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EIGHTH NEPAL GEOLOGICAL CONGRESS (NGC-VIII)

"Geosciences in National Development and Disaster Management"

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Kathmandu, Nepal

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Nepal Geological Society (NGS) is pleased to host the Eighth Nepal Geological Congress (NGC-VIII) in Kathmandu, Nepal during November 27-29, 2016. The main objectives of the Congress are to exchange expertise, experiences and knowledge for building effective cooperation among the geoscientists from all over the world. As part of its geoscientific activities, the NGS is regularly organizing Nepal Geological Congress or another regional or international scientific event biennially since 1995, in which geoscientists from most of the continents have participated. It has successfully organized seven congresses and a number of regional and international symposiums and conferences, including the Himalaya-Karakoram-Tibet (HKT) workshops, Asian Regional Conference on Engineering Geology, International Symposium on Engineering Geology, Hydrogeology and Natural Disaster and International Seminar on Hydrology. Geoscientists from across the world have contributed and have benefited much from each other during such scientific undertakings.

This volume contains 140 abstracts of scientists from 14 different countries comprising Bangladesh, Bhutan, China, France, Germany, India, Iran, Italy, Japan, Nepal, Pakistan, Singapore and the USA. The abstracts cover a wide range of topics under geosciences, such as regional geology, stratigraphy, tectonics, mineral resources and mining, oil and natural gas, seismology and seismotectonics, 2015-Gorkha Earthquake, post-earthquake reconstruction and recovery, hydropower and other infrastructure development, engineering geology, hydrogeology, Quaternary geology, exploration geophysics, geohazards, disaster management, climate change, paleoclimate, geo-heritage and geo-park conservation and development, geosciences education, and remote sensing and GIS. About 250 participants are expected to attend the Congress with 75 oral presentations and 20 posters. We extend our warmest welcome to the delegates of the Congress and look forward to hosting you in Kathmandu, Nepal. We anticipate an exciting week of scientific exchanges, renewing friendships and making new friends. We hope you will find NGC-VIII a memorable event and the Abstract Volume a useful collection.

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Emplacement and cooling history of the Himalayan metamorphic nappe, originated from the partially-melted middle crust of Tibet

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We undertook the Himalayan nappe project in eastern and central Nepal Himalaya, in order to reveal the kinematic and thermal history of the nappe that have a key to understand how the Himalaya was built. We carried out zircon and apatite Fission-Track (FT) dating, zircon U-Pb dating and muscovite ^{40}Ar-^{39}Ar dating for the metamorphic nappe and underlying metamorphosed Lesser Himalayan Sediments (LHS). The metamorphic nappe exposed on the ground at 15~14 Ma, judging from the same cooling age of 14.4 Ma on zircon, apatite, muscovite from the Yellow Band and granite intruded into the Qomolangma detachment (Sakai et al. 2005). It advanced the southward at 3~4 cm/yr, and the nappe front reached the present position behind the MBT by 11~10 Ma (Sakai et al. 2013b). The nappe front and underlying LHS cooled down till 240º of closure temperature of zircon FT by 10 Ma, and those of middle part of the nappe cooled down till 240º by 6~5 Ma. The northern part of the nappe to the south of Mt. Everest, Lantang and Kodari area commonly shows much younger zircon FT age of 4~1.9 Ma and apatite age of 1.2~0.8 Ma. It indicates that the isotherm of 240º within the nappe retreated toward the NNE at the rate of ~10 km/myr (Sakai et al. 2013a,b). After simple calculation on the position of the metamorphic rocks in the Higher Himalaya under ~750º and 12 kb at peak metamorphic condition, it is concluded that the rocks were located at 53 km to the north of the partially melted mid-crust of Tibet than at present. It suggests that the Himalayan nappe was originated from partially-melted mid-crust of Tibet. Delamination and following break-off of the mantle from the Indian continental crust must have caused rapid exhumation of the metamorphic belt and following emplacement of nappe.

Some matters of geotechnical concern for rational reconstruction of areas hit by the April 25th, 2015 Gorkha earthquake

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Gorkha earthquake (Mw 7.8) struck central Nepal on April 25th, 2015 at 11:56 a.m. local time (6:11 a.m. UTC), one of the worst natural disaster to strike central Nepal since the 1934 Nepal-Bihar earthquake. The Japan Society of Civil Engineers (JSCE) dispatched reconnaissance teams to areas affected by the earthquake, and one of worries they have highlighted in their reports was signs of creeping grounds observed at some locations. Pasang Lhamu highway is increasing its importance, particularly after the earthquake and its largest aftershock hit very hard Araniko highway, which has been of crucial importance to Nepal as it had been carrying a very large amount of goods from China. After the highway was suspended by a number of slope failures, China did supply its petro assistance of 1300 KL of oil through Pasang Lhamu highway to Nepal. During this period country has been facing an economic and humanitarian crisis caused by a blockade in the country's south, leading to acute shortages of fuel and medicine. However, this twisty mountain road has some unpaved narrow dangerous sections on creeping slopes. Actually on November 4th, 2015, a bus skidded off the road and fell some 150 meters at the exact location of the authors' survey. At least 35 people were killed and more than 50 others were injured. Its direct cause was surely the over-crowded vehicle due to the fuel shortage crisis. However we need to recognize the risk of passing through these dangerous sections of the highway by over-crowded and over-loaded vehicles. Monitoring of creeping behaviors of slopes along the highway is thus of crucial importance for taking necessary safety measures. A section of the Araniko highway crosses a small valley at Kausaltar with an embankment. This section has sunken seriously in the Gorkha earthquake. Several lines of vertical ground offsets appeared diagonally across this road making up a swath of ground offset lines. The author's team conducted a surface wave survey, SWS, at this damaged section. The estimated soil profiles for a 72 m and a 210 m stretches in the transverse and longitudinal directions of the highway indicated the wide-spread presence of weak shallow soil that covers an area where offsets and cracks appeared in the earthquake. The weak soil is considered to be an organic substance from soil samples taken from a borehole near the highway. Moreover a terrain map of this area shows a low-lying depression north behind the damaged section of the highway, suggesting the presence of the small paleo-lake, which had been drying/emptying leaving organic substance over its entire shallow water area. Given the above mentioned creeping nature of slopes and the suspected presence of subsurface weak soils, rehabilitation plans for these areas should be carefully made taking into account the weak natures of the hidden subsoils.

Some structural and stratigraphic issues of Himalaya: a need for transboundary correlation

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The geological maps of Nepal are not concordant with those from the adjoining Indian territory of Kumaun in the west and Darjeeling in the east. In some instances the maps from the two countries are drastically different, and to join them, one has to place a transboundary "fault" following our common border. The problem is related mainly to the Lesser Himalayan succession with varied tectonic, structural, and stratigraphic aspects. Tectonically, the number, size, and spatial distribution of thrust sheets in border areas of the two countries require further investigation. Similarly, the number of imbricate faults crossing the border, their nature, and extension is another unresolved issue. Stratigraphically, the distribution of Proterozoic carbonate sequences, slates, and quartzites with amphibolites is not well worked out. The Eocene–Miocene Tertiary rocks in the Lesser Himalaya of west Nepal occur mainly in three separate zones: adjacent to the Siwalik in the outer Lesser Himalaya, and in two approximately parallel zones in the inner Lesser Himalaya. While in the outer Lesser Himalaya, the Tertiary beds are intermittently distributed at various places, they are continuous in the two inner belts, where they occupy the tectonic windows formed by the erosion the Great Midland Antiform, made up of a Higher Himalayan crystalline thrust sheet. The equivalents of the Tertiary rocks from Nepal have been mapped as the Precambrian Chakrata and Rautgara Formations or Saknidhar Formation in Kumaun. The Lower Gondwanas are well known from Darjeeling and Sikkim. The coal-bearing rocks of Barahakshetra in east Nepal are also believed to be of the same age. On the other hand, the upper Gondwanas occur in Tansen and Dang, but no Gondwanas are reported from Kumaun. The Tal Formation is distributed in the Lesser Himalaya of northwest India and this formation contains Cambrian fossils. But, such a rock succession has not yet been identified in Nepal. Similarly, the Permo-Carboniferous Sisne Diamictite sequence of west Nepal has not been identified in the northwest Himalaya of India. To overcome these difficulties, it is necessary to carry out detailed geological field investigation in the border region of both the countries, preferably by a joint research team.

The 2015, Mw 7.8 Gorkha earthquake, learnings from GPS and seismological observations

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Geodetic measurements collected over the last ~20 years had indicated that the Main Himalayan Thrust fault (MHT) along which the Himalaya wedge is thrust over India, had remained locked south of the High Himalaya. The locked zone extends over 100-120 km from the foothills, where it surfaces, to beneath the High Himalaya where it roots into a décollement which slips aseismically at a rate of ~2 cm/yr. We used GPS, seismological and radar interferometry (inSAR) to produce a detailed image of the seismic rupture and investigate. The earthquake ruptured a ~150 x 50 km patch, north of Kathmandu, and well confined to the previously locked portion of the MHT. The earthquake initiated at western end of the ruptured patch, 75 km northwest of Kathmandu. A slip pulse of ~20 km width, ~6 s duration with peak sliding velocity of ~1 m/s propagated eastwards at ~2.8 km/s. High frequency seismic waves (~1 Hz) were radiated continuously as the earthquake unzipped the northern edge of the locked portion of the MHT, a zone of presumably high and heterogeneous pre-seismic stress. Most of the moment was actually released south of the sources of high frequency seismic waves, as a result of a rather smooth slip pulse. This characteristics explains the moderate ground shaking at high frequencies (>1Hz) and the limited damage to regular dwellings within Kathmandu Basin. By contrast, the entire basin resonated at ~4-5 s for 30 s resulting in the collapse of some tall buildings. Postseismic geodetic measurements indicate significant aseismic slip downdip of the mainshock rupture, which contributed to trigger aftershocks and to loading the shallower portion of the MHT. The risk for further large earthquakes in Nepal remains high, both south and west of Kathmandu Basin where the MHT has remained locked.

Site effects of the 2015 Gorkha earthquake sequence: observations, open questions, and future research avenues

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We present the analysis of strong motion records and high-rate GPS measurements from the M 7.8 Gorkha earthquake sequence, which were recorded on the Kathmandu Basin sediments and on rock outcrop. Recordings on soil from all events showed systematic amplification relative to the rock sites in the low frequency range (<2Hz), and de-amplification of higher frequencies (>2.5Hz). Also, the soil-to-rock amplification ratios of the M 7.8 mainshock and M 7.3 Dolakha aftershock had lower amplitude and frequency peaks relative to the ratios of smaller aftershocks. Although these effects are strongly suggestive of nonlinear site response, we could not draw any definite conclusions due to lack of detailed site characterization of the basin sediments and laboratory data of the Kathmandu unconsolidated clay. Furthermore, comparisons to ground motion prediction equations (GMPEs) from subduction zones show that 1) both soil and rock mainshock recordings had much lower high frequency content than the GMPE predicted spectra, and that 2) the depletion at high frequencies was not present in the aftershocks. These observations indicate that the high frequency de-amplification was additionally related to source effects; that these effects are not captured by global GMPEs; and that seismic hazard analyses in Nepal would significantly benefit from the development of region-specific GMPEs, informed by simulations and observations of large magnitude, near-source events such as the 2015 Gorkha mainshock.

Learning for Bangladesh from Manipur earthquake 2016

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The 6.7 magnitude Manipur earthquake jolted almost entire Bangladesh in the early morning (05:05) of 4 January 2016. Its epicentre was 351 km NE of Dhaka, the capital city. Due to the earthquake shaking, majority of the people woke up from sleep and most of them rushed out of their residences from panic, and out of fear some also jumped from buildings. Six people died of heart attack because of fear in different parts of the country. More than one hundred people became injured during rushing or jumping out of the buildings and many of them needed hospital treatment. Although no serious damage occurred but reports of development of cracks in buildings came from different places of the country and few buildings tilted in Dhaka city. Bangladesh experienced similar wide-spread panic situations among the people during the recent earthquakes of Mawlaik 2016 (6.9), Nepal 2015 (7.8) and Sikkim 2011 (6.8) and their responses were same whereas impacts on buildings were more than the Manipur earthquake. Occurrences of these recent earthquakes are warnings for us to be aware about the probable earthquake shaking, especially about what to do during a quake. Preparedness for risk reduction is very important for this highly- and densely-populated country where the geologic condition is considered to be an essential element. Because of tectonic characteristics this region will experience earthquake shaking in future like in the past which occurred in and around Bangladesh in 1762, 1869, 1885, 1897, 1918, 1930, 1934, 1950 AD.

