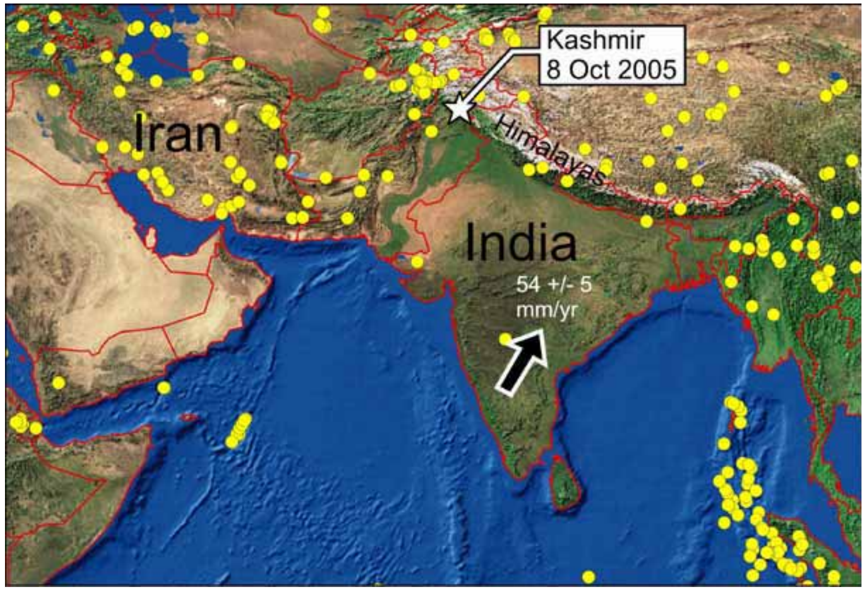
CHAPTER 2.0

8TH OCTOBER, 2005 EARTHQUAKE & FOCUS VILLAGES

This chapter gives a brief of the earthquake event and details the focus villages

2.1 The Event

A devastating earthquake hit the Kashmir region across the political borders in the morning of 8th October, 2005 leaving nearly 75,000 dead, several injured and maimed and a near complete destruction of houses in the epicentral tract. Its epicenter was determined by the USGS to be located at 34.402°N, 73.560°E. Muzaffarabad, capital town of the Pakistan administered Kashmir which is about 20 kilometer SE of the epicenter, suffered the heaviest casualties. Aftershocks numbering over 500, including one of magnitude as high as 6.2 continued to traumatise people for several months. Early aftershocks were sufficiently severe to further damage already weakened structures.



DATE	ORIGIN TIME (UTC) HR MN SEC	GEOGRAPHIC COORDINATES LAT LONG	DEPTH	MAG	No. STA Used
OCT 08	03 50 40.8	34.539 N 73.588 E	26 G	7.6	724

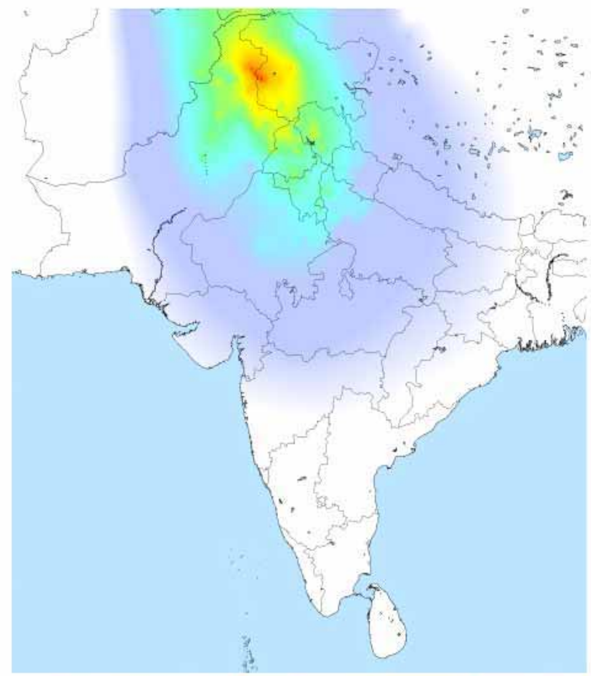
The heaviest damage occurred in the Muzaffarabad area, Kashmir where entire villages were destroyed and at Uri where 80 percent of the town was destroyed. At least 32,335 buildings collapsed in Anantnag, Baramula, Jammu and Srinagar, Kashmir. Buildings collapsed in Abbottabad, Gujranwala, Gujrat, Islamabad, Lahore and Rawalpindi, Pakistan.

Maximum intensity VIII. Felt (VII) at Topi; (VI) at Islamabad, Peshawar and Rawalpindi; (V) at Faisalabad and Lahore. Felt at Chakwal, Jhang, Sargodha and as far as Quetta. At least 1,350 people killed and 6,266 injured in India. Felt (V) at Chandigarh and New Delhi; (IV) at Delhi and Gurgaon, India. Felt in Gujarat, Haryana, Himachal Pradesh, Madhya Pradesh, Punjab, Rajasthan, Uttaranchal and Uttar Pradesh, India. At least one person killed and some buildings collapsed in Afghanistan. Felt (IV) at Kabul and (III) at Bagrami, Afghanistan. An estimated 4 million people in the area left homeless. Landslides and rockfalls damaged or destroyed several mountain roads and highways cutting off access to the region for several days. Landslides occurred farther north near the towns of Gilgit and Skardu, Kashmir. Liquefaction and sandblows occurred in the western part of Vale of Kashmir and near Jammu. Landslides and rockfalls also occurred in parts of Himachal Pradesh, India. The Broadband Seismological Observatory of GSI at Jabalpur also recorded the main event and evaluated the origin time as 03 hr 50 min 56 sec. The short period MEQ digital recorders stationed at GSI Office, Chandigarh for purpose of seismic microzonation of the urban complex gave the following attributes of the earthquake.

Arrival time of P-wave: 03: 51 : 51.27 (GMT). Time gap between arrival of P and S waves (S-P): 55.08 seconds Signal duration at Chandigarh: 15 minutes. Epicentral distance of the earthquake from Chandigarh: 496 km (approx).

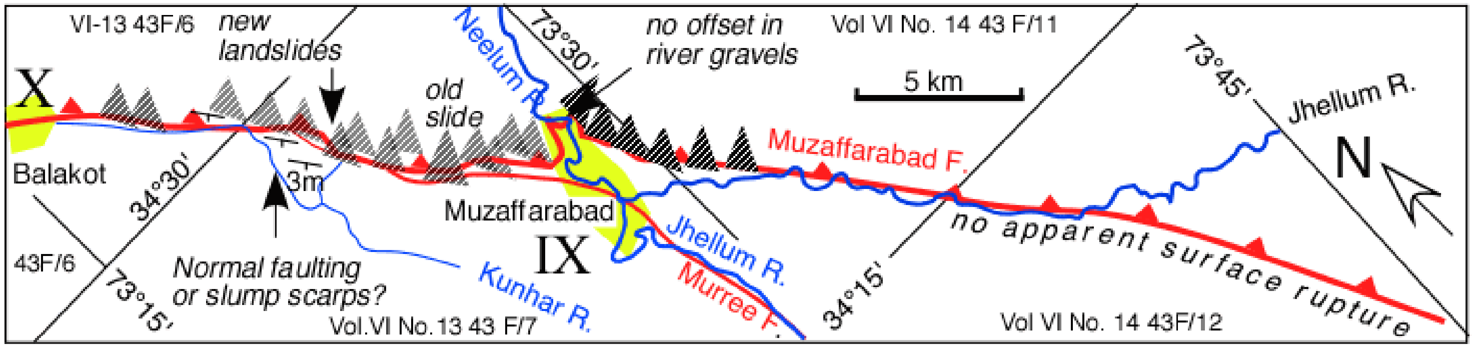
A three-station MEQ network operating at Chandigarh recorded as many as 160 aftershocks till 11.30 hrs of 10.10.2005. A TV News Channel of Pakistan reported occurrence of 575 aftershocks between 8th and 14th October 2005. The date-wise distribution of numbers of the aftershocks during this period was 102, 122, 75, 76, 63, 78 and 59, respectively.

From USGS, GSI and websources

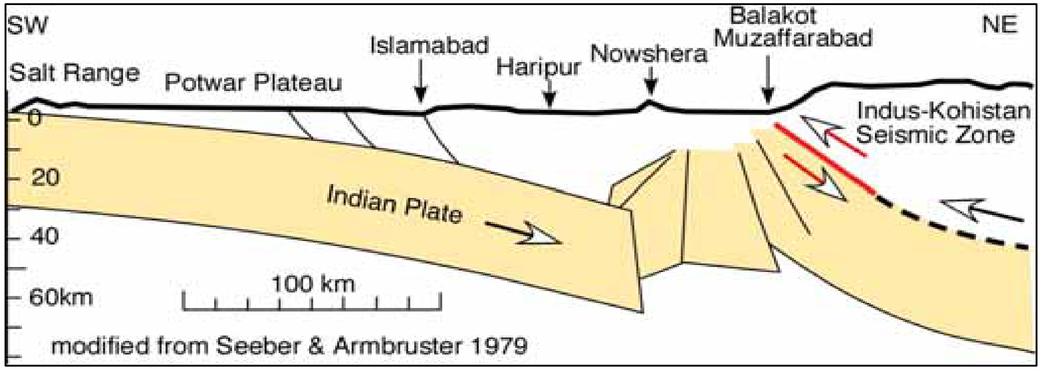


I	II-III	IV	V	VI	VII	VIII	IX	X+
Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

The 2005 Kashmir earthquake was caused by approximately 5 m of south-west directed slip of the western Himalayan ranges along a 30 degree NE dipping fault that had been mapped by geologists, but which had not slipped in historical times. The resultant slip raised the mountains locally by 2.5 m and long term slip on the fault is clearly responsible for the presence of substantial step in the mean topography in this part of the range. The surface rupture is mapped for at least 90 km along the strike, but aftershocks suggest that the rupture in the subsurface extended a further 20 km to the NW (Gaur, 2006).

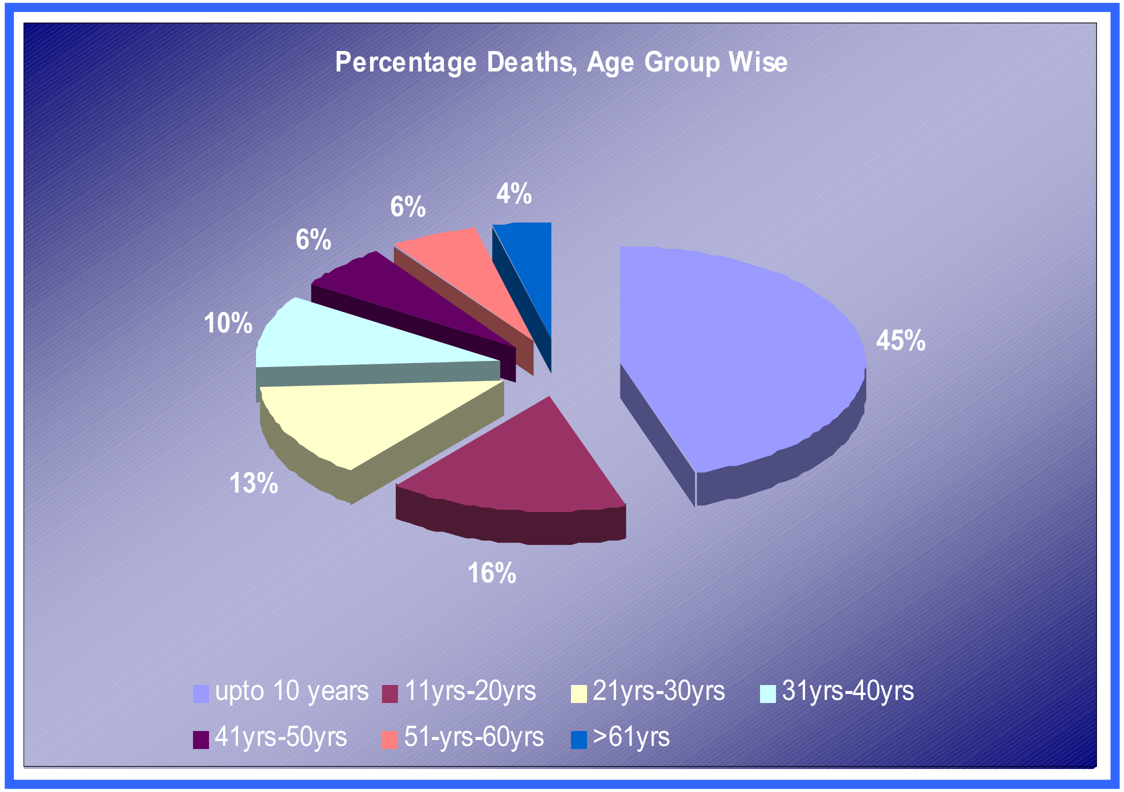


The generalized NE-SW cross section across the area indicates that the rupture occurred along the well described Indus-Kohistan rupture. A cartoon section of the rupture geometry is presented below (Gaur, 2006):



2.2 Impacts in Uri and Villages in Focus

While the occurrence of such a large magnitude earthquake in any populated zone will cause huge human and property losses, it was unfortunate that the time – early morning school time - and period – the month of Ramadan - of occurrence, lead to an unusually large number of school-going children and the elderly to perish, totally altering the demographic patterns of several settlements. Over seven thousand schools were completely destroyed – starkly demanding utmost care in the future construction of such vital infrastructure.



A look at the age distribution of people dead in the Uri Tehsil itself is a disturbing fact that over 61% of the deceased were under 20 years of age.

The Uri Tehsil is spread in an area of 255 sq. kms. In all there are 99 villages in the tehsil. Uri forms a very distinctive feature as it can be largely described as linearly partitioned landform cut across by the Jhelum River and numerous streams draining into the river. The major and access road to the settlements across the river are Haji Pir road, Salamabad - Sarai Road, Sarai-Kamalkote Road, Kalgi-Jabla Road etc. Uri has very favourable climatic conditions for temperate fruits and people of the region survive on a limited rice and maize cultivation. The region has been under turmoil due to its closeness to the LoC but this region has always been a point of peace and people speak a `pahari' dialect.

Key Features of Uri Tehsil of District Baramulla, J&K

S.No.	Characteristics	Uri Tehsil, District Baramulla
1	Number of Households	16,695
2	Total Population	1,13,571
3	Sex Ratio	861
4	Number of Villages	99
5	Approximate area of Tehsil	255 sq. km
6	Urban Area	4.9 sq km

Source: Census of India

The AKDN has initiated its activities in the 17 programme villages, which are spread in and around Uri town and have been grouped together in three clusters. The cluster-wise list of settlements provided in the adjoining table.

No.	Cluster I
1	Sultan Daki
2	Basgran
3	Sarai
4	Shahdra
5	Chappar
6	Dulanja
7	Jabra
8	Kinari
	Cluster II
9	Isham
10	Urusa
11	Gwalta
12	Chakra
13	Dardkot
14	Nawarundan
	Cluster III
15	Gohalan
16	Jabla
17	Sangrian

Land has always been a constrained resource in the hilly regions for livelihoods and shelter. As settlements expanded and as housing could be only in the `abadi' lands, most of the expansions have taken place without giving much consideration to the safety factors from natural disasters. Looking at the altitudinal profile of villages in the programme villages there is a variation of micro climatic factors, aspects, slopes, erodability and vegetation cover.

Cluster I located on the right bank of River Jhelum and extends over a large area. Except Jabra/Kinari, Dulanja, which are off the track, all the villages in sequential order of their accessibility. An important tectonic feature of region and critical for our analysis, the Main Boundary Thrust runs across this cluster.

Demographic Characteristics of the villages is as follows:

Cluster I					
Name of the Village	**Households**	**Population**	**Male**	**Female**	**Sex Ratio**
Sultan Daki	286	2410	1302	1108	851
Basgran	125	913	500	413	826
Shahdra	122	828	403	425	1055
Chappar	50	360	207	153	739
Dulanja	40	257	145	112	772
Jabra (Kinari is a part of Jabla)	84	450			

Cluster II and Cluster III are located on the left bank and are largely located over the Muree Deposits. Cluster III comprises of three villages of Jabla, Sangrian and Gohalan in sequential order of their accessibility and all the three villages fall under the Gohalan halqa. Jabla is accessible through a motorable road (bad in rainy seasons) whereas Sangrian and Gohalan are connected only through a mule track and pathway.

Cluster II					
Name of the Village	**Households**	**Population**	**Male**	**Female**	**Sex Ratio**
Isham	147	1154	592	562	949
Urusa (NA)	55	610			
Gwalta	165	1240	654	586	896
Chakra	30	265	142	123	866
Dardkot	225	1523	800	723	904
Nawarundan	183	1118	614	504	821
Cluster III					
Gohalan#	262	1963	1132	831	734
Jabla	238	1598	858	740	862
Other Villages					
Dachi	182	1273	651	622	955
Param Pilla	295	2017	1021	996	976
Salamabad	182	1126	596	540	922
Uri	67	475	238	237	996
Uri (Urban)	589	4246	2328	1918	824
Source: Census of India					

 # Sangrian is a hamlet of Gohalan

The number of houses that have been destroyed by the earthquake is as follows:

S.No.	Patwari Halqa	Villages	Fully Damaged
1	Isham	Isham	145
		Chakra	32
		Urusa	39
		Nawarunda	221
		Gwaltha	172
2	Sultan Daki	Sultan Daki	263
		Basgran	120
		Dachi	180
		Paran Pilan	292
3	Dardkot	Dardkot	238
		Kalgi	182
		Salamabad	210
		Naupora	87
4	Jabla	Jabla	201
		Gohalan	315
		Sukhdar	68
		Badan (Sing tung)	11
5	Kamalkote	Kamalkote	308
		Chappar	47
		Shahdra	89
		Dhulanja	57
		Saraie Bandi	179
		Kundi Barjala	145
6	Uri	Uri	449
		Thajal	103
		Batgran	76
		Tilawari	51
		Churunda	218
		Sokar	20
		Pawdian	51
	Total		**4569**

Source: Baramulla NIC website

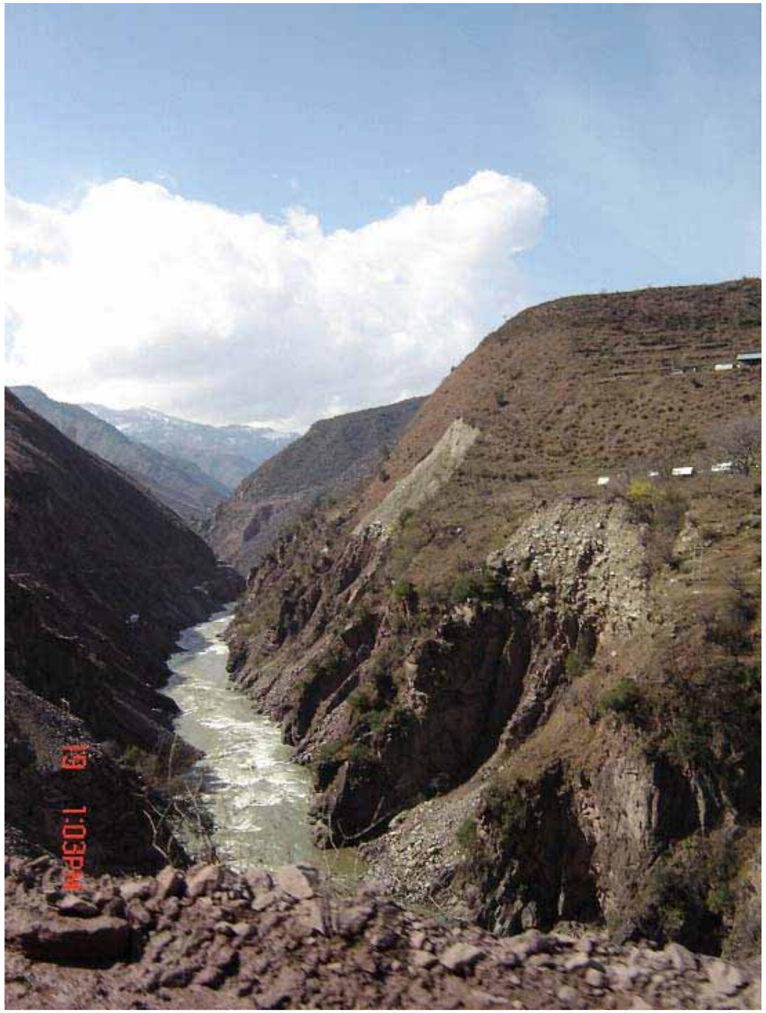
The number of deaths and the age-wise break-up is as follows:

VILLAGE	DEATH CASES	AGE GROUP						
Cluster I		upto 10 years	11-20	21-30	31-40	41-50	51--60	>61
SULTAN DAKI	46	18	8	4	4	5	5	2
BASGRAN	22	8	6	4	1	1	2	0
SHAHDRA*								
CHAPPAR	10	6	1	0	0	1	1	1
DHULANJA	16	8	2	1	0	3	2	0
JABRA KINARI*	10							
Cluster II								
ISHAM*	28							
URUSA*								
GWALTA	67	27	7	13	5	4	5	6
CHAKRA	10	8	0	2	0	0	0	0
DARDKOT	31	17	5	2	1	3	2	0
NAWARUNDAN	25	6	8	2	8	0	0	1
Cluster III								
GOHALAN	26	12	5	3	5	0	1	0
JABLA	18	9	3	0	1	1	2	2
SANGRIAN*								
Other Villages								
DACHI	4	2	1	1	0	0	0	0
KAMALKOTE	86	49	9	9	10	5	0	3
URI	18	4	4	3	4	1	0	2
PARAM PILLAN	9	1	1	3	2	1	1	0
TOTAL	**501**	**207**	**74**	**61**	**46**	**28**	**27**	**18**

Source: baramulla.nic.in

* indicates lack of information

2.3 Photographic Features of the Area



(Left) – River Jhelum flowing quietly and cutting through the valley. On the immediate right is seen the landslips. On the immediate left is the National Highway running from Uri to Muzaffarabad.

(Right) – The snow capped peaks as seen from Nambla

(Right) A village resting over a moderately sloping terrace. Erosive activity at the edge of the terrace is a common phenomenon making edges vulnerable.

(Left) – This is a seasonal rivulet commonly known as Kalla Nallah originating from the Chamba peak (in the background) The fractured carbonaceous belt and is an expression of the MBT.

Massive folded sequence seen (a part of it got visible after the 2005 earthquake) immediately after the Red Bridge on the right banks of River Jhelum.

On the left bank of River Jhelum, the open profile clearly indicates the boulder bed or river bed material resting over soft strata and indicates unconformity.

The Village of Dhulanja resting on an almost flat ground surrounded by hills

A moderately sloping terrace extending towards the Jhelum. Small patches of agricultural plots are seen and exposed sequences seen on the other side of the river

Another exposure of the Main Boundary Thrust seen from the Uri-Muzzafarabad Road

The immediate area around the Paran Pillan Gurudwara with exposed purple shales.

A steeply dipping bedding planes close to the Red bridge.

CHAPTER 3.0

OBJECTIVES AND METHODOLOGY

This chapter outlines the objectives and overall methodology

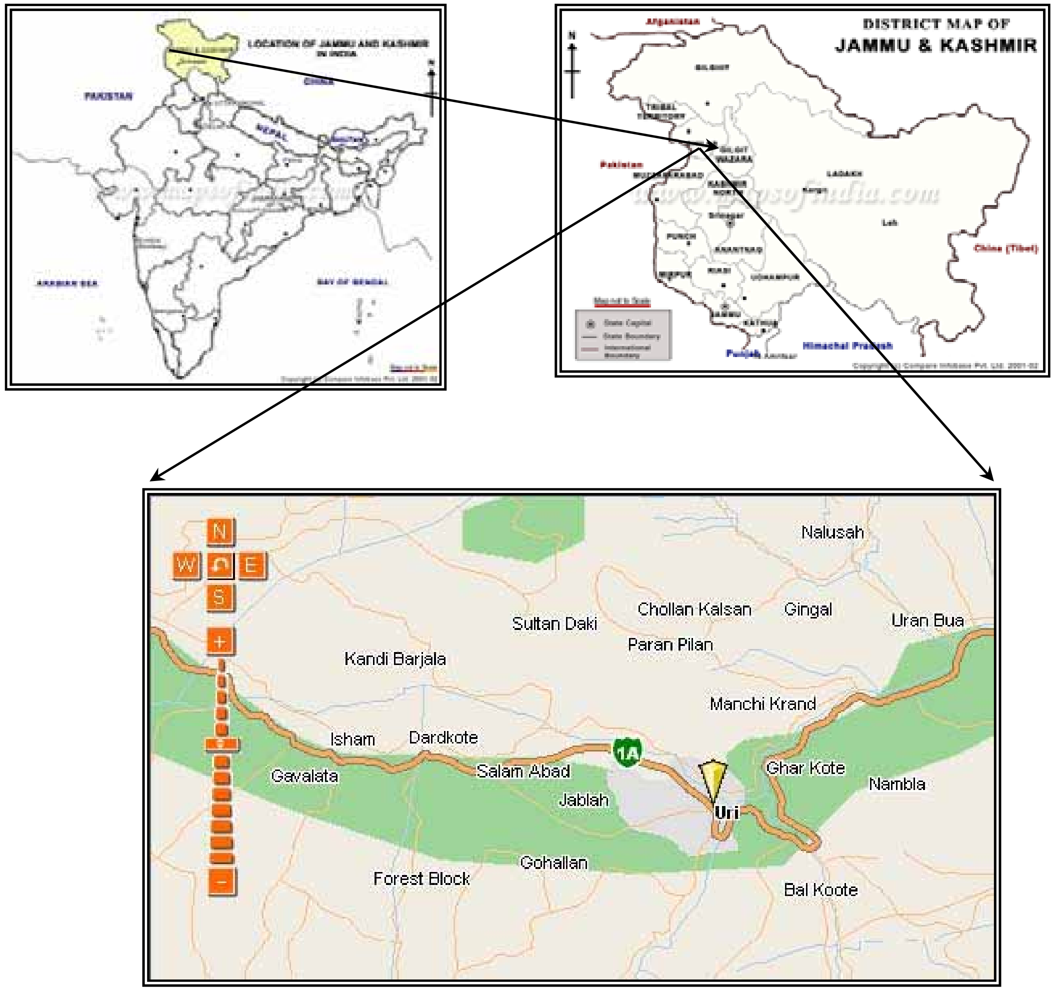
3.1 Objectives

Seismic Hazard Microzonation has evolved as a tool for risk mitigation planning which involves attributes of different nature and class. It is a process of modeling that involves incorporation of geologic, seismologic and geotechnical concerns into economically, sociologically and politically tenable land-use planning for mitigating earthquake effects. Such models should aid architects and engineers site their buildings and design structures that will be less susceptible to damage. Engineering approaches to earthquake resistant structural design will be successful to the extent that forces due to future shocks are accurately estimated at the location of a given structure. Dealing with events such as occurrences of earthquakes that are inherently unpredictable and involving complex near-surface interactions with built environment obviously calls for a significant level of field information and sophisticated .

Study Area

In terms of geographical co-ordinates the area of interest falls between 34° 01'45" N 73° 52'45" E and 34 ° 08'45" N 74° 07'45" E. While the focus villages are spread in a much lesser area a larger area is taken into consideration, as it is essential in order to understand the regional geological and seismotectonic conditions and correlating the micro and macro trends. Regional perspective is particularly very useful for demarcation of lineaments, such as of geological features like faults, joints, folds etc. Thus a region of approximately 300 sq km between the Panjal Thrust and Muree Thrust has been identified as the ideal tectonic segment for Seismic Hazard Microzonation.

LOCATION MAP



Methodology

Seismic hazard, in the context of engineering design, is generally defined as the predictive level of ground acceleration which would be exceeded with 10% probability at the site under consideration, in the next 50 years, due to the occurrence of an earthquake anywhere in the region. A lot of complex scientific perception and analytical modeling is involved in seismic hazard estimation. A computational scheme for discrete element analysis essentially involves delineation of seismic source zones and their characterization, selection of an appropriate ground motion attenuation relation and choosing a predictive model of seismic hazard. Some of the fundamental questions to be addressed in a practical hazard scenario assessment are:

- Which are the potential faults that are likely to generate future earthquakes and what would be the expected size?
- What type of ground shaking is expected at a specific site?
- How do buildings and other infrastructure situated on a rock surface or soil strata respond to the expected ground shaking?

