National Seismic Network & It's Contribution to Seismological Research in Nepal Himalaya

GOVERNMENT OF NEPAL
MINISTRY OF INDUSTRY, COMMERCE AND SUPPLIES
DEPARTMENT OF MINES AND GEOLOGY

National Earthquake Monitoring and Research Centre

Lainchaur, Kathmandu, Nepal

2022

MESSAGE FROM THE DIRECTOR GENERAL

History of destructive earthquakes has shown that Nepal is one of the most earthquake disaster prone countries in the world. Nepal has suffered from several destructive earthquakes in the past causing unimaginable loss in terms of life and property. The 1934 AD Nepal-Bihar Earthquake (Mw 8.1), which claimed more than 10000 lives in Nepal and adjoining region in India and the 2015 AD Gorkha Earthquake of Local Magnitude 7.6 (Mw 7.8) that killed about 9000 lives in Nepal are lessons for us to wake up for better tomorrow.

National Earthquake Monitoring and Research Centre (NEMRC) of the Department of Mines & Geology (DMG) has played a significant role in the understanding of seismic activity, seismicity pattern, seismicity distribution in space and time, crustal deformation and seismic hazard in Nepal Himalaya. The NEMRC comprises a network of 42 seismic stations located in different parts of Nepal, which regularly transmit signals to recording centers located in Kathmandu and Surkhet. The seismic network is the continuation of Nepal's first seismic station installed at Phulchoki hill top, south of Kathmandu valley, installed in collaboration of the Laboratorie de Geophysique Applique, (LGA) Paris University, France in 1978. The network is capable to record any local earthquake of local magnitude as low as 2, which occur in Nepal. NEMRC/DMG has published Seismic Hazard Map and Epicentre Maps of Nepal Himalaya in the past, which are used as references in the evaluation of seismic hazard in infrastructure development projects in Nepal. Researchers, geoscientists, earthquake engineers and planners, related to this field, can take advantage from these maps.

The collision between the Indian Plate and the Eurasian Plate is the cause of earthquakes in the region. NEMRC/DMG has been playing a vital role in the field of other geophysical research activities, such as crustal movement monitoring with the help of 51 continuous Global Positioning System (cGPS) stations and Strong Ground Motion recording system with 36 Accelerometric stations.

I am quite sure that this handbook "National Seismic Network and its contribution in Seismological Research in Nepal" will be able to provide basic information to researchers as well as all other interested ones on seismic activity, seismicity pattern, and seismic hazard in the Nepal Himalaya. Likewise, I am hopeful that this publication will enlighten research activities and achievements made from the operation of seismic as well as GPS network. The challenge, now, is to operate the networks in a high level of efficiency to inform the concerned authorities immediately after any strong earthquake occurs in any part of Nepal and undertake seismological researches to resolve problems of earthquake hazard assessment and disaster mitigation. Collaboration and support from interested national as well as international agencies are highly appreciated in this regard.

I would like to thank Ms Monika Jha, Chief of the National Earthquake Monitoring and Research Centre and appreciate the efforts of its staff members for bringing this handbook in its present shape.

Dr. S. Rajaure

Director General

INTRODUCTION

Nepal Himalaya occupies approximately one-third arc length of the 2400 km long, seismically active, Himalaya chain from Afghanistan in the west to Myanmar in the east.

Nepal lies in one of the active continental collision zone of the world; the Himalaya, where the probability of earthquake occurrence is very high. Many destructive earthquakes have been reported in historical records that have devastated different parts of Nepal at different times. The nightmare of the 15 January 1934 Bihar–Nepal Great Earthquake of magnitude Ms 8.1 still haunts the minds of many elderly people. After the 1934 great earthquake, one strong earthquake (Gorkha earthquake 2015) with ML 7.6 (Mw 7.8) and three moderate earthquakes with magnitude greater than 6.0; (Udayapur earthquake ML 6.5 (1988), Bajhang earthquake ML 6.5 (1980) and Taplejung-Sikkim border earthquake ML 6.8 (2011)) occurred within the Nepal Himalaya.

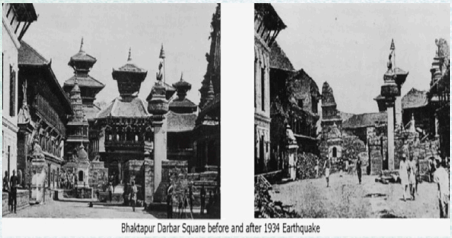


Fig.1: Bhaktapur Darbar Square before and after the Bihar-Nepal Earthquake 1934.