Comparison of shear wave velocity derived from PS logging, MASW and refraction wave method – case study in different areas of Bangladesh

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The paper highlights the outcome of fifteen down hole tests and twenty two MASW tests conducted at Mymensingh Pourashava, Bangladesh. These two tests are being widely used to determine shear wave velocity in many countries of the world. PS (Primary and Secondary waves) logging and MASW (multi-channel analysis of surface wave) are widely used tools to calculate shear wave velocity in various countries of the world. PS logging is one of the most accurate tools to determine AVS 30 (average shear wave velocity of upper 30m layer). In comparison to the conventional seismic survey methods such as cross-hole and down-hole, the MASW proves to be less expensive and less time consuming and it provides the benefit of precision and swiftness to estimate the subsurface shear wave velocity profile over a large area. Fifteen PS logging and twenty two MASW tests have been performed at various locations in Mymensingh Pourashava to determine shear wave velocity profile and model and compressional wave velocity. Some other engineering geological parameters (Poisson's ratio, shear modulus, constrained modulus and Young modulus) can also be determined from the derived shear wave and compressional wave velocity. It is found that, the average shear wave velocity of upper 30m layer of different sites of Mymensingh Purashava varies 125-255m/sec derived from PS logging, 161-269 m/sec from MASW (active) and 172-374 m/sec from MASW (passive). Surface refraction survey is a very common method for geotechnical and geo-environmental studies. Shallow refraction surveys are easy to execute, less time consuming and cost effective. Refraction of S waves can easily be identified in the seismogram as first breaks in case of using horizontal geophone as receiver and horizontally striking energy on an wooden plank from opposite sides as the source. First arrival of S wave travel time is calculated from the first opposite phase arrival. Down hole PS logging along 4 boreholes of 45m depth and 7 refraction profiles of P and S waves are conducted. From the comparison of performed tests for this study, the MASW can give a close estimate to of AVS 30 and therefore considered as a cost and time effective alternative over the down hole seismic test. But in terms of greater accuracy PS logging (down hole seismic) is more preferable. Refraction wave method provides shear wave velocity Vs very similar to the down hole PS logging velocity Vs. Refraction wave method is an another strong alternative to determine shear wave velocity for geotechnical studies minimizing the number of down hole PS logging which ultimately help reducing time and expenditure. In order to quantify the near-surface seismic properties (P- and S-wave velocities and the dynamic elastic properties) with respect to the depth at a specific area (6^{th} of October club), the non-invasive and low cost active seismic survey were conducted. The primary wave velocity is determined by conducting the P-wave shallow seismic refraction. The dispersive characteristics of the Rayleigh type surface waves were utilized for imaging the shallow subsurface layers by estimating the 1D (depth) and 2D (depth and surface location) shear wave velocities. The Vs30 for the area of interest varies between 348 m/s at site R2C1 and 560 m/s at site R6C5. According to the NEHRP standard, three sites (R1C2, R2C1 and R3C1) are belonging to Class D, occupying the area of high soil thickness, while the rest sites are belonging to the category C. The higher the velocity sites occupy the lower soil thickness sites.

Adsorption of acid blue 25 from solution using zeolite and surfactant modified zeolite

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The surfactant modified zeolite, zeolite-CTAB, was prepared from zeolite. The modification effect on the surface of zeolite was analyzed using Fourier transform infrared spectroscopy (FTIR), Scanning electron microscopy (FE-SEM), Energy-dispersive X-ray spectroscopy (EDX), X-ray fluorescence (XRF) and X-ray Diffraction (XRD). The effects of adsorbent dosage, pH, temperature, time and the initial dyes concentrations were investigated in batch adsorption experiments. The maximum removal of dye was obtained under acidic conditions; in particular at pH 2. The percentage removal of dye initially increases with increase in dye concentration and with time. After that the dye removal percentage decreases. The adsorption equilibrium and kinetic studies of anionic dyes were carried out. The kinetic experimental results imply that the adsorption of AB25 onto these adsorbents nicely followed the second order kinetic model. Equilibrium isotherms were analyzed by Langmuir and Freundlich isotherms. From the concentration effect it is indicated that due to modification of zeolite the adsorption capacity for AB25 increases 36.84%. The maximum adsorption capacity from the temperature effect was found to be 43.48 mg/g for zeolite at 30^{o}C and 71.43 mg/g for zeolite-CTAB at 40^{o}C. However, it follows an increase and decrease trend with increase in temperature. The adsorption of AB25 onto zeolite-CTAB better fitted using Langmuir model and onto zeolite better fitted with the Freundlich model. A decrease in AB25 adsorption on zeolite-CTAB has been observed with an increase in temperature which indicates that the preferential adsorption may occur at low temperature. The negative value of enthalpy indicating the process was exothermic and the presence of possible physisorption phenomenon. The negative values of entropy both for zeolite and zeolite-CTAB indicate the decrease in randomness at the adsorbent and solution interface. The results of the present study substantiate that zeolite modified by CTAB material are promising adsorbents for the removal of the dye AB25.

Gorkha earthquake, Nepal and building damage in greater Dhaka city: ignorance of geo-information in building construction practice

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Bangladesh is situated in a complex tectonic zone at the junction of Indian plate and the Burmese sub-plate, which are colliding with Eurasian plate in the north. Earthquake occurs regularly along these plate boundaries and fault lines in this region. The Gorkha earthquake of 7.8 magnitude occurred on 25 April, 2015 in Nepal jolted the whole region from Bangladesh up to Pakistan including India and adjacent southern parts of China. The tremor caused damages and panic in Bangladesh, though the epicenter was about 750 km northwest from Dhaka. Field data and other information about the damage of infrastructures and local geology were collected immediately after the earthquake in Dhaka city. The investigated area is covered mainly by two types of geological units: a) Madhupur Terrace of Pleistocene age and b) flood plain deposits of Recent age. Most of the damaged buildings are located at southern side of Dhaka Metropolitan city and northern side of Keraniganj Upazila, adjacent to the Buriganga River. Few buildings were tilted up to 30 cm causing major and minor cracks in walls and along floor level due to that earthquake. The degree of tilting depends on the building height, subsurface geology, construction method, age etc. Most of the severely tilted/cracked buildings are non-engineered masonry building without proper foundation and are situated on unconsolidated flood plain deposit rather than on Pleistocene Madhupur Terrace. It is found that no standard geo-technical investigations were performed prior to the construction of those buildings. The ignorance of sub-surface geological information and building code during construction is the probable cause of damage due to the earthquake. Safety of urban infrastructures could only be assured by strictly following geo-information and building code during planning and construction stage; special emphasis must be given in the geologically complex, unstable and unconsolidated sedimentary areas.

Mid Holocene marine transgression and reconstruction of paleoenvironment in and around Dhaka city, Bangladesh

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The Bengal Basin, the largest fluvio-deltaic sedimentary system on Earth, is located in Bangladesh and three eastern states of India. Sediment accumulates in the basin from the Ganges, Brahmaputra, and Meghna (GBM) river systems and is dispersed into the Bay of Bengal, forming the largest submarine fan in the world. The present-day geomorphology is dominated by the extensive Holocene GBM floodplain and delta. The initiation of the modern GBM delta at the onset of the Pleistocene glacial maximum and its evolution to the present configuration are intricately related to Holocene fluvio-dynamic processes, eustatic sea-level changes, and tectonic movements. Quaternary System in Bengal Basin has varieties of depositional environment. Sediment characteristics of different geomorphic units are different. Late Quaternary monsoon climatic episodes played the vital role in creating the present morphology of the Madhupur surfaces. During Holocene central part of the basin experience cyclic transgression and regression phase in several times. This was evidenced by mangrove pollens. The presence of mangrove pollen specially *Phoenix paludosa*, *Avicennia* sp., *Phoenix sylvestris*, *Prosopis grandis*, *Sonneratiopollis* sp. found in Chatbari, Dubadia and Mirertek area of Dhaka city along with radiocarbon dating indicate that marine influence occurred during Mid Holocene time. Two phases of transgression and regression is noticed during mid Holocene time. First transgression is observed during 75000 cal BP followed by regression between around 6500 and 7000 cal BP. Second phase of transgression is noticed between around 6000 and 5500 cal BP and then a regression during between around 4500 and 1500 cal BP.

Major issues of post earthquake housing construction during resettlement

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Natural disasters provide an acute image of how man-made technologies are a cause of conflict when it comes to nature. It is man versus wild in its true means. The nature lets us grow and increase our settlements. We encroach on other animals' territories and it is only when the environment's patience runs out; that it retaliates in forms of natural disasters. These disasters affect numerous lives and kill a lot of humans. This is the main reason why we require more stable structures and preventive measures to battle the wrath of the nature. Rescue and search operations are conducted by many different government and private agencies including NGO's. These operations aim at providing the required relief and supplies after the disaster. Injured people need to be treated. People in danger zones need to be evacuated. Help is needed in many forms. Out of the many natural disasters, this paper will focus on the occurrence of earthquakes. Severe earthquakes destroy buildings and structures like roads, bridges etc. and wreak havoc in the community. Earthquakes largely damage all human constructions, including houses. This is the reason why a reconstruction program for dwellings and housings is of utmost importance. A home is only secondary to basic needs such as food and water. A well-planned strategy is important when it comes to launching a post-earthquake reconstruction program. The strategy should be reasonable and should consider the best interests of everyone affected; self – help and imported fabrication should play no part in the decision-making procedures. Creating awareness, physically demonstrating options and delivering are the three steps for the success of reconstruction programs. The extent of affected area and the magnitude of earthquakes are variable in nature and it is on these two aspects that the reconstruction strategy is devised. Technical aspects are focused towards the development of the affected areas and conceptual design of surrounding neighborhoods. It also aims to look the possiblities for easy financing for a new home. Along with these, review processes are conducted for the analysis of new residential needs based on optimizing the use of available land for planning and development. The paper discusses the construction of housing and resettlements as prioritized activities that must be undertaken post an earthquake. Earthquakes physically only destroy structures and buildings but for the people affected, they destroy lives, jobs, companies, sources of food and the sense of safety and traumatizes the ones who come out alive.

Application of geosynthetics to reduce landslide risk in earthquake prone Bhutan

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The young and developing Himalayas are characterized by large topographic energy, excessive rainfalls, and poor geological formation. In mountainous areas of Bhutan, the occurrence of the gravitational movement of masses that are actively effectuated and extensively propagated, as landslides, rock falls, mudflows, avalanches, and snow avalanches are common phenomena. The most frequent and destructive of them is the landslides, which recurs on hilly slopes under dynamic loading. The rapid human settlements on steep slopes, such as in Phuentsholing-Pasakha areas of Bhutan, have also extensively attributed towards failure of land mass. The present study exhibits the mitigation of landslide risk in earthquake prone Bhutan by using finite element based numerical modelling. The literature study puts forth the hazards associated with dynamic slope instability for both natural and man-made slopes. This paper assesses the dynamic slope stability to know the behavior of the geotextile reinforced soil slope during any earthquake in this area. The parameters like soil characteristics, slope, drainage density and reinforcement spacing are considered for susceptibility of slope failure.

Eocene-Miocene middle crustal flow in southern Tibet: geochronology of Yardoi dome

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New zircon U–Pb and mica 40Ar/39Ar ages provide constraints on the timing of formation and exhumation of the Yardoi Dome, southern Tibet. The core of Yardoi Dome contains granitic intrusion. The country rocks of the intrusion primarily include high-grade metamorphic rock sequences that are close to the core and low-grade metamorphic sediments at the rim. The high-grade metamorphic rocks are intruded by syn-tectonic leucogranite dikes and sills of Eocene to Miocene age. LA-ICP-MS zircon U–Pb dating yielded a crystallization age of 40~15.5 Ma for the leucogranite dyke swarm, which suggest that the magma lifetime of the Yardoi Dome was as long as 25 Ma. Muscovite from the three studied samples yielded 40Ar/39Ar ages between 14.05 ± 0.2 Ma and 13.2 ± 0.2 Ma. However, the biotite from the garnet-bearing two-mica gneiss have 40Ar/39Ar age of 13.15 ± 0.2 Ma. These results suggest that the exhumation led to cooling through the 350°C Ar closure temperature in muscovite at ~14 Ma to the 350°C Ar closure temperature in biotite at ~13 Ma. The mica 40Ar-39Ar dating results showed that the Yardoi Dome was formed before 14 Ma. Between 8 and 13 Ma, the cooling rate at the core of the dome (88°C/Ma) was faster than the cooling rate at the rim of the dome (51°C/Ma). The structural and geochronologic histories documented at the Yardoi Dome are similar to other Dome, suggesting a common mode of occurrence of these events throughout southern Tibet.