An attempt is being made here to ensure satisfactory answers for the above stated questions in the context of Uri by preparing seismic hazard microzonation map using state-of-the-art probabilistic seismic hazard analysis (PSHA) methods which gives due consideration to the geological, seismological, geo-technical factors affecting the seismic vulnerability of the area under consideration. In addition to this space technology is being utilized through the use of satellite imageries to obtain various information important for the study. Multitask functionality of Geographic Information System (GIS) makes it ideally suited in seismic hazard microzonation as it enables automation of repetitive task and search procedure. This comes as a great relief in the manipulation of information and map generation. GIS is being utilized for the complex spatial analysis to undertake a discrete element analysis incorporating various parameters associated with the seismic hazard microzonation.

The following steps have been followed in order to prepare the seismic microzonation hazard map of Uri:

- **Preparation of Base Map and Digital Terrain Model (DTM) of Uri using Satellite data -** The satellite data acquired from NRSA, Hyderabad and RRSSC, Kharagpur led to image processing and creation of base map for Uri using IRS imageries[1] of LISS III and PAN sensor. The imageries from these two sensors are rectified to a common co-ordinate system and then merged together to achieve a spatial resolution of 5 m, which enables mapping of the area at 1:10,000 scale. In addition to this, Cartosat imageries (stereo-pairs) enabled refine digital terrain model of the area. Apart from this, the digital and visual interpretation of the satellite imageries resulted in the generation of various thematic layers such as drainage, soil class, rock outcrop, percentage slope and landslides.

- **Identification of lineaments/faults –** Potential Rupture Lineaments along which movements that can cause ground vibration at Uri have been identified following the Seismo-Tectonic Atlas of India published by Geological Survey of India (GSI) and traced in the field in specific traverse and the estimation of the maximum magnitude that a particular fault may be able to produce has been source from technical literature.

- **Identification of Epicenters of past earthquakes** - A catalogue of seismic event of $M_L > 3$ in the region were prepared from the historical data obtained mainly from Indian Meteorological Department (IMD) and other relevant sources. Aftershocks of large events have been omitted from this list.

- **Measurement of Peak Ground Acceleration (PGA), Site Response (SR), Predominant Frequency (PR) -** PGA at a site depends strongly on the magnitude of an event and the corresponding hypocentral distance. The pattern of decay of PGA with distance is a property depending upon the quality factor appropriate for the region. The current practice is to obtain

[1] *Classification of image products is generally based on the level of processing, output media/scale and area of coverage.*

the attenuation relation by empirical methods, based on instrumental data. For North India, several researchers have worked out such empirical relations.

- **Assessment of the Soil Conditions and Rock Outcrop of Uri -** It is well established from past damage surveys that structures built on rock behave differently from those founded on soft soil. It is documented that tall buildings with low natural frequencies are vulnerable for greater damage when founded on soft soil deposits.

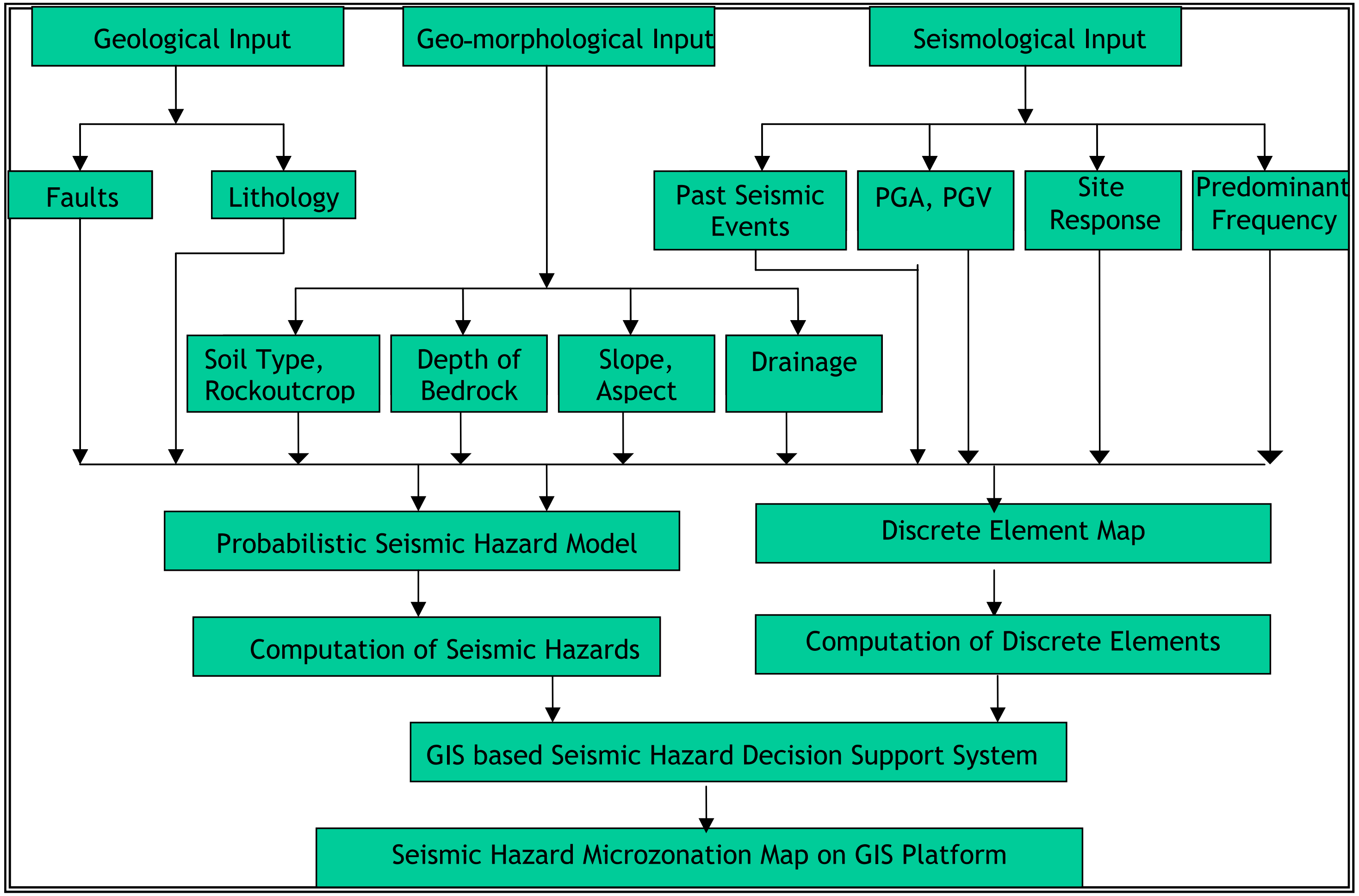
- **Assessment of Depth of Bedrock, which** is another key parameter in assessing the nature of amplification.

- **Creation of Discrete Elements –** Discrete elements are formed essentially from the imagery integration and picking regions of identical feature class.

- **Detailed Geo-technical of Suitable Sites** – Construction sites are small, of the order of few tens of meters, the local ground vibration transferred to the structure depends on the detailed vertical make-up of soil at the site and calls for intensive geotechnical investigations focusing on layering details, their shear failure, settlement analysis and other parameters. Given the constraints on land availability, geotechnical assessment provides for appropriate designing of foundations and reduce the vulnerability.

- **Creation of Seismic Hazard Microzonation maps using GIS as decision support system -** Based on the above steps the hazard maps are prepared. The geological and geomorphological attributes derived as mentioned above are united to form the basic site condition coverage of the region. The seismological themes are assigned normalized weights and feature ranks following a pair-wise comparison hierarchical approach and integrated to evolve seismic hazard maps.

Adopted Framework for Seismic Hazard Microzonation



CHAPTER 4.0

COLLATERAL INFORMATION LAYERS

This chapter presents relevant inputs into the hazard analysis through specific maps.

4.1 Collateral Information

Seismic Hazard microzonation calls for a variety of adjunct information apart from seismicity of the region. These are the causative or attenuative aspects that need to analysed and incorporated in the process of zonation.

4.2 Information Layers Developed

The following layers have been developed from primary field investigations, image interpretation and secondary sources and have been utilized in the process of evolving the final zonation maps;

1) LISS III FCC of 25 December 2006
2) Cartosat Image of November 07 2006
3) Aspect
4) Slope
5) Streams
6) Geology
7) Tectonics
8) Landslides
9) Normalised Difference Vegetation Index
10) Land Cover
11) Settlement Location
12) Peak Ground Acceleration
13) Peak Ground Velocity
14) Damage Intensity of October 8th Earthquake (MMI)

Aspect Map

Aspect is an important element; particularly in the hilly regions as the vegetation cover is controlled by factors of rain, slope, exposure to sun (N or S) etc.

Slope Map

Slope map is derived using the satellite imagery and the unit of measurement is in degrees. Slope is an important element for any settlement or site, the settlements located at steeply sloping terrains i.e. >45^0 could be more prone to denudation, instability depending upon the other surface and sub surface features and may involve engineering measures for site preparation. Largely the area is steeply sloping i.e. >45^0. Gwaltha, Gohalan are located on steeply sloping regions.

Streams Map

Streams are one of the important features and the region is drained by small to medium seasonal local streams. Several of the streams flow and drain into the main river system of Jhelum, which flows EW. The high sloping regions and the dendritic pattern suggests that the drainage follows the natural lines confined by the micro watersheds created as a result of natural factors like vegetation, slope breaks and aspect. The River Jhelum, the major river flows along a fault line.

Geology Map

The Geology of the region was first mapped extensively by D.N.Wadia and reported in his monumental work – The Syntaxis of the NW Himalayas: Its Rocks, Tectonics and Orogeny (1931). This has been the basis for the current GSI maps. A large part of the area is underlain by the Muree group, which stretches across into Pakistan. The MBT running though the region brings the Murees in juxtaposition with Precambrian Gneisses & Granites and the Salkhala series. Overlying this is the unfossiliferous Paleozoic formation of Dogra Slates, which is in turn overlain by the Permo-traissic.

Local Tectonics Map

The local tectonics is a result of the available information from available sources, field visits and those, which are inferred from the images, procured for the region. The area is also engulfed between the two major thrusts, which are commonly known as Main Boundary Thrust, and the Pir Panjal Thrust. These thrust cuts across the River Jhelum and for a short distance run parallel to the river. The local fractures are also marked on the map to indicate direction, extent and settlement locations.

Landslides Map

The earthquake also triggered several of the small landslides due to the cosiesmic activity in the region. Some of the landslides are marked using the image interpretation tools as well as through the field surveys. The large area indicated in the map falls in the region of lagama where the thrust also passes through and is a slip zone.

Normalised Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index is a model for converting satellite-based measurements into surface vegetation types. The NDVI uses a complex ratio of reflectance in the red and near-infrared portions of the spectrum to accomplish this. Reflectance in the red region decreases with increasing chlorophyll content of the plant canopy, while reflectance in the infrared increases with increasing wet plant biomass. It has been defined in three classes – Low Vegetation/Shadow, Medium Vegetation and Dense Vegetation in the map. The SW and NW regions have zones of medium to dense vegetations and these regions are also high altitude regions and very less human interference is present.

Land Cover Map

Land cover map largely depicts and marks the derived land classes and it is not the exact land utilization pattern. The settlements are marked in red colour, the approximate regions are marked using the images. The image returns colour codes for a particular land like scrub, agriculture, barren. Most of the degraded vegetation, scrub land, barren land is noticed in the near vicinity of the settlements.

Peak Ground Acceleration (PGA)

Peak ground acceleration is measurement of earthquake acceleration. It is measures as percent of 'g' or acceleration due to gravity. The normal acceleration of gravity is 980 cm/s^2 is the rate at which an object falls when dropped from being at rest in a vacuum. It is quite a high rate of acceleration. It is approximately the same as a car traveling 100 meters from rest in just 4.5 seconds. Higher the value of peak ground acceleration indicates the shaking intensity of earth in given geographic regions. The similar values for a region are picked and are joined to form contours of such values. However, the mean and peak ground accelerations do have much to do with the intensity of damage a building may have to withstand. Consequently, engineers and designers rely a great deal on the measure of the peak ground acceleration to determine how strong an earthquake force a new building may have to withstand. The PGA values in the map are of the October, 2005 Earthquake.

[The acceleration due to gravity is 980 cm/sec/sec, so an acceleration of 10 feet/sec/sec is about 305/980 = 0.31 g. Expressed as a percent, 0.31 g is 31 % g.]

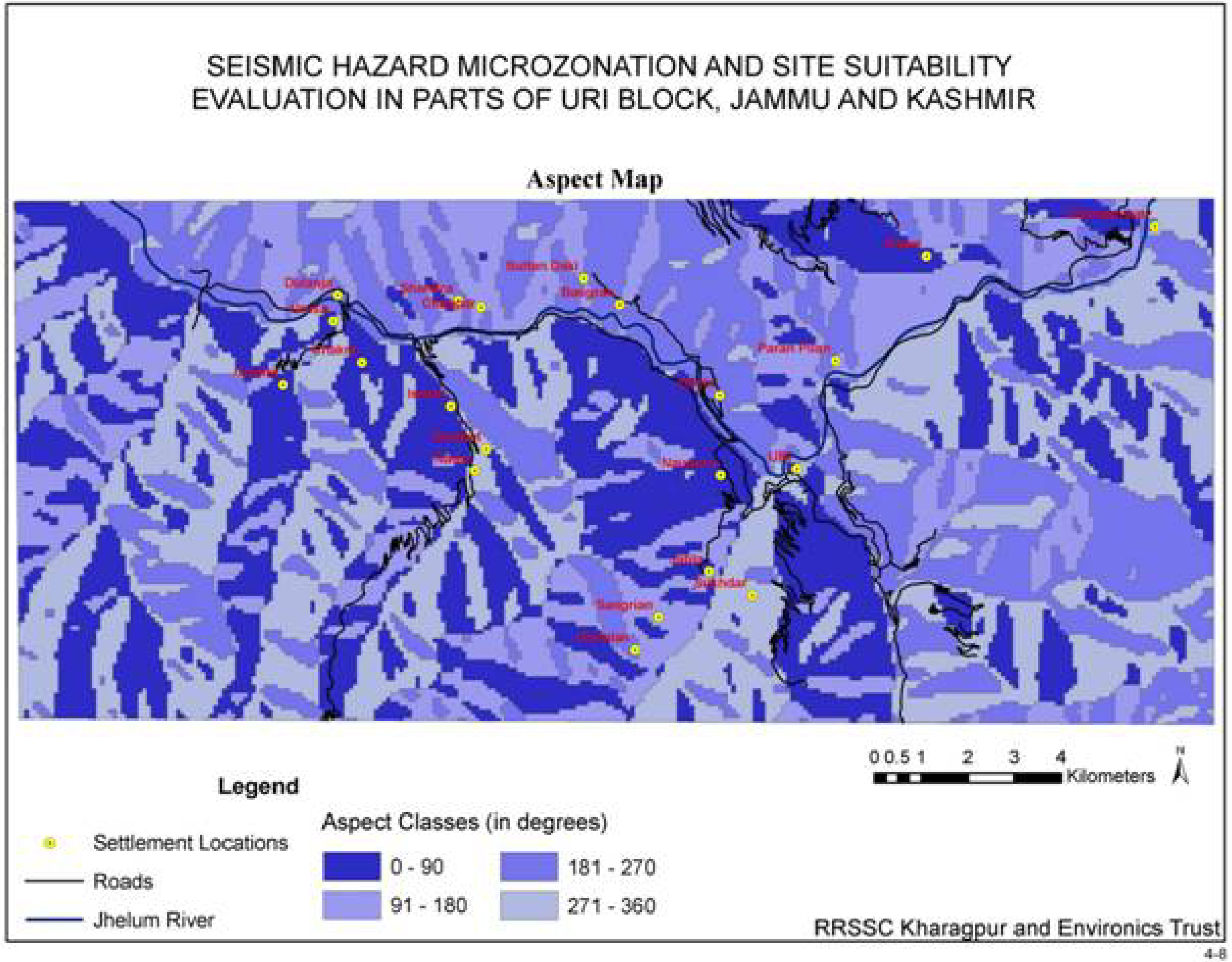
Peak Ground Velocity (PGV)

Peak ground velocity measures how fast the shaking has happened during the October 2005 event. The units are measured in cm/s. One can notice that the values decrease moving from west towards east from the epicentral region near Muzzafarabad.

Modified Mercalli's Intensity (MMI)

Modified Mercalli's Intensity index is ranked on a scale of 1 to 12, 1 indicating the lowest intensity and 12 is the maximum. The current MMI has been adapted from the available data from the USGS. The values of MMI are generated and interpreted relative to the epicentral distances. The map suggests that the region falls in the scale range of 7 - 9.4. The following intensity scale has been described as below:

I. Instrumental	Not felt except by a very few under especially favorable conditions.
II. Feeble	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III. Slight	Felt quite noticeably by persons indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV. Moderate	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. Dishes and windows rattle.
V. Rather Strong	Felt by nearly everyone; many awakened. Some dishes and windows broken. Unstable objects overturned. Clocks may stop.
VI. Strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
VII. Very Strong	Difficult to stand; furniture broken; damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII. Destructive	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.
IX. Ruinous	General panic; damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Disastrous	Some well built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent.
XI. Very Disastrous	Few, if any masonry structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Catastrophic	Total damage - Almost everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move.


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Aspect Map
Uri
0 0.5 1 2 3 4
Kilometers
N
Legend
Settlement Locations
Roads
Jhelum River
Aspect Classes (in degrees)
0 - 90
91 - 180
181 - 270
271 - 360
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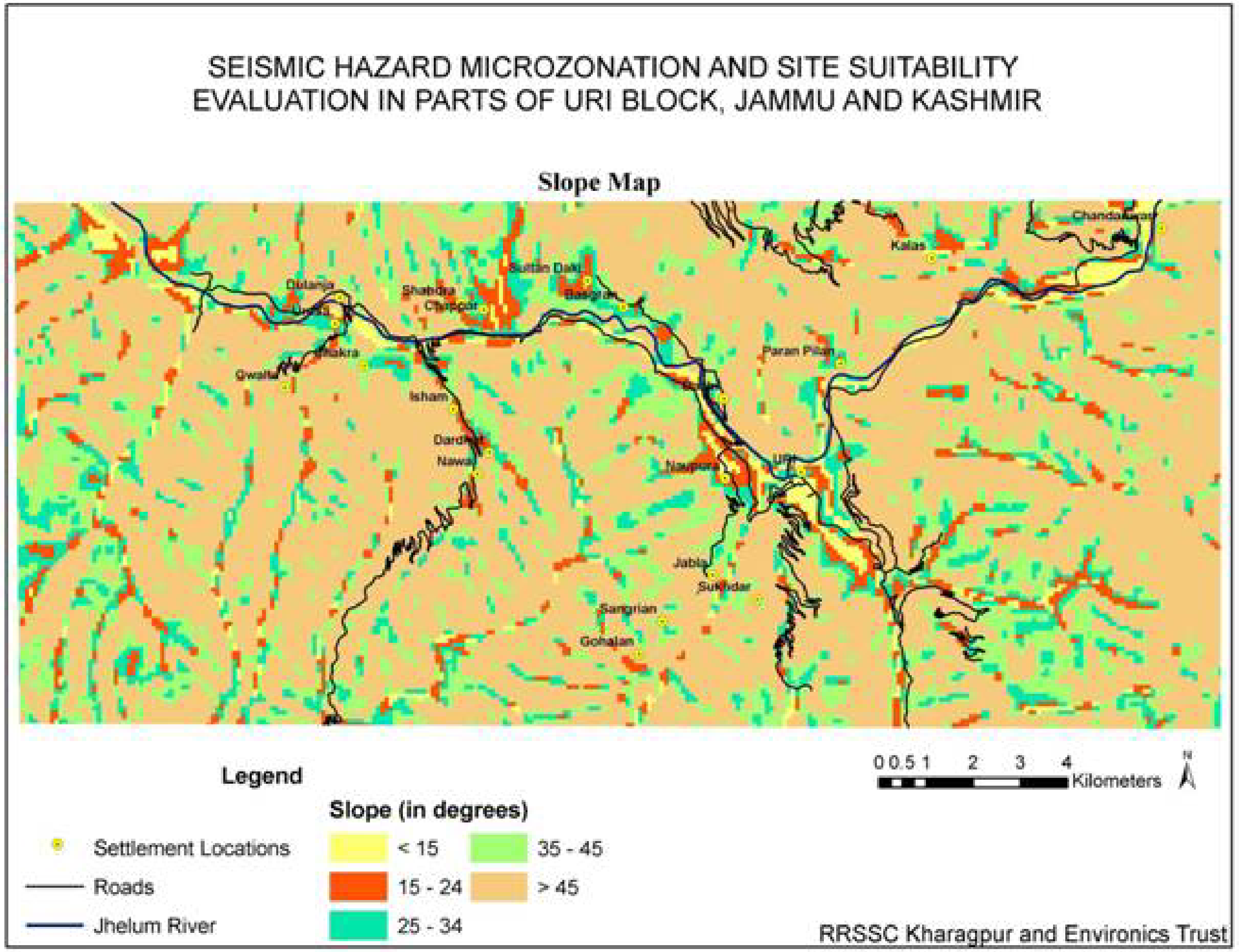
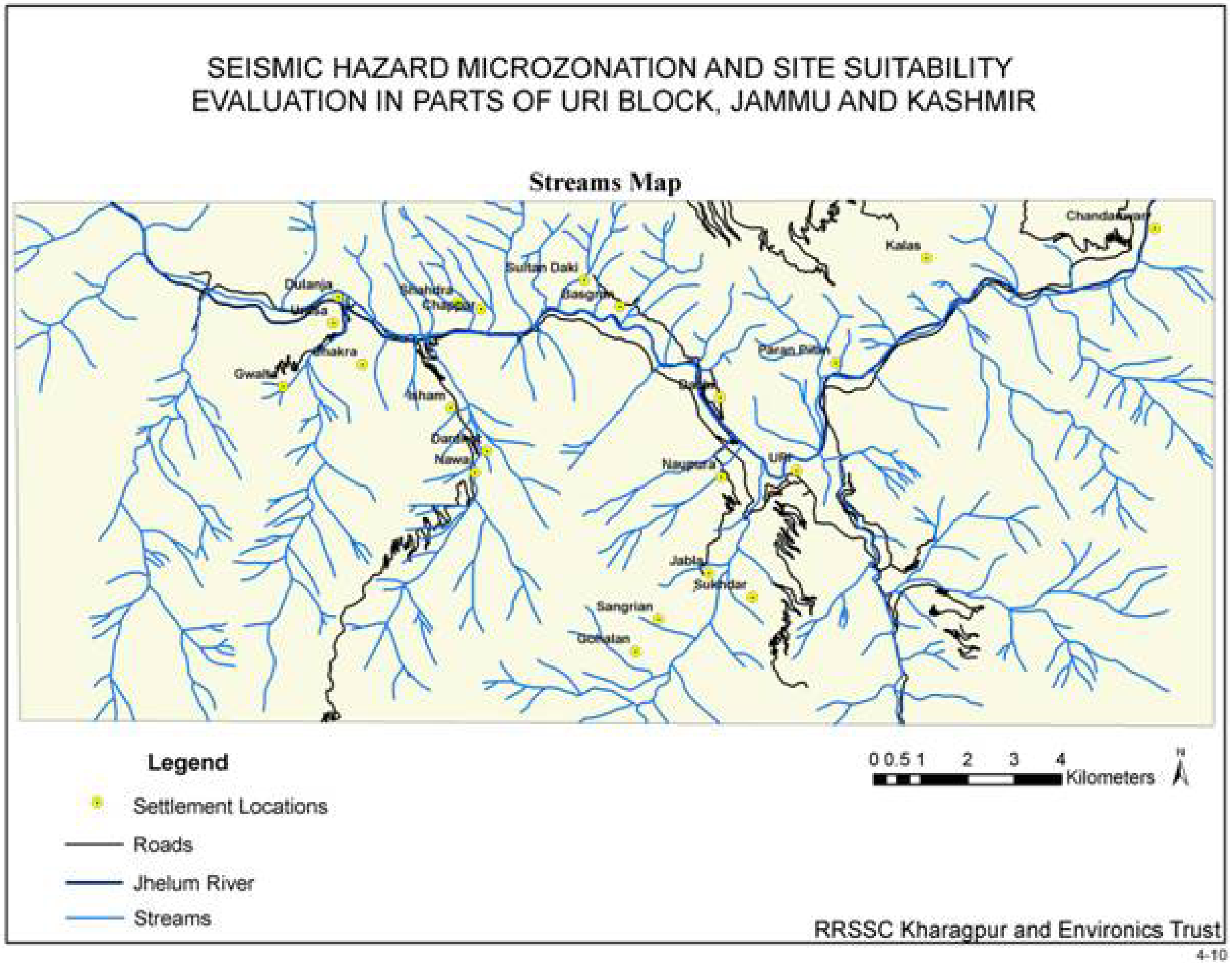
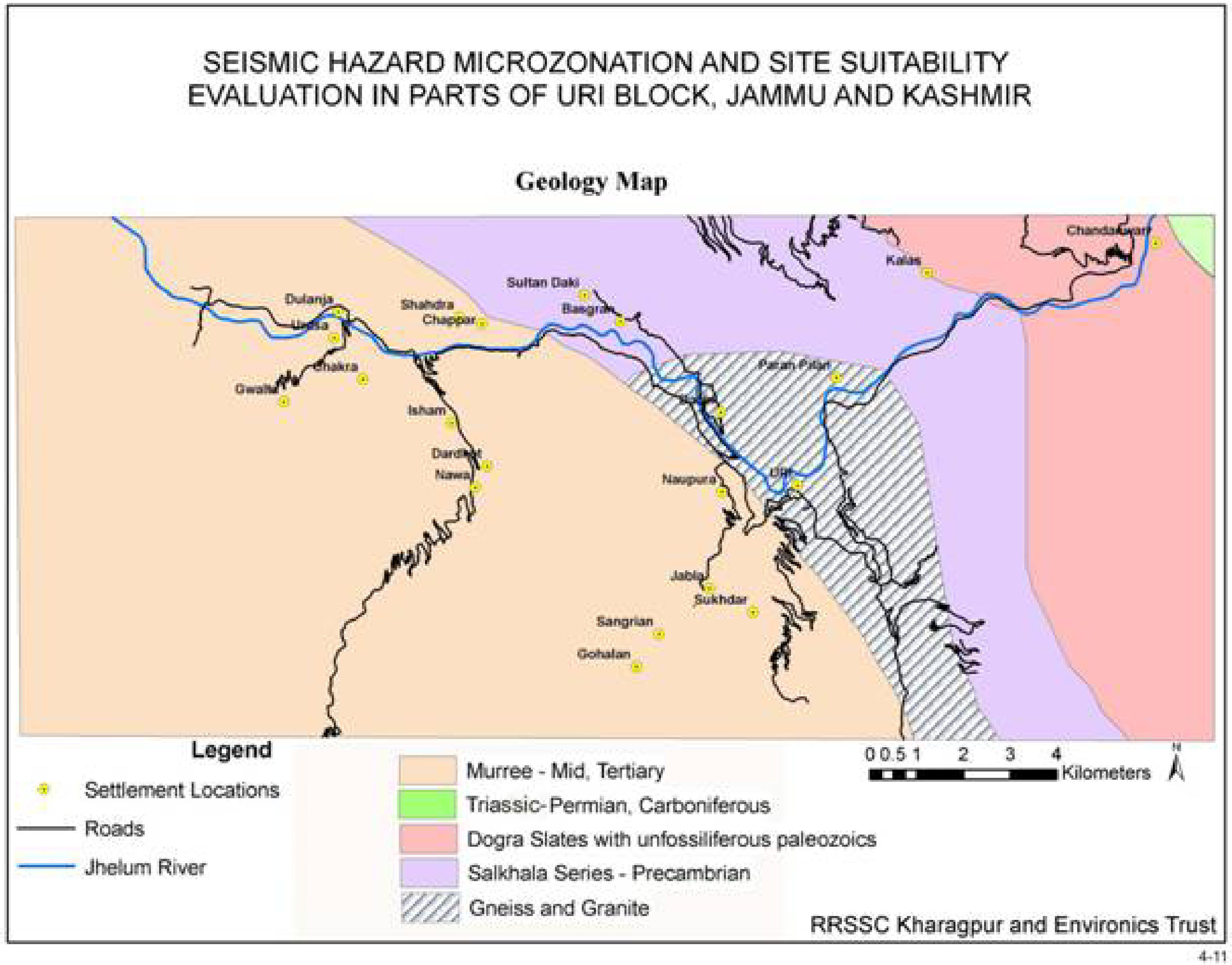
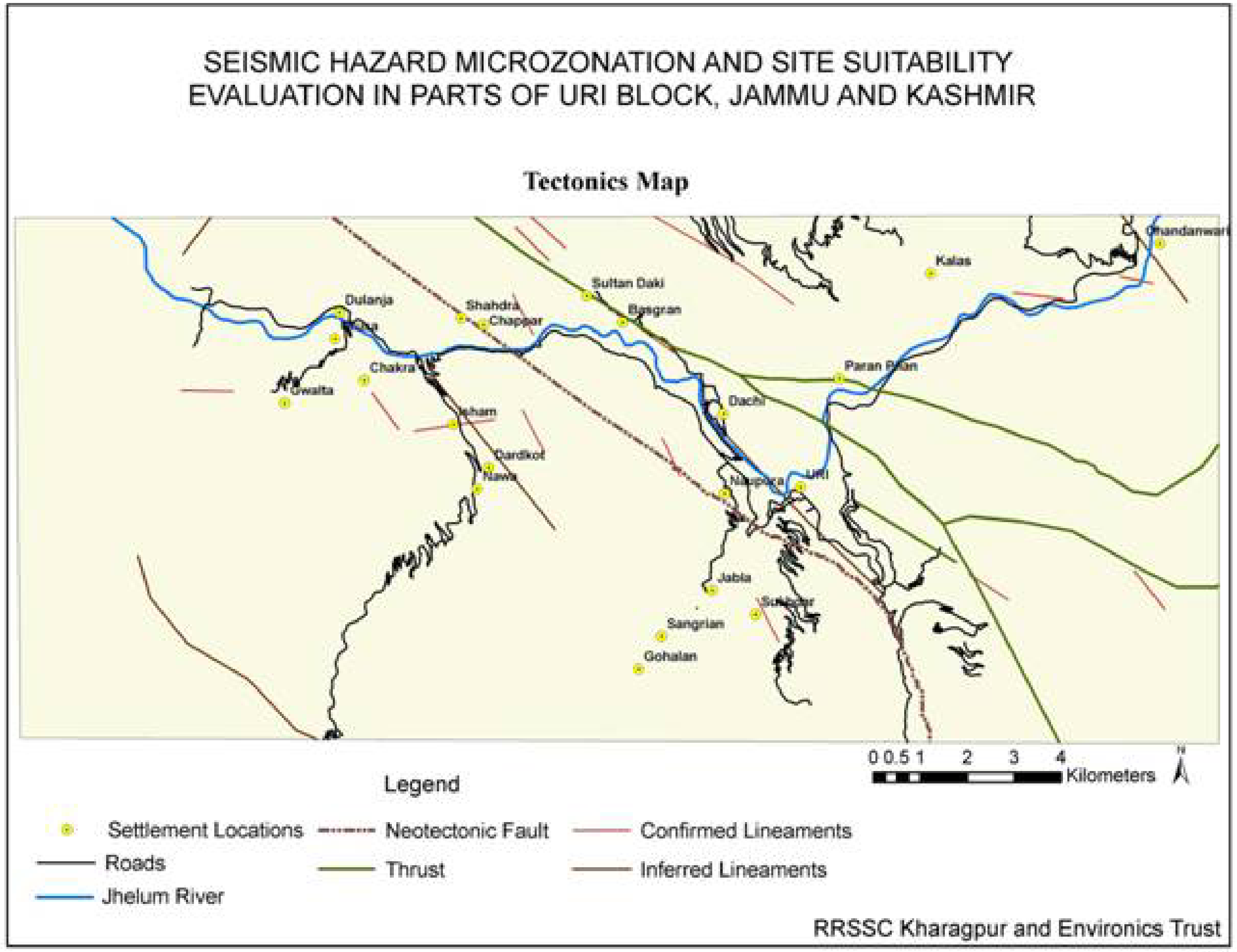
4-8