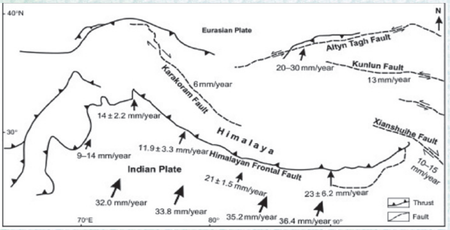
The Himalayan region, from Assam in the east to Kumaon in the west, has experienced four great earthquakes in the last 100 years. Among them the 1934 earthquake occurred in Nepal. The area west of Gorkha, Nepal and east of Dehradun, India has been reported not to have ruptured, at least, since the last five hundred years and therefore, stands as a potential site for next great Himalayan earthquake.

Fig 2: Dharahara before and after Gorkha Earthquake 2015

Worldwide efforts are underway to understand the cause and devastating effect of the earthquakes and to contribute in the mitigation of the associated hazard. The Department of Mines and Geology (DMG), in collaboration with the then Laboratorie de Geophysique Applique (LGA), Paris University, installed a short period vertical seismometer at Phulchoki hilltop in the southern part of Kathmandu Valley in 1978. The signal from this station was telemetered to the then Seismological Laboratory of DMG at Lainchaur, Kathmandu, Nepal. After the successful operation of this station, four more stations were installed in Eastern and Central Nepal. After the 1988 Udayapur earthquake, the necessity of a nationwide dense network of seismic stations was realized to cover the entire territory of Nepal in order to understand the seismic activity, seismicity pattern and evaluate seismic hazard in Nepal.

TECTONIC SETTING AND GEOLOGY

Nepal is situated within the seismically active Himalayan Mountain belt. The seismicity of the Himalayas and similar mountain belts of the Alps is a result of their tectonic setting. According to the prevailing concept of plate tectonics, the outer shell of the earth is made up of several big chunks of continental and oceanic crust with some portion of the upper mantle (about 100 km) called tectonic plates, which float over the viscous asthenosphere, slipping and sliding laterally along each other and generating earthquakes. These tectonic plates move as the results of the deep earth dynamic processes, which govern the formation of plates at the oceanic ridges and their destruction at the oceanic trenches. About 250 million years ago, the Tethys Sea used to separate the continental plates of India from Eurasia. This sea was gradually consumed due to the subduction of the oceanic floor beneath Tibet. Sometimes between 55 and 40 million years ago, the Indian plate collided with Eurasia along the Indus-Tsangpo suture.



https://www.sciencedirect.com/topics/earth-and-planetary-sciences/indian-plate

Fig. 3: Tectonic Setting of the Himalaya

The continuing northward motion of the Indian plate (relative to Eurasia) at a rate of about 4 centimeters per year induced widespread deformation, faulting and thrusting of its rocks at the collision front giving rise to the world's highest mountains. Intense seismic activity in Asia, and in particular along the Himalayan arc, is related to this ongoing orogenic process.

The large-scale thrusting developed from north to south in the last 25 million years gave rise to the Main Central Thrust (MCT) separating the Lesser Himalayas from the Higher Himalayas, Main Boundary Thrust (MBT) separating the lesser Himalayas from the Sub Himalayas (the Churia range) and Main Frontal Thrust (MFT) separating Churia range from the Indo–Gangetic plain. The seismicity of the Himalayas is the direct consequence of this ongoing process of faulting and thrusting.

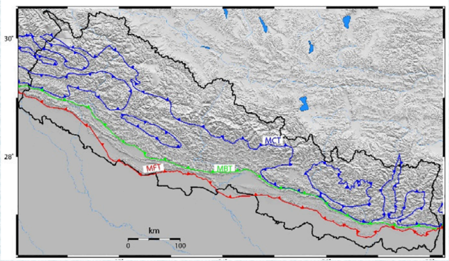


Fig. 4: Major Fault Map of Nepal Himalaya

NATIONAL SEISMIC NETWORK

National Seismic Network project was launched in 1991 and completed in 1993, with an aim to cover the entire territory to monitor and study the seismicity of the Himalaya. This project was completed in collaboration with the then Laboratoire de Détection et de Géophysique (LDG), France, now known as the Départment Analyse Surveillance Environnement

(DASE), with two well-equipped independent recording centres, one in Lainchaur, Kathmandu and another in Birendrangar, Surkhet.