Foreland basin evolution in the southern Tibet and central Nepal: implications for timing of India–Asia collision

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The Tibetan Plateau and the Himalayan region formed after 55–50 Ma, as a result of the intracontinental collision of the India–Asia plates in the central Asia. Active tectonic movements play a fundamental role in basin formation along the Tibet–Nepal Himalayan region. Different foreland basins of the Tibetan Plateau (e.g. Lhasa terrain, Hoh Xil Basin, Qaidam Basin, and Jiuquan Basin) and the Himalayan foreland basins (e.g. Gondwanaland depress Basin, Siwalik and Quaternary Basin) experience direct effects in terms of tectonic and sedimentary evolution. Siliciclastic sedimentary rocks of the Lhasa terrain from northern flank of the Indian passive continental margin, and Tansen Basin– southern flank provide an estimate of the age of initial contact between the two continental parts of the Indian and Asian plates. We report sedimentological, sedimentary petrological, and geochronological data from Upper Cretaceous-Neogene strata in the Lhasa terrain and Tansen Basin, located along the southern flank of the Indus-Yarlung suture zone in southern Tibet and southern flank of Main Boundary Thrust (MBT) respectively. For the provenance analysis, detrital zircon age from 1170 Ma to 950 Ma in the Lhasa terrain most likely derived from the Qiangtang, Tethys Himalaya, and southwest Australia. Similarly, detrital zircon age from 1000 to 750 Ma of the Bhainskati and Dumri Formation are the similar age terrain of Tethys and Higher Himalaya. Cretaceous to Paleocene pre-collisional Amile Formation; the detrital zircon age of 120 Ma indicates either Cretaceous volcanic rocks of Rajmahal– Garo Gap (about 600 km south– west of western Nepal) or the Gangdese batholith in southern Tibet north of the Indus–Tsangpo suture zone. Similar age of the optical petrography data and resulting QtFL and QmFLt plots classify Tansen sediments as “recycled orogenic” and “Quartzose recycled”, indicating that Indian cratonal sediments as the likely source of sediments for the Amile Formations, and the Tethyan Himalaya as the source for the Bhainskati Formation, and both the Tethys and Higher Himalaya as the major sources for the Dumri Formation.

Segmentation of the Himalayan megathrust around the Gorkha earthquake (25 April 2015) in Nepal

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We put the 25.04.2015 earthquake (Mw 7.9) into its structural context in order to specify the segmentation of the Himalayan megathrust. The rupture is located NW of Kathmandu on a flat portion of the Main Himalayan Thrust (MHT). Its northern bound is the transition towards a steeper crustal ramp. This ramp, which is partly coupled during the interseismic period, is only locally affected by the earthquake. The southern bound of the rupture was near the leading edge of the Lesser Himalaya antiformal duplex and near the frontal footwall ramp of the upper Nawakot duplex. The rupture has been affected by transversal structures: on the western side, the Judi lineament separates the main rupture zone from the nucleation area; on the eastern side, the Gaurishankar lineament separates the 25.04.2015 rupture from the 12.05.2015 (Mw 7.2) rupture. The origin of the lineaments is complex: they could be linked to pre-Himalayan faults that induce transverse warping of the lithosphere, control the location of lateral ramps and concentrate the hanging wall deformation at the lateral edge of the ruptures. The MHT is therefore segmented by stable barriers in at least five patches that influence earthquakes: The 1833 (Mw 7.6) earthquake was similar in extent to the 2015 event but its rupture propagated from an epicentre located NE of Kathmandu; the patch south of Kathmandu was probably affected by three earthquakes of Mw $\geq$7 that followed the 1833 event a few days or 33 years later; the 1934 earthquake (Mw 8.4) may have propagated as far as Kathmandu and jumped the Gaurishankar lineament. This combined approach indicates that the MHT is affected by barrier-type earthquake families. For each earthquake, the rupture histories could be different and the greatest earthquakes could affect the patches of several families. There is therefore no regular recurrence of characteristic earthquakes in Himalaya.

Landslides and other damage to buildings and infrastructures from the April-May 2015 earthquake sequence, Solukhumbu district, Nepal

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The unpredictability and low frequency of large earthquakes make the recognition of their role in triggering slope instability quite obscure. The earthquakes (Mw 7.8 and 7.3) that struck Nepal during the April-May 2015 period provide an exceptional opportunity to assess their role and specify the type, size and site of disruptions. The study focuses on the eastern margin of the zone affected by the earthquakes, i.e. the Dudh Kosi section between Khari Khola and Manjo. Three visits in these areas carried out in March 2015, November 2015 and April 2016, allowed us to compare the geomorphic evolution (mountain slopes, river beds) and damage to buildings and infrastructures, before and after the earthquakes. The studied area straddles the Main Central Thrust zone, and includes both the lower Higher Himalayan crystallines and Lesser Himalayan meta-sediments. It is also dominated by very large rockslide deposits (Namche-Khumjung, Lukla, Kharikhola), their related valley fills (lacustrine deposits, gravelly, sandy river terraces and debris fans), and by relicts of glaciations (morainic deposits). We surveyed and mapped new, earthquake-induced slope instabilities such as rock falls, rockslides, landslides, gullies and debris flows, or their combination, and cross-check our inventory from satellite images of the three periods. Noteworthy are the limited size and shallow depth of the newly generated slope failures, compared to what is commonly observed after severe monsoon rainfalls. Landslides distribution indicates three significant control factors: (1) Lithology: weak fractured bedrock supplied rock falls and rockslides, whereas superficial deposits (alluvial, lacustrine, and colluvial soils) favoured larger failures (south of Manjo, near Ghat); (2) Slope convexities, steepness (>45°) and height (500-1000 m) favoured landslide initiation near the ridges top, whereas a series of cascading processes ensured the transfer of debris downslope, locally resulting in temporary valley damming (Toktok, Jubing); (3) Vicinity to deeply incised streams and to Dudh Kosi River increased the volume of collapsed material, all the more so because of the presence of terrace of unconsolidated gravels and sands (Nakchun), resulting in the destruction of agricultural land. Collectively, landsliding was an efficient process to directly supply coarse debris to rivers (bedload). Earthquakes impacts on buildings, trails and existing infrastructures (canals, hydropower plants, trails) were also investigated. Very few buildings (private, shops, tourism lodges) remained safe, and many repairing and/or re-building appear necessary. If the age and construction quality of the buildings matter, other parameters such as the nature and depth of colluvium appear as significant factors susceptible to amplify the effects of ground shaking, as observed on large block-fields SW of the Kharikhola catchment, blocks belonging to a large rockslope deposit, which might be inherited from, and triggered by, former undated seismic events. More generally, the destruction of microhydropower canals (Manjo), the burying of water springs (Thulo Gumela), put water resource, water use, and power supply at threat, so that adaptations (canal realignment, relocation of mills, etc.) are urgently required in order to maintain agricultural and tourism based livelihood options, a specificity of this area.

Neogene Himalayan exhumation and weathering from apatite fission-track thermochronology and clay mineralogy, middle Bengal fan (IODP expedition 354)

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The International Ocean Discovery Programme 354 expedition (February-March 2015) focused on the middle part of the Bengal Fan (8°N). Seven sites were drilled along a 320 km-long transect and provided good recovery and excellent data to study the evolution of both the Himalayan orogen and the Asian monsoon. Neogene sediments consist of an alternation of rapidly deposited, silty to muddy turbidites (sedimentation rate 10-100 cm/kyr) forming levees of channels, intercalated with minor slowly deposited hemipelagic clays (sedimentation rate 1-2 cm/kyr). Thick interlevee sand sheet units also occur between channel levees. The easternmost drilling site is located close to the Ninety-east Ridge, which permitted to recover the oldest fan deposits (1200 mbsf), therefore extending the record of Himalayan exhumation and erosion to at least the Late Oligocene, which will greatly increase our knowledge of the early development of the range and Indian Summer Monsoon. Clayey assemblages of the turbidites are dominated by detrital illite and chlorite whereas hemipelagic clayey assemblages are complex with high amount of illite-smectite mixed layers. Clay mineralogy of turbidites as well as major element analysis (Si, Al, Fe) are very similar to the modern Himalayan rivers and are relatively constant throughout the Neogene. These analysis suggest that erosion conditions are relatively steady over the Neogene with a low weathering. This is confirmed by detrital Apatite Fission Track thermochronology. Our first results of good quality apatites show a wide range of ages up to 50-60 Ma. Two to three main populations may be distinguished with in particular an important (30% to 75% of grains) young age peak with very short (<1 My) lag-time. We discuss the potential source of this major and apparently persistent population.

The riddle of the Sabche cirque, the huge high-mountain depression in Annapurna range, western Nepal

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The Sabche cirque in Annapurna Range in western Nepal is unique in at least 3 aspects: It forms a giant amphitheatre with 3 peaks of around 7000 m height; the spillway is an extremely narrow deep gorge; the centre of the depression is filled by a huge pile of lacustrine sediments. South of the Sabche cirque lies the Pokhara valley at a mean altitude of roughly 800 m; it has an extension of about 25 km. The valley was filled two times during the Holocene by several km^3 of debris each which had been transported by giant debris flows from the Sabche cirque. That means that at that time the narrow Seti River gorge cannot have been in existence. For the risk evaluation for the Pokhara valley a thorough understanding of Holocene history of the Sabche cirque is indispensable. A conclusive geological and rock-mechanical model for the sequence of devastating debris flows from the Ghachok and Pokhara events (12,000 and 750 BP) to the May 5 disaster of 2012 is presented here: Probably during the latest glaciation, the glacier tongues extended down the Seti River valley about 15 km from the present spill point of Sabche cirque to an altitude of about 1400 m. Therefore the valley should have had a typical U-shaped cross-section. At the end of this glaciation a giant glacier-lake outburst should have been the reason for the first giant debris-flow event (12,000 ± 1000 BP). As a result of the retreat of the Sabche glacier, rock-mechanical processes seem to have closed the uppermost Seti River valley by a rockslide dam giving rise to the Sabche cirque creating an up to 1,600 m deep lake. The rockslide dam should have burst one day giving rise to the second giant debris-flow event when a total volume of 3 to 5 km^3 of mainly glacial debris mixed with huge amounts of fines from the lake sediments in Sabche cirque rushed down in several surges. The trigger for this might have been the 1255 AD earthquake.

Landslides from the 2015 Gorkha earthquake in the Bhote Koshi River valley – post-earthquake modification and implications for sediment export

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Large earthquakes trigger widespread mass failures, and the estimated volumes of landslide material are often used to estimate seismically triggered erosion, assuming that all landslide material is transported out of the affected area. The expectation that earthquakes can generate a pulse of sediment output from the affected area can also potentially be used to recognize large seismic events in the sedimentary record. However, in order to properly understand the relationship between earthquakes triggered landslides, sediment flux, and erosion, we need to consider how and when the landslide debris is mobilized in the fluvial system and exported from the catchment. We present observations from four field excursions to the upper Bhote Koshi River following the April 25, 2015 Gorkha earthquake, which triggered extensive landsliding in this region. Our observations, from early June, late July, and October 2015, and November 2016 cover the 2015 pre-monsoon, mid-monsoon, and post-monsoon, and the 2016 post-monsoon periods, allowing us to constrain monsoon-driven changes to coseismic landslides. In order to quantify post-earthquake modification of individual landslides, we conducted surveys using terrestrial LiDAR. Immediately following the earthquake, a large number of landslides were disconnected from the channels, with significant amounts of material stored on the hillslopes. As expected, the monsoon caused new landslides, the expansion of existing landslides, and the modification of coseisimic landslide deposits. In late July we observed ongoing mobilization of this stored material, with repeated downslope delivery of material from multiple landslides during a several day period. The mobilization of landslide debris continued through the monsoon, however, in October 2015 a significant amount of debris remained stored on hillslopes above the main channel, as well as in the upper parts of small tributaries. These deposits represent a major potential hazard during the next monsoon, and infrastructure in this area remains particularly vulnerable. We have also installed hourly time-lapse cameras in several locations along the Bhote Koshi to observe changes in the river channel. Aside from local perturbations due to individual landslides and debris flows, the river showed negligible change from June to October 2015. However, during the 2016 monsoon, the river was heavily affected by an outburst flood on the 5th of July, which moved a significant amount of sediment, restructured the river bed, and caused ongoing erosion of the river banks over the following weeks, doing considerable damage to infrastructure and destroying many houses. We can use data from a seismic network installed along the river valley in June 2015 to constrain the timing, duration, origin, and bedload transport properties of the outburst flood. The impact of the flood on the river can also be observed with our time-lapse photographs and daily measurements of suspended sediment load. These data indicate that despite the very short duration of the flood itself, it dominated the changes to the river channel during the 2016 monsoon.