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Slope Map
Dulanja
Shahdra
Chapoor
Sultan Dakl
Basgran
Kalas
Paran Pilan
Qwalta
Isham
Dardkot
Nawa
Naupora
Uri
Jabla
Sukhdar
Sangrian
Gohalan
0 0.5 1 2 3 4
Kilometers
N
Legend
Settlement Locations
Roads
Jhelum River
Slope (in degrees)
< 15
15 - 24
25 - 34
35 - 45
> 45
RRSSC Kharagpur and Environics Trust

4-9


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Streams Map
Dulanja
Gwalta
Chakra
Sultan Daki
Basgran
Kalas
Paran Pilan
Nawa
Nayapura
URI
Jabla
Sukhdar
Sangrian
Legend
Settlement Locations
Roads
Jhelum River
Streams
0 0.5 1 2 3 4
Kilometers
N
RRSSC Kharagpur and Environics Trust
4-10


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Geology Map
Sultan Daki
Shahdra
Chappar
Dulanja
Chakra
Isham
Nawa
Naupura
Patan Palan
Kalas
Jabla
Sukhdar
Sangrian
Gohalan
Legend
Settlement Locations
Roads
Jhelum River
Murree - Mid, Tertiary
Triassic-Permian, Carboniferous
Dogra Slates with unfossiliferous paleozoics
Salkhala Series - Precambrian
Gneiss and Granite
0 0.5 1 2 3 4
Kilometers
RRSSC Kharagpur and Environics Trust
4-11


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Tectonics Map
Dulanja
Gwalta
Chakra
Shahdra
Sultan Daki
Basgran
Kalas
Paran Pilan
Dachi
Dardkot
Nawa
Uri
Jabla
Sangrian
Gohalan
0 0.5 1 2 3 4
Kilometers
N
Legend
Settlement Locations
Roads
Jhelum River
Neotectonic Fault
Thrust
Confirmed Lineaments
Inferred Lineaments
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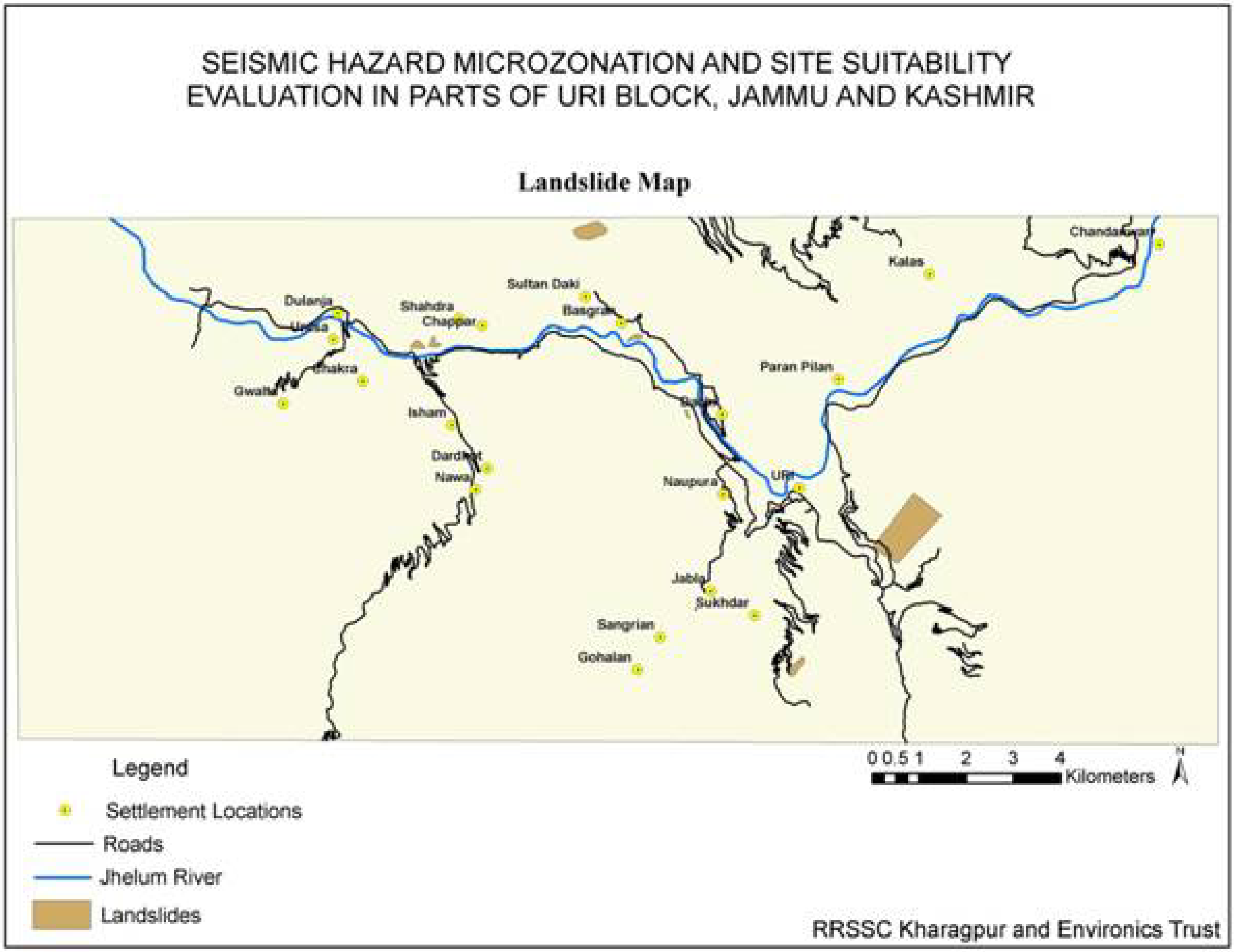
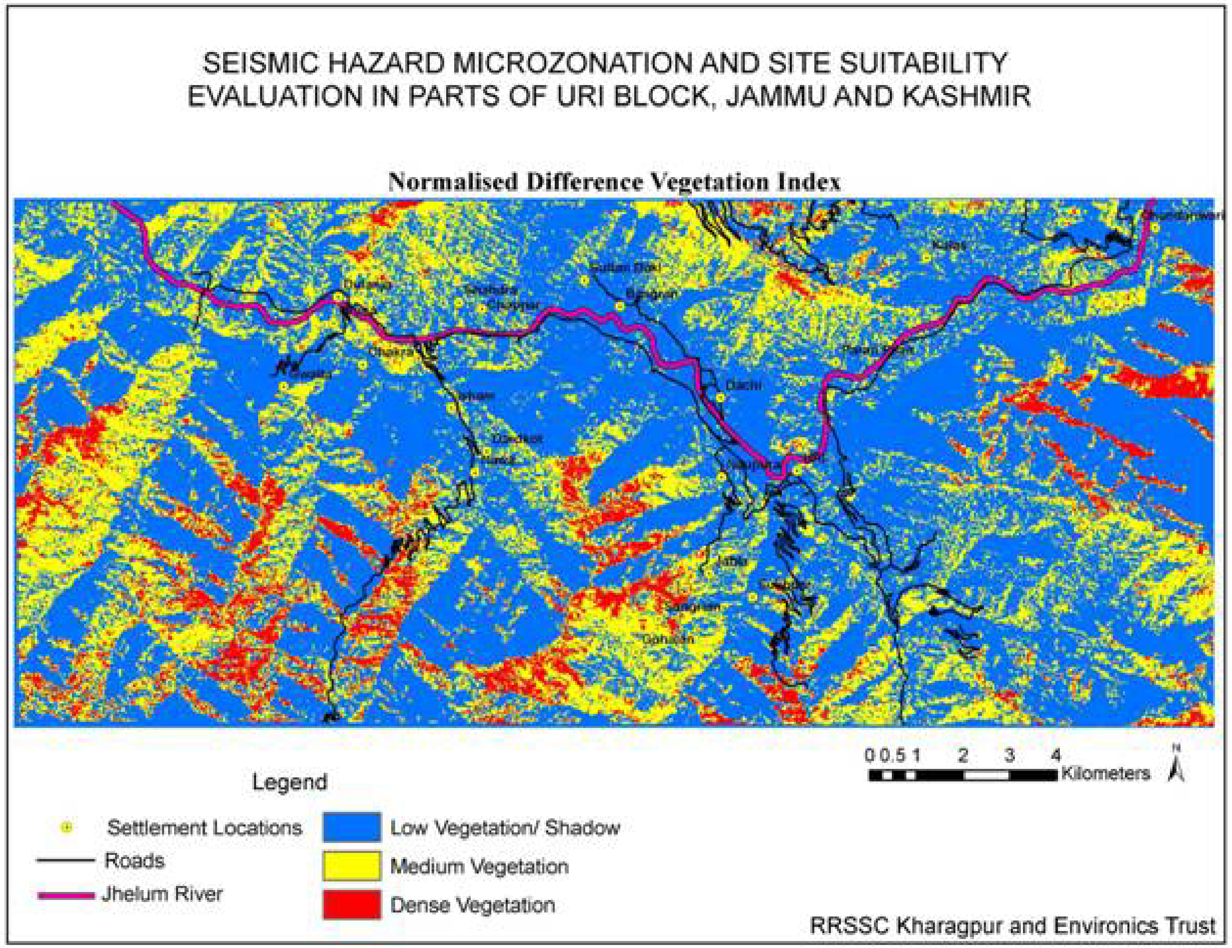
4-12


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Landslide Map
Chandanwari
Kalas
Sultan Daki
Basgran
Dulanja
Shahdra
Chappar
Paran Pilan
Gwalta
Isham
Naupura
Uri
Nawa
Jabla
Sukhdar
Sangrian
Gohalan
0 0.5 1 2 3 4
Kilometers
N
Legend
Settlement Locations
Roads
Jhelum River
Landslides
RRSSC Kharagpur and Environics Trust

4-13


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Normalised Difference Vegetation Index
Dachi
0 0.5 1 2 3 4
Kilometers
N
Legend
Settlement Locations
Roads
Jhelum River
Low Vegetation/ Shadow
Medium Vegetation
Dense Vegetation
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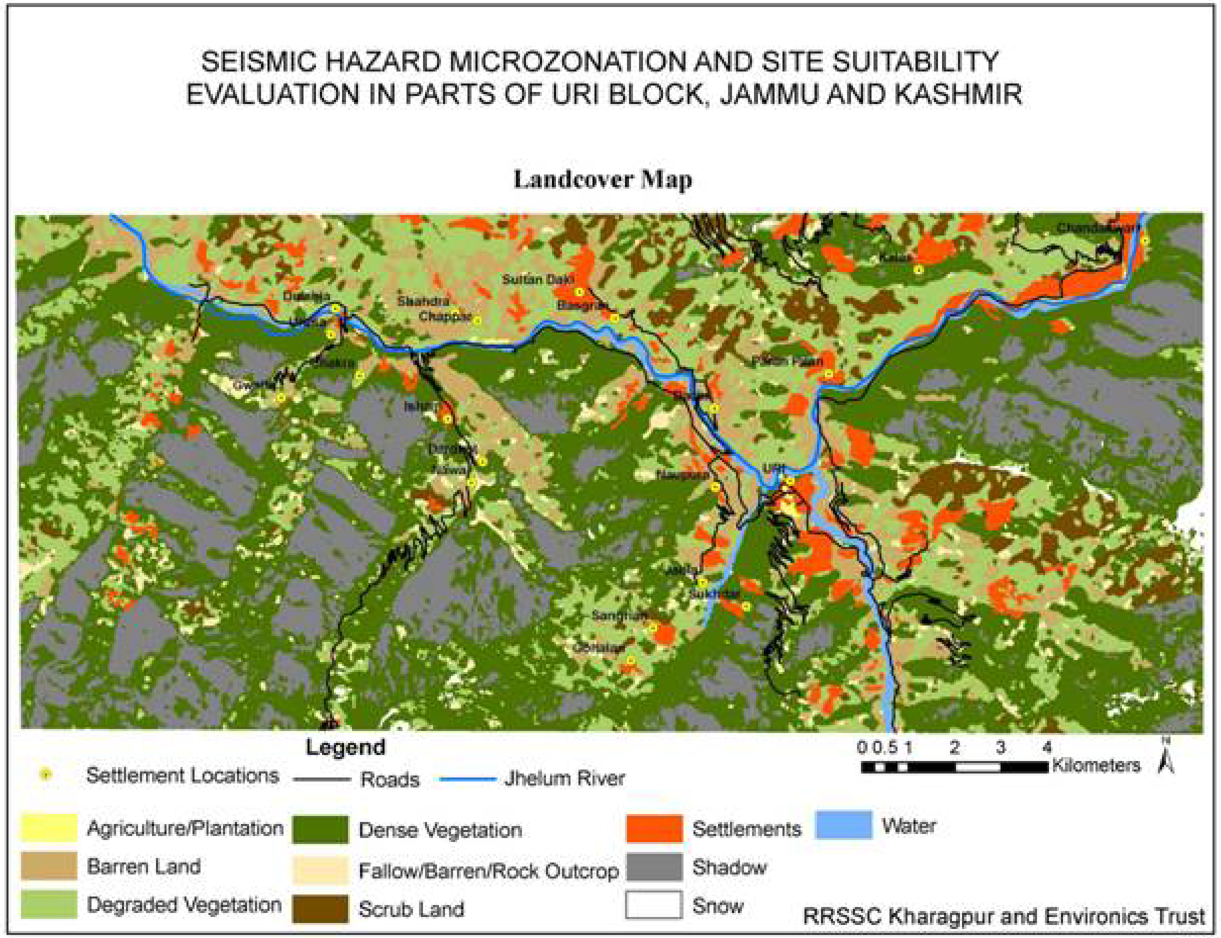
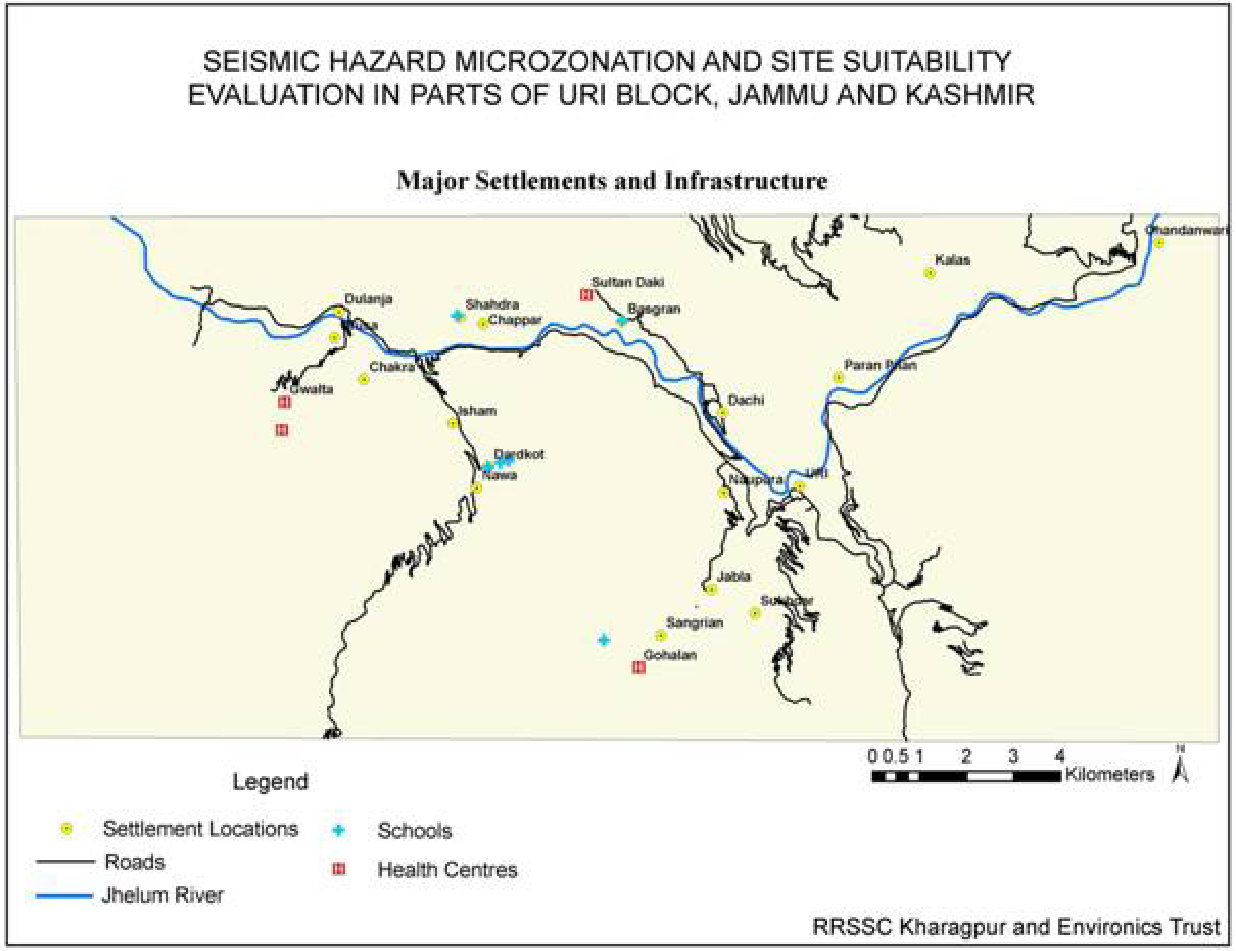
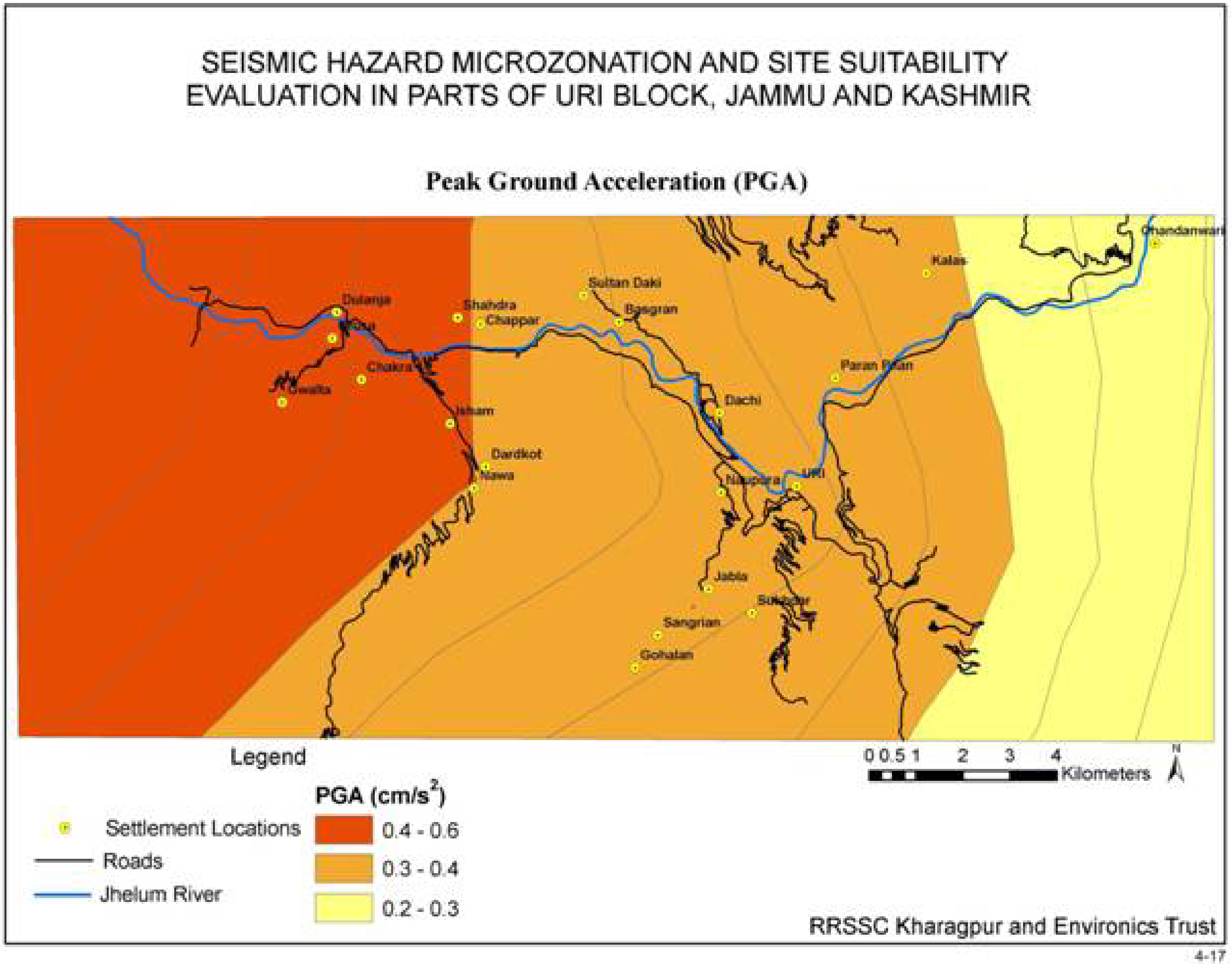
4-14


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Landcover Map
Sultan Daki
Legend
Settlement Locations
Roads
Jhelum River
Agriculture/Plantation
Barren Land
Degraded Vegetation
Dense Vegetation
Fallow/Barren/Rock Outcrop
Scrub Land
Settlements
Shadow
Snow
Water
0 0.5 1 2 3 4
Kilometers
RRSSC Kharagpur and Environics Trust
4-15


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Major Settlements and Infrastructure
Dulanja
Shahdra
Chappar
Sultan Daki
Chakra
Gwalta
Isham
Nawa
Dachi
Kalas
Paran
Uri
Jabla
Sangrian
Gohalan
Chandanwari
0 0.5 1 2 3 4
Kilometers
N
Legend
Settlement Locations
Roads
Jhelum River
Schools
Health Centres
RRSSC Kharagpur and Environics Trust