1) National Earthquake Monitoring and Research Centre (NEMRC), Kathmandu

NEMRC records seismic (time series) data from stations located at Lukagoan (Pyuthan), Koldanda (Palpa), Dansing (Kaski), Gorkha (Gorkha), Daman (Makawanpur), Kakani (Nuwakot), Phulchoki (Lalitpur), Gumba (Sindhupalchok), Jiri (Dolakha), Ramite (Udayapur), Odare (Dhankuta) and Taplejung (Taplejung). It is equipped with an electronic maintenance and control laboratory. It administrates and controls the above twelve stations of the network as well as the other 20 stations installed after the Gorkha earthquake. The Centre has an automatic Technical Alert System (TAS) in case of technical failure in the network. This center is also equipped with a data processing Ethernet network for the routine processing, mixing and analysis of the seismic data acquired by Seismological Center (SC), Surkhet and NEMRC. The acquired data in Kathmandu are connected to the data processing network of National Earthquake Monitoring and Research Centre. NEMRC processes the acquired signals in real time. Processing results are linked with GIS system that facilitates the direct plotting of the epicentre on the globe. NEMRC is also equipped with an automatic Seismic Alert System (SAS) designed to inform the concerned personnel, in case of an earthquake with a local magnitude greater than 4.0 or the earthquakes felt by people occurring inside Nepal. Those events are reported to concerned authorities and media as soon as possible to help rescue and relief operation at the earliest.

Fig. 5: Server cabinets at NEMRC

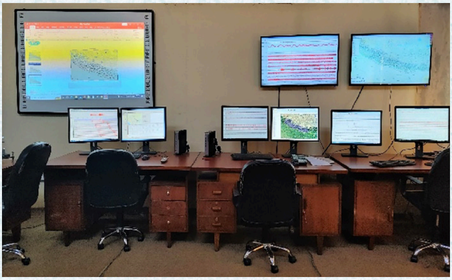


Fig. 6: Seismic Lab of NEMRC

2) Seismological Centre, (SC), Birendranagar, Surkhet

SC is an autonomous centre for recording and processing data received from ten stations of the National Seismic Network including the four seismic stations of the Karnali basin. The centre is responsible for the operation and maintenance of the stations located in Ghanteshwar (Dandeldhura), Ganjiri (Baitadi), Badegauja (Kailali), Pushma (Surkhet), Bayana (Bajhang), Gainekanda (Surkhet), Gaibana (Surkhet/Dailekh), Bhimchula (Surkhet) and Harre (Surkhet). The center is equipped with data processing, an earthquake location facility, Technical Alert System (TAS) and Seismic Alert System (SAS). Regular submission of acquired seismic data is made to NEMRC in Kathmandu.

Effective and timely mobilization of post-earthquake rescue operations can minimize the loss of lives and property considerably. Faster the epicentre and magnitude of an earthquake are computed and communicated to concerned authorities and media, sooner the rescue operation can be mobilized. The operation of a seismic alert system allows for an effective and almost instantaneous earthquake location and magnitude assignment. The smaller the magnitude of earthquakes the more frequent their occurrence. Therefore, a relatively large amount of data can be acquired even in a small span of time by recording small earthquakes. The microseismic data are instrumental to the definition and are important for the delineation of potentially damaging earthquake sources. Besides, they allow monitoring of seismic activities of different parts of potential belts in time and space. Additionally, seismic data is the fundamental input in seismic hazard assessment and in the worldwide effort to earthquake forecasting for disaster preparedness of different time frames.

Seismic bulletins are shared to National Earthquake Information Center (NEIC), United States Geological Survey (USGS), USA, International Seismological Centre (ISC), UK and Department Analyse Surveillance Environment (DASE), France in a regular basis. This seismological network is contributing valuable seismic data for global seismic hazard assessment and research.

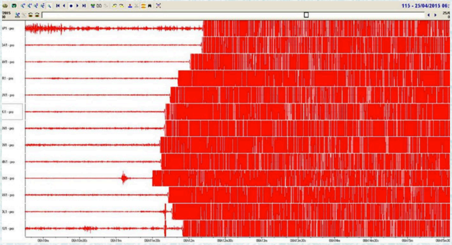


Fig. 7: Seismogram of 2015 Gorkha earthquake

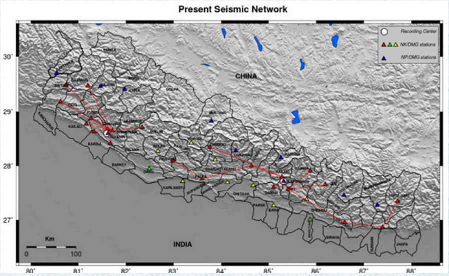


Fig. 8: Seismic Network of Nepal

Fig. 9 provides an overview of the earthquakes recorded by the national network from 1994 to 2014.