Perturbation of earth surface process by the 2015 Gorkha earthquake

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Large earthquakes can substantially perturb a wide range of Earth surface processes. The strong shaking caused by large earthquakes weakens rockmass, causes extensive landsliding, and alter the hydrological conductivity of the near surface. This leads to subsequent responses that include sediment loading of rivers and changes in subsurface water flow paths. The long term perturbation often last several years and even might outstrip the immediate co-seismic impact in their magnitude. Over time the system restores to background conditions, and the recovery process and transient timescales of different systems provide particularly valuable insights for predicting natural risks associated with the aftermath of earthquakes. Here we will present results of the first 1.5 years of monitoring surface processes in the epicentral area of the 2015 Gorkha earthquake. The observations started immediately after the event and are planned to continue for a total of four monsoon seasons, in order to capture the full recovery process of the system until pre-earthquake conditions have been reached. We have installed a comprehensive network of twelve river sampling stations for daily water and sediment sampling, covering all major rivers draining the earthquake-affected areas. Nested within this regional network, we have installed an array of 16 seismometers and 6 weather stations in the upper Bhotekoshi catchment. The field measurements are accompanied by repeated mapping of landslide activities using satellite imagery. Our results show pronounced changes of the hydrological regime, underpinned by a marked change of seismic noise velocities, both indications of significant changes of the subsurface rock properties. Alongside, our landslide mapping documents about ten times greater landslide activity during the 2015 monsoon season than typically expected for this monsoon season. Very preliminary estimates for the exceptionally strong 2016 monsoon season are also elevated. This demonstrates the lingering natural hazards, lasting several years, due to earthquakes in perturbed landscapes.

Evaluation of groundwater quality and contamination of fluoride in Medak region, Telangana, south India

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Hydrogeochemical investigation of fluoride contaminated groundwater samples from Medak district in Telangana are undertaken to understand the quality and portability of groundwater from the study area, the level of fluoride contamination, the origin and geochemical mechanisms driving the fluoride enrichment. The groundwater is the main source of water for their living. The groundwater in villages and its surrounding are affected by fluoride contamination and consequently the majority of the people living in these villages has health hazards and is facing fluorosis. The purpose of this study is to identify geochemical processes and using characterization of the major physico-chemical parameters of groundwater from study area. For this purpose, 194 groundwater samples were collected and analyzed for different water quality parameters, such as pH, EC, TDS, TH, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, nitrate, sulfate and fluoride with the help of standard methods recommended by American Public Health Association. The results of the analyzed parameters formed the attribute database for geographical information system (GIS) analysis and final output maps. Fluoride ion concentrations ranged between 0.4 and 7.1 mg/L with mean values of 1.69 mg/L in the groundwater suggesting that favorable conditions exist for the dissolution of fluoride bearing minerals present in the granite and gneissic rocks in the study area, whereas, distribution pattern showed high concentrations in the vicinity of Siddipet, Chinnakodur and Nangnoor. Due to the higher fluoride level in drinking water, several cases of dental and skeletal fluorosis have appeared at alarming rate in this region. The highly alkaline conditions indicated fluorite dissolution as major process responsible for high concentration of fluoride in eastern part of the Medak. Fluoride has a very weak correlation with pH which may be due to the increase of alkalinity resulting from the increase of bicarbonate ions. While the deficiency of calcium ion concentration in the groundwater from calcite precipitation favours fluorite dissolution leading to excess fluoride concentration. The comparison of TDS versus Na/(Na+Ca) and Cl/(Cl+HCO_3) points to the dominance of rock weathering as the main process, which promotes the availability of fluoride in the groundwater. The presence of high fluoride in groundwater poses a serious health threat to the rural populace in the region.

On the nature of Indian Moho

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The contact of the crust and uppermost mantle is termed as Moho and it has become a fundamental first order discontinuity of the Earth. The structure and nature of the Moho constitute a key element in understanding the physics behind the dynamic processes acting in the Earth's interior. It is generally one of the most important boundaries in theories of isostasy, orogenesis and constrains models of early Earth evolution. Another intriguing feature and ongoing debate in crustal evolution is about the base of the crust i.e. Moho – its nature and vertical extent (sharp or diffused). In order to understand the nature of Moho, the most important parameters are its morphology, compressional- and shear- wave velocity contrasts, which govern its coupling with mantle and its genesis. It was the job of the deep seismic refraction/reflection methods to provide its nature, using the uppermost mantle velocities by the observations of Pn and Sn phases. However, in most cases, observing enough sub-Moho phases are a challenging job because of their weak amplitudes and mixing with crustal Pg phases. To describe the nature of the Moho we have used receiver function method along with a newly developed technique to estimate the shear-wave velocity contrast across Indian Moho using large amount of seismological waveforms (from 82 broadband seismic stations). The new method uses transmitted P-to-S wave amplitude variations with ray-parameter, similar to the AVO technique of exploration seismology. Such attempt is first of its kind in a comprehensive manner for a continental crust. The shear-wave velocity contrast map (δβ) clearly reveals that the Indian Moho is highly variable for P-to-S conversion coefficient. It varies from 0.08 to 1.1 km/s. The Aravalli regions are characterized by δβ ~0.35 km/s. However, near the Bundelkhand Craton (BhC) it reaches up to ~0.7 km/s. Other cratons of Indian shield shows the similar range of values i.e. Below Bastar Craton (BC) has ~0.6 km/s; eastern and western Dharwar Cratons have ~0.52 km/s and ~0.61 km/s respectively. Across the Moho beneath Deccan Volcanic Province δβ is ~0.67 km/s. These variations in δβ are proportion to the transition in the lower crust that implies that the seismological nature of the Moho undergoes a long evolutionary process since its genesis until they became stable continental block. The origin for such transition in Moho is either due to the fact that Indian mantle is fertile or due to the underplating of magmatic materials fed by the plumes. The scaling relationship between heat flow and different crustal parameters shows that the regions with large transition zone formed thick lower crustal rocks (i.e. low heat producing) and thin upper crustal rocks (i.e. high heat producing). In other words, thick transition zone is responsible for making thick lower crust and consequently low heat flow.

Hypsometric analysis and effect of major thrusts on Sub-Himalaya region using geo-spatial technologies

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Hypsometric analysis explains the segmentation of horizontal cross sectional area of basin with respect to elevation. Morphology of a river plays a major role for the study of tectonic activities. Aim of this paper is to carry out the Hypsometric analysis of Sub-Himalaya region, using Digital Elevation Model (DEM). The present study takes into consideration the watersheds developed over actively deforming anticlinal ridge in the frontal part of NW Himalaya. Remote sensing and GIS are the best tools for such analysis. The hypsometric analysis has been used as a morphometric parameter, i.e. hypsometric integral, to deduce its relationship with the area of watersheds. Hypsometric curves were derived and analyzed for each of the river basins close to HFT and MBT from 30 meter ASTER GDEM. It has been observed that some river basins have been subjected to tectonic disturbances relative to others. Removal of this anomalous watershed always brings out much stronger relationships. The anomalous watershed has been directly attributed to the difference in geologic structure.

Spatio-temporal variability of landslides in the Sikkim Himalaya, India

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Sikkim state of India lies in the seismically very active zone of the eastern Himalaya and vulnerable to natural hazards like frequent landslides and earthquakes. A series of landslides occur between the two major thrusts, the Main Boundary Thrust (MBT) in the south and Main Central Thrust (MCT) in the north. Landslides in the Sikkim region create many problems like deforestation or loss of vegetation, transportation and displacement of people as well as loss of life and properties. On the basis of last 15 years (1999-2013) data collected from review of literature and various other sources, large variations were reported as far as the distribution of landslide in Sikkim Himalaya is concerned. The maximum numbers of landslides were reported in the east district followed by north, west and south districts. It is also observed that the frequency of landslides has drastically increased after 2006 in the west Sikkim. The frequency of landslides is higher in eastern part of Sikkim but the intensity of landslide has been noticed higher in the northern part of Sikkim. We have also observed that occurrences of landslides are not uniform over the time period. The cases of landslides were very low during the winter season and the number of cases increased immediately after the winter season. During monsoon the reported cases of landslides were very high due to the heavy precipitation and it shows declining trend after the end of monsoon. Variation of landslides in Sikkim also reveals that there was a sharp increase of reported cases of landslides in Sikkim from the year 2007 onwards. The high variability of landslides in the Sikkim Himalaya is attributed to lithological variation as well as magnitude of structural deformation in the rocks. In addition to geological and tectonoclimatic factors, high rainfall, steep topographical slope (Fig. 1), high weathering rate, loss of vegetative cover, and slope modification for construction and widening of roads and construction of tunnels etc. are other major contributing factors for the increased landslide occurrences in the Sikkim. The construction of many hydroelectric power plants in the Teesta and Rangeet River valley is another crucial factor for triggering of landslides in the Sikkim state. These large scale construction activities and removal of vast amounts of rock mass from the unstable slopes significantly interferes with the ground water and also the surface water conditions. In the present paper we have discussed the causes and remedies of the landslides in the Sikkim Himalaya and the sustainable development.

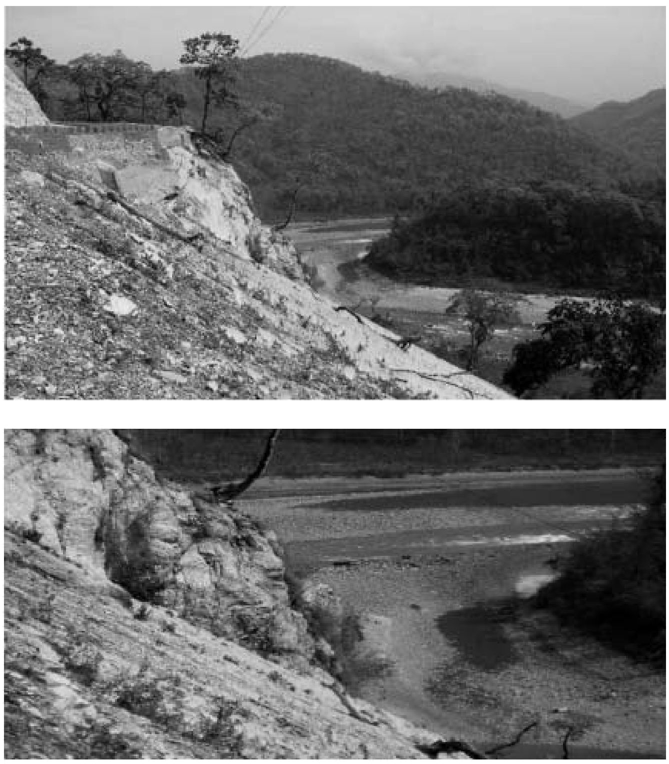

Fig. 1: Landslides along the National Highway from Siliguri to Gangtok along Teesta River.

Seismic vulnerability assessment of existing hospital buildings in Imphal city

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Modern civilization has faced frequent devastating disaster in the last decade due to major earthquakes. Therefore, it has jeopardized the existing building stock and hence necessitated their vulnerability assessment. Such assessments are helpful for the administrators to adopt appropriate measures that can reduce the loss of human lives and properties. Imphal is a growing city in the north-east part of India, which lies under Zone V. The past history of earthquake, particularly the damage associated to the structures is an important unit in seismic vulnerability. The present study deals with the seismic vulnerability assessment of an important existing reinforced concrete building of public interest- a hospital- situated in Imphal city, Manipur. Imphal city lies in a longitude of 93°56'E and a latitude of 24°44'N, which is the capital of Manipur state in the north-east part in India. North-east India is one of the seismically active regions out of the most active regions in the world. This region falls under Zone-V of the earthquake hazard zonation map of India (zone of most severe seismic hazard) according to IS1893:2002. A field survey of some of the existing hospital buildings in Imphal was carried out and a preliminary assessment of seismic vulnerability was made. The Rapid Visual Screening (RVS) was done by using RVS form by Prof. Arya. One of the hospital buildings which were found to be vulnerable from RVS was evaluated using numerical analysis, using SAP2000 in order to assess their vulnerability for Simplified Vulnerability Assessment (SVA). The deficient members observed from the output are suggested for strengthening and retrofitting.