4-16


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Peak Ground Acceleration (PGA)
Chandanwari
Kalas
Sultan Daki
Basgran
Dulanja
Shahdra
Chappar
Chakra
Gwalta
Isham
Dardkot
Nawa
Dachi
Paran Pilan
Uri
Jabla
Sangrian
Gohalan
Legend
Settlement Locations
Roads
Jhelum River
PGA (cm/s²)
0.4 - 0.6
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0.2 - 0.3
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Kilometers
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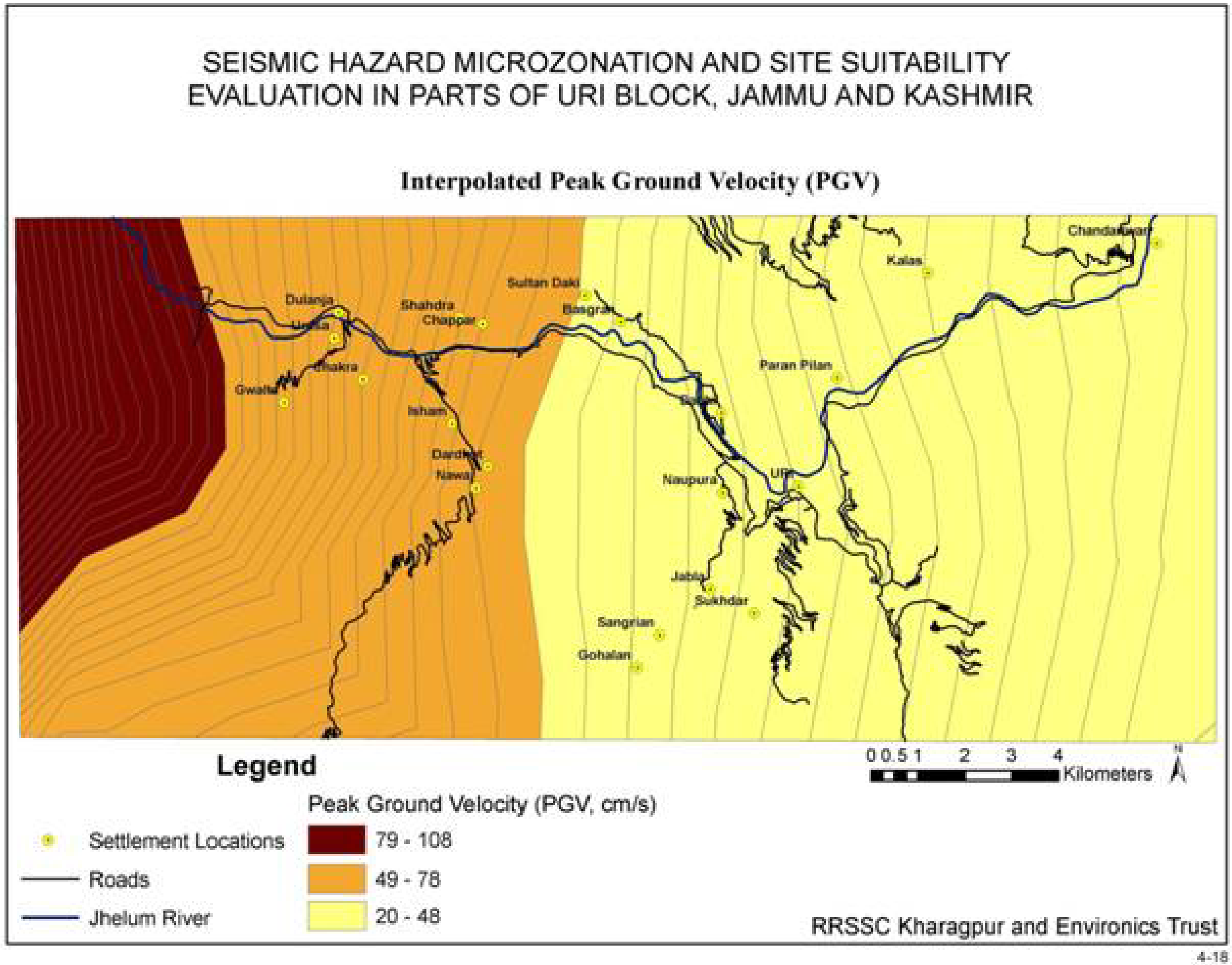
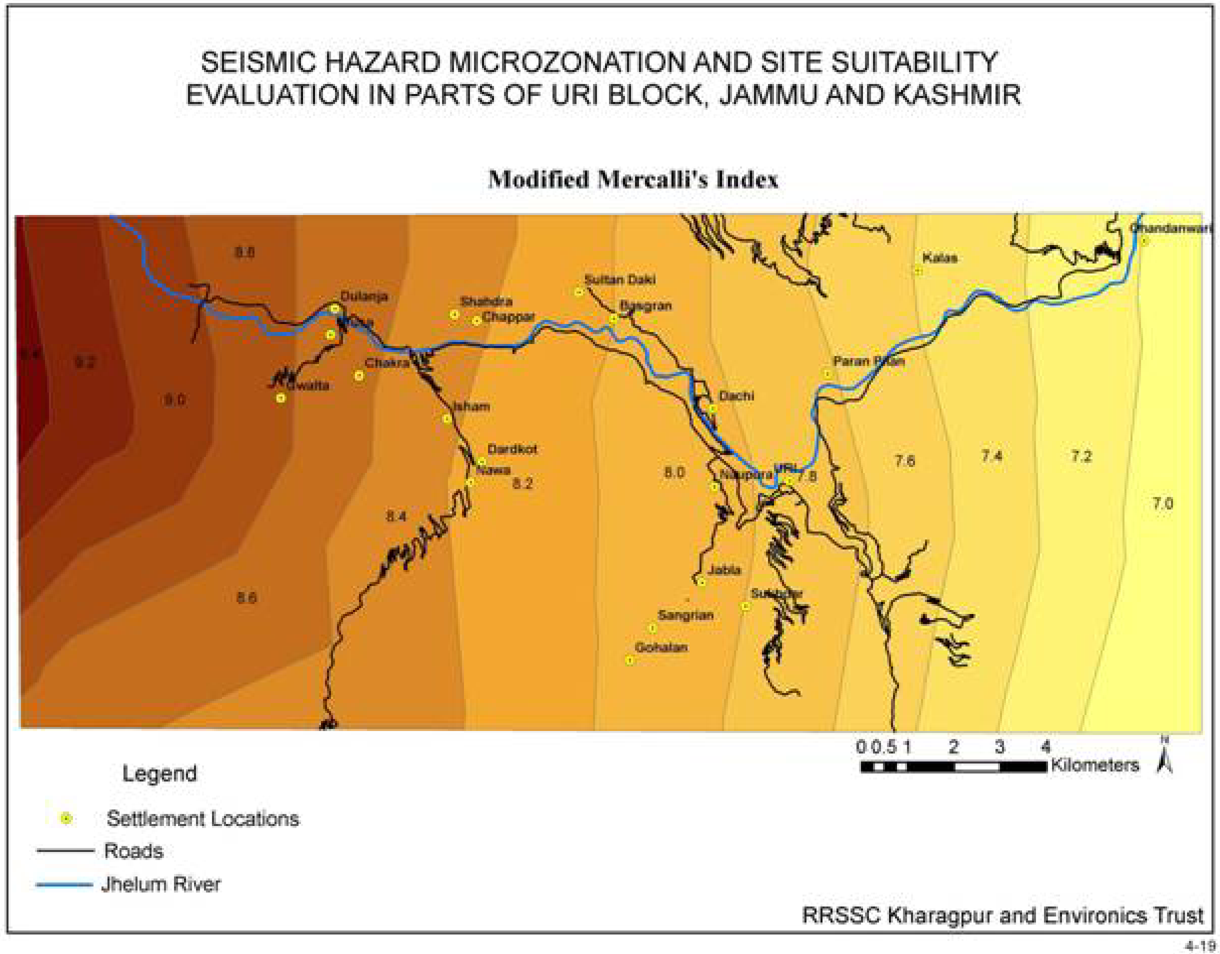
RRSSC Kharagpur and Environics Trust
4-17


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Interpolated Peak Ground Velocity (PGV)
Chandanwari
Kalas
Sultan Dakl
Basgran
Dulanja
Shahdra
Chappar
Paran Pilan
Chakra
Gwalta
Isham
Dardkot
Nawaj
Naupura
URI
Jabla
Sukhdar
Sangrian
Gohalan
Legend
Peak Ground Velocity (PGV, cm/s)
Settlement Locations
Roads
Jhelum River
79 - 108
49 - 78
20 - 48
0 0.5 1 2 3 4
Kilometers
RRSSC Kharagpur and Environics Trust
4-18


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Modified Mercalli's Index
8.8
9.2
9.0
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
Dulanja
Gwalta
Chakra
Shahdra
Chappar
Isham
Dardkot
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Sultan Daki
Dachi
Jabla
Sangrian
Gohalan
Paran
Kalas
URI
Chandanwari
0 0.5 1 2 3 4
Kilometers
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Legend
Settlement Locations
Roads
Jhelum River
RRSSC Kharagpur and Environics Trust
4-19

CHAPTER 5.0

PROBABILISTIC SEISMIC HAZARD ANALYSIS

This chapter highlights the seismotectonic set-up and evolves a probabilistic model for earthquake recurrence.

5.1 Regional Tectonic Framework

The Main Boundary Fault passes through the region and is recognized to be an active fault with recent movements. The MBT is not a single thrust plane and the configuration is produced on the surface by an overlapping of thrust sheets. Some faults that are transverse and sub-parallel to the Himalayan trends are observed to be associated with neotectonic activity. The N-S trending Jhelum fault among these is most extensively present. It is a left lateral wrench fault, which separated Peshawar Basin from the Kashmir Basin (GSI, 2000). Towards south of this fault, the Mangla fault crosses it with right lateral wrench movement along the fault. The Tarbela fault, located within the Peshawar Basin is sub-parallel to the Jhelum fault. Another alike fault is Shinkiari Fault developed along the eastern margin of the Peshawar Basin. These faults cut across the alluvium and exhibit dislocation of strata and streams. The Attock fault sub parallel to the Himalayan trend also displays neotectonic activity. The Salt Range Thrust (SRT) marks the thin skinned thrusting localised within the Salt Range formation that underlies the Potwar Plateau and extends eastward into the Jhelum re-entrant. The Salt Range is considered to be an up thrown block of a low angle thrust fault and forms a decollement structure. The Reasi Thrust is the western extension of the Jwalamukhi Thrust.

One of the major seismogenic sources in the region, Main Central Thrust (MCT) located south of Indus suture zone is terminated against the Kishtwar fault towards the east. The MCT is considered as one of the most important tectonic surfaces throughout the entire Himalaya almost up to the eastern syntaxis. MCT forms the northern boundary of the Lesser Himalayan belt, which, is separated from the Frontal Belt by the Main Boundary Thrust (MBT).

North of the project area, the Main Mantle Thrust, Indus Suture Zone and Shyok Suture are the prominent tectonic features. Main Central Thrust is exposed in the far eastern side, which is terminated against the Kishtwar Fault. Other prominent tectonic features of the region are Jhelum and Kishtwar faults, Reasi and Salt Range Thrusts. The crystalline terrains of the western Himalaya have complicated tectonic history and the major belts of the region are demarcated by major thrusts. The Main Mantle Thrust (MMT) separates the Kohistan arc from Peshawar and Kashmir basins of the Indian Plate whereas the Main Karakoram Thrust separates the Hindukush-Karakoram belt from the island arc of Kohistan. The most spectacular structural feature of the western Himalayan orogen is the Syntaxis. This syntaxial bend is reflected by the Jhelum re-entrant, which is flanked on either side by the Kashmir and Peshwar basins.

The south-eastward extension of the Karakoram Fault is the northernmost prominent tectonic feature present in the northeastern part of the study area and has affected the region with a huge dextral offset. Three splays curving westward through the central Pamir; the Tangkul, Murghab and Karasu faults accommodate the movement in the central part of the Karakoram Fault (Searle, 1996). This fault controls the alignment of Siachen glacier and the Nubra-Shyok valley. The Shyok Suture Zone with a NW-SE trend represents an oceanic suture (Gansser, 1977) or a relic of back-arc basin (Sharma, 1991). This suture zone is located north of project site and show huge displacement affected by the strike slip movement of the rock masses of the region along the Karakoram fault. The tectonic evolution of this suture zone is believed to have resulted from collision of the Kohistan island arc with Asian margin. The Kohistan and Asian plate rocks are separated by a series of brittle faults called the Main Karakoram Fault. The sedimentary, volcanic and plutonic rocks of the Shyok suture zone are intensely deformed and occur as tectonic slices between the

Ladakh and Karakoram batholiths. The major tectonic slices of this suture zone are, Khardung Formation; Hundri Formation; Shyok Volcanics; Saltoro Molasse, Shyok Ophiolitic Melange and Tirit Granitoids.

The Main Mantle Thrust (MMT) marks the collision of the Asian plate and Kohistan which began with initial tectonic thickening and high pressure, high temperature metamorphism, followed by post metamorphic southward-directed thrusting as rocks of the Asian plate were thrust over Kohistan. The MMT is represented by thick zone of highly disrupted mélange along with abundant mylonite affected by set of brittle normal faults (Chamberlain and Zeitler, 1996). The geology of the northern margin of the Indian plate is remarkably uniform along hundreds of kilometer of the MMT. The rocks in the Indian plate consist of low to high-grade calcareous schists, minor marbles and amphibolites, and basement gneisses affected by thrusting. Whereas, the Indus Suture Zone (ISZ) marks the boundary between the Indian and Tibetan plates and south of this, litho-units of the main Himalayan belt are exposed. This zone is represented by the obducted materials of the Neotethyan oceanic crust together with deep marine Triassic to Eocene sediments. The Ophiolite Melange Zone consisting of ultramafic rocks is exposed as a discontinuous linear belt along ISZ in Ladakh. This zone is overthrusted by the south dipping Lamayuru Complex deposited on the leading passive edge of the Indian subcontinent (Upadhyay and Sinha, 1998). Other important geological units are Nindan Formation, Dras Volcanics, Indus Formation, Kargil Formation, Ladakh Batholith and Spongtang Klippe in Sanskar.

5.2 Regional Geology

The basement is constituted of Precambrian high-grade metamorphic and plutonic rocks including granites and migmatites that belong to Central Crystalline, is overlain by the Tethyan sedimentary rocks with a tectonic contact. The Tethyan sequence comprises over 10 km thick sedimentary rocks whereas, the crystalline rocks consist of a 5 to 40 km thick metamorphic sequence, composed mainly of deformed amphibolite to lower granulite facies para-gneiss and minor granitic gneiss (Upadhyay, 2002).

Further, this Higher Himalayan Crystalline forms an orogenic wedge, bounded by the MCT at its base and by the extensional structures of the south Tibetan Detachment system at the top (Hodges, et al., 1992). The Tso-Morari Crystalline Complex is a well-known feature in the Higher Himalayan Crystalline, which, is tectonically uplifted basement rocks of Precambrian age (Virdi, et al., 1978, Thakur, 1992). The doubly plunging anticlinal fold of this represents a domal upwarp of the basement.

The region is occupied by the high mountain range called the Pir Panjal range in the North of MBT. This range is composed of highly compressed and altered rocks of various ages forming high mountains. North of this a saucer shaped valley with a length of 135 km and width of 40 km is the Valley of Kashmir and is bounded by the Laddakh Himalayas towards north. In this region the rock units as well as structural features trend in arcuate fashion with southwestward concavity and in the intervening areas the concavity is in the opposite direction. According to Krishna Rao and Rao (1979) the three prominent tectonic units recognizable in this area are: (i) the broad Autochthonous Zone, exposing chiefly the Neogene sediments with local inliers of Eocene and Pre-Tertiary limestone with a series of prominent anticlines and synclines and a number of strike faults; (ii) the narrow parautochthon zone, between the Murree and Panjal thrusts, consists of upper Carboniferous-Permian sediments, volcanics and the Eocene outliers; and (iii) the allochthonous zone, thrust over the parautochthon, consists of rocks of Salkhala/Dogra units with granitised portions within folded synclines of Paleozoic, Mesozoic and Triassic sediments.

Among the two concurrent thrusts on the southern part of the Himalayas which delimits the autochthonous belt (Wadia, 1966) the Panjal Thrust is considered most significant involving large-scale displacements. The Murree thrust shows greater vertical displacements and steeper inclinations with persistence over the whole region. The autochthonous belt between the two thrusts consists of a series of inverted folds of Eocene rocks enclosing Permo-Carboniferous Panjal volcanics and Triassic formations. Panjal volcanics (traps) is underlain by Tanawals. The contact between the Murree and Tanawals named as Panjal thrust. In Jammu foothills two major structural units can be recognized and these are (i) the Suruin-Mastgarh antcline bordering the plains and (ii) the folded and faulted belt to the northeast of Suruin-Mastgarh antclinal unit (Karunakaran and Rao, 1979)

5.3 Probabilistic Seismic Hazard Assessment

Many earthquakes, having medium to large size, have occurred around this area as per data based on historical and instrumental records. The information is compiled using the data by India Meteorological Department, United States Geological Survey and International Seismological Centre. The 1905 Kangra earthquake of magnitude 8.0 affected the area followed by a large number of aftershocks. The maximum intensity of IX on RF scale was recorded around Dhauladhar. Another significant earthquake occurred on June 22, 1945 near Chamba with magnitude 6.5. The Kinnaur earthquake of January 19, 1975 with magnitude 6.8 was strongly felt in Himachal Pradesh and surrounding areas.

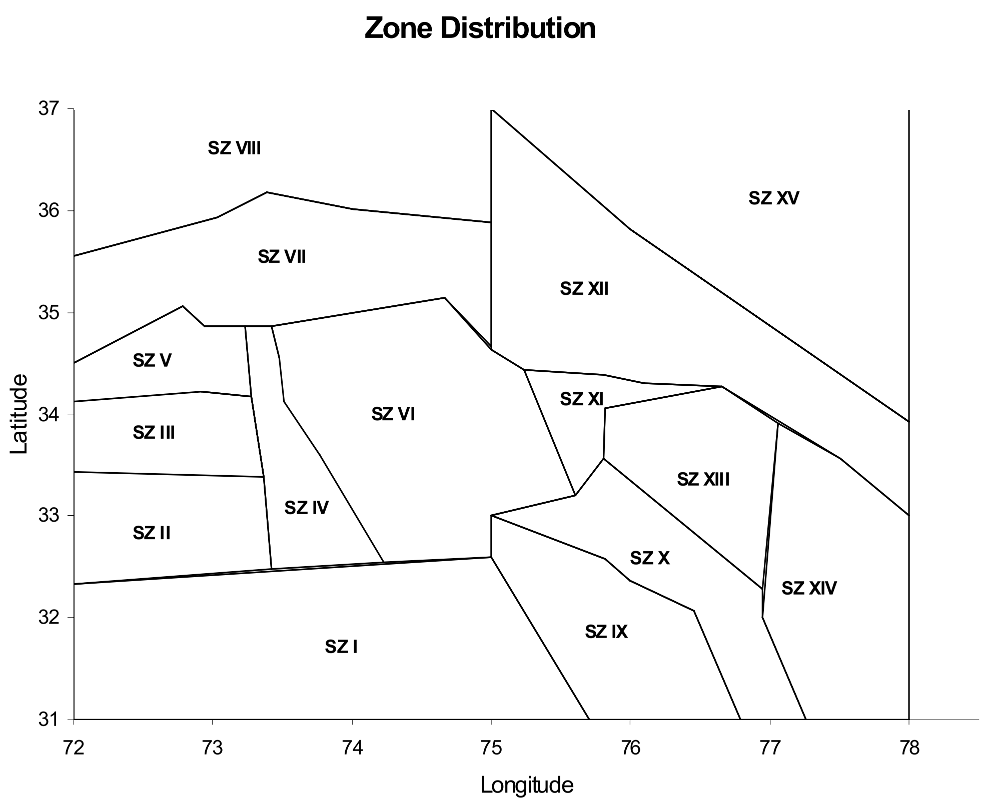
The probabilistic seismic hazard assessment has been carried out considering the complete and the extreme data sets for the individual three sources considered in the present study. After checking the completeness of the data the Mc values were assumed based on the fitting of the GR relationship to the observed seismicity of the individual source zones considered for the analysis. A well-known technique (Kijko and Sellevoll, 1989) for the estimation of seismic hazard parameters has been used. Poissonian occurrence of earthquakes with doubly truncated Gutenberg-Richter distribution is assumed for seismic hazard assessment. The region is divided into ten seismogenic sources as follows. The major events in each of the seismogenic sources are shown in Table I.

Table I Major Events In The Seismogenic Sources

Zone	Origin					Latitude	Longitude	Magnitude
	Year	Month	Day	Hour	Min.			
I	1827	9	24	0	0	31.600	74.400	6.5
III	1669	6	4	0	0	33.400	73.300	6.5
III	1669	6	23	0	0	33.900	72.300	6.5
III	1852	1	24	0	0	34.000	73.000	6.0
V	1955	3	12	16	42	34.600	73.200	6.0
VI	1778	1	1	0	0	34.000	75.000	7.7
VI	1552	1	1	0	0	34.000	74.500	7.5
VI	1662	1	1	0	0	34.000	75.000	7.5
VI	1735	1	1	0	0	34.000	75.000	7.5
VI	1784	1	1	0	0	34.000	75.000	7.3
VI	1884	5	30	0	0	33.500	75.500	7.3
VI	1803	1	1	0	0	34.000	75.000	7.0
VI	1863	1	1	0	0	33.500	75.500	7.0
VI	1885	5	30	0	0	34.100	74.800	7.0
VI	1885	6	6	0	0	34.000	75.000	6.5
VI	1828	6	6	0	0	34.000	74.000	6.0
VI	1999	4	22	7	19	33.170	75.260	6.0
VII	1972	9	3	16	48	35.940	73.330	6.2
VII	1981	9	12	7	15	35.680	73.600	6.1
VII	1871	5	22	0	0	35.900	74.300	6.0
VII	1949	8	1	7	39	35.800	74.200	6.0
VIII	1943	9	24	11	31	36.400	73.500	6.5
VIII	1924	0	13	16	17	37.000	72.000	6.0
VIII	1925	6	20	13	4	37.000	72.000	6.0
VIII	1930	9	5	10	13	37.000	72.000	6.0

Zone	Origin					Latitude	Longitude	Magnitude
	Year	Month	Day	Hour	Min.			
VIII	1931	1	20	9	27	37.000	72.000	6.0
VIII	1958	5	29	3	15	36.660	72.190	6.0
X	1905	4	4	0	50	32.300	76.250	8.0
X	1945	6	22	18	0	32.600	75.900	6.5
X	1947	7	10	10	19	32.600	75.900	6.2
XIV	1906	2	28	0	0	32.000	77.000	7.0
XV	1669	6	22	0	0	35.000	77.000	6.5
XV	1925	12	7	8	34	37.000	75.500	6.0
XV	1980	2	13	22	9	36.470	76.860	6.0

The schematic diagram for the sources is shown in fig. 1. The input to the seismic hazard estimation is given in the Table II. While the extreme and complete part of the data is used in eleven sources, four of the sources have used only complete part of the data.



(Fig. 1) Division of area around Uri in seismogenic source zones

Table II Data Inputs For Seismic Hazard Estimation

Zone	Maximum Observed Mmax	Second Maximum Observed Mmax	Data contribution % (β)		Data contribution % (λ)	
			Complete	Extreme	Complete	Extreme
SZ I	6.5	5.5	45.0	55.0	89.2	10.8
SZ II	4.6	4.5	Only complete part of catalogue used			
SZ III	6.5	6.5	47.9	52.1	87.5	12.5
SZ IV	5.0	4.8	Only complete part of catalogue used			
SZ V	6.0	5.0	41.6	58.4	75.0	25.0
SZ VI	7.0	7.0	89.0	11.0	51.3	48.7
SZ VII	6.0	5.6	53.1	46.9	98.9	1.1
SZ VIII	6.5	6.0	51.5	48.5	95.9	4.1
SZ IX	5.5	5.0	Only complete part of catalogue used			
SZ X	8.0	6.5	33.5	66.5	94.5	5.5
SZ XI	4.9	4.7	Only complete part of catalogue used			
SZ XII	5.7	5.5	55.4	44.6	93.8	6.2
SZ XIII	5.5	5.5	44.8	55.2	97.1	2.9
SZ XIV	7.0	5.2	81.2	18.8	98.0	2.0
SZ XV	6.5	6.0	45.1	54.9	97.8	2.2

Table III Seismic Hazard Parameters And Estimation Of Mmax For The Seismogenic Sources Around Uri

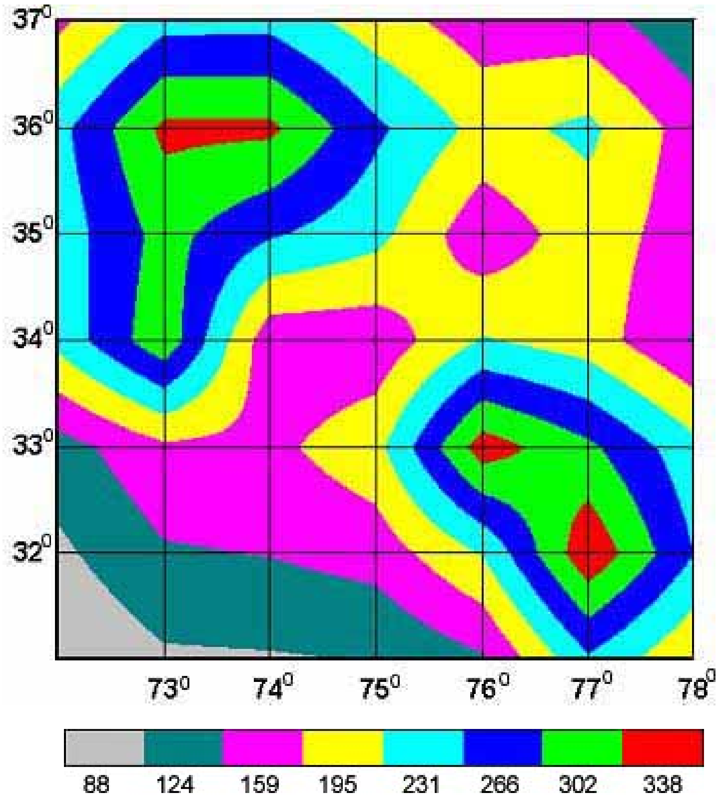
Seismogenic Zone	Seismicity Parameter β	b-value of Gutenberg-Richter equation	Seismicity Parameter λ	Estimated Mmax
SZ I	0.48±0.02	0.21±0.01	0.61±0.11	6.55±0.33
SZ II	0.73±0.02	0.32±0.01	0.34±0.10	4.73±0.35
SZ III	0.65±0.04	0.28±0.02	0.45±0.08	6.55±0.30
SZ IV	0.94±0.05	0.41±0.02	0.50±0.12	5.50±0.58
SZ V	0.57±0.02	0.25±0.01	0.20±0.05	6.07±0.34
SZ VI	0.50±0.03	0.22±0.01	1.99±0.21	7.74±0.33
SZ VII	0.76±0.04	0.33±0.02	2.40±0.24	6.21±0.33
SZ VIII	0.68±0.03	0.29±0.01	1.82±0.18	6.52±0.33
SZ IX	0.59±0.07	0.26±0.03	0.68±0.13	6.06±0.69
SZ X	0.75±0.05	0.33±0.02	1.82±0.20	8.16±0.37
SZ XI	0.56±0.10	0.24±0.04	0.35±0.10	5.24±0.47
SZ XII	0.59±0.08	0.26±0.03	0.72±0.13	5.73±0.33
SZ XIII	0.23±0.03	0.10±0.01	0.72±0.10	5.51±0.33
SZ XIV	0.25±0.03	0.11±0.10	0.98±0.16	7.04±0.33
SZ XV	0.64±0.03	0.28±0.01	1.88±0.19	6.53±0.33

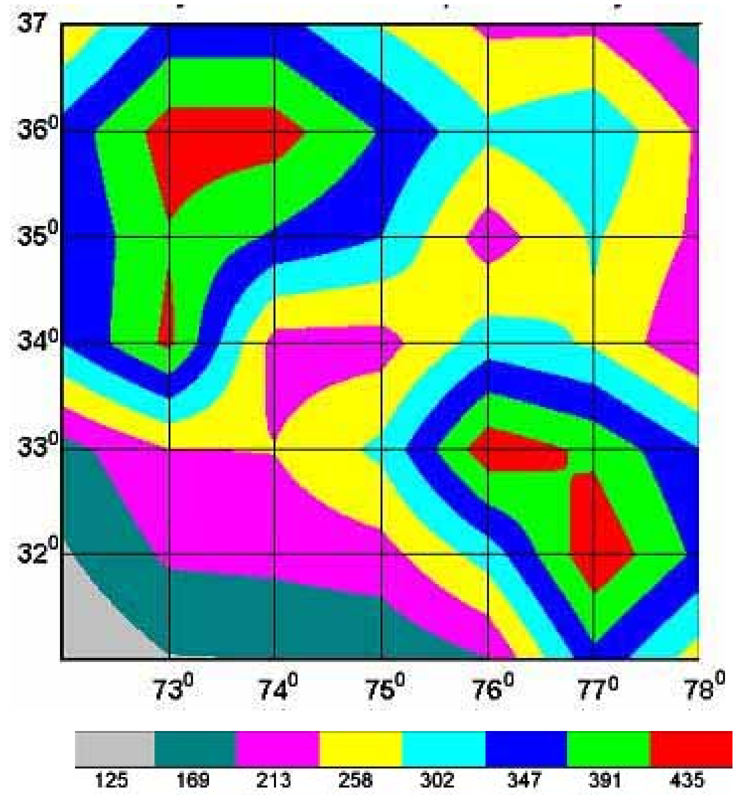
The seismic hazard parameters thus estimated are reported in Table III. After the seismic hazard assessment is complete the strong ground motion parameters has been estimated using the spectral attenuation relationship. Since no strong motion data is available from the region, the spectral attenuation relationship based on world wide data has been used. The strong motion estimates are made using empirical formulae worked out by some of the research workers for various tectonic environment. Attenuation relationships are derived by regression analysis using different distance measures and magnitude measures. Thus different relationships provide different strong ground motion and a judicious dicision to estimate ground motion is therefore required for adoption in any particular situation. The spectral attenuation relationships are generally given for the subduction zones and the shallow crustal earthquakes. The spectral attenuation relationship given by Youngs et al (1997) has been used in this study.