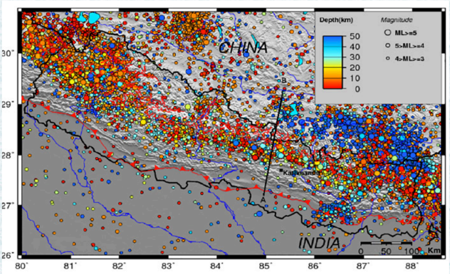


Fig. 9: Epicentre Map of Nepal Himalaya (1994-2014)

RESEARCH ACTIVITIES

A number of geophysical experiments have been carried out by DMG in collaboration with various institutions from France, USA, China and Japan to image and understand the subsurface structures of the Himalayan Range and asses seismic hazard. Several geophysical techniques like Gravity, Seismic Reflection, Microtremor and Magnetotelluric and continuous GPS surveys have been applied in this study.

Crustal Deformation Monitoring

The understanding of the seismic cycle in the Himalayas has greatly improved following the results achieved from research activities carried out in the field of seismology, geology and geophysics. Over the last decade, crustal deformation monitoring from continuous GPS stations has emerged as the most useful complement to seismic monitoring. This technique offers the possibility to measure crustal deformation that may be too slow to generate seismic waves. Such transient deformation events have been detected along some subduction zones, and possibly it might also occur in an intra-continental setting such as along the Himalayas.

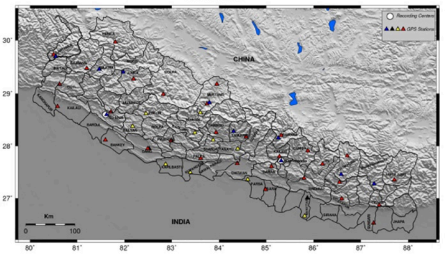


Fig. 10: GPS network of Nepal

If transient aseismic deformation occurs at seismogenic depths in the Himalaya, it would have direct implications for seismic hazard assessment because all the deformation might not necessarily be released by major recurring earthquakes only. Also, there is a possibility that the rate of deformation might vary during the seismic cycle and could provide some indications on the timing of future earthquakes. In 2003, DMG, DASE and CALTECH agreed to install permanent continuous global position system (cGP) stations encompassing the zone of interseismic straining across the range to monitor the crustal deformation continuously. This additional network complements the existing seismic network. Twenty-six cGPS stations have been installed by the end of 2011.

The movement of tectonic plates can be precisely monitored using Global Positioning System (GPS) stations. Monitoring of crustal movements in a region like the Himalaya could reveal the geometry of locked portion of the characteristic faults and its activity, which could help to assess the seismic hazard. GPS data can also reveal if any portion is slipping without generating big earthquakes. To address this problem, DMG is monitoring crustal deformation by operating cGPS stations. After Gorkha earthquake 22 additional cGPS stations were installed in the Central part of Nepal with the technical support of different international organizations.

Paleoseismological Study

Earthquake catalogue is fundamental input in any seismic hazard assessment. Earthquake catalogue is very short in comparison to the recurrence interval of great earthquakes. To assess the seismic hazard of any region, we need seismic data of that region, available for a long period of time. In Nepal, the historical records of earthquakes don't go back beyond 1100 and instrumental recording of earthquake doesn't go back beyond the last 100 years. Earthquake monitoring in Nepal started in 1978 that was expanded later to cover the entire stretch of Nepal Himalaya. So-far available earthquake catalogue covers short span of time that is not sufficient for proper seismic hazard assessment.

To complement such shortfalls, paleoseismological studies of the past earthquakes have been carried out by excavating trenches across presumed active fault structures on the surface of the earth, as determined from the study of aerial photos, satellite images and other geomorphological means. Paleoseismological studies have been carried out to identify past earthquakes and their recurrence period, which could assist in the assessment of seismic hazard.