Geodynamic evolution of the northeast India and the recent disasters in Himalaya with special reference to Sikkim Himalaya

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India was part of the Gondwanaland supercontinent till early Cretaceous. It was a period of intense plate tectonics leading to the development of new sedimentary basins. Further anti clockwise movement (northward flight) of India caused emergence of passive margin setting. Indian Plate completely got detached from Antarctica in early Albian. The passive margin setting from Late Cretaceous to Oligocene continued until the collision of the Indian Plate with Eurasian and Burmese Plates in the NE India. The thick sedimentary pile was deposited in Late Mesozoic to Cenozoic in shallow shelf, inner and outer ramps to basinal facies in the NE India. Two distinct shelf and basin sedimentation facies has been recognized. The sediments of the inner and outer shelf are well developed in the Shillong Plateau, Meghalaya. The geodynamic evolution, paleogeography and the paleoclimatic changes in the northeastern region including Sikkim Himalaya during Proterozoic, Paleozoic, Mesozoic Tertiary and Quaternary Period has been discussed. Northeastern States (Assam, Meghalaya, Arunachal Pradesh) are rich in natural resources in hydrocarbons (oil, coal, shale oil), uranium, copper, iron and other minerals. Coal and base metal mineralization is also known from the Sikkim Himalaya. The Meso - Neoproterozoic stromatolites are very well preserved in the Buxa Dolomite Formation in the Rangeet River valley near Tatapani, along the road from Tatapani to Reshi and Namchi town to Mamley village. The other important evidence of Permian glaciation is also well preserved at Tatapani where large Gondwana Ranjeet Boulder Beds (glacial diamictites) indicate strong past evidence of glacial cool climate on this part of the Earth in the eastern Himalaya. South Sikkim Gondwana deposits are also characterised by the excellent development and preservation of plant fossils like *Glossopteris* sp, *Gangamopteris* sp., *Vertebraria* sp. and other plant groups found in the coal beds near Namchi town named as Namchi Sandstone and also traced along Jorethang – Legship road section. The glacial boulder beds of the lower Gondwana have been studied from the northern Sikkim and Lachi Formation is correlated with the Lesser Himalayan Rangeet Boulder beds. The geology, structure, stratigraphy and the geomorphology of the Sub, Lesser and the Higher Himalaya is very fascinating and significant geological features must be preserved and these sites must be developed as geological and fossil parks. Some very important and geologically significant sites in the south Sikkim Lesser Himalaya needs to be preserved immediately and developed as fossil parks since these are located very close to the ongoing and proposed new hydro power projects, road constructions and other developmental civil constructions. Sikkim has vast potential for the sustainable and eco-friendly development in future. Since geologically it is fragile and lies in the highly seismically active zone V of the Himalaya, falling between Main Boundary Thrust and Main Central Thrust. The state is highly vulnerable to major earthquake occurred in 2011 (Sikkim earthquake) near the India- Nepal border. Sikkim is very prone to natural hazards like landslides and there is possibility of Glacial Lake Outburst Flood (GLOF) in the Higher Himalaya where large glacial lakes are located. Landslides are frequently triggering along the National Highway 10A, therefore, the construction of roads and dams along Teesta River must be constructed with care and modern technology, keeping in mind the geological instability of the area. Recent natural disasters in the Uttarakhand Himalaya and possibility of such disaster in the Sikkim Himalaya has been discussed and mitigation is suggested.

Mitigation and bioengineering of Surbhi resort landslide, Mussoorie syncline, Lesser Himalaya, Uttarakhand, India

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Surbhi landslide is located in the Krol C Limestone of the Upper Krol Formation, Mussoorie Syncline, Garhwal Lesser Himalaya, Uttarakhand, India. In August, 1998, after intense rains, the slope suddenly gave way and washed away several water mills and destroyed 5 hectares of agricultural land. Geotechnical and geological studies have shown that the slope is still inherently unstable. In our earlier studies the parameters such as grain size, UCS, permeability, liquid limit, point load test and petrography of the soil and rocks have been determined, which concludes that the shear strength reduces drastically when the soil gets saturated. Since the pore water pressure is a major reason for the failure, excess water must be prevented from reaching the slope by installing proper drainage trenches (40 cm in diameter) with culverts on Mussoorie-Kempty road to lead the water over the slopes around Siyagaon village. Secondly, the slope should be drained by horizontal drains at the toe of the detachment zone spaced 3 m apart. In the present paper we suggest bioengineering solutions for stabilization of Surbhi Landslide. To stabilize the surface layer of the soil, woody vegetation of *Quercus leucotricophora* and *Pinus roxburghii* has to be developed by artificial reforestation or assisted natural reforestation. This includes lying out of geomesh and live fascines of *Salix tetraderma* to help the seedlings get a better grip on the steep (60°-70°) slopes and to increase the organic matter content. Fibrous roots have a very high soil binding capacity, but they will not penetrate deep enough to cross the failure plane of the landslide (30 m deep). Tap roots penetrate deeper and especially along the edges of the landslide will have the effect of stitches in a surgical suture. The increased transpiration of the vegetation will further help in draining the slope, while the texture of the soil will be improved by increasing the porosity due to root penetration. Increased porosity leads to better drainage and less changes of the soil reaching saturated conditions. The rain water which falls on the slope together with the ground water follows the Rangoan-ka-Khala down to Aglar River. To prevent further erosion of the channel, the velocity of the discharge should be reduced by gabions constructed at regular intervals along the entire length of the channel. The banks should be planted with grasses and shrubs such as *Saccharum spontanum*, *Wordfordia fructosa* and *Eriophorum comosum* and trees such as *Dalbergia sissoo* and *Alnus napelensis*. Due to the length of the landslide (3.5 km) retaining walls or wire-mesh are not economical. If such measures are not initiated, another large scale failure as seen in 1998 is very likely to reoccur.

Lessons learned from the 2015 Mw 7.8 Gorkha earthquake, Nepal

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On April 25, 2015 a powerful Mw 7.8 earthquake occurred in the shallow depth of 8.2 km (USGS, 2015), beneath the Gorkha district of Nepal, leaving more than 8,800 people dead and nearly 22,000 injured. Following the event, the most damaged villages within the epicentral region as well as the cities of Kathmandu, Bhaktapur, Gorkha, Kaski and their adjacent areas were visited by the author during 6 to 11 May 2015, in order to survey the geologic effects and damage distributions as well as to investigate the disaster management measures and responses. Based on my visit, coordination between the national and international disaster management measures and emergency responses such as shelters, public camps, treated water, health amenities and so on are assessed and ongoing challenges and some key lessons learned from the Nepal earthquake are highlighted.

INTRODUCTION

An intense Mw 7.8 earthquake struck the central Nepal on April 25, 2015 at 11:46 A.M. in local time. This event –also known as the Gorkha earthquake- caused large damages to the structures and infrastructures of the society of Nepal claiming more than 8000 lives and 22,000 injuries. To assess the performance of disaster management and emergency responses to the 2015 Gorkha earthquake, the most damaged villages of the epicentral region in Gorkha district and the affected cities of Kathmandu, Bhaktapur, Kaski and their adjacent villages were visited by the author during 6-11 May 2015. In this respect, the physical damages to the building and historic monuments are pointed out briefly. Logistics, disaster management performance, along with such emergency response as shelters, health, food, treated water and medical supplies are described in detail. Meanwhile, several key lessons learned from the 2015 Nepal earthquake response are highlighted.

PROCEDURE

Most of the damages caused by this earthquake were observed in the mountainous villages within the epicentral region specially in the Barpak, Laprak, Saurpani and Langtang villages. Based on the observations related to the damage level to the structures as well as the secondary geologic-geotechnical evidences, the earthquake intensity was estimated to be about VIII, VII, VII and V on the EMS98 intensity scale in the epicentral region, Kathmandu, Bhaktapur and Pokhara, respectively. As the aftermaths of the 2015 earthquake, several secondary geologic phenomenon such as earthquake-induced landslides and avalanches in the mountainous areas, site effects due to topography and soil amplifications, liquefactions, surface ruptures and ground fissures occurred. We investigated a relatively large earthquake-induced landslide in the size of about 100*50 m (width and length) that was triggered in the Seti River valley, 62 km west of Kathmandu. Between Bhaktapur and Kathmandu, many surface ruptures and fissures were created in the NE-SW direction with the measured azimuth of 196-208°, having about two-meter vertical surface displacement. The available strong motion data of the 2015 mainshock and eight large aftershocks, which were recorded at the KATNP (USGS) station located in Kathmandu and available by the Center for Engineering Strong Motion Data (CESMD), were also processed and analyzed in this study. Calculating the horizontal-to-vertical (H/V) Fourier spectral ratios, a low-frequency (high-period) peak at 0.2-0.3 Hz as well as a peak at 2-3 Hz are emerged in all the records which can imply site effects due to the thick alluvial deposits and high groundwater level in the Kathmandu valley and certainly at the KATNP station. Keeping in mind the low angle of the fault plane (about 10°) and thus the possibility of a near-source directivity effect in the vertical component, the vertical-to-horizontal (V/N and V/E) Fourier spectral ratios were also calculated for all the records. Calculating the V/H ratios, two peaks at the frequency of 0.7-0.8 Hz and 1.5-2 Hz were seen only in the spectral ratio of the 2015 mainshock, while they were not observed in the aftershock spectrums, and this result can indicate the pulse of directivity effect on the fault surface towards Kathmandu.

CONCLUSION

Nepal is located in an earthquake-prone area where occurrence of a major earthquake is always expected. This country has almost non-resilient infrastructures which are so vulnerable to a natural disaster like the April 25, 2015 earthquake. Fortunately, the event occurred in a remote sparsely populated region. If it occurred inside or in the vicinity of Kathmandu, the extent of life losses might be multiplied. Moreover, due to large damages, the reconstruction in such a society might take several years in order to return to the situation before 25 April 2015.

Although there are many DRR programs and NGOs, the operational emergency management plan in Nepal was not practically ready to conduct the emergency management. Nepal's Army seemed to be the well-organized national authority who intervened positively in the event so that about 90% of the troops were involved. In addition, there are some modern NGO's in Nepal worked well in the recent decades in disaster risk reduction, however these efforts are far to be enough to build up the resiliency of this country. The United Nation Organization was the best helping hand to arrange the disaster management efforts by setting up logistic camps and coordinating response clusters in Nepal.

The status of infrastructures and lifelines of the affected society is an important factor in DRR efforts. There is a complicated and dangerous wires system transmitting electric power in Kathmandu. According to the local residents of Kathmandu, even before the earthquake, the city suffered of electricity cut up to 14 hours a day. During the 25 April 2015 Nepal earthquake, energy systems such as fuel and electrical power networks were seriously interrupted so that emergency generators were used to provide the power. German and French teams provided enough amount of treated water in Kathmandu and Bhaktapur in the weeks after the mainshock while there was a shortage in transportation systems such as enough trucks and helicopters to distribute the clean water and relief packages from logistic camps to the affected areas and the roads were unsafe.

The internet was one of the best organized communication tools in Nepal, so that it was in a continuous service and the social networks were the first ways of communication for the Nepali citizens in the very early minutes after the mainshock.

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Study of the current status of active landslide with stabilization design

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Landslide as one of the problems that have caused annual losses of thousands of people and causing heavy damage to the economic, financial and residential areas, is of particular importance. In this paper, the stability of a relatively large slip in Golestan-Iran has been analyzed. This case is in a paved road that connects two villages. This way passes through the mountains and forest and due to weather conditions, small and large landslides in different parts of the road can be seen. Due to environment condition, there is no possibility of changing the route and the stabilization of the slopes is inevitable option. According to available information, including topography of the area, experiments and observations, geometry of landslide specified and modeled in a critical section. With this model the slope stability was evaluated in the circumstances and different solutions to achieve the minimum required confidence were studied.

Crustal structure and mapping the decollement beneath Nepal

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Retrieval of the crustal structure and mapping of the decollement beneath Nepal are crucial for both earthquake location and seismic hazard. It is challenging to identify the exact location and geometry of the decollement using converted phases of teleseismic P-waves (after removing both instrument response and source - path effects). This is due to a weak velocity contrast at the decollement when compared to well-resolved discontinuities like the one between the crust and mantle. Previous studies suggest the presence of anisotropy due to the shearing motion in-between the subducting and the over-riding plates. However, such studies are limited by the trade-off between layer properties. Additionally these studies cannot provide a rigorous estimate of the uncertainties of layer properties as a function of depth. In this work, we apply a Bayesian inference, in which the physical properties of the layers (model parameters) are considered as unknown random variables and represented by probability densities. The prior knowledge of model parameters is updated with the data information to produce the inversion results (isotropic, anisotropic, and dipping layer properties) which is expressed in terms of the posterior probability distribution (PPD). A highly efficient interacting Markov Chain Monte Carlo is applied to sample the PPD. The parameter values and their uncertainties can be extracted from the PPD. Moreover, data noise is also considered as unknown and estimated as part of the inversion. We performed the feasibility of this approach through several synthetic tests. These tests show that both isotropic and anisotropic parameters are better constrained when considering the multiple conversions in the receiver functions. We then applied this approach to the observed receiver functions measured in southern Nepal. The result indicates the presence of strongly anisotropic layer between a very slow-velocity above and a faster layer below it. In this presentation, we will show the results of the data collected from Hi-CLIMB and HIMNT temporary networks in Nepal.