The probability of exceedance can be written as

$$P[Y > y^*] = \int \int P[Y > y^* | m, r] \; f_{Mi}(m) \, f_{Ri}(r) \, dm \, dr$$

Where $P[Y > y^* | m, r]$ is obtained from the predictive relationship where Youngs et al (1997) has been used and $f_M(m)$ and $f_R(r)$ are the probability density functions for magnitude and distance, respectively. The program CRISIS program (Ordaz, 2003) has been used to estimate the spectral accelerations and estimations for the exceedance rate has been proposed for the present site. The seismic hazard is estimated using a probabilistic model that considers the rates of occurrence, attenuation characteristics and geographical distribution of earthquakes. Earthquake occurrence has been modeled as a Poissonian process in the present study. Three sources considered in this region are modeled as line sources. A dynamic integration procedure is followed for fast computation of hazard in extended areas. The ground motion parameter in terms of PGA has been estimated for the whole region for 10 % and 20% exceedance in 50 years and are shown in fig 2 and 3.



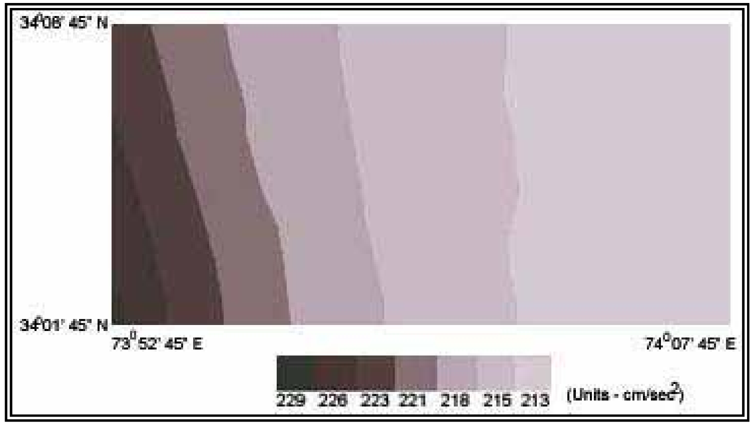


Scale Values Relative to Colour Coding in cm/s²

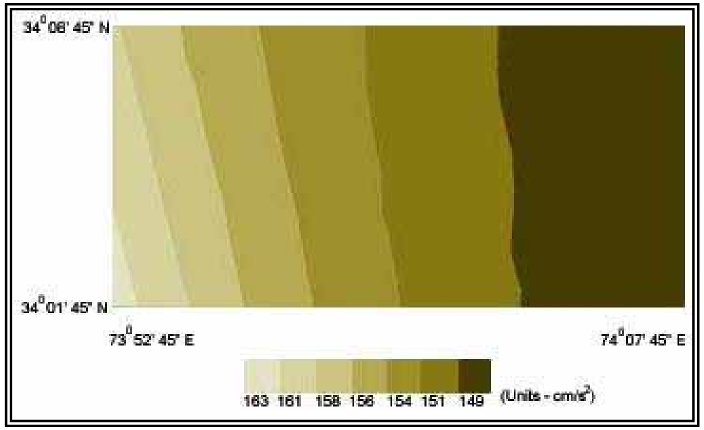
(Fig. 2) PGA for the region for 20% exceedance in 50 years

(Fig 3) PGA values for 10 % exceedance in 50 years

The PGA distribution in the area of interest is shown in Fig. 4 and 5, which shows the exceedance of PGA for 10% and 20% exceedance values. The PGA values vary between 149 cm/sec^2 to 165 cm / sec^2 in case of 20% exceedance while it varies between 213 cm/sec^2 to 231 cm/sec^2 in case of 10% exceedance for a return period of 50 years. Conservatively the values to be used are recommended in fig 6 and 7 in form of spectral accelerations.

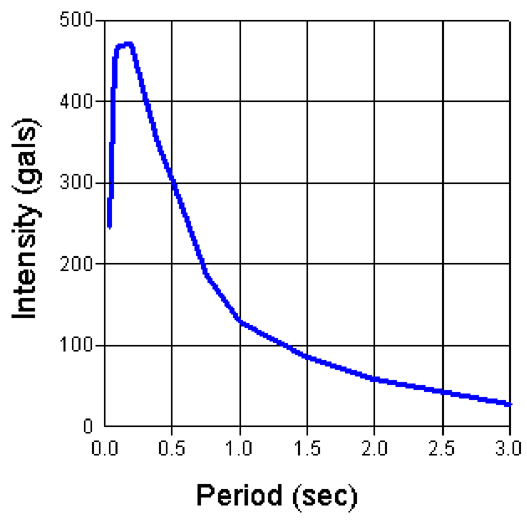


(Fig. 4)10% exceedance values for PGA in the area of interest

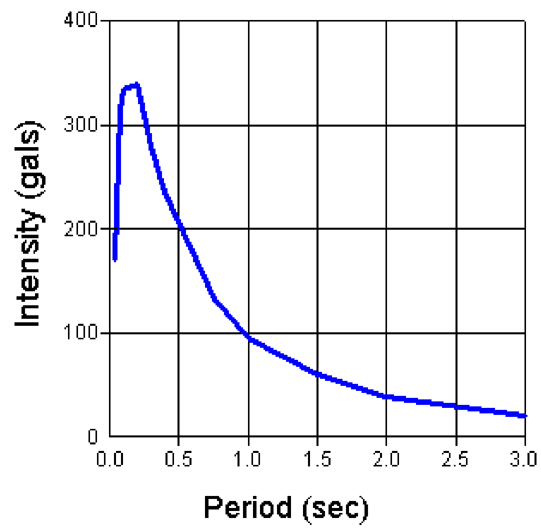


(Fig. 5) 20% exceedance values for PGA in the area of interest

The spectral level for the region is shown in fig. 6 and 7 for 10% and 20% for 50 years. These spectral accelerations are defined at the bed rock level. It may be noted that the local site amplifications due to the soil columns at the site are to be considered while working out the spectral levels at the surface.



(Fig. 6) Spectral acceleration for 10% exceedance in 50 years



(Fig. 7) Spectral acceleration for 20% exceedance in 50 years

The spectral ground motion is estimated based on probabilistic seismic hazard assessment carried out for this region. The PSHA is carried out using the Poissonian distribution and the bounded GR relationship including the extreme values for the period where the seismicity is not completely reported. The spectral attenuation relationship developed for subduction zones based on the worldwide strong motion data set has been used to develop the spectra at the bedrock. The PSHA results provide the seismic hazard elements and for such a small region do not exhibit significant variations. The integration with the discrete element analysis been used to derive the hazard zonation at much higher resolution.

CHAPTER 6.0

HAZARD ZONATION MAPS

This chapter underlines the technique and analysis used for deriving hazard zonation map for the region.

6.1 Satellite Data

IRS P5 Cartosat stereo pair and IRS 1D LISS III scenes were used for the study. Cartosat-1 carries two panchromatic cameras that can acquire single-band stereoscopic pictures in the visible region of the electromagnetic spectrum. The imageries have a spatial resolution of 2.5 meter. The cameras cover a swath of 30 km and they are mounted in such a way that near simultaneous imaging of the same area from two different angles is possible. The stereo images thus produced can be used to generate a DEM. Details of the cartosat and LISS-III sensors are given in table 1 and table 2 respectively. Cartosat sensor has a spatial resolution of 2.5 m and is available in stereo pairs. This data was orthorectified using GCP from GPS observations and a DEM of the area was also derived for the study area. LISS III data was rectified taking rectified cartosat data and available maps from the web as base. RMS error was made as low as < 1 pixel. A second order polynomial approximation was used for resampling. The images were resampled to Universal Transverse Mercator (UTM) projection as detailed in table 3. SRTM DEMs at 90m spatial resolution was also used for orthorectifying the cartosat images.

Technical details of the payloads onboard Resourcesat – 1 are given in table 1.

Table 1: Characteristics of IRS P5 Cartosat - 1 sensor

Orbit Characteristics	**Specification**
Nominal Altitude(km)	617.99
Number of Orbits per day	15
Orbital Repetivity cycle (No. of days)	116
Nominal wait time to acquire adj. Path	11 days
Maximum wait time for revisit	5
Node for P/L operations	Descending Node
Local time for equatorial crossing	10:30 AM
Orbital Parameters	
a.) Semi-major axis	6996.128
b.) Eccentricity	0.001
c.) Inclination	97.87 deg.
Date of pass	26/11/2006

Table 2: Characteristics of the LISS III sensor

Sensor	**Resolution Meters**	**Swath kms**	**Revisit**	**Image Size kms x kms**	**Radiometric Resolution**
LISS III					7 bits
Visible	23.5	141	24 Days	142 x 141	
SWIR	23.5	141	24 Days	142 x 141	

Table 3: Projection parameters used in the study.

Parameter	**Value**
Projection:	Universal Transverse Mercator
Spheroid :	WGS84
Datum :	WGS84
Zone :	45

6.2 Image Classification

The remote sensing and GIS analysis is carried out at the Regional Remote Sensing Service Centre Kharagpur. Satellite data is procured from the Data centre of National Remote Sensing Agency, Hyderabad and geometrically corrected. Available Maps are used for the geometric correction of the cartosat data. A second order polynomial approximation is used to resample the images keeping RMSE less than one pixel. The projection parameters used for resampling are given in table 3. Geometrically corrected scenes are subset using the vector coverage of the study area and used for further analysis. Derivation of the landcover map is done by a hybrid classification approach. Digital images are unsupervised classified first the resultant classes are visually analyzed, recoded and reclassified when necessary. Ground truth information was also used for classifying recoding the images. Vector coverages of settlement areas, roads and drainages are separately prepared by digitizing the base map and updating using the satellite data or by deriving them with the assistance of appropriate software. These layers are overlaid on the classified map and the map is vectorised.

- **Generation of Discrete Element Map**

  It is convenient to divide the study are into small elements of unique nature for the analysis. Discrete elements in this study form a unique area in the region having similar type of topography *viz*. slope and aspect. Minimum area of each element is approximately 1 sq km.

- **Generation of slope and aspect**

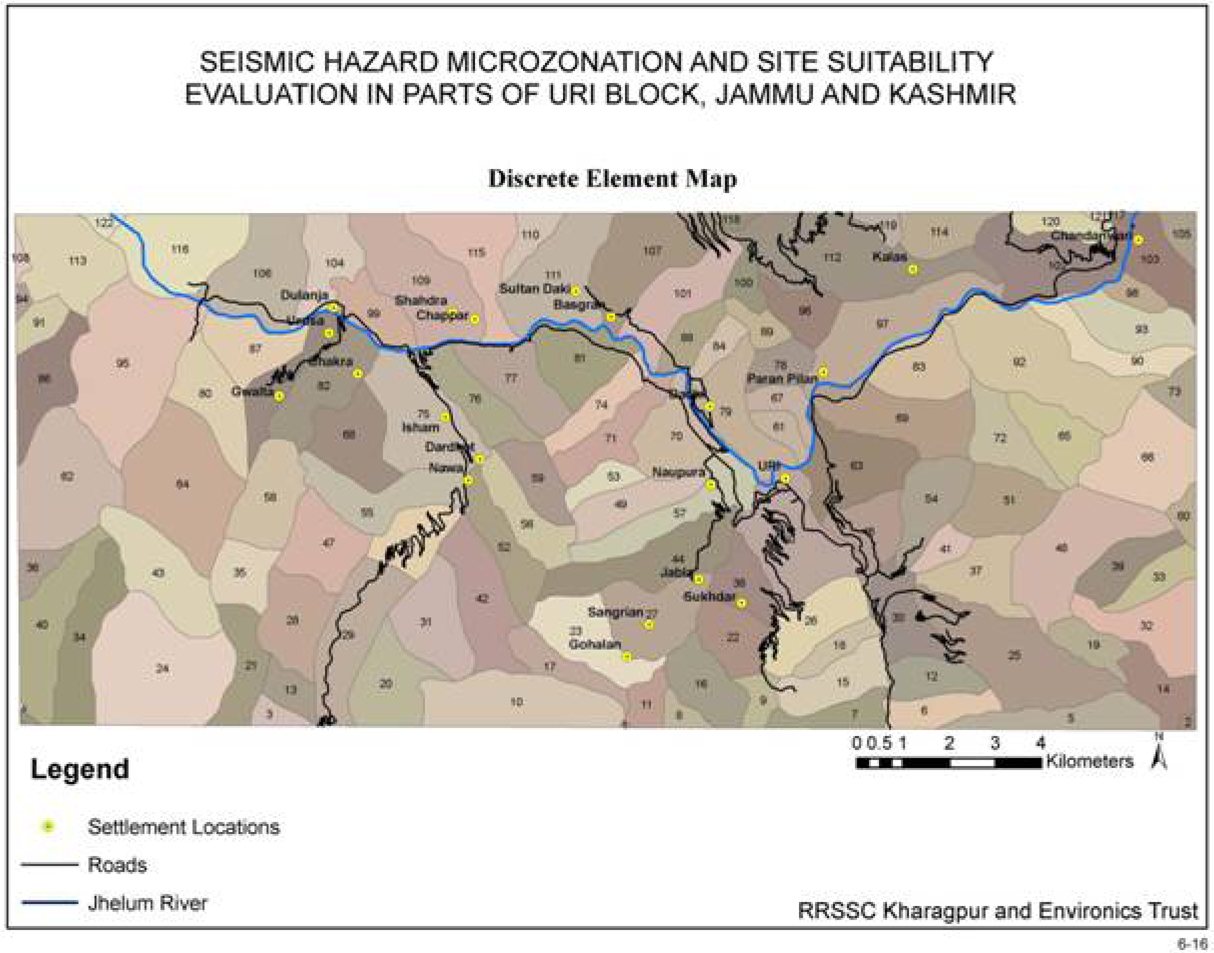
  The slope and aspect maps are generated from the SRTM digital elevation model using the topography tool of Erdas Imagine software.

- **Generation of geology and structure**

  The geological map is generated by updating the existing geological maps with field visits and satellite data. The lineament map is delineated from the satellite data after enhancing the imagery. Field based knowledge also is considered during generation of the lineament map. All the spatial vector data are prepared and stored in ArcMap 9.0 personal geodatabase.

- **Other data used**

  - Satellite data in the optical region – LISS III and Cartosat.
  - Collateral data on geology, geotechnical properties, seismicity, structure, tectonics, topography and hydrology.
  - Field data on soil and landslides.
  - Regional maps


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Discrete Element Map
Dulanja
Shahdra
Chappar
Sultan Daki
Basgran
Kalas
Chandanwari
Paran Pilan
Gwalta
Shakra
Isham
Dardkot
Nawa
Naupura
URI
Jabla
Sukhdar
Sangrian
Gohalan
0 0.5 1 2 3 4 Kilometers
Legend
Settlement Locations
Roads
Jhelum River
RRSSC Kharagpur and Environics Trust
6-16

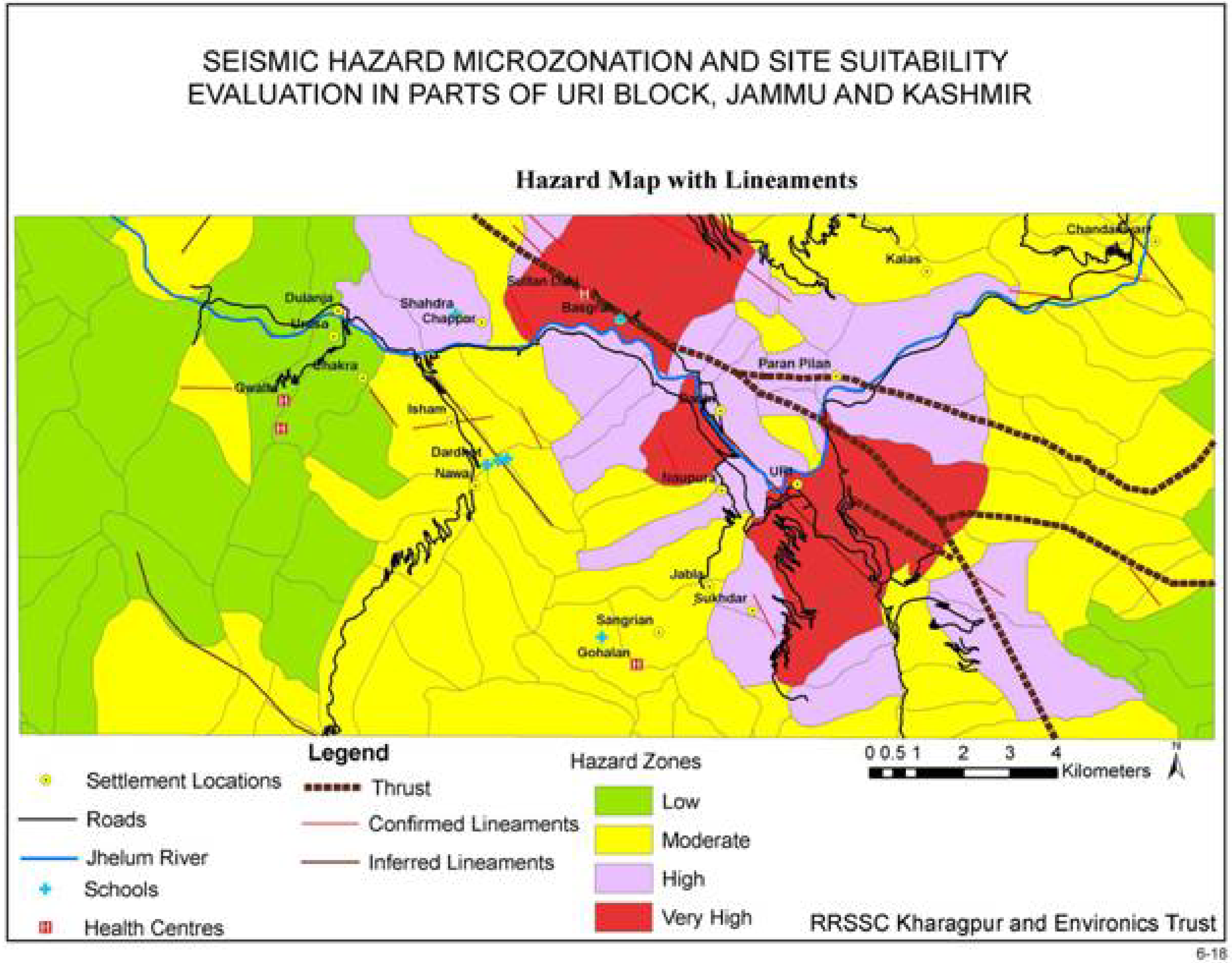
Software used

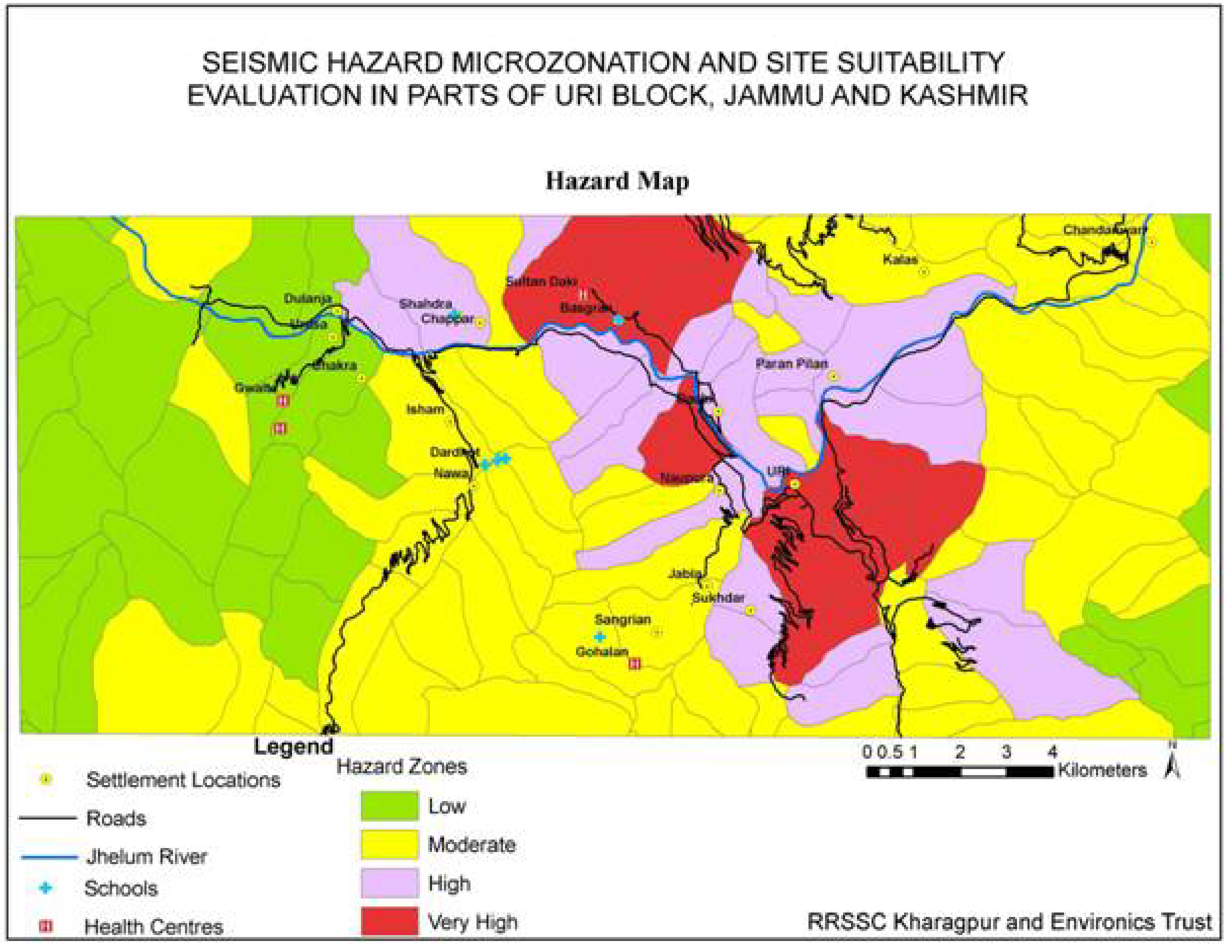
The satellite data rectification, enhancement, classification and related image processing are carried out using Erdas Imagine version 9.0 software. Orthorectification and DEM generation of cartosat data is done using Leica Photogrammerty Suite (LPS).
Vector based spatial data generation and editing was carried out with ArcMap software ver 9.0. Automatic generation of Streams and watershed are carried out using Digital Terrain Analyst (DTA) software developed in the centre. Statistical analysis for the empirical modeling is carried out using SPSS and MS Excel software.

6.3 Hazard Zonation

Discrete element map is a combination of basic polygon layers formed from the identical features. These features like slope and aspect are derived from the different combination of satellite imageries and hence it aids in defining the discrete or distinct features of similar class and nature so that a comparative analysis could be done. The role of image interpretation along with ground truthing becomes extremely important for reducing the errors. Discrete element analysis is a product, which requires inputs from several sources, which are described hereafter.

The discrete element map gives a base for Hazard zonation has been done using the collateral layers and the discrete elements map. Each discrete element is treated in a feature environment incorporating the available information and empirical evidences in the regions and supported by the field observation that were used in deriving the thematic layers of different class features. Thirty variables were used in zoning the area using information theory technique. Information values of the elements varied from -0.54 to 3.48. Segmentation of the area for landslide hazard revealed that about 9 elements in the area falls under the very high risk zone. About 21 elements fall under the high-risk zone and the rest fall under moderate and low risk category.


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Hazard Map with Lineaments
Dulanja
Shahdra
Chappar
Chakra
Isham
Nawa
Paran Pilan
Kalas
Uri
Jabla
Sukhdar
Sangrian
Gohalan
Legend
Settlement Locations
Roads
Jhelum River
Schools
Health Centres
Thrust
Confirmed Lineaments
Inferred Lineaments
Hazard Zones
Low
Moderate
High
Very High
0 0.5 1 2 3 4
Kilometers
N
RRSSC Kharagpur and Environics Trust
6-18


SEISMIC HAZARD MICROZONATION AND SITE SUITABILITY
EVALUATION IN PARTS OF URI BLOCK, JAMMU AND KASHMIR
Hazard Map
Dulanja
Shahdra
Chappar
Sultan Daki
Basgran
Chakra
Gwalta
Isham
Nawa
Paran Pilan
Kalas
Uri
Naupora
Jabla
Sukhdar
Sangrian
Gohalan
Legend
Settlement Locations
Roads
Jhelum River
Schools
Health Centres
Hazard Zones
Low
Moderate
High
Very High
0 0.5 1 2 3 4
Kilometers
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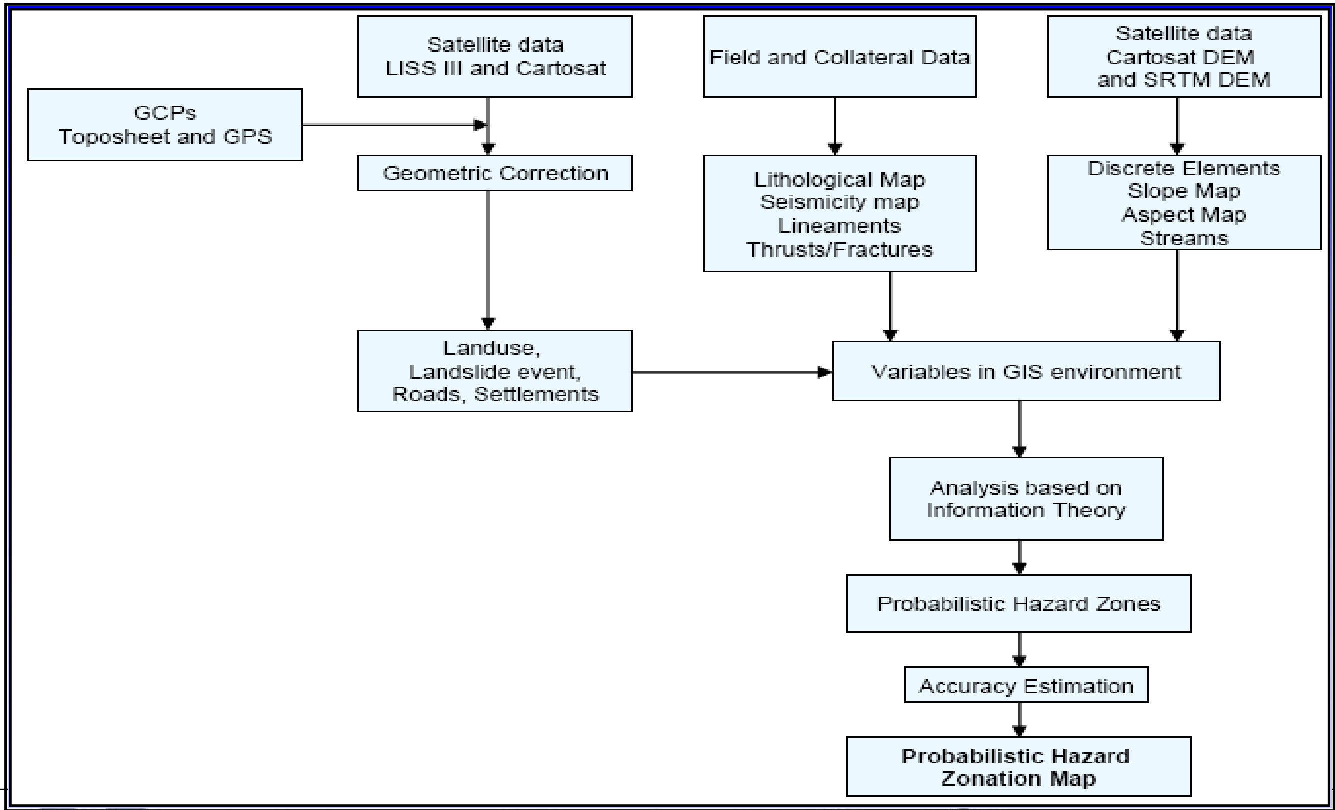
6-17

Mapping of hazard prone areas were done in three broad steps and the detailed methodology is explained in the chart below.