Fig. 11: Charcoal Sampling for Paleoseismological Study

Microtremor Survey

Microtremor (ambient noise) survey is carried out for recording the passive natural ground vibration during minimum noise level and utilized for ground classification in engineering seismology. It is mostly useful in sedimentary basins like Kathmandu valley. The NEMRC/DMG carried out the first microtremor survey in Kathmandu Valley in 1985 with a view to evaluate sub-surface geological variability of ground conditions and its correlation with earthquake intensity distribution caused by the 1934 Bihar-Nepal Earthquake. Similarly, microtremor surveys had been carried out in Hetauda and Pokhara Valley in 1986. After the devastating Gorkha earthquake microtremor surveys have been completed in the Kathmandu valley, Pokhara valley, Bhardrapur of Jhapa district and Gulariya of Bardiya District. Such surveys will be extended to other major cities of Nepal in near future. The velocity structure models obtained from long and short period microtremor studies can be utilized as an additional input in seismic hazard assessments.

Accelerometric Network

The seismic network allows detection and localization of any earthquake with magnitude as low as ML 2.0, which occur in Nepal. However, their dynamic range is not sufficient to determine the magnitude at short distance during large earthquakes due to instrumental scale saturation. To address this problem, we began with eight accelerometres (GeoSIG AC-23 sensor and GSR-24 digitizer with sampling rate 200 Hz). Dynamic range of the instruments is larger than 125 dB within the 0.1-35 Hz band. The full scale is set at ± 1 g. This network helps in the determination of peak ground acceleration (PGA), peak ground velocity (PGV) and peak ground displacement (PGD) required in the estimation of attenuation pattern of seismic waves in the subsurface. An attenuation relation is an empirical relation that is required in the seismic hazard assessments. Additionally, the network helps in the estimation of spectral characteristics of recorded signals.

After the 2015 Gorkha earthquake, five accelerometric sensor (Guralp 5T) are installed at Phulchoki, Kakani, Daman, Gumba and Gorkha collocating with the existing seismic stations connected to a 24-bit digitizer (Staneo), sampling at 100 Hz. The dynamic range of the instruments is larger than 127 dB within the 3-30 Hz band. The full scale is set at ± 2 g. The accelerometers deployed in the Kathmandu valley in collaboration with SATREPS project are servo accelerometer CV-374A2 (Tokyo Sokushin Company) with full scale set ± 2 g, whereas that installed in collaboration with RIMES are Nanometrics, Titan EA, Strong Motion Accelerometer.

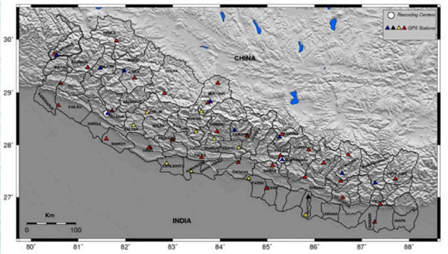


Fig. 12: Acceleromentric Network of Nepal

INTERNATIONAL COLLABORATIONS

The Department of Mines and Geology has received support/collaboration from several international institutions. Some of them are summarized below.

A collaborative research project "Himalayan Nepal Tibet Broadband Seismic Experiment" (HIMNT) between DMG and Colorado University, Boulder, USA was initiated from September 2001 to September 2002 in Eastern Nepal. The main objectives of this experiment include: improvement of the velocity model for locating earthquake, determination of focal mechanism to understand the kinematics of deformation, calculation of teleseismic receiver function to image crust and mantle discontinuity and geometry of mid-crustal ramp.

Research Project "Himalayan–Tibet Continental Lithosphere during Mountain Building" (Hi–CLIMB) between DMG and Oregon State University and University of lllinois, USA with involvement of Chinese Academy of geological Sciences (CAGS), China begun from September 2002 to April 2004. The expected outcomes of the seismic experiments include extraction of unprecedented image of the earth's crust and mantle at depth and detailed subsurface image of the Main Himalayan Thrust (MHT) along its width from Southern Nepal to Higher Himalaya and to measure seismic anisotropy, which will detect mantle flow at depth.

Earthquake precursor studies in Nepal Himalaya have been carried out by monitoring radon and carbon dioxide at around hot water springs of Nepal in collaboration with Institut de physique du globe de Paris (IPGP), Paris, France since 2006. Many scientific research papers have been published in international journals based on this collaboration.

The Earth Observatory of Singapore (EOS), Singapore and the Department of Mines and Geology (DMG) have carried out research in the field of seismo-tectonic and earthquake hazard studies since 2013. The principal goal is precise mapping and characterization of active faults (geology, geomorphology, paleo-seismology).