Himalayan earthquake museum

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I have experienced the 2015 Nepal Earthquake at Kathmandu University (KU) in Dhulikhel, and it is my first impression that the earthquake was not so strong, as I used to experience the similar one in Japan and there were no damages except a small crack with 1-2 mm width and 1 m length in my room at KU. So, I didn't expect such a large casualties that the central part of Nepal was suffered from victims of more than 9 thousands and I started to make a field survey in Kathmandu Basin and also along the road route to Nawakot and to Pokhara right after the earthquake due to the KU's shut down. After my one month field survey, I found two fundamental issues to cause such a large damage; one is the people's perception to natural disaster and the other is related to not only the building itself but also the lake sediments on where buildings stand. As we cannot stop the earthquake, but we can reduce the risks, so finally, I came to the conclusion that the Himalayan earthquake museum is needed in order to reduce various kind of risks caused by earthquake for the future Nepal.

Source fault geometry of the 2015 Gorkha earthquake (Mw 7.8), Nepal, derived from a dense aftershock observation

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The megathrust of the Himalayan foothills produced the Mw 7.8 Gorkha earthquake, on 25 April 2015, in Nepal. The geometry of the source fault provides basic information for understanding the active tectonics of the area and for forecasting seismic hazards. To constrain the geometry of the source fault, observation of aftershocks by dense linear array was performed across the focal area from Hetauda to Syabru Besi, passing through Kathmandu, along a 90 km-long, NS trending seismic line. The aftershocks were observed at 35 stations, deployed at intervals of 3 – 10 km. Earthquakes were recorded using 4.5 Hz three-component sensors and off-line recorders for a total of two months in two separate deployments between August 15 and November 28, 2015. A total 716 of earthquake events were detected and their hypocenters determined using a 1-dimensional velocity structure. Precise hypocenters were determined for 609 events, with an error of less than ±0.5 km per event, using double-difference tomographic analysis. The obtained hypocenter distribution portrays a gently northward-dipping zone at 5-10 km depth with a dip of 9 degrees. The aftershock distribution accords well with the rupture area estimated from crustal movements. Seismicity is very low in the area 65-85 km north of the Main Boundary Thrust (MBT), which coincides with an area of large co-seismic slip as deduced from InSAR and GPS data. Due to a lack of aftershocks in the large co-seismic slip area, detailed geometry of the estimated ramp is obscure; however, the dip-angle of the ramp is shallower than it's of geological estimate. There were no aftershocks along the southern part of the MBT. The depth of the unruptured portion of the MBT is shallower than 5 km, and it is unlikely to slip further due to its shallow depth. The highly resolved aftershock distribution provides basic constraints for the geometry of the source fault.

Nagdhunga tunnel plan

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Nagdhunga tunnel, possibly the first road tunnel to be constructed in Nepal is currently under the planning stage. The tunnel is planned at the west verge of the Kathmandu valley at the most critical section of Tribhuvan highway, which is aimed at resolving the issues of consecutive sharp turns and steep vertical alignment that is causing heavy traffic congestion and many deadly accidents. The geology of the area is composed of Tistung Formation and Sopyang Formation that belongs to the Lower Paleozoic, and comprise of alternate layers of sandstone and phyllite. Tistung Formation is distributed on the northern side of Nagdhunga and contains characteristically layers of massive sandstone. Weathered grey or whitish grey soil is observed at the surface. Sopyang Formation consists of alternating layers of thin grey sandstone and psammitic phyllite. The surface is formed of weathered red or grey soil. The east (Kathmandu side) part of the project area has a thick deposit of unconsolidated sand, silt and clay layer of the Kalimati Formation that belongs to Quaternary age which is further covered with Talus deposit composed of fan and debris deposit at the foothill area and Recent river deposit composed of gravel sand and silt alongside the river. Several surveys were carried out for identifying the geology of the area. These mainly include i) Geological survey, ii) Aerial photo interpretation, iii) Electrical Resistivity Tomography, iv) Microtremor Array Measurement, and v) Drilling survey. The survey results indicate existence of a fault that runs in an oblique angle with the planned alignment of the tunnel. Some of the major issues to be taken into consideration for design and construction of the tunnel are, i) the alignment is desirable to pass through intact rock, ii) special attention is required for construction of tunnel portals and sections passing through faults, iii) Avoid leakage of groundwater that may cause the water level at the community wells to fall down.

Records of natural hazard in the Kathmandu-valley-fill succession

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The earthquakes of the high recurrence frequency (~ ca. 200 years) type, centered in Barpak (Gorkha- Mw 7.8) and Sun Khani (Dolakha- Mw 7.3), hit the Kathmandu valley in 2015, resulting in serious human and economic losses in the country. Nonetheless, the low recurrence frequency and large-scale earthquakes (LFEs) like Lo Mustang earthquake (1505) will be in due course. However, the recurrence interval of such earthquakes in the Himalaya is still uncertain. Natural hazards recorded in the Pleistocene succession of Kathmandu valley fill are introduced and are used to approximate the recurrence interval of the LFEs. The upper part of the Kathmandu valley fill consists mainly of fluvio-deltaic to lacustrine deposits (Gokarna, Thimi, Tokha and Patan Formations) ranging in age from 50 to 10 ka (uncalibrated age). The fluvially-dominated-delta deposits in the eastern basin, unaffected by redistributing wave processes, provide higher preservation potential of hazard-event beds related to earthquakes. As the results of extensive sedimentological works, slide and tsunami deposits, and liquefied-fluidized layers were found in the deltaic succession. Around 38 and 16 ka slide deposits are extensively distributed in the eastern part of the Kathmandu valley and have thickness of up to 4 m. The basal part of the slide deposits exhibits a massive sand layer with liquefaction structures, which is overlain by a muddy interval containing breccia and having folds and thrusts. The slide deposits are very gently inclined in broad scale around the buried flexure in the eastern part of Kathmandu. The trigger of the slides may have been the tilting of the basin associated with large earthquakes. Minor slide deposits are also interbedded in other horizons. The tsunami deposits are represented by hummocky cross-stratified, parallel- and wave-ripple-laminated sand layers, revealed by evidence of landward flows in the flood plain and delta front deposits. Some of them directly overly the slide deposits. The triggers of the most of tsunamis may have been slumps on the delta front or slides that have occurred on the delta plain and have moved into the lake. The liquefied and fluidized mud layers of maximum 1 m thick, are frequently observed in the eastern part of Kathmandu, where the buried flexure is present. The layers are basically similar to seismites reported from lake deposits, but the layers are encrusted by mud showing brittle deformation, which suggests that the liquefaction and fluidization may have occurred just below the ground surface. The liquefaction and fluidization may have also been triggered by earthquakes and tilting of the basin. But the inferred scale of the earthquakes seems to have been smaller than those triggered the large-scale slide mentioned above. For the discussion of the LFE recurrence interval, information from the Thimi (33 – 24 ka) and Patan (14 – 10 ka) Formations are excluded, because these formations have a poor record of large-scale event beds. This was probably due to their distribution area, in which the buried flexure that could have led the large-scale events is not running. Based on the wide lateral extent and thickness (at most 4 m), the two slide deposits may have been triggered by the LFEs. In addition to these events, at least 5 times of rapid and large lake-level fall events, that would have been caused by plug destruction of the lake at the basin outlet, have been reconstructed from the study of the lake-level history (around 39, 34, 17, 14 and 10 ka). During the Gokarna and Tokha phases, at least 6 times of the major hazards (lake-level falls and slides: ca. 39, 38, 34, 17, 16 and 14 ka) occurred. Supposing that all of these events could have been triggered by LFEs, the recurrence time of such events is inferred to be 1 – 4 ka More studies related to such major hazard events in the past may provide crucial information for future precaution against mega-earthquakes in the Himalaya.

Climate change impact assessment on hydrological regime of Kali Gandaki basin in Nepal using RCP scenarios

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Himalayan region is the resources of solid fresh water but the hydrological regime is vulnerable due to the climate change impact. Most of the previous studies were concentrated on climate change analysis based on SRES scenarios to quantify the impact. In this study six GCMs of coupled model intercomparison project phase 5 (CMIP5) based on new representative concentration pathways (RCP) scenarios were used for the future projection of temperature and precipitation of Kali Gandaki River basin. Quantile mapping method was used for bias correction of future temperature and precipitation of the study area. The ensemble average temperature projection shows average inclination by up to 2.2 ºC and 4.16 ºC, under RCP 4.5 and RCP 8.5 scenario respectively by the end of the century. The projected precipitation varies from -5.38% to +31.8%. Soil water assessment tool (SWAT) was used to simulate the hydrological processes of the basin. The model was calibrated and validated for Kali Gandaki River basin using the observed discharge data of Seti Beni station at Kali Gandaki River. The analysis of the streamflow using the calibrated SWAT model for the future timeline shows significant variation. Average annual discharge at Seti Beni is expected to vary between minimum -20 percent to maximum more than 40 percent in average annual discharge.

Lithology and geologic structure associated with recent landslides in Nepal

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The first-order geologic rock units of Nepal seem to have a strong bearing on where landslides occurred as a result of the Gorkha earthquake (April 25, 2015), but there has been insufficient study of the lithology of the recent earthquake- and meteorologically induced landslides and their adjoining rocks to prove this. The M 7.8 Gorkha earthquake on April 25, 2015, and subsequent aftershocks up to M 7.3 on May 12, 2015 produced thousands of landslides. We mapped their distribution and found that there were some likely geologic controls on their overall occurrence. Here we offer a preliminary examination of the lithology of several landslides and make note of significant rock structures, such as faults and conformable transitions in lithology, which might have played a role in localizing a few selected quake-caused landslides. In addition to seismically induced landslides, we also examine some landslides affected by anomalous extreme rainfall, and others by road and aqueduct construction for a small hydroelectric power plant. We have used direct field investigations of exposed bedrock lithologies in and near several landslides, and examined the rock outcrops and topography for evidence of faulting or other structural control or lithologic control of landslides. We seek resources to enable detailed geologic mapping of selected landslides and their close proximity, to assess landslide susceptibility using standard criteria such as slope stability, and make rock mechanical testing of major lithologies to assist the understanding of reasons for failure of certain lithologies. In general, we found that the studied landslides occurred in terrain that may have been predisposed to failure due to steep slopes and the presence of (1) weak lithologies, especially of highly weathered low-grade metamorphic rocks such as phyllite, and (2) juxtaposed rocks of distinctive lithologic contrast. An expected climate-change increase in regional precipitation and especially an increase in extreme rainfall and snowmelt events in eastern Nepal might increase the frequency and magnitude of weather-related landslides. Glacier thinning and retreat and consequent debuttressing of moraines and hanging glaciers may aggravate collapse of those. Overall, however, the natural Earth system and demographic/land use change mandates that whatever happens with climate change, destructive landslides of many types will always be commonplace in the Himalaya. Geologic susceptibility factors must be better understood. Slope aspect, vegetation state and recent changes, topographic ridge-and-valley structure and its orientation with respect to seismic energy sources, detailed and accurate maps of lithology and rock properties, and many other variables are likely to be important controls on landslides both past and future. These variables should be considered together for improved landslide susceptibility mapping for seismic and meteorological triggers.

Geological setting and quality of Bandipur slate, Tanahu district, western Nepal Himalaya

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Slate is a widely used industrial rock for decorative and roofing purposes in Nepal and worldwide. The main objectives of the present study were to prepare regional geological map, to unravel the stratigraphic setting of the slate deposit in Bandipur area, testing and evaluating the quality and quantity of slate for roofing and other purposes, to see the relation between petrographic and metamorphic characteristics of slate with its quality as roofing stone. We evaluate a slate deposit in terms of the physicochemical properties and its volume reserves. We review the geologic setting of the deposit, summarize the slate's physiochemical properties, and give an estimate of the reserve's volume. The Bandipur Slate in the Lesser Himalaya, Tanahun District, Western Nepal, is historically known for slate mining. The area comprises the rocks of the Kuncha Formation, Fagfog Quartzite, Dandagoan Phyllite, Nourpul Formation and Dhading Dolomite of the Lower Nawakot Group, respectively, from bottom to top. The Bandipur Slate occupies the axial part of the Bandipur syncline and stratigraphically belongs to the Nourpul Formation. The slates are well-foliated and splitable into smooth, thin slabs. Although it is commercially called slate, petrographically it is phyllite and shows a low grade of metamorphism. Phyllosilicates are well-developed, and show a shiny and soapy luster. Physico-chemical tests, e.g., flexure testing, water absorption, weather resistance, permeability, sulphuric acid immersion, and wetting and drying test, show that most values are close to the ASTM and SI standard. For example, Flexure testing values are useful for strength and elasticity determination of rock slab, that value suitable for roofing. The probable slate reserve is 0.062 MM3. For thickness of 0.64 cm, 25% waste, and 50% headlap (shingle overlap), an average of 100 m2 per covered area of the house, and a roof pitch of 25 degrees, we calculate that 1.88 m3 of slate deposit is needed per house. Hence, this deposit could produce enough slate to roof 33,000 homes, i.e., a significant fraction of slate demand in Pokhara.