1. Generation of various GIS layers from satellite imagery and other collateral data.
2. Empirical modeling and mapping of the probable hazard zones
3. Comparison with the field collected data.



Accuracy Estimation

The accuracy of information theory in predicting the slope stability is evaluated by the experimental probability equation (4). Thus, the derived accuracy of slope instability prediction for the Uri sector is 93%.

Empirical Modeling

Information theory is a tool for multicriteria analysis for hazard zonation studies (Ramakrishnan et al., 2005). Information theory was first used in 1948 by Claude Shannon "A mathematical theory of communication". This technique aims at measuring the information associated with occurrence of certain events having a probability '**p**'. The first reduction towards this process will be to ignore any particular features of the event and only observe whether or not it happened. In essence it means that one can think of the event as the observance of the symbol whose probability of occurring is '**p**'. Thus the information can be defined in terms of the probability '**p**' as the information measure i(p) have several properties.

1. Information is a non-negative quantity $I(p) \geq 0$.
2. If an event has probability 1, we get no information from the occurrence of the event: $I(1) = 0$.
3. If two independent events occur (whose joint probability is the product of their individual probabilities), then the information we get from observing the events is the sum of the two information: $I(p1 \times p2) = Ip1 + Ip2$.
4. The information measure is a continuous (and, infact, monotonic) function of the probability (slight changes in probability should result in slight changes in information).

Thus

1. $I(p2) = I(p * p) = I(p) + I(p) = 2 * I(p)$

2. or I (pn) = n * I (p).
3. I (p) = I ((p1/m)m) = m * I (p1/m)
4. I (p1/m) = 1/m * I (p)

    I (pn/m) = n/m * I (p)
5. and thus by continuity, we get for

    0 < p ≤ 1 and a > 0 a real number: I (pa) = a * I (p)

    From this, we can derive

    I (p) = -logb (p) = logb (1/p) for some base b. ------------------ (1)

Summarizing from the four properties,

1. I (p) ≥ 0
2. I (p1 * p2) = I (p1) + I (p2)
3. I (p) is monotonic and continuous in p

6.4 Information theory and probable hazard zones

The analysis used for micro hazard zonation is the information value method based on probability theory as summarized here. Suppose there are N potential factors/variables that affect the slope instability, then the degree of potential hazard in an area can be estimated on the basis of number of fatigue factors and their severity and interactions. However, the main objective is to predict the areas of various degrees of susceptibility. For this, first a given area is divided analytically into a number of polygon elements by considering the micro-watershed boundaries and different aspect and slope classes in the DEM. As per the law of information theory, every element j (j =1, 2, …., N) can be defined stable or unstable on the basis of the information value (**Ij**) of that element. Higher the value of **Ij** more unstable the element j is, within the slope. The total information value in the element j can be calculated as:

$$I_j = \sum_{I=1}^{M} I_i X_{ji} \text{ -------------------------- } (2)$$

- X_{ji} = value of ith variable (I = 1, 2, ……, M) for the jth element (j = 1, 2, ……N);
  - = 1, if variable i exists in element j;
  - = 0 if variable i does not exist in element j.
- M = number of variables associated with a given area;
- I_i = information value supplied to land slide by variable i
  - = $\log [(S_i/N_i) / (S/N)]$
- N = total number of elements
- S = number of elements with history of landslide occurrence
- S_i = number of elements with history of landslide occurrence involving variable i.
- N_i = number of elements involving variable i

6.5 Accuracy of prediction

The experimental probability of prediction is evaluated using the following equation

$$P = KS/ S * (1-(K - KS) / N-S)1/3 \text{ ------------------- } (3)$$

N = Total number of elements

S = Number of elements containing landslides

K = Number of elements falling into High and moderate classes

KS = Number of elements falling into high and moderate classes containing landslides

6.6 Input Thematic Layers and Program Structure

Microhazard zonation in the area requires identification of the total number of polygon elements associated with the given area (N) and the terrain specific conditioning and triggering factors (variables). For this purpose, the study area is divided into small blocks/elements on the basis of slope, aspect and watershed divide. This technique is helpful in better understanding the relationship between landslide events and variables. From the analysis and field investigation, the following variables (M) are identified as key conditioning and triggering factors.

Geology

The geology of the Uri sector comprises five major types *viz*. Gneiss and Granite; Dogra Slates with unfossiliferous paleozoics; Triassic, Permian, Carboniferous; Murree - Mid, Tertiary; Salkhala Series - Precambrian. The geology is represented by X1 and X2. The presence of Gneiss and Granite is represented in variable X1, i.e. if Gneiss and Granite group is present, then X1 = 1 else 0. Similarly if X2 = 1 if any of the classes Dogra Slates with unfossiliferous paleozoics; Triassic, Permian, Carboniferous; Murree - Mid, Tertiary; Salkhala Series – Precambrian is present else 0.

Structure

Fractures are identified from the available maps or delineated from the satellite imagery. Variables X3 and X4 are assigned 1 if Confirmed Fracture or Inferred Fracture is present respectively. Variable X12 represented the thrust. If thrust is present in a particular element, variable X12 for that element is set to 1 else 0.

Landcover

Satellite derived Landcover classes (four variables, X5-X8) are assigned 1 or 0 based on the five major landuse classes *viz*. dense vegetation, barren land, fallow land and degraded vegetation.

Historic Landslide Activity

Historic landslides were mapped from the field data or from the cartosat images. Presence or absence of landslide events signifies the tendency for new / reactivation of landslides and hence need to be studied with an emphasis on the susceptibility. Discrete element with a Landslide event is represented by a variable X9 set to 1. X9 is set to 0 for the elements with no recorded landslide activity.

Anthropogenic Activities

Variables X10 and X11 represent the anthropogenic interferences in the area such as road cuttings and settlements respectively.

Slope Angle

Four classes of slope categories are made based on field observation, between slope amount and incidence of landslides. Accordingly the following variables were set as shown below,

. if slope > 46° then X17 = 1 else 0
. if slope 35-45° then X16 = 1 else 0
. if slope 25-34° then X15 = 1 else 0
. if slope 15-24° then X14 = 1 else 0
. if slope <15° then X13 = 1 else 0

Aspect

On the basis of Aspect four classes are made. Accordingly the slope variables X19 – X22 are set as shown below,

. if aspect is 0-90° then X18=1 else 0
. if aspect is 91-180° then X19=1 else 0
. if aspect is 181-270° then X20=1 else 0
. if aspect is 270-360° then X21=1 else 0

Seismotectonic factors

Peak Ground Velocity (PGV), Peak Ground Acceleration (PGA) and Modified Mercalli's Index (MMI) are used as input in the variables X23-X29.

For PGA, variables are assigned values as

. if PGA is 0.2 – 0.33 then X22 = 1 else 0
. if PGA is 0.33 - 0.43 then X23 = 1 else 0

. if PGA is 0.43 – 0.56 then X24 = 1 else 0

For PGV, variables are assigned values as

. if PGV is 20 - 50 then X25=1 else 0

. if PGV is 51 - 78 then X26=1 else 0

. if PGV is 79 - 108 then X27=1 else 0

For MMI, variables are assigned values as

. if MMI is 7 – 7.8 then X28=1 else 0

. if MMI is 7.8 – 8.6 then X29=1 else 0

. if MMI is 8.6 – 9.4 then X30=1 else 0

All the different input layers are analyzed using ArcMap ver 9.0 and the statistical analyses are done on the resultant layer in MS Excel using Visual Basic script. Results from this analysis are attributed to the corresponding discrete elements and a map is obtained. The output comprises of the details on the information value of each element and minimum and maximum information value and grades of instability associated with each element. This data is further classified into different grades of instability based on the range of information value, element number and grades of instability associated with each element. The results of the information variable (Xi) are tabulated in table 4.

Accordingly, the information value of the element j with respect to above tables will be for the area.

$$I_j = -0.007 X_{j1} + 0.090 X_{j2} + 0.073 X_{j3} + \ldots\ldots - 0.232 X_{j30} \qquad \text{-------------------- (4)}$$

Table 4. Variables And The Corresponding Information Values Of The Variables.

Variable	Parameter	Information Values
X1	Geology – Gneiss and Granite	0.007
X2	Geology - All other classes	0.090
X3	Confirmed Fractures	0.073
X4	Inferred Fractures	0.033
X5	Dense Vegetation	0.379
X6	Barren Land	- 0.023
X7	Fallow Land	0.270
X8	Degraded Vegetation	0.233
X9	Historic Activity	1.011
X10	Anthropogenic Interference - Roads	0.319
X11	Anthropogenic Interference - Settlements	0.195
X12	Thrust	0.358
X13	Slope - <15	0.047
X14	Slope - 15-24	0.033
X15	Slope - 25-34	0.014

Variable	Parameter	Information Values
X16	Slope - 35-45	0.014
X17	Slope - >46	0.011
X18	Aspect - 0-90	0.011
X19	Aspect - 91-180	0.065
X20	Aspect - 181-270	0.041
X21	Aspect - 270-360	0.003
X22	PGV - 0.2 – 0.33	- 0.135
X23	PGV - 0.33 – 0.43	0.233
X24	PGV - 0.43 - 0.56	- 0.268
X25	PGA - 20 – 49	0.102
X26	PGA - 49 - 79	- 0.021
X27	PGA - 79-108	NA
X28	MMI – 7.0 – 7.8	0.0565
X29	MMI – 7.8 – 8.6	0.239
X30	MMI – 8.6 - 9.4	- 0.232

The information values of all the polygon elements are found using these equations. The information values of the polygons varied from -0.54 to 3.48. On the basis of histogram distribution, the polygon elements are classified into four hazard classes *viz.*low (-0.54

< Ij < 0.51), moderate (0.51 < Ij < 1.53), high (1.53 < Ij < 2.55) and very high (Ij > 2.55) landslide hazard prone zones. On the basis of this information, probable landslide hazard zonation maps are prepared for the area.

Uri, Baramulla district in Jammu and Kashmir is a vulnerable zone from a natural hazard point of view. For delineating the hazard prone areas in the region, the study area was divided into smaller polygons/elements. This is advantageous for attributing and mapping. Each element represents a small area having more or less uniform slope and aspect and hence forms a micro-watershed or a part of it. Various physical and geological factors that contribute to landslide event was analysed to assign an information value to each element. The information value has been determined using the information technique. Information value was then categorized based on the ranges, into five grades. These five grades of instability are defined as very low, low, medium, high and very high. The accuracy of estimation is 93%. It is found that 9 polygons in the area fall under very high-risk category and 21 fall under high risk category. From the overlay analysis of landslide incidences and hazard zones, it was found that the hazard maps generated correlate well with the landslide event map. There is high degree of conformity among the hazard zones and the event maps in terms of landslide incidences.

CHAPTER 7.0

SITE GEOTECHNICAL ANALYSIS

This chapter describes the key features regarding the morphology of the settlements as well as the technical geo investigation parameters for the respective sites. The abbreviations used in the chapter are annexed at the end of this chapter.

7.1 Landform

The region is marked by several small rivulets (*nallahs*) often named after the local or prominent settlement and are marked by deep cutting on the southern slopes of the valley. Frequent slope breaks are very common in the region and one comes across several small springs, streams flowing through the sections of the road to meet River Jhelum. People at several places have utilized the potential of naturally flowing water for irrigation by means of channelising water through man made channels, locally known as *guls*. But most of these *guls* suffered damages and are also not being effectively used. The soils in the region are typically hill soils with alluvial composition, in the lower reaches on the region like in the range of 1300-1500mts, clayey pockets of soil are present and as one moves to higher altitudes, there are intervening pockets of clay and boulders or alluvial material. The physical appearances of soils indicate that these are shallow and excessively drained Mesic-loamy-skeletal soils on steep slopes with loamy surface. Severe erosion and strong stoniness associated with medium deep but excessively drained. Several of the landslides occurred as an event of coseismic activity along the main Uri-Muzaffarabad highway and along the banks of River Jhelum.

The texture of the soil is from light reddish brown to light brown in colour except for the region surrounding carbonaceous material like that of Sultan Daki, Sarai etc. At some instances there could be seen small chunk of flat agricultural lands very near to the river where the terrace ends.

The region of Uri has been experiencing spurt of public investments over the last several years like the hydropower projects, roads etc. There has been a considerable respite to the people over the last several years when linkages to the villages started developing on different routes. Though these routes are still weak and are not all weather roads but it has somehow eased the movement of goods and people between villages and the nearest town of Uri.

Quantum of land and its location has been one of the limiting factors in the hills and specifically in this region, which has seen military retaliation as well as faced the damaging earthquake at the fag end of year 2005. Ownership has been one of the other important issues that has been disturbing and limits the expansion of agriculture as well as other public infrastructure works. Now the recently modified Roshni scheme has been introduced, which envisages vesting ownership to occupants. People have some hopes from this scheme.

7.2 Geotechnical Investigations

Site Analysis

The techniques and tools used for geotechnical investigations provide a detailed analytical behaviour of the site incorporating the factor of safety while looking at the standardized process as adopted under the IS codes for scrutinizing the field observations. Since most of the available sites are positioned in tectonic environment, the investigations were carried out in order to increase the validation of the results and future design parameters for a particular site. Apart from the locational parameters, which attribute vulnerability to site from adjoining features, the laboratory testing of samples gives a specific lead into design parameters and an understanding of the variables.

The objective of the geotechnical investigations was to obtain sequence and extent of sub-soil and to ascertain the characteristics of sub-soil so as to arrive at design parameters for the foundations of proposed structures as well as understand the geological parameters that may become the determining parameters for the site suitability analysis.

The techniques used for geo technical investigations comprise of three sequential steps;

- Field Testing – SPT or Borehole depending on the site conditions while following the prescribed IS codes
- Sample collection and laboratory analysis of samples for mechanical and engineering properties
- Formulation of design parameters for safety

Brief introduction to the field procedures as well as the defining parameters is explained as under:

Standard Penetration Test

The test is performed in the borehole/pit. The standard split spoon sampler, attached to a string of drill rods in lowered to the bottom of the hole/pit and allowed to rest under self weight. The drill rods are connected to driving assembly, which consists of hoisting equipment, a drive weight (Hammer) of 63.5 kg, and a guide to ensure a 75 cm free fall of hammer on an anvil. The number of hammer blows required to penetrate the sampler through three runs of 150 mm each are recorded. Initial driving of 150mm is disregarded and the number of blows required to drive the sampler through the remaining 300 mm is called BLOW COUNT or PENETRATION NUMBER, N. At the end of the test, the sampler is withdrawn and the soil extracted for subsequent testing in the laboratory.

Refusal is deemed to have been met, if under 50 blows, penetration achieved is less than 30 cms.

The design of a foundation unit normally requires that both bearing capacity and settlement criteria be checked. Bearing capacity analysis for foundations resting in bouldry/rocky strata is complicated by many factors. The major distressing factors are as under:

i. Elastic compression of foundation and underlying bearing strata;
ii. Ground movement on slopes due to erosion, creep or land slides;
iii. Ingress of water may soften the joint fill material causing slippage along the joints;
iv. Post construction settlements due to likely weathering of bouldry/rocky strata;
v. Other causes such as adjacent excavation, mining, subsidence and underground erosion

Thus a highly conservative approach should be adopted in the bearing capacity analysis. By highly conservative approach we mean that a large factor of safety against shear failure should be adopted and permissible settlement should be used as low as possible using engineering judgement.

Certain other parameters like shear failure analysis, settlement analysis and other site specific issues are addressed in the following sections of the chapter.

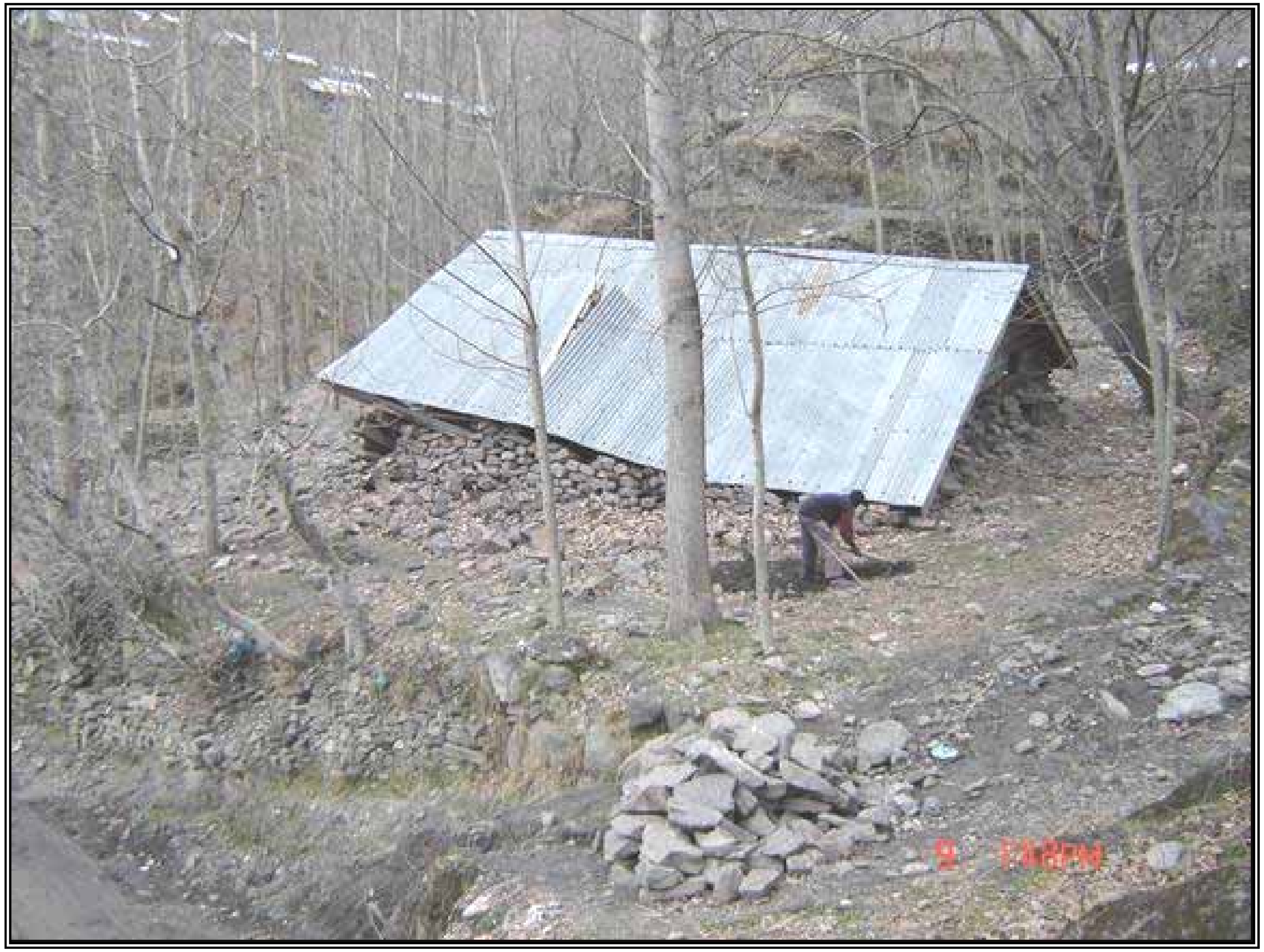
7.3 Site Specific Details

CLUSTER I

SITE: SULTAN DAKI (HEALTH CENTRE)

The *Chamba pahar* stands guard to the village of Sultan Daki, which is located in between the *kalla nallah* section (carbonatious shale sequence depicting contact with the MBT). The village of Sultan Daki suffered near complete damage to the buildings; including housing units, masjids, public infrastructure like health centre and schools. As one approaches towards the village of Sultan Daki an open profile of carbonatious material along the road is seen with a little moisture content. During rainy seasons this zone becomes a slipping zone due to the properties of the carbonatious material.

The health center constructed in random rubble masonary structure and wooden roof collapsed during the earthquake. Apart from the earthquake intensity, poor workmanship seems to be one of the critical factors in building damages in the village. The site is approachable by road at an altitude of 1460m. The site has a very moderate slope i.e. 16% sloping towards the road and is quite often noticed in the hilly regions. The exposures noticed around the site were those of carbonatious material and shales but no prominent feature is present. Soil types in this part of the region are confined to the local geological conditions and being closer to the MBT interface, blackish dry soil with aggregates is noticed. The site is safe from any shooting stones but a little work for the drainage alignment may need to be taken up in the immediate catchment of the site.

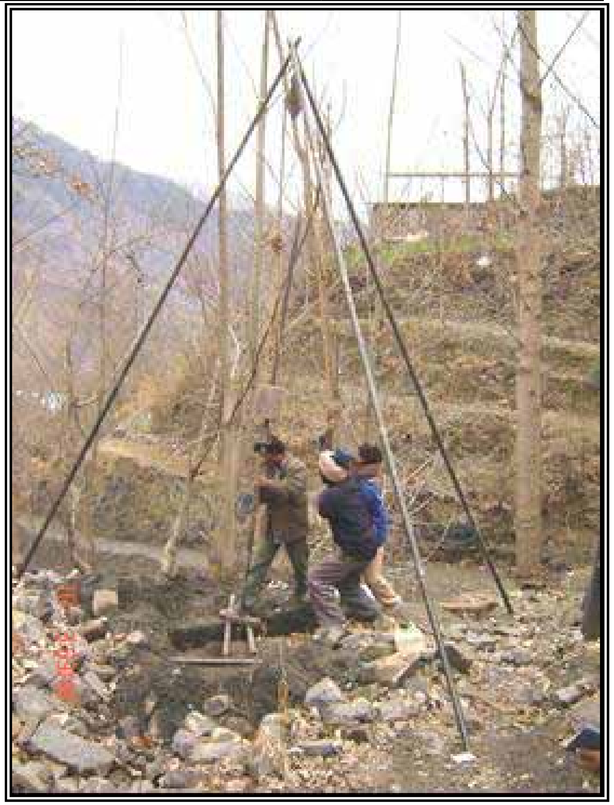


COLLAPSED HEALTH CENTRE AND THE EXISTING SITE SURROUNDED BY TREES

At each location, open pitting was done upto a depth of 2.0 m. As pitting progressed at each location, N-values were observed at depths of 1.0 m and 2.0 m. Refusal to SPT was met at 2.0 m depth at both the locations. Soil samples upto gravel fraction from different depths from within the pits were obtained for subsequent analysis in the laboratory. The nature of strata met at different depths is,

Strata Profile

Location	Depth Range	Nature of Strata
1	ESL to 1.5	Very Loose Fill by SM
	1.5 - 2.0	Dense Bouldry deposit
2	ESL to 1.5	Very Loose Fill by SM
	1.5 - 2.0	Dense Bouldry deposit



Strata Properties

Location	Depth from ESL	N	Soil Composition			Atterberg Limits (%)		% Moisture Content
	In meters		% Gravel	% Sand	% Fines	LL	PL	
Point 1	1	4	18.7	59.3	22	Non Plastic		13
	2	50 (blows for 50 cm penetration (refusal)	50.7	40.4	5.9	Non Plastic		10.2
Point 2	1	3	12.9	50	37.1	Non Plastic		12.3
	2	50	56.8	33.9	9.3	Non Plastic		8.7

The supporting strata at the site is Dense bouldry deposit. Since refusal to SPT was met in the supporting strata at both the locations and as such a value of N = 50 can be adopted in the bearing capacity analysis so as to be on the conservative side. Sub-soil water was not met at the site upto the explored depths.

As per IS, against N = 50, $Ø = 40.7^{o}$. Ingress of water is bound to soften the Joint planes existing in rocky strata/bouldry strata falling within significant depth of proposed footings. As such fully submerged conditions are being incorporated in the analysis.

It is a case of wall as well as column footings. Fill exists upto a depth of 1.50 m and as such depth of footings should be adopted as 1.50 m.

SITE INVESTIGATIONS IN PROGRESS IN SULTAN DAKI

Allowable bearing capacity values are based on the following parameters.

Depth of Footings at each location (D) = 1.50 m

i) Strip or Wall Footings

Width of footings = 1.2 m, 1.5 m

ii) Column Footings

Size of footings (B x L) = 1.5 m x 2.0 m
2.0 m x 2.5 m
2.5 m x 3.0 m

Shear Failure Analysis

$$Ø = 40.7^0$$

Now,

q_{nf} = $q (Nq - 1) Sq\ dq + 0.5\gamma\ B N_\gamma\ S_\gamma\ d_\gamma W'$

D = 1.50 m ; q = 1.7 x 1.5 = 2.55 t/m2; γ = 2.0 t/m3 ; W' = 0.5

Since `Ø' is more than 36^0 and as such it is a case of General Shear Failure. Bearing capacity factors work out to be as under:

$$N_q = 74.0; \quad N_\gamma = 132$$

Computation of `q_{ns}' for footing parameters leading to its least value. These parameters are as under:-

B = 1.20 m (Wall footing)

$S_q = S_\gamma = 1$ (Strip action)

$$d_q = d_\gamma = 1 + 0.1 \times \frac{D}{B} \tan(45 + Ø/2) = 1.272$$

So,

$$q_{nf} = 337.5 \text{ t/m2}$$

Taking into consideration the apprehensions of rocky strata associated with the heterogeneity, anisotropy, deformability and unfavourable rock conditions that tend to influence the behaviour of rock masses, a factor of safety of 10 is adopted.

Using FOS (factor of safety) = 10,

$$q_{ns} = 33.8 \text{ t/m2}$$

Obviously, the values of `q_{ns}' for rest of footing parameters being analysed shall be greater than the above value. Thus, allowable bearing capacity values are governed by the settlement criteria.

Settlement Analysis

IS : 13063-1991 recommends that maximum permissible settlement for footings resting on Intact Rock masses values can be taken as 12mm. Higher values can be adopted for weathered and disintegrated rock masses as their capacity to absorb settlements is more than that of intact rocks. Taking into consideration the feed back of field observations a permissible value of 1.50 cms is being adopted in the present case. At all these locations, refusal to SPT was met at levels covering the allowable bearing capacity values. As such, as a conservative approach, bearing capacity analysis is based on N = 50.

The following equation is used to compute `Sob' values.

$$S_{ob} = \frac{14.44 \left(\frac{2B}{B + 0.3}\right)^2}{N-3}$$

$$= \frac{14.44}{47} \left(\frac{2B}{B + 0.3}\right)^2$$

$$= 0.3072 \left(\frac{2B}{B + 0.3}\right)^2$$

`S_{ob}' values for footing widths being analysed work out to be as under:-

Width(m)	1.2	1.5	2.0	2.5
S_{ob}(cms)	0.79	0.85	0.93	0.98

To satisfy the settlement criteria, `q_n' values work out to be as under:-

i) Wall Footings

Width of footings	1.20 m	1.5 m
$q_n (t/m^2)$	19.0	17.6

ii) Column Footings

Size of footings	1.5 m x 2.0 m	2.0 m x 2.5 m	2.5 m x 3.0 m
$q_n (t/m^2)$	17.6	16.1	15.3

RECOMMENDATIONS

Allowable Bearing Capacity Values

Following values of allowable bearing capacity are valid for footings resting at a depth of 1.50 m at the proposed site.

i) Wall Footings

Width of footing	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.20 m	19.0	21.6
1.50 m	17.6	22.2

Average value of $(q_a)_{NET}$ = 18.3 t/m^2 can be adopted for design of foundations resting at a depth of 1.50 m at the proposed site.

ii) Column Footings

Size of footing (B x L)	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.5 m x 2.0 m	17.6	20.2
2.0 m x 2.5 m	16.1	18.7
2.5 m x 3.0 m	15.3	17.9

An average value of $(q_a)_{NET}$ = 16.3 t/m^2 can be adopted for design of foundations resting at a depth of 1.5 m at the proposed site.