After the 2015 Gorkha earthquake the Science and Technology Research Partnership for Sustainable Development (SATREPS), Japan was conducted in Nepal over a period 2016-2021 in collaboration with the Department of Mines and Geology (DMG) and other relevant organizations. The overall goal of this project was to contribute reducing the seismic risk future of Nepal.

Department of Mines and Geology (DMG) and Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), Thailand established 2 sets of earthquake monitoring stations in the southern part of Nepal from 2016 to 2019.

A Memorandum of Understanding (MoU) between the Ministry of Finance, Government of Nepal and the Ministry of Commerce of the People's Republic China was signed on 23rd July, 2015 for the period 2016-2018 under Post-Disaster Reconstruction Aid project plan. The objective of the project was capacity buildings in disaster prevention by establishing seismic network.

ACHIEVEMENTS AND PUBLICATIONS

- Determination of epicentre of earthquakes with local magnitude greater than 4.0 occurring inside the territory of Nepal as soon as possible and immediate reporting to concerned authorities for quick mobilization of rescue team in the earthquake affected area in case of disastrous earthquake.
- Contribution of seismic data to International Seismological Centre (ISC), UK, United States Geological Survey (USGS), and European-Mediterranean Seismological Centre (EMSC) for global seismological studies and hazard assessment,.
- Seismic data acquisition, processing and interpretation for seismic database starting from 1994 to carryout research in the field of seismology, and seismic hazard evaluation
- Distribution of seismic database for safe construction of infrastructures like power-house, dam, canal, reservoir and other major civil construction, upon request.
- Ground classification of Kathmandu basin, Pokhara basin and Hetauda foothill (Dune Valley) through microtremor survey.
- Preparation of a refined seismotectonic model of the Central Nepal Himalaya.
- Estimation of short-term rate of convergence from GPS survey and long-term average (over Holocene period).
- Paleoseismological research to know about the historical and pre-historical earthquakes and their return period to help in seismic hazard assessment.
- Preparation of seismic hazard map of Nepal showing the bedrock peak ground horizontal acceleration counters in gal with return period of 500 years, which approximately corresponds to 10% chance of exceedance in 50 years.
- Publication of epicentre map of the Nepal Himalaya of scale 1:1,000,000 (1994–2014).
- Distribution of seismic database for the research purpose to researchers from different institutions.
- Conduct awareness programs to share

the knowledge of/about earthquake preparedness.

- Many national and international publications related to Earthquakes in Nepal and Gorkha Earthquake 2015.

ACRONYMS

CAGS Chinese Academy of Geological Sciences

CALTECH California Institute of Technology

CEA China Earthquake Administration

CNRS Centre National Recherche Scientifique

DASE Départment Analyse Surveillance Environnement

DMG Department of Mines and Geology

DUDBC Department of Urban Development and Building Construction

EMSC European-Mediterranean Seismological Centre

EOS Earth Observatory of Singapore

GPS Global Positioning System

Hi–CLIMB Himalayan Tibet Continental Lithosphere during Mountain Building

HIMNT Himalayan Nepal Tibet Broadband Seismic Experiment

IDYLHIM Imagerie et Dynamique de la Lithosphere de Himalaya

IPGP Institut de physique du globe de Paris

ISC International Seismological Centre

LGA Laboretoire de Geophysique Applique

LDG Laboretorie de Detection de Geophysique

LIDAR Long Detection and Ranging

MBT Main Boundary Thrust

MCT Main Central Thrust

MFT Main Frontal Thrust

MHT Main Himalayan Thrust

NEIC National Earthquake Information Centre

NEIS National Earthquake Information Service

NEMRC National Earthquake Monitoring and Research Centre

OSU Oregon State University

RIMES Regional Integrated Multi-Hazard Early Warning System for Africa and Asia

SATREPS Science and Technology Research Partnership for Sustainable Development

TU Tribhuvan University

SC Seismological Centre

SAS Seismic Alert System

TAS Technical Alert System

USGS United States Geological Survey

Table below shows the published maps.

S.N.	Title
1	Microseismicity Epicentre Map (1985-1990)
2	Microseismic Map of Nepal Himalaya and Adjoining Region (March1994-Dec 1996)
3	Epicenter Map of Nepal Himalaya (1994-2014)
4	Probabilistic Seismic Hazard Map of Nepal, 2002

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