Landslide susceptibility assessment of the coseismic landslides induced by April 2015 Gorkha earthquake of Nepal

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Nepal was hit by a 7.8 magnitude earthquake on 25th April, 2015, which along with its many large aftershocks generated a great number of co-seismic landslips in central Nepal. Based on the satellite image interpretation and field work, we were able to map about 3,716 co-seismic landslides which were used to develop a landslide susceptibility map of the affected region. Out of 3,716 landslide data, 80% were used as training data and the remaining 20% were taken for validating the model. A total of 11 different landslide-influencing parameters including slope gradient, slope aspect, plan curvature, elevation, relative relief, Peak Ground Acceleration (PGA), distance from epicenters of the mainshock and major aftershocks, lithology, distance of the landslide from the fault, fold, and drainage line were considered for this study. We also tried to understand the major controlling factors for the formation of co-seismic landslides in the study area. For this, we developed susceptibility maps based on (a) all the conditioning factors, (b) from topographic and geological factors, (c) from geological, topographical and seismic factors, and (d) from all the factors excluding relief, fold and drainage maps. Their performances were evaluated from the success rate curve developed from training data. The result shows that PGA, lithology, slope angle and elevation have played a major role in triggering the co-seismic mass movements. The final susceptibility was validated using the perdition rate curve. The prediction rate of 86.26% indicates that the model is in good agreement between the developed susceptibility map and the existing landslides data. This susceptibility map can be used for relocating the people in the affected regions as well as for future land development.

Behavior of slope failures before and after the Gorkha earthquake in the upper Trishuli watershed and their susceptibility evaluation

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The 2015 Gorkha earthquake (Mw 7.8) triggered about 4,000 mass movements in the mountainous areas of Nepal. We investigated the mass movements in the upper Trishuli River valley, which is one of the most severely affected regions in central Nepal. In that valley, there were about 200 landslips before the earthquake and more than 600 new shallow (less than 5 m deep) failures were initiated by the quake. The landslide investigation was carried out based on detailed fieldwork and satellite image interpretation. We have classified the landslides into rock falls, rockslides, debris flows or slides, and colluvial slides. The distribution of mass movements in the study area is strongly controlled by their position on the landscape, topography, lithology and hydrology. Most of the rock falls were located at higher elevations with very steep slopes consisting of hard rocks, such as quartzites and gneiss; rockslides occurred mainly on moderate to steep slopes; while most of the debris and colluvial slides developed on moderately steep slopes. Besides it was observed that most of the pre-earthquake landslides were insensitive to seismic shaking. We have prepared two inventories: one set containing all the landslides that had occurred before the earthquake, mostly triggered by rainfall and the other set consisting exclusively of slope failures caused by the Gorkha earthquake. The two sets were then used for the preparation of landslide susceptibility maps of the region before and after the earthquake using GIS and an evidential belief function model. These susceptibility maps can be utilized for future land-use planning and infrastructural development in the region.

2015 Gorkha earthquake of Nepal- a test of time

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The Gorkha earthquake sequence of 2015 has become a test for all works that Nepal implemented in aspects of earthquake risk management that covers the entire process starting from hazard, vulnerability and risk assessment to risk reduction and preparedness for earthquake risks. While Nepal has a long history of documented earthquake events and their effects, a scientific treatment of earthquake as a natural phenomenon to reckon with started only after the M 6.6 Udaypur earthquake of southeast Nepal although the Department of Mines and Geology (DMG) started instrumental seismic monitoring with technical assistance of the French Government as early as 1978. The 1988 Udaypur earthquake was an eye opener and it demanded organized approaches on the use of earthquake and building construction sciences for enhancing safety in Nepal. Accordingly several initiatives sprung up; building code development, enhancement of seismic monitoring nation-wide capabilities and human resources development, enhancement of capacity in geophysical studies including in the private sector, emergence of the National Society for earthquake Technology-Nepal, a non-governmental technical not-for-profit technical organization focused on earthquake risk management mainly through earthquake awareness and implementation of earthquake risk assessment and reduction initiatives. Nepal apparently was on a sound path for understanding and reducing earthquake risks. NSET, under the guidance and leadership of the government initiated and successfully implemented several milestone programs such as the school earthquake safety program, annual earthquake safety day, mason training for earthquake resistant construction, program for enhancement of emergency response, community-centered disaster risk management program, municipality earthquake safety program, public private partnership for earthquake risk management, community level disaster preparedness and planning and so on. These works were acknowledged positively nationally and globally. The Sikkim earthquake of September 18, 2014 was another event that subjected all these initiatives to test. However, limited scale of damage due to this earthquake in Nepal did not make it strong enough to warrant significant impact in Nepal. The M7.8 Gorkha earthquake sequence of 2015 that took a toll of more than 9,000 human deaths and several thousand injuries, with more than 5 million houses totally damaged in almost a third of Nepal's territory was strong enough judge what worked and where improvements are necessary. This paper tries to evaluate earthquake risk management initiatives of Nepal in the light of the Gorkha earthquake and to explore areas of improvements for the country considering also the stipulations of the Sendai Framework for Disaster Risk Reduction (SFDRR) to which Nepal has made national commitments for implementation.

Ongoing research on sediment and geochemical cycles following the Gorkha earthquake

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The Mw 7.8 Gorkha earthquake struck central Nepal on April 25, 2015. This earthquake and its subsequent strong aftershocks induced significant co-seismic and post-seismic landsliding, mostly in the Gorkha, Rasuwa, Sindhupalchok and Dolakha districts of Nepal. The combination of landsliding and a monsoonal climate not only represents a threat to inhabitants and infrastructure, but the sediment mobilized by these landslides may also have potential effects on physical and chemical fluxes exported by Nepalese rivers. In this contribution we highlight the ongoing joint research efforts carried out by Tribhuvan University (Nepal) and the ETH Zürich (Switzerland) to quantify and better understand the impact of the Gorkha earthquake on these fluxes. These research projects seek to: (i) Study the relationship between sediment production from co-seismic landsliding and the export of material through fluvial processes. This will be done by combining UAV and other remotely sensed data with geochemical sediment production tracers such as cosmogenic nuclides and modeling approaches, (ii) Assess the effect of the Gorkha earthquake on the mobilization and export of organic carbon (a main forcing of the long term carbon cycle) by Nepalese rivers using stable and radiocarbon measurements as geochemical fingerprints. Four post-earthquake field campaigns offer preliminary data and time series samplings from the last two monsoons. Future work will add to these data and will be used in collaboration with other international groups currently working in Nepal.

Liquefaction susceptibility mapping of Kathmandu valley basin floor

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Kathmandu valley has been established as being under high risk of liquefaction hazard during several past studies. Eyewitness accounts and visitors log during 1934 Nepal-Bihar earthquake also mentions observations that may be attributed to liquefaction related phenomena and observations made during the recent 2015 Gorkha earthquake further vindicates the predictions. This study is based on SPT based probabilistic model. Sixty borehole logs are evaluated taking reference of earthquake magnitude of 7.8 Mw and peak ground acceleration of 0.16 g. Probability of ground failure is computed, based on liquefaction potential index adjusted for probabilistic model and liquefaction susceptibility map of Kathmandu valley is prepared based on probability of ground failure. More than half of Kathmandu valley is found to be under high and very high risk of liquefaction hazard. Liquefaction sites during the earthquake are found to comply with susceptibility map prepared in this study. However, the extent of liquefaction was not observed as severe.

Calcareous nannofossil assemblages during the Quaternary in Bengal fan, Indian Ocean (International Ocean Discovery Program Expedition 354)

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The effects of Quaternary climatic events in the Bengal Fan, including the Mid-Pleistocene Transition (MPT) are poorly understood. Furthermore, understanding the relationships between these climatic events and the paleoceanographic conditions and monsoonal activities during that period are limited. International Ocean Discovery Program (IODP) Expedition 354 drilled seven sites in the Indian Ocean along an E–W transect at 8°N in the middle part of the Bengal Fan to investigate interactions between the growth of the Himalaya, the development of the Indian monsoon and processes affecting the carbon cycle. To recognize and correlate these global climatic processes age constraints are very important. To this end, we studied the calcareous nannofossils for the Quaternary Period using the sediments from the IODP Expedition 354 Site U1451. Calcareous nannofossil abundances range from barren in the fine-grained turbidites to very abundant in the nannofossil oozes with moderate to good preservation. Here, we present the revised calcareous nannofossil biostratigraphy with bioevents in addition to shipboard data. Together with foraminifera and magnetostratigraphic age data, calcareous nannofossil biomarkers suggest a sedimentation rate of about 32 cm/kyr within the turbidites and of about 3–4 cm/kyr for the nannofossil oozes. Preliminary results show that the mid-Pleistocene represents a period with no direct turbiditic supply in this section of the fan. It is marked by relatively high $CaCO_3$ content, very abundant calcareous nannofossils and the calcareous nannofossil assemblages is dominated by small and medium *Gephyrocapsa* spp. and *Pseudoemiliania* spp. (France-Lanord et al. 2015).

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Estimation of above ground biomass and carbon stock using high resolution satellite image

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Trees and other forest plants play an important role to remove carbon and other greenhouse gases from the environment. It is necessary for all the countries to update the inventories of emission of greenhouse gases and estimate the amount of carbon stock. The estimation of carbon stock from field measurement is difficult and tedious task. Thus, this study aims to estimate the carbon stock in the natural forest of Palpa, Nepal using very high resolution satellite image. Ortho rectified geo eye satellite image with resolution of 0.5 m was used to obtain the individual tree crown area. Object based image analysis was used to delineate the individual tree crown area. Automatically delineated tree crowns were validated from the manually delineated tree crowns from field measurement. The delineated CPA has the accuracy of 80.43%. Based on field measurement of stem diameter (DBH) above ground biomass was estimated using allometric equation and then converted to carbon stock using conversion factor. The relationship between CPA and Carbon Stock was established using carbon stock of 212 trees recognized in the field and CPA derived from the image. A non-linear model was developed between the CPA and carbon stock to estimate the carbon stock of the whole study area. The model was validated using the data collected in the field. The model was used to produce carbon map with the carbon stock of approximately 315 ton. The non-linear model explained 78% of predicted carbon. Thus, carbon stock mapping can be done using very high resolution satellite images in the sub-tropical forest.

Vertical electrical sounding for delineating subsurface geology of the Armala valley area, Kaski district, western Nepal

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Electrical resistivity investigation was carried out around Armala valley of Kaski district in order to study the subsurface geologic layer with a view of determining the depth to the bedrock and thickness of the geologic layers. Data were acquired using Resistivity meter WDJD-4 and analyzed using computer software IPI2Win, which is used for processing and interpretation of the apparent resistivity. Resistivity Data were correlated with available lithologs. The simulated results of the 15 VES points conducted using Schlumberger configuration with AB/2 varying from 2 to 400 m and MN/2 varying from 0.5 to 50 m reveal the presence of 4 to 8 geo-electric layers. The top layer comprises intercalations of silty sand and silty clay. Layers underneath the top soil are the dry angular boulder, cobble sized gravels, sandy silts, gravels, sands, fractured bedrocks and fresh basement rocks. The resistivity values of the different layers' ranges from 40 Ωm to 52042 Ωm and were statistically analyzed. The depth of the bedrock from the topsoil or earth's surface ranges from 40.9 m on outer edges of valley to 71 m on the central part. Contour map and 3D map of bedrock for the conceptual model shows that the gradient of the contour is high in the surrounding parts and flat in the center of valley.