SITE: SHAHDRA (SCHOOL)

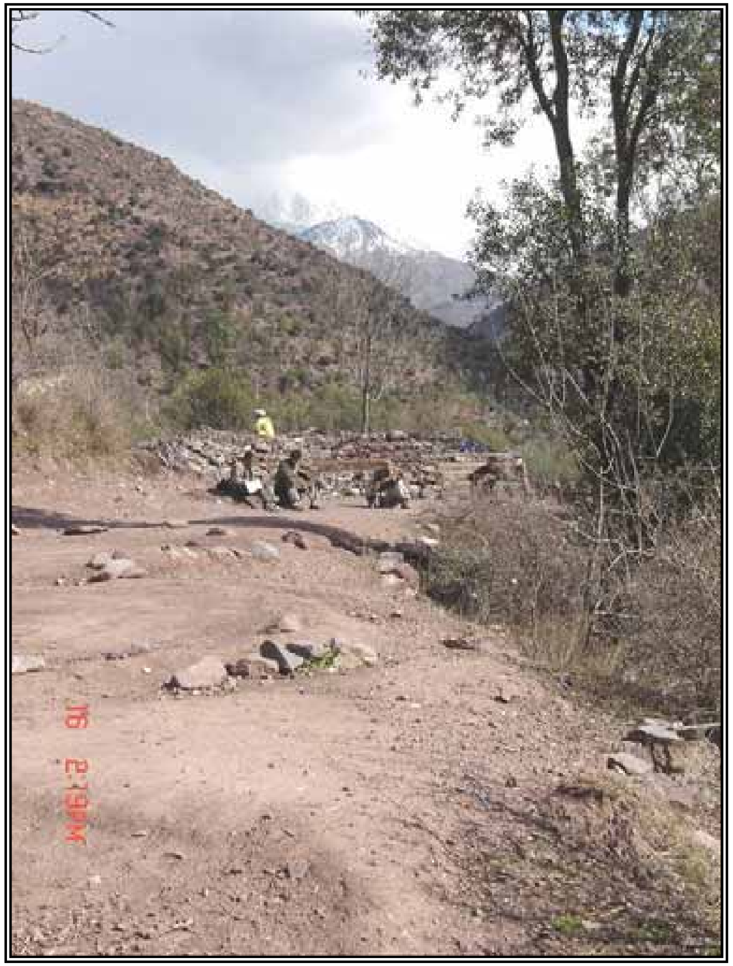
Shahdra site is accessible by motorable route till Sarai followed by a pathway to the village. The school building suffered complete damage during the earthquake and the existing site is the only available location where the school is proposed. The school serves the adjoining villages and hamlets in the vicinity. Shahdra school site is located at an altitude of 1387m and a seasonal nallah flows by the side of this side. The nallah is approximately 20' down from this site and it has no impacts as regard to side slopes. The supporting stratum at the site is hard but friable rock.

Strata Profile

Point	Depth (m)	Nature of Strata
1	ESL to 0.9	CL (Stiff clay)
	0.9 - 2.0	Dense matrix of Cobbles and GC
2	ESL to 0.6	CL (Stiff clay)
	0.6 - 2.0	Dense matrix of Cobbles and GC
3	ESL to 0.6	CL (Stiff clay)
	0.6 - 2.0	Dense matrix of Cobbles and GC
4	ESL to 0.75	CL (Stiff clay)
	0.75 - 2.0	Dense matrix of Cobbles and GC

Profile Properties

Location	Depth from ESL	N
Point 1	In meters	
	1	50 (blows for 21 cm penetration (refusal)
	2	50 (blows for 14 cm penetration (refusal)
Point 2	1	50 (blows for 16 cm penetration (refusal)
	2	50 (blows for 18 cm penetration (refusal)
Point 3	1	50 (blows for 7 cm penetration (refusal)
	2	50 (blows for 14 cm penetration (refusal)
Point 4	1	50 (blows for 19 cm penetration (refusal)
	2	50 (blows for 24 cm penetration (refusal)



SHAHDRA SCHOOL SITE BEING INVESTIGATED

Location	Depth from ESL	Soil Composition			Atterberg Limits (%)		Moisture Content
Point 1	In meters	% Gravel	% Sand	% Fines	LL	PL	%
	1	60.3	21.0	18.7	31.7	21	9.3
	2	50.7	33	16.3	30.8	20.5	10.7
Point 2	1	54.7	27.5	17.8	32.1	21.2	11.7
	2	63.7	23.6	12.7	31.1	21	10.3
Point 3	1	70.4	16.8	12.8	34.2	22.8	8.7
	2	60.3	12.7	27	33	21.9	9.3
Point 4	1	59.3	27	13.7	35	23	9.3
	2	60.3	25	14.7	32.8	22.1	10.2

As per the shear failure analysis, the net ultimate bearing capacity is worked out to be 277.9 t/m^2. Net safe bearing capacity against shear failure works out to be 27.80 t/m^2 considering the factor of safety.

Settlement Analysis

\`S_{ob}' values for footing widths being analysed work out to be as under:-

Width (m)	1.2	1.5	2.0	2.5
S_{ob} (cms)	0.79	0.85	0.93	0.98

To satisfy the settlement criteria, \`q_n' values work out to be as under:-

i) Wall Footings

Width of footings	1.20 m	1.5 m

$q_n (t/m^2)$	19.0	17.6

ii) Column Footings

Size of footings	1.5 m x 2.0 m	2.0 m x 2.5 m	2.5 m x 3.0 m
Q_n (t/m^2)	17.6	16.1	15.3

RECOMMENDATIONS

Allowable Bearing Capacity Values

Following values of allowable bearing capacity are valid for footings resting at a depth of 1.20 m at the proposed site.

i) Wall Footings

Width of footing	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.20 m	19.0	21.0
1.50 m	17.6	19.6

Average value of $(q_a)_{NET}$ = 18.3 t/m^2 can be adopted for design of foundations resting at a depth of 1.20 m at the proposed site.

ii) Column Footings

Size of footing (B x L)	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2

1.5 m x 2.0 m	17.6	19.6
2.0 m x 2.5 m	16.1	18.1
2.5 m x 3.0 m	15.3	17.3

An average value of $(q_a)_{NET}$ = 16.3 t/m^2 can be adopted for design of foundations resting at a depth of 1.2 m at the proposed site.

SITE: BASIGRAN (SCHOOL)

Basigran village is enroute to Sarai, the last destination for motorable route on this route. The site is an elongated patch of land followed by series of patches varying 10-12' thick terraces downwards from the site. The rock exposures are seen at the road head inclining towards the site whereas no shooting stones or rock fall zones are noticed in the vicinity of the site. The geotechnical

BASIGRAN SCHOOL – RETROFITTED BUILDING IS SEEN IN ENCLOSED WHITE BOX investigations also suggested that at about 2m depth the strata is incompressible as per the standard procedures of testing. A seasonal nallah flows by the side of the site. Sub-soil water strata were not met at the site upto a depth of 3.5 meters. The strata at this site is layered with clay fill, very stiff clay and incompressible strata.

Strata Profile

Point	Depth (m)	Nature of Strata
1	ESL to 0.9	Fill by clayey soil
	0.9 - 2.0	CI (Stiff clay)
	Beyond 2.0	Incompressible strata
2	ESL to 1.2	Fill by clayey soil
	1.2 - 3.5	CI (Stiff clay)
	Beyond 3.5	Incompressible strata
3	ESL to 1.2	Fill by clayey soil
	1.2 - 2.5	CI (Stiff clay)
	Beyond 2.5	Incompressible strata
4	ESL to 0.9	Fill by clayey soil
	0.9 - 2.0	Friable rock (Composed of CI)
	Beyond 2.0	Incompressible strata

Profile Properties

Location	Depth from ESL	N	Soil Composition			Atterberg Limits (%)		Moisture Content
Point 1	In meters		% Sand	% Silt	% Clay	LL	PL	%
	0.90	10	13.2	67.7	19.1	37	24.3	12.1
	2	28	11	42	17	36.1	23.2	12.1
Point 2	1	5	10.6	68.4	21	41	24.3	11.9
	2	16	10	57.3	22.7	42.4	25.5	11.9
	3	20	13.2	68.1	18.7	37.4	24.1	10.8

Location	Depth from ESL	N	Soil Composition			Atterberg Limits (%)		Moisture Content
	3.5	50 (blows for 23 cm penetration (refusal)	Incompressible strata					
Point 3	1	6	11.3	64.7	24	44	25	12.5
	2	17	9.6	67.7	22.7	42.9	24.4	12.5
	2.5	50 blows between 2 to 2.5 mts	Incompressible strata					
Point 4	1	39	13.9	64.1	22	43.2	24.8	11.5
	2	50 blows	Incompressible strata					

Shear Failure Analysis

The value of `q_{ns}' is governed by the shear strength characteristics of the supporting strata. Location wise, the nature of supporting strata and the corresponding governing shear strength parameters are given here under:

Location	Nature of Strata Strength Parameters	Governing Shear
Loc-1	CI	$C_u = 0.46$ Kg/cm^2
Loc-2	CI	$C_u = 0.53$ Kg/cm^2
Loc-3	CI	$C_u = 0.55$ Kg/cm^2
Loc-4	Friable Rock	N = 39
	$Ø = 38.5^o$ (As per IS)	

Obviously, Cu = 0.46 Kg/cm^2 leads to conservative values of `q_{ns}'.

Now,

$q_{nf} = C_u \times N_c \times S_c \times d_c$

N_c = Bearing Capacity factor = 5.14 (undrained conditions)

S_c = Shape factor

d_c = Depth factor = 1 + 0.2 x D/B

Using FOS = 2.5,

$q_{ns} = 9.4576 \times S_c \times d_c$

i) Wall Footings

S_c = 1 (Strip action)

`q_{ns}' values for footing widths being analysed work out to be as under :

Width of footing	d_c	q_{ns} (t/m^2)
1.05 m	1.229	11.6
1.20 m	1.20	11.3

ii) Column Footings

$S_c = 1 + 0.2 \times B/L$

`q_{ns}' values for footing sizes being analysed work out to be as under :

Size of footing	S_c	d_c	q_{ns} (t/m^2)
1.2 m x 1.5 m	1.16	1.20	13.2
1.5 m x 1.8 m	1.167	1.16	12.8

Settlement Analysis

The value of `q_n' is governed by the physical and compressibility characteristics of the strata falling within the significant depth of proposed foundations. Results of shear failure analysis lead to the conclusion that if following parameters satisfy settlement criteria, then the rest of the parameters being analysed also satisfy settlement criteria under identical conditions.

a) Wall Footing

B = 1.2 m

$q_n = q_{ns} = 11.3$ t/m^2

b) Column Footing

B x L = 1.5 m x 1.8 m

$q_n = q_{ns} = 12.8$ t/m^2

Perusal of the data shows that characteristics of Loc-2 are critical w.r.t. settlement analysis.

Following expression is used to compute settlement of footings under loads.

$$\text{Sett.} = \frac{H \times C_c}{1 + e_o} \text{ Log } \frac{\acute{o} + \Delta\sigma}{\sigma\acute{o}} \times D_f \times \lambda$$

As per BIS recommendations, maximum permissible settlement values for Wall and columns footings resting on clays can be taken as 6.0 cms. and 7.5 cms respectively .

i) ***Wall Footings***

$q_n = q_{ns} = 11.3$ t/m^2

Sett. = 5.40 cms < 6.0 cms, O'k

ii) ***Column Footings***

$q_n = q_{ns} = 12.8$ t/m^2

Sett. = 5.43 cms < 7.5 cms, O'k

RECOMMENDATIONS

Allowable Bearing Capacity Values
Following values of allowable bearing capacity are valid for footings resting at a depth of 1.2 m at the proposed site.

i) ***Wall Footings***

Width of footings	$(q_a)_{NET}$ (t/m^2)	$(q_a)_{GROSS}$(t/m^2)

1.05 m	11.6	13.6
1.20 m	11.3	13.3

An average value of $(q_a)_{NET}$ = 11.5 t/m^2 can be adopted for design of foundations resting at a depth of 1.2 m at the proposed site.

ii) Column Footings

Size of footings	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.2 m x 1.5 m	13.2	15.2
1.5 m x 1.8 m	12.8	14.8

An average value of $(q_a)_{NET}$ = 13.0 t/m^2 may be adopted for design of foundations resting at a depth of 1.2 m at the proposed site.

CLUSTER II

SITE: GOALTA (HEALTH CENTRE)

Geographically and traditionally Gwalta village is classified in to three sections comprising of different patti's - Gwaltha A including Dapatti and Saugarh; B including Mooripatti and C including Khalsa Patti / Hundi Patti & Bhatakot. The village is located over Murree group of rocks and spread on fairly steep banks of Goalta Nallah. The existing make shift sub centre is operational in Hundi Patti.

SITE AT KHALSA PATTI, GWALTA ACCESSIBLE THROUGH A ROAD.

Khalsa Patti: Khalsa patti is approachable by road and the site is located at an altitude of 1560m. This site has been one of the favourable sites as far as accessibility is concerned to the existing sub centre in hundi patti. The altitude difference between the two sites is approximately 215 m. In principle, the lower order facility should be closer and linked to the higher order facility, which is available in Uri, a distance of approximately 17 kms from Gohalta. The site is an elongated agricultural terrace and very safe in terms of adjoining features.

Hundi Patti: As per the locals, cracks have developed at the top of the ridge and it also resulted in rockfall towards the village as a post earthquake event also. The rock outcrop of shale and metabasics is seen in the vicinity of the site, which are the probable weaker zones in case of a mild earthquake or heavy rains. The slopes are fairly on higher side adjoining the site which is located at 1775 mts.

The site has a moderate slope and is also aligned towards the valley side. The site soil conditions indicated clayey soil with dense matrix of big boulders and GC.

The soil conditions for both the sites is of similar type and constitutes of Soft clay Fill (CL) continuing till the depth of 1.5m and dense matrix of big boulders and GC till 2m. No rock outcrop in the near vicinity is seen.

SITE AT HUNDI PATTI, GWALTA

ADJOINING FEATURES – ROCK OUTCROP – AROUND THE SITE IN HUNDI PATTI

Strata Profile

Location	Point	Depth (M)	Nature of Strata
Gwalta Health Centre (Khalsa Patti)	1	ESL to 1.5	Soft clay Fill (CL)
		1.5 - 2.0	Dense matrix of Big Boulders and GC
	2	ESL to 1.5	Soft clay Fill (CL)
		1.5 - 2.0	Dense matrix of Big Boulders and GC
Gwalta Health Centre (Hundi Patti)	3	ESL to 1.5	Soft clay Fill (CL)
		1.5 - 2.0	Dense matrix of Big Boulders and GC
	4	ESL to 0.5	Soft clay Fill (CL)
		0.5 - 2.0	Dense matrix of Big Boulders and GC

Profile Properties

Location	Depth from ESL	N	Soil Composition			Atterberg Limits (%)		Moisture Content
	In meters		% Sand	% Silt	% Clay	LL	PL	%
Point 1	1	4	-	9.3	87.7	34	23.1	13.9
	1.5	50 blows for 18 cm penetration (refusal)	57.4	20.4	22.2	27.8	20	12.7
Point 2	1	3	-	13.6	86.4	29.6	20.3	10.9
	1.5	50 blows for 12 cm penetration (refusal)	70.3	11	18.7	30.2	21	12.8
Point 3	1	50 blows for 16 cm penetration (refusal)	76	7.9	17.1	29.9	20.7	10.9
	1.5	50 blows for 17 cm penetration (refusal)	66	11.2	22.8	28.6	20.3	10.6
Point 4	1	50 blows for 20 cm penetration (refusal)	66	12.3	21.7	28.9	20.4	12.6
	1.5	50 blows for 16 cm penetration (refusal)	56	14.3	29.7	29.5	20.3	9.2

Under the shear failure analysis, the net ultimate bearing capacity is worked out to be 337.5 t/m^2. Net safe bearing capacity against shear failure works out to be 33.80 t/m^2 considering the factor of safety. The values of `q_{ns}' for rest of footing parameters being analysed shall be greater than the above value. Thus, allowable bearing capacity values are governed by settlement criteria.

As per the settlement criteria and using the prescribed equations as discussed earlier, `S_{ob}' values for footing widths being analysed work out to be as under:-

Width(m)	1.2	1.5	2.0	2.5
S_{ob}(cms)	0.79	0.85	0.93	0.98

To satisfy the settlement criteria, `q_n' values work out to be as under:-

i) Wall Footings

Width of footings	1.20 m	1.5 m
q_n(t/m^2)	22.2	20.6

ii) Column Footings

Size of footings	1.5 m x 2.0 m	2.0 m x 2.5 m	2.5 m x 3.0 m
q_n(t/m^2)	20.6	18.8	17.9

RECOMMENDATIONS

Allowable Bearing Capacity Values

Following values of allowable bearing capacity are valid for footings resting at a depth of 1.50 m at the proposed site.

i) Wall Footings

Width of footing t/m²	$(q_a)_{NET}$ t/m²	$(q_a)_{GROSS}$
1.20 m	22.2	24.8
1.50 m	20.6	23.2

Average value of $(q_a)_{NET}$ = 21.4 t/m² may be adopted for design of foundations resting at a depth of 1.50 m at the proposed site.

ii) Column Footings

Size of footing (B x L)	$(q_a)_{NET}$ t/m²	$(q_a)_{GROSS}$ t/m²
1.5 m x 2.0 m	20.6	23.2
2.0 m x 2.5 m	18.8	21.4
2.5 m x 3.0 m	17.9	20.5

An average value of $(q_a)_{NET}$ = 19.1 t/m² may be adopted for design of foundations resting at a depth of 1.50 m at the proposed site.

SITE: DARDKOT (SCHOOL)

DARDKOT SITE 1 – A NEWLY CONSTRUCTED HOUSE, ADJOINING THE SCHOOL SITE.

THE SITE IS ENCLOSED BETWEEN BASE ROCKS AND IS INDICATED BY ARROWS

The village is located along the upper banks of dardkot nallah, tributary of Nawa rundan stream and rests over a terrace of moderately sloping hills of murree group of rocks. The lower potion of the village is spread over this plateau like terrace. Intensely folded sections are seen in this stretch looking towards NE.

The school site is located along the road to the village over a terrace with a thickness of around 20' with breaks of 6'and 12' each. Dardkot is water rich pocket, a canal runs beside the school site. The site is totally enclosed between the base rocks visible at the site, which are also from the murree group of rocks. Between these are seen the rock exposures and loose profile.

LOOKING NW OF DARDKOT SCHOOL – ROAD TO NAWA IS SHOWN WITH WHITE LINE AND FOLDED SEQUENCE OF ROCKS IS SEEN ABOVE

There are another two sites in series. The second one is the land where the construction of a three-room building for middle school has been completed. Here rock exposures are seen in the background and the site morphology is again of very moderate slope with irregular plots, which is very common.

Strata Profile

Location	Point	Depth (m)	Nature of Strata
Dardkot School - 1 (Kamar Ali Land)	1	ESL to 1.5	CI (Stiff clay)
		1.5 - 2.0	Dense Bouldry Strata

	2	ESL to 0.6	CL (Stiff clay)
		0.6 - 2.0	Big Boulders having gravely clay as an intervening material (Dense Matrix)
	3	ESL to 0.7	CL (Stiff clay)
		0.7 - 2.0	Big Boulders having gravely clay as an intervening material (Dense Matrix)
Dardkot School – 2 (Mir Ahmed Land)	4	ESL to 1.1	CL (Stiff clay)
		1.1 - 2.0	Big Boulders having gravely clay as an intervening material (Dense Matrix)
Dardkot School – 3 (Ali Khan's Land)	5	ESL to 1.0	CL (Stiff clay)
		1.0 - 2.0	Big Boulders having gravely clay as an intervening material (Dense Matrix)
	6	ESL to 0.9	CL (Top Layer of clay of low plasticity)
		0.9 - 2.0	Big Boulders having gravely clay as an intervening material (Dense Matrix)
	7	ESL to 0.7	CL (Top Layer of clay of low plasticity)
		0.7 - 2.0	Clay Shale (Composed of CL)

Strata Properties

Location	Depth from ESL	N	Soil Composition			Atterberg Limits (%)		Moisture Content
Dardkot	In meters		% Sand	% Silt	% Clay	LL	PL	%
Site 1	1	10	4	9.2	86.8	36.8	24.3	15
	2	50 blows for 16 cm penetration (refusal)	60.3	21	18.7	30.7	20.3	12.7
	1	50 blows for 21 cm penetration (refusal)	58.1	10.1	31.4	37.3	24.5	12.4
	2	50 blows for 12 cm penetration (refusal)	64.3	9	26.7	34	23.1	11.8
Site 2	1	50 blows for 17 cm penetration (refusal)	60.2	8.7	31.1	38.3	24.4	12
	2	50 blows for 14 cm penetration (refusal)	67.3	7.6	25.1	37.1	23.9	10.8
	1	50 blows for 20 cm penetration (refusal)	25	11.7	63.3	38.7	24.5	14
	2	50 blows for 18 cm penetration (refusal)	70.2	8.9	20.9	35.3	23.4	10.1
Site 3	1	50 blows for 16 cm penetration (refusal)	56.3	11.2	35.5	36.2	23.8	10.7
	2	50 blows for 12 cm penetration (refusal)	67.8	9.6	22.6	37.1	24.2	9.3

DARDKOT SCHOOL SITE 2 – MUSHTAQ MIR'S LAND. THE BROWN ENCLOSED BOX INDICATES TWO BUILDINGS WHICH WERE DAMAGED DURING THE EARTHQUAKE AND THE WHITE BOX INDICATES THE NEWLY CONSTRUCTED BLOCK.

Shear Failure Analysis

Location wise governing parameters are as under:

Location	Nature of Strata	Governing Parameters
Loc-1	CI	$C_u = 0.48$ Kg/cm^2
Loc-2	Bouldry Strata	N = 50 ; Ø = 40.7^o (As per IS)
Loc-3	Bouldry Strata	N = 50 ; Ø = 40.7^o (As per IS)
Loc-4	Bouldry Strata	N = 50 ; Ø = 40.7^o (As per IS)
Loc-5	Bouldry Strata	N = 50 ; Ø = 40.7^o (As per IS)

It is Judicious as well as Justifiable to base the analysis on the data representing the least favourable condition. This condition pertains to the data of Loc-1.

As such, C_u = 0.48 kg/cm^2 leads to conservative values of q_{ns}.

Now,

$q_{nf} = C_u \times N_c \times S_c \times d_c$

N_c = Bearing Capacity Factor = 5.14 (Undrained conditions)

S_c = Shape factor = 1 +0.2 x B/L

d_c = Depth factor = 1 + 0.2 x D/B

Using FOS = 2.5,

$q_{ns} = 9.8688 \times S_c \times d_c$

i) Wall Footings

S_c = 1 (Strip action)

`q_{ns}' values for footing widths being analysed work out to be as under :

Width of footing	d_c	q_{ns} (t/m^2)
1.05 m	1.229	12.1
1.20 m	1.20	11.8

ii) Column Footings

$S_c = 1 + 0.2 \times B/L$

`q_{ns}' values for footing sizes being analysed work out to be as under :

Size of footing	S_c	d_c	q_{ns} (t/m^2)
1.2 m x 1.5 m	1.16	1.20	13.7
1.5 m x 1.8 m	1.167	1.16	13.3

Settlement Analysis

The value of `q_n' is governed by the physical and compressibility characteristics of the strata falling within the significant depth of proposed foundations. Results of shear failure analysis lead to the conclusion that if following parameters satisfy settlement criteria, then the rest of the parameters being analysed also satisfy settlement criteria under identical conditions.

i) Wall Footing

$B = 1.20$ m

$q_n = q_{ns} = 11.8\ t/m^2$

ii) Column Footing

$B \times L = 1.5$ m x 1.8 m

$q_n = q_{ns} = 13.3\ t/m^2$

Perusal of the data shows that characteristics of Loc-1 are critical w.r.t. settlement analysis.
Following expressions are used to compute settlement of footings under loads.

a) Clay Layer

$$\text{Sett.} = \frac{H \times C_c}{1 + e_o} \text{Log} \frac{\sigma ó + \Delta\sigma}{\sigma ó} \times D_f \times \qquad \ldots\ldots\ldots\ldots.(1)$$

b) Bouldry/ Rocky Layer

Sett. = $S_o \times \Delta\sigma_t$ ....(2)

As a conservative approach, maximum permissible settlement value for the layered system governing settlement can be adopted as 2.50 cms.

i) Wall Footings

$q_n = q_{ns} = 11.8\ t/m^2$

S_1 = Sett. due to Layer I = 1.49 cms

S_2 = Sett. due to Layer II = 0.68 cms

S_t = 2.17 cms < 2.5 cms, O'k

ii) Column Footings

$q_n = q_{ns} = 13.3\ t/m^2$

S_1 = Sett. due to Layer I = 1.42 cms

S_2 = Sett. due to Layer II = 0.78 cms

S_t = 2.20 cms < 2.5 cms, O'k

RECOMMENDATIONS

Allowable Bearing Capacity Values

Following values of allowable bearing capacity are valid for footings resting at a depth of 1.2 m at the proposed site.

i) Wall Footings

Width of footings	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.05 m	12.1	14.1
1.20 m	11.8	13.8

An average value of $(q_a)_{NET}$ = 12.0 t/m^2 may be adopted for design of foundations resting at a depth of 1.2 m at the proposed site.

ii) Column Footings

Size of footings	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.2 m x 1.5 m	13.7	15.7
1.5 m x 1.8 m	13.3	15.3

An average value of $(q_a)_{NET}$ = 13.5 t/m^2 may be adopted for design of foundations resting at a depth of 1.2 m at the proposed site.

Cluster III

SITE: GOHALAN (HIGH SCHOOL)

Gohalan village is one amongst the farthest of all the programme villages and is located at an altitude ranging from 1850m to 1990m. The other two sites i.e. near masjid and old school building are not among the favourables among the community due to their concerns regarding security/safety. The probable site for the high school is a stable terrace of much in elongated shape and generally a flat land. A local nallah flows by the side of the site. The rock outcrop is observed in the background of the site, the rock types are largely quartzite and murree shale group. A dense matrix of cobbles and GC was observed till the top layer followed by big boulders (sandstone) and GC.

HIGH SCHOOL SITE IN GOHALAN. A STREAM FLOWS ALONG THE SITE INDICATED WITH BLUE LINE

Strata Profile

Site	Point	Depth (m)	Nature of Strata
Gohalan High School	1	ESL - 2.0	Dense matrix of Big Boulders and GC
	2	ESL - 1.0	Dense matrix of Cobbles and GC
		1.0 - 2.0	Dense matrix of Big Boulders and GC
	3	ESL - 2.0	Dense matrix of Big Boulders and GC

Profile Properties

Location	Depth from ESL	N	Soil Composition			Atterberg Limits (%)		Moisture Content
	In meters		% Sand	% Silt	% Clay	LL	PL	%
Point 1	1	15 blows for 17 cm penetration	62	13.9	24.1	37.4	24.4	11.2
	2	15 blows for 12 cm penetration (refusal)	70	18.5	11.5	36.8	24	10.8
Point 2	1	15 blows for 18 cm penetration (refusal)	60	12.9	27.1	32.7	22.4	11
	2	15 blows for 13 cm penetration (refusal)	58	24.40	17.6	36.2	23.8	10.1
Point 3	1	15 blows for 12 cm penetration (refusal)	58.4	15.7	25.9	31.7	23.7	7.8
	2	15 blows for 9 cm penetration (refusal)	60.3	16.3	23.4	32.4	22.5	8.6

Under the shear failure analysis, the net ultimate bearing capacity is worked out to be 277.9 t/m^2. Net safe bearing capacity against shear failure works out to be 27.80 t/m2 considering the factor of safety. The values of \`q_{ns}' for rest of footing parameters being analysed shall be greater than the above value. Thus, allowable bearing capacity values are governed by settlement criteria.

Settlement Analysis indicate the following results:

\`S_{ob}' values for footing widths being analysed work out to be as under:-

Width(m)	1.2	1.5	2.0	2.5
S_{ob}(cms)	0.79	0.85	0.93	0.98

To satisfy the settlement criteria, `q_n' values work out to be as under:-

i) ***Wall Footings***

Width of footings	1.20 m	1.5 m
$q_n(t/m^2)$	20.3	18.8

ii) ***Column Footings***

Size of footings	1.5 m x 2.0 m	2.0 m x 2.5 m	2.5 m x 3.0 m
$q_n(t/m^2)$	18.8	17.2	16.3

RECOMMENDATIONS

Allowable Bearing Capacity Values

Following values of allowable bearing capacity are valid for footings resting at a depth of 1.20 m at the proposed site.

i) Wall Footings

Width of footing	$(q_a)_{NET}$ t/m²	$(q_a)_{GROSS}$ t/m²
1.20 m	20.3	22.3
1.50 m	18.8	20.8

Average value of $(q_a)_{NET}$ = 19.6 t/m² may be adopted for design of foundations resting at a depth of 1.20 m at the proposed site.

ii) Column Footings

Size of footing (B x L)	$(q_a)_{NET}$ t/m²	$(q_a)_{GROSS}$ t/m²
1.5 m x 2.0 m	18.8	20.8
2.0 m x 2.5 m	17.2	19.2
2.5 m x 3.0 m	16.3	18.3

An average value of $(q_a)_{NET}$ = 17.4 t/m² may be adopted for design of foundations resting at a depth of 1.2 m at the proposed site.

SITE : GOHALAN (HEALTH CENTRE)

The existing health centre in the village is being planned for expansion and the available site is not sufficient as well as not in use due to the damage done during the earthquake. The site for health centre is a very small patch of agricultural land located near the old health centre at an altitude of 1870 m. The site slopes nearly 10^0.

Strata Profile

Point	Depth (m)	Nature of Strata
1	ESL to 1.2	Gravels mixed with clay (CL)
	1.2 - 2.0	Dense Bouldry deposit
2	ESL to 0.9	Gravels mixed with clay (CL)
	0.9 - 2.0	Dense Bouldry deposit

HEALTH CENTRE SITE IN GOHALAN - A SMALL AGRICULTURAL TERRACE JUST ABOVE THE EXISTING HEALTH CENTRE

Profile Properties

Location	Depth from ESL	N	Soil Composition			Atterberg Limits (%)		Moisture Content
	In meters		% Sand	% Silt	% Clay	LL	PL	%
Point 1	1	15 blows for 21cm penetration	13	9.3	77.7	33.4	22.6	5.2
	2	15 blows for 14 cm penetration (refusal)	60.7	25	14.3	27.4	19	8.4
Point 2	1	15 blows for 12 cm penetration (refusal)	60.4	24.9	14.7	25.4	18	7.8
	2	15 blows for 16 cm penetration (refusal)	70.4	15.9	13.7	26.7	18.9	8.4

RECOMMENDATIONS

Allowable Bearing Capacity Values

i) Wall Footings

Width of footing	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.20 m	20.3	22.3
1.50 m	18.8	20.8

Average value of $(q_a)_{NET}$ = 19.6 t/m^2 may be adopted for design of foundations resting at a depth of 1.20 m at the proposed site.

ii) Column Footings

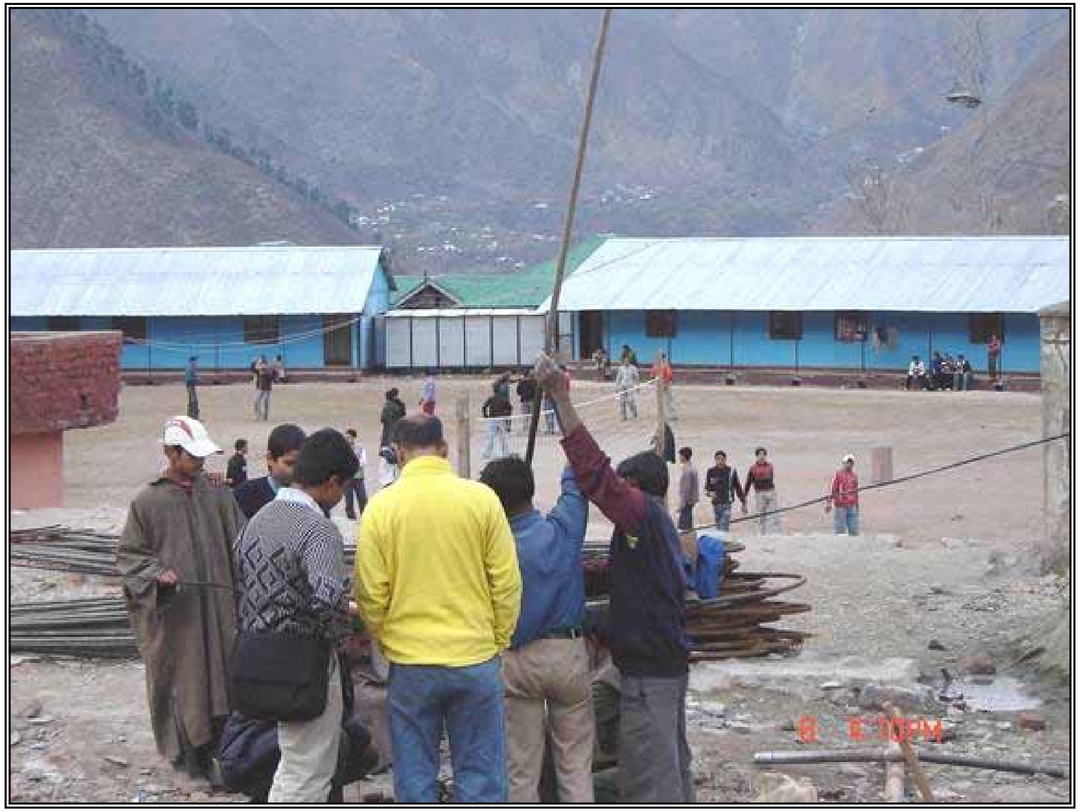
Size of footing (B x L)	$(q_a)_{NET}$ t/m^2	$(q_a)_{GROSS}$ t/m^2
1.5 m x 2.0 m	18.8	20.8

2.0 m x 2.5 m	17.2	19.2
2.5 m x 3.0 m	16.3	18.3

An average value of $(q_a)_{NET}$ = 17.4 t/m^2 may be adopted for design of foundations resting at a depth of 1.2 m at the proposed site.

SITE: URI SCHOOL

The site is located well within the Uri town. A middle and high school is proposed for construction. This will be the higher hierarchy facility over an area of 3000 sq mts. The site is flat and the level difference between the high and the middle school is approximately 6'. A nallah flowing down has primary interface with the sub surface of the site, this might be due to the unconfined hill acquifer pocket beneath the site. This fact is also supported by the fact that out of four places, water pocket was struck at a depth of 3 m at three points.



URI SCHOOL SITE - AROUND THE SCHOOL IS A LARGE OPEN SPACE, THE SITE IS BOUNDED BY ROADS ON TWO SIDES.

No rock exposures are seen at the site and its vicinity. The nallah is flowing nearly 50 mts away from the side in NWN flow.

SUBSURFACE WATER EMERGED AT THE SITE – THREE OUT OF FOUR BOREHOLES REPRESENTED THE SIMILAR FEATURE.

Strata Profile

Location	Point	Depth (m)	Nature of Strata
Uri High and Middle School	1	NSL - 1.2	CL (Stiff clay)
		1.2 - 6	CI (Stiff/very stiff clay)
	2	NSL - 1.2	CL (Stiff clay)
		1.2 - 2.5	CL (Stiff clay)
		2.5 - 6.0	CI (Stiff/very stiff clay)
	3	NSL - 2.2	CI (Stiff/very stiff clay)
		2.2 - 3.3	CL (Stiff clay)
		3.3 - 6.0	CL (Stiff clay)
	4	NSL - 6.0	CI (Firm to Stiff clay)

Four boreholes, each manually drilled upto a depth of 6.0 m were used so as to carry out the desired investigations. Sub-soil water was met at a depth of around 2.5 m at the proposed site. Though the strata is of stiff to very stiff clay but liquefaction is ruled out on the grounds that liquefaction is most commonly observed in shallow, loose, saturated deposits of cohesionless soils subjected to strong ground motions in large magnitude earthquakes. Unsaturated soils are not subject to liquefaction because volume compression does not generate excess pore pressures. Liquefaction and large deformations are more likely with contractive soils while cyclic softening and limited deformations are associated with dilative soils. Soils deposited prior to the Holocene epoch (more than 10,000 years old) are usually not prone to liquefaction (Youd and Perkins 1978), perhaps due to weak cementation at the grain contacts. While liquefaction is usually associated with sands or silts, gravelly soils have also been known to liquefy. Rounded soil particles of uniform size are generally the most susceptible to liquefaction (Poulos et al. 1985). Clays with measurable plasticity are resistant to the relative movement of particles during cyclic shear loading and are generally not prone to pore pressure generation and liquefaction. Soils with significant plastic fines content are rarely observed to liquefy in earthquakes. In general soils with a significant plasticity are not susceptible to liquefaction.

Shear Failure Analysis

The value of \`q_{ns}' is governed by the shear strength characteristics of the supporting strata. Borehole wise the nature of supporting strata and the corresponding governing shear strength parameters are given here under:

Borehole	Nature of Strata	Governing Shear Strength Parameters
BH-1	ML-CL	C_u = 0.51 Kg/cm^2
BH-2	ML-CL	C_u = 0.49 Kg/cm^2
BH-3	ML-CL	C_u = 0.47 Kg/cm^2
BH-4	ML-CL	C_u = 0.45 Kg/cm^2

Obviously, C_u = 0.45 Kg/cm^2 leads to conservative values of `q_{ns}'.

Now,

q_{nf} = $C_u \times N_c \times S_c \times d_c$

N_c = Bearing Capacity factor = 5.14 (undrained conditions)

S_c = Shape factor

d_c = Depth factor = 1 + 0.2 x D/B

Using FOS = 2.5,

$q_{ns} = 9.252 \times S_c \times d_c$

i) Wall Footings

S_c = 1 (Strip action)

`q_{ns}' values for the footing widths being analysed work out to be as under :

Width of footings	d_c	q_{ns} (t/m^2)
1.05 m	1.229	11.4
1.20 m	1.20	11.1

ii) Column Footings

$S_c = 1 + 0.2 \times B/L$

`q_{ns}' values for the footing sizes being analysed work out to be as under :

Size of footing	S_c	d_c	$q_{ns}(t/m^2)$
1.2 m x 1.5 m	1.16	1.20	12.9
1.5 m x 1.8 m	1.167	1.16	12.5

Settlement Analysis

Results of shear failure analysis reveal that if the following footing sizes under their respective `$q_n = q_{ns}$' values satisfy settlement criteria, then the rest of the footing sizes under their respective `$q_n = q_{ns}$' values shall also satisfy the settlement analysis.

D = 1.2 m

a) Wall Footing

B = 1.2 m

$q_n = q_{ns} = 11.1\ t/m^2$

b) Column Footing

B x L = 15 m x 1.8 m

$q_n = q_{ns} = 12.5\ t/m^2$

Perusal of the borehole data shows that characteristics of BH-4 are critical w.r.t. settlement analysis. Computation from the shear failure and results for settlement in both cases is

i) Wall Footings

$q_n = q_{ns} = 11.1\ t/m^2$

Sett. = 5.69 cms < 6.0 cms, O'k

ii) Column Footings

$q_n = q_{ns} = 12.5\ t/m^2$

Sett. = 5.70 cms < 7.5 cms, O'k

RECOMMENDATIONS

Allowable Bearing Capacity Values

Following values of allowable bearing capacity are valid for footings resting at a depth of 1.2 m at the proposed site.

i) Wall Footings

Width of footing	$(q_a)_{NET}$ (t/m²)	$(q_a)_{GROSS}$ (t/m²)
1.05 m	11.4	13.4
1.20 m	11.1	13.1

An average value of $(q_a)_{NET}$ = 11.3 t/m^2 may be adopted in footing design.

ii) Column Footings

Size of footing (B x L)	$(q_a)_{NET}$ (t/m^2)	$(q_a)_{GROSS}$ (t/m^2)
1.2 m x 1.5 m	12.9	14.9
1.5 m x 1.8 m	12.5	14.5

An average value of $(q_a)_{NET}$ = 12.7 t/m^2 may be adopted in footing design.

Apart from the site specific analysis and data for foundation designing for both framed and load bearing structures, the following are the basic key measures which shall be kept in mind while planning the construction of the respective infrastructure in the locality.

A diagrammatical representation of the wall and column footings alongwith the stress distribution pyramid is presented. The various symbols in the figures represent the following;

e_0 = Original void ratio

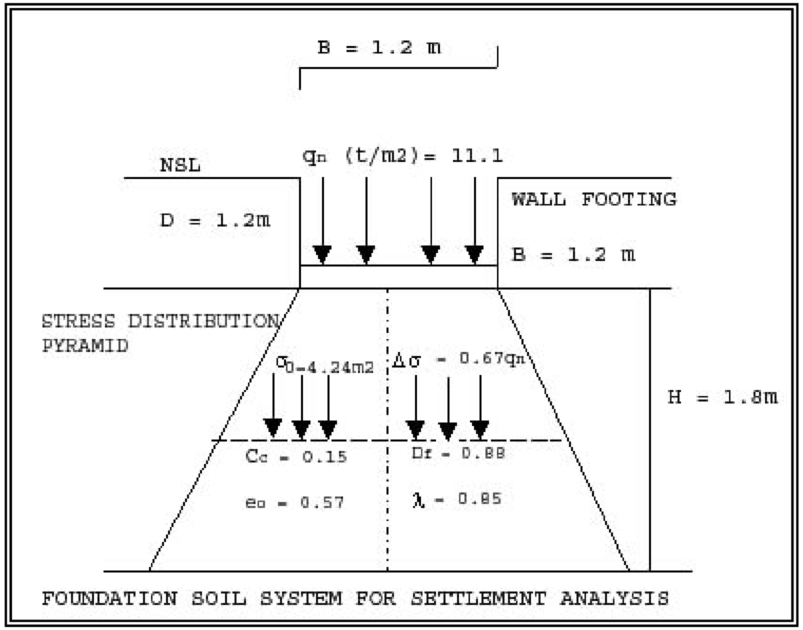
σ_0 = Original effective overburden pressure

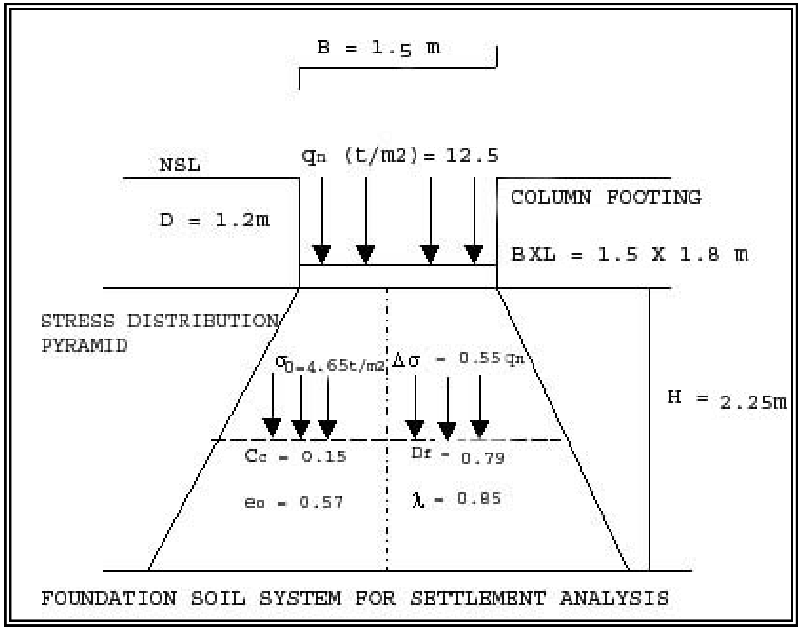
$\Delta\sigma$ = Vertical stress increment

C_c = Compression Index

D_f = Depth factor

λ = Lateral yield factor





Suggested Measures Against Damages/Distresses Due to Earthquake and Differential Settlements

Tie Beams

In case of RCC framed structures without basement all columns should be connected to each other in both directions at or below plinth level.

Plinth Beams and RCC Bands

Load bearing masonry should be braced using Plinth beams and RCC Bands (Lintel and Roof).

8.4 Chemical Analysis of Soil Samples

The object of the chemical analysis of soil samples is to assess their aggressive nature towards concrete foundations. The results of chemical analysis based on maximum value obtained from three samples for various sites are reported hereunder:

Site	pH Value	Sulphates as SO_4 (%)	Chlorides as Cl (%)
Health Centre at Sultan Daki	7.5	0.037	0.015
Middle School at Village Shahdra	7.7	0.029	0.011
Middle School at Village Basigran	7.4	0.023	0.013
Health Centre at Khalsa Pati and Hundi Patti at Village Gwaltha,	7.6	0.025	0.018
Middle School at Village Dardkot	7.6	0.028	0.013
High School at Village Gohalan	7.8	0.034	0.019
Health Centre at Village Gohalan	7.7	0.029	0.028
Girls Higher Secondary and Middle School URI	7.6	0.028	0.023

Note: Chemical analysis at alternative site of Dardkot, Gwaltha indicated negligible variation and are consolidated in the table above

The pH value of soil samples vary from 7.4 to 7.8. The soils having pH less than 6.0 are acidic and deterimental to concrete. Hence, the soil at the sites is not harmful to concrete w.r.t. pH value. The sulphate content varies from 0.023% to 0.037%. As per Table-5 given in CP-110: Part-1: 1972 (The structural use of concrete, British Standards Institution), sulphates as SO_4 less than 0.24% are not harmful for concrete. Since the sulphate content is less than 0.24% as such, the soil at sites is non- aggressive w.r.t. sulphates.

In so far as chlorides are concerned, a similar classification is not available. However, a fifty-year survey of foundations of certain concrete structures made else where has shown that chlorides of the order of 0.5% to 1.0% would be positively aggressive. The chloride contents in our case vary from 0.011% to 0.028%. Thus, the soil at sites is non-aggressive w.r.t. chloride contents.

Thus investigations lead to the conclusion that the sub-soil is non-aggressive to concrete structures at all the sites.

Abbreviations

N	=	Observed SPT value
N'	=	Normalised SPT value
γ	=	Bulk unit weight
γ'	=	Submerged unit weight
γ_d	=	Dry unit weight
γ_{sat}	=	Saturated unit weight
LL	=	Liquid limit
PL	=	Plastic limit
$\varnothing'$	=	Effective angle of shearing resistance
$\varnothing_m$	=	Mobilised angle of shearing resistance
$N\varnothing$	=	Flow value $Tan^2 (45+\varnothing/2)$
GSF	=	General shear failure
LSF	=	Local shear failure
B	=	Width of foundation
L	=	Length of foundation
D	=	Depth of foundation
q	=	Effective surcharge
N_γ, N_q & N_c	=	Bearing capacity factors
S_γ, S_q & S_c	=	Shape factors
d_γ, d_q & d_c	=	Depth factors
H	=	Thickness of clayey layer
σ'_o	=	Original effective overburden pressure
$\Delta\sigma$	=	Vertical stress increment
e_o	=	Original void ratio
w	=	Water content
H_t	=	Thickness of sandy layer
B_t	=	Top width of sandy layer
$\Delta\sigma_t$	=	Stress increment at the top of a sandy layer
D_f	=	Depth factor
λ	=	Lateral yield factor
R_f	=	Rigidity factor
q_{nf}	=	Net ultimate bearing capacity
q_{ns}	=	Net safe bearing capacity against shear failure
q_n	=	Net foundation loading intensity for a given settlement
q_a	=	Allowable bearing capacity
S_o	=	Settlement due to a net unit foundation loading intensity ($1 kg/cm^2$)
S_{ob}	=	Settlement due to a net unit foundation

loading intensity under submerged conditions (1kg/cm^2)

WT	=	Water table
S_t	=	Total settlement
S_a	=	Maximum allowable settlement
GW	=	Well graded gravels
GP	=	Poorly graded gravels
GM	=	Silty gravels
GC	=	Clayey gravels
SW	=	Well graded sands
SP	=	Poorly graded sands
SM	=	Silty sands
SC	=	Clayey sands
ML	=	Silt of low compressibility
CL	=	Clay of low plasticity
MI	=	Silt of medium compressibility
CI	=	Clay of medium plasticity
MH	=	Silt of high compressibility
CH	=	Clay of high plasticity
M(NP)	=	Non plastic silt
ML-CL	=	Mixture of ML and CL

CHAPTER 8.0

CONCLUSIONS AND RECOMMENDATIONS

The study of the earthquake-affected Uri region clearly indicates that it is a highly disturbed tectonic zone. Numerous neotectonic events bear witness to this and the intepretation of seismic and collateral information forewarns of continuing seismic activity. The region is emerging out of the trauma caused by seismic activity and reconstruction is still in progress. Uri was the worst affected on the Indian part and intensity of damage progressively decreased towards the South East. The folded rock sequences along the Jhelum, the imbricate and splayed nature of faults and the recurring landslides are indicative of the region being under continuous movement. These add to the structural complications in the Kashmir syntaxis.

Based on the Probabalistic Seismic Hazard Analysis, the PGA values vary between 149 cm/sec^2 to 165 cm / sec^2 in case of 20% exceedance while it varies between 213 cm/sec^2 to 231 cm/sec^2 in case of 10% exceedance for a return period of 50 years. The entire region is thus highly risk prone.

The discrete element analysis for the region has allowed us to distinguish the following classes ranging from low – moderate – high – very high hazard zones. Nine elements were found to be in the 'very high' hazard zone followed by 21 in 'high' hazard zone.

The town of Uri, Village Sultan Daki, Basgran are the localities in the very high risk zone, the MBT funtioning as a dominant propagator and several of the lineaments noticed and inferred also adding to very high hazard factor, apart from the physiogrpahical features. The splay of MBT also passes through the localities of paran pillan and lagama, which are located NE and

SE respectively. This is a region, which is differentiated by the neotectonic fault, which bisects the region and runs NNW and also defines the Murree group from the others in the region. The well knowm *kala nallah* also passes very close to the village of Sultan Daki and extends downwards towards jhelum. Three sites were investigated in this risk zone.

The high hazard zone is the one surrounding the ‘very high’ risk zone. The villages of Dachi, Naupura, Sukdhar, Shahdra and Chappar are in the high hazard zone. The neotectonic fault runs through the villages of Shahdra and Chappar. In this zone too, several local fractures and ground features have been noticed. One site i.e. Shahdra was taken up for geotechnical investigations in this hazard zone.

The villages of Gohalan, Sangrain, Jabla, Isham, Nawa, Dardkot are in the moderate hazard zone. These localities are located within the Murree group. This region is also marked by severely folded sequence of rocks and several fracture lineaments are noticed in this zone. There are several lineaments running near to the villages of Dardkot, Nawa and Isham. Five sites were investigated for geotechnical interpretations.

The low hazard zone is predominantly in the NW and SW part of the region and the zone is inhabited by lesser number of settlements as compared to another zones. The villages of Gwaltha, Chakra, Urusa and Dulanja are in this low hazard zone. Two sites were investigated in this zone.

Though there are four varying classes of hazard but these are relative to each other and do not declare the region as a whole as a low hazard zone. All recommended measures regarding specific sites, need to be followed in order to mitigate the risk from future earthquakes.

The clay strata were found in Uri School and Basigran School. The index and engineering properties of the clay strata show that the over consolidated clays possess stiff to very stiff consistency. Infact such clays develop negative pore pressures when subjected to shear strains under undrained conditions due to earthquake types of loadings. As a result shear strength increases and strata remains stable. The compression index C_c vary over a narrow range of 0.10 to 0.15 which indicates that the strata is subject to low compressibility.

The bouldary strata are a matrix of boulders, cobbles, pebbles, gravels and soil as intervening material. The intervening soils have binding and cementatious effects and the whole matrix met at several locations was found to have dense state of compactness as established by the penetration tests. The chemical analysis of the soils also indicates that sub-soil is non-aggressive to concrete structures at all the sites. The site-specific recommendations are as follows:

S.No	Site	Remarks	Recommendations
1.	Sultan Daki Health Centre	A single site was available where the earlier health center building was constructed which collapsed during the earthquake. The site fulfils the criteria of accessibility, safety from rockfall zone and bounded by standing trees. However as per the analysis the site falls under the high hazard zone as the thrust pass through this region.	The site requires proper drainage work for storm water, which during the heavy rains might affect the building structures. Retention walls along the road shall also be thought of by the site engineers. The site is suitable while considering the use of recommended parameters worked out for the site.
2.	Shahdra School	A single site was available for the school. Though the site is accessible by pathway but it has been serving the adjoining hamlets and villages (Chappar, Sarai,	Across the nala loose rock exposures along the cliff are noticed, but are of no threat to the school site as sufficient buffer is available. It is

		Jabra, Marthan etc). In the vicinity there are no specific risk factors, which may affect the site.	recommended to construct retention wall along the nala to prevent land subsidence by the sides of nallah. The site is suitable for construction, incorporating recommended engineering measures and site preparation aspects associated with it.
3.	Basigran School	The school is located over an elongated patch of land of approximately 30' width. A portion of the old building has been retrofitted. The strata comprise of stiff clay and friable rock till 2.0 mts. No sub surface water intrusion is noticed.	The site is safe from any rockfall zone and the particular site has also indicated hard strata when compared to the available rock types found near the road head (exposures noticed around were that of shale and sandstone). Moreover the expanding terrace towards River Jhelum was also observed to be stable (expanding from school site towards Jhelum). The site is suitable for construction of the school building.
4.	Gwalta Health Centre	Two sites were investigated; one in Khalsa Patti and the other in Hundi Patti. In comparison to both the sites the Khalsa patti site is the best suitable site as per its accessibility and safety factors.	As no major fracture patterns were seen during the site visits, the Khalsa patti site offers accessibility, safer zone as far as adjoining features are concerned. Though both the sites returned the similar strata but the Hundi patti site is not recommended due to site layout and its closeness to exposed rock outcrops and

			probable cracks developed on top of hill. It is recommended that Khalsa patti site is suitable for construction purposes.
5.	Dardkot School	Largely the whole settlement is located over moderately sloping terrace of Murree group of rocks. Three sites were investigated for locating the safer site. The site no. 2 i.e. of Mushtaq Mir's land is ruled out due to lack of space requirements while looking at other factors of safety. The site no. 1 is accessible through road and the previous school was also constructed at this location. The clear visibility of base rock at the site further strengthens the site parameters. The site no. 3 (Ali Khan) is a more flatter and space requirements could be met, if land requirements are negotiated with the owner.	As per the existing conditions the site no. 1 holds the higher priority than the site no. 3 due to certain constraints as discussed in this section. As site no. 1 (Kamar Ali's Land) is also prone to rockfall, it is recommended that site no. 3 i.e. Ali Khan's land be negotiated for the construction of the school building as the site offers consolidated area and less prone to risks of sliding and subsistence.
6.	Gohalan High School	Sufficient land has been earmarked for the school and the site pose no serious risks from the adjoining hills, which are moderately sloping, rock outcrops are seen but there is no close contact treats to the site as such.	The site offers sufficient evacuation and accessibility options, and is recommended for construction of school while incorporating the design parameters suggested. The education department and administration have already initiated the preparatory work for the school.
7	Gohalan	The site is located in the inner part of the Chootawali	It is however recommended to select better

	Health Centre	hamlet. Though the site is safe from any probable landslide, rockfall/shooting stone or any other type of mass wasting phenomena in near vicinity but eastern stretch of the hill lock had developed cracks during the past earthquake and land slipping is reported. Small pieces of loose boulders also reported to have fallen during the rainy season.	location within the village and if possible near the roadside for long term safety and better use of the facility proposed to be developed in the village The ridge of the hillock has developed ground cracks with loose land mass which may get destabilized during heavy rains or due to ground shaking even with mild tremors.
8	Uri School	Uri school is one of the largest school area buildings to be constructed by Aga Khan Foundation. A high and a middle school are planned. The striking feature of this site has been that out of four boreholes, three of them showed water intrusion at a depth of 2.5 mts. Though liquefaction was observed by team of experts in the Baramulla region and near Kichama-Shala Teng village, about 9 km from Baramulla town on the Baramulla-Muzaffarabad road on the left bank of Jhelum river. However the liquefaction of the site for Uri school is ruled out as the geotechnical parameters suggested.	The nature of supporting strata met at the site is stiff to very stiff clay upto explored depth where the sub soil water occurred at 2.5mts. Liquefaction phenomenon due to earthquake type of loadings occurs only in loose saturated cohesionless soils. Clays become quick if they are of soft consistency. As the strata is stiff clay and chances of such strata becoming quick due to an event of earthquake type of loading is ruled out. Thus the present site is suitable to build the school with recommended design parameters.

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