South-facing slopes of Himalayan mountains are more dangerous for landsliding: a case study of Nepal Himalaya

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As the mountain range of Himalaya is formed due to the tectonic force acting towards north-south direction (controlled by the collision between Indian plate and Asian plate), its northern slope is relatively gentle whereas southern face is steep to very steep, having sub-vertical to vertical joint sets with perpendicular and/or oblique relation to the bedding or foliation plane. Most landslides occur on south-facing slopes of the Himalayan ranges, as it was the case with the devastating Gorkha earthquake of 25 April 2015. The settlements that were damaged due to the coseismic landslides were also situated mainly on the southern slopes of Himalayan Range. Hence, one of the objectives of this study was to make the national planners and public aware of choosing settlement areas in the future to minimize the loss of life and property due to slope failures. The study is based on the landslide investigation of the Syabrubensi area lying in the Higher Himalaya of central Nepal, Budar-Dadeldhura area in the Lesser Himalaya of far west Nepal, Tribeni–Tripura area (Dolpa district) in the Lesser Himalaya of west Nepal, and Tinau-Jhumsa area in the Siwalik of west Nepal. The study also includes the analysis of landslide density, kinematic analysis of major joint sets in various rock succession investigated in the field. The inventory of old and active landslides was carried out using satellite images and topographic maps. The statistical analysis of landslides (old as well as active) was done for both the north-facing and south-facing slopes. All the selected study areas indicate that the density of landslide is higher on south-facing slopes in comparison to the north-facing slopes. The kinematic analysis of joint sets shows that sub-vertical to vertical joints are nearly parallel to the south-facing natural slope. Similarly, the relationship between the slope aspect and landslide distribution in the study areas also confirms that the south-facing slopes are more landslide prone than any other direction.

Probabilistic seismic hazard analysis of Nepal

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Probabilistic seismic hazard assessment of Nepal has been carried out in this study. Nepal lies in the geological boundary of 26°22'E to 30°27'E latitude and 80°04'N to 88°12'N longitude. Review of available information on tectonic setting, seismicity and predictive relationships has been done for Nepal, which is high seismic zone with history of great earthquakes and identified 92 small faults underlying big three fault systems parallel to the Himalaya. However, faults being close, it is not applicable to develop magnitude-frequency relationship for each of them. Hence, four area sources have been considered with different densities based upon historical earthquakes. At each sources, earthquake data was collected from various sources. All data has been converted to moment magnitude, aftershocks and repeated events have been removed, and completeness analysis has been performed. And magnitude-frequency relationship has been developed. Entire area of Nepal has been divided into 1.2°*0.6° grid size and seismicity within 300 km radius was considered. Separate earthquake densities are calculated based upon historical earthquakes using kernel estimation method which accounts the significance of both numbers of earthquakes and size. Then, considering various attenuation laws developed for subduction zone, peak ground acceleration and spectral acceleration for return periods 475, 975, 2000 and 5000 years are calculated at 64 sites.

Reviving livelihoods in the earthquake-affected area: policy, program and prospects

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The destructive earthquake of 2015 rocked the entire Nepal devastating the half of Nepal, affecting over one-third of population and damaging completely as well as partially more than one million physical structures (such as houses, government buildings, heritage sites, school, health facilities and infrastructures). It was a disaster for a small country like Nepal where over 9,790 persons were killed injuring another 22,300 persons. Not only the loss and damage of properties and human life, but also almost 132 thousand households from the 14 severely affected districts lost their livelihood means, especially home-based workplaces and small and cottage industries. Besides, many people lost their villages as well. For example, 475 settlements are not suitable for habitation due to their geological vulnerability. The estimation of social and cultural loss is beyond assessment and calculation. The primary purpose of the paper is to highlight the necessity of the livelihood in recovery and reconstruction process. It begins with the statement of the policy related to livelihoods and its strategies in the reconstruction and rehabilitation policy of the national reconstruction policy 2072. The paper also gives a brief summary of the thematic areas presented in the post disaster recovery framework, a five-year roadmap that covers four sectors; social, productive, infrastructure and cross-cutting. About 56 thematic areas are concerned with livelihoods within a total 512 areas. Then the paper reviews the activities of the line ministries included in the LMBIS (Line Ministry Budget Information System). The LMBIS has included activities of only four ministries for 31 districts of the affected areas. This paper also mentions the implementation of 24 livelihood activities (mainly skill development and livelihoods) of some 21 international non-governmental organizations mainly, in the fourteen severely affected districts. The paper concludes stressing an emphasis that the NRA should take up the following activities in order to mainstream livelihoods in recovery and reconstruction. These activities are mapping of skills, providing revival package to those who lost their livelihood opportunities, integrating livelihood into the donor-driven house construction and regular monitoring of these activities.

Chemical, XRD and SEM studies of Eocene coals, Nepal

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The Eocene basins of the Tosh and Jhadewa coalfield were selected for sample collection. A total of 6 coal samples, 3 for each coalfield were collected directly from the underground coal mine and outcrop coal seams in the western and central Nepal. All of the coal seams both exposed or under production were sampled. Using petrographic, geochemical data, and SEM, an attempt has been made to understand the microstructural relation, depositional environment of the paleomire in the Eocene basin of this region. Samples were subjected to proximate analysis to determine the coal components. The proximate analysis results illustrates that the coals are mainly medium ash, with the volatile matter (VM) ranging from 9.61% to 15.59%, moisture (M) varying from 0.79% to 3.28%, Fix Carbon (FC) ranging from 31.98% to 71.69%. As the standard of measuring the coalification degree of coal, coal rank is quantified by FC, the western Nepal coal is classified as Lignite coal whereas the central is Bituminous Coal. X-ray diffraction (XRD) techniques were used to identify the mineral phases present in coal samples and the results indicates that quartz and kaolinite are the major minerals present in all the six coals. The occurrence of micro structural and mineral matter of Eocene coals were characterized by scanning electron micrography (SEM), which illustrates different macropores and mesopores, whereas width of the microcrack are 0.31 and 0.59 nm. It was further confirmed by microscopic study where the mineral matter associated with the coal is largely separable and on its physical processing the grade of coal may be further improved.

Challenges and opportunities for integrated community development in the context of post-earthquake reconstruction in Nepal

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The earthquake of April 25, 2015 and consecutive aftershocks devastated 755,549 private houses and 6,278 office buildings. Additional 50,000 class rooms were also affected. About 475 settlements are under investigation for ascertaining their magnitude of vulnerability and about 50% of them may require relocating. On the other hand, Nepal's sparse settlement pattern has been one of the reasons for under-development. The scattered settlements trigger high per capita construction and maintenance cost and such infrastructures yield very low rate of return. Having extremely low economic opportunities, rural-urban migration has been accelerated. However, promoting integrated community development involves fairly huge challenges. Unavailability of adequate appropriate land for housing and livelihood purpose, cultural values which inhibit shifting from one place to another, scarcity of resources for developing infrastructure are the major factors that need to be considered. Dearth of water has become another major constraining factor which must be considered while developing settlement plans. Scale of intervention will depend upon the potential settlement hierarchy. Hierarchy of settlements could be: rural hamlet, service centers, market town and municipalities. All infrastructures should fit to their hierarchy. Demand driven and beneficiary owned land pooling can be one of the strategies for the promotion of the integrated settlements. Beneficiaries construct their own houses and the Government provides infrastructures. The promoted settlement needs to be integrated with the transport networks and other higher level service and urban centers. Development of compact and integrated settlements will need to take care of beneficiaries' ethnic background and their customs, rituals and architectures. The vulnerable settlements and landless people will require fresh development of new settlements. Ensuring beneficiaries' livelihood will become the major challenge. The settlements which have potential for developing as market towns and municipalities will need to take care of the required facilities and amenities. Such settlements may require proper bus and truck stops, agro-collection centers, commercial banks, higher secondary schools and other specialized stores. The present reconstruction period has to be used as an opportunity for restructuring our settlements for increasing efficiency in the economy, lowering construction and maintenance cost of infrastructures, enhancing production and distribution base of agricultural and industrial outputs. Ultimately it will lead towards prosperity.

An overview of the 2015 Gorkha earthquake-induced geohazards in Nepal and emerging resettlement questions in the face of recovery

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Located in the central part of the Himalaya, Nepal has been known to be one of the most seismically hazard prone countries in the world. This fact was tragically illustrated, when two high magnitude earthquakes (Mw 7.8 Gorkha earthquake and Mw 7.3 aftershock) on April 25, 2015 and May 12, 2015 and series of aftershocks struck Nepal and resulted in 9,000 casualties, 22,300 people injured and 750,000 homes damaged or destroyed, in addition to tremendous suffering or loss of livelihoods of hundreds of thousands of people. Though severe in its nature, the time and day the first earthquake was experienced saved thousands of lives. Being a Saturday, the weekly holiday, schools across Nepal were closed on 25 April. The death toll of young people could have been much higher considering that nearly 7,000 schools were completely or significantly damaged (GoN 2015). Similarly, if the earthquake had struck at night, and not in the middle of the day, there would certainly have been greater casualties. The total value of disaster effects (damage and losses) caused by the earthquake is estimated at US$ 7 billion. Nepal had not faced a disaster of this magnitude for over last 80 years. For the devastation to aggravate, the earthquakes triggered widespread shallow landslides, rock falls and avalanches in the mountains, flattened villages and severely damaged or destroyed life lines. Beyond that, mountain slopes in many areas were shattered, fissured and soil tension-cracks formed along the crest of mountains or edge of elevated landforms where communities have been settled for generations. Depths of the cracks and fissures were not well known but they were kilometers long around the epicenter area. In the face of ongoing disaster recovery, geohazard concerns to the mountain communities, such as renewed landslide, subsidence, slope failure and rock fall from the mountain slopes that have fissures and soil tension-cracks, have created a lot of confusions for resettlement decisions though the affected areas did not experience much adverse changes, as expected, during the last two summer monsoons. To avoid future loss of life and property from possible future geohazards and to make the best use of the investment on recovery, a sound geo-scientific field investigation is necessary. This paper gives an overview of the geohazard conditions in some of the hardest hit parts of the 2015-Gorkha earthquake affected areas, and urges geo-scientific communities to come up with affordable and applicable solutions.

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Geological observations on history and future of large earthquakes along the Himalayan Frontal Fault relative to the April 25, 2015 M7.8 Gorkha earthquake near Kathmandu, Nepal

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The 2015 Gorkha earthquake produced displacement on the lower half of a shallow decollement that extends 100 km south, and upward from beneath the High Himalaya and Kathmandu to where it breaks the surface to form the trace of the Himalayan Frontal Thrust (HFT), leaving unruptured the shallowest ~50 km of the decollement. The presence of fault scarps in young alluvium along strike of the HFT in both Nepal and India attests to the occurrence of past earthquakes that have ruptured the up dip portion of the HFT. To address the potential of future earthquakes along this section of the HFT, we examine structural, stratigraphic, and radiocarbon relationships in exposures created by emplacement of trenches across the HFT where it has produced scarps in young alluvium at the mouths of major rivers at Tribeni and Bagmati. The Bagmati site is located south of Kathmandu and directly up dip from the Gorkha rupture, whereas the Tribeni site is located ~200 km to the west and outside the up dip projection of the Gorkha earthquake rupture plane. The most recent rupture at Tribeni occurred 1221–1262 AD to produce a scarp of ~7 m vertical separation. Vertical separation across the scarp at Bagmati registers ~10 m, possibly greater, and formed between 1031–1321 AD. The temporal constraints and large displacements allow the interpretation that the two sites separated by ~200 km each ruptured simultaneously, possibly during 1255 AD, the year of a historically reported earthquake that produced damage in Kathmandu. In light of geodetic data that show ~20 mm/yr of crustal shortening is occurring across the Himalayan front, the sum of observations is interpreted to suggest that the HFT extending from Tribeni to Bagmati may rupture simultaneously, that the next great earthquake near Kathmandu may rupture an area significantly greater than the section of HFT up dip from the Gorkha earthquake, and that it is prudent to consider that the HFT near Kathmandu is well along in a strain accumulation cycle prior to a great thrust earthquake, most likely much greater than occurred in 2015.

Basin modeling for assessment of hydrocarbon prospectivity: case studies from the exterior belt (Terai) and Siwalik fold and thrust belt, exploration block-2, western Nepal

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The Siwalik Foreland Basin that lies in the central sector of the Himalaya is a result of geodynamic processes related to flexural subsidence of the Indian Plate beneath the Tibetan Plate. BasinMod-1D software with faulting module was used in order to model two synthetic wells taken from a geoseismic section in exploration block-2 in western Nepal to understand the burial and thermal history of both the exterior belt (Terai) and Siwalik fold and thrust belt. Particular emphasis had been placed on the timing of trap formation against hydrocarbon generation from the potential source rocks. The stratigraphy of exploration block-2 was based on the surface and subsurface data from the Lesser Himalaya and Siwalik sediments. The Surkhet Group, which has been recognized as equivalent with the Paleogene wedge in the Siwalik Foreland Basin, has both source and reservoir rock potential. This study focuses on the Swat shale whose equivalents have been proved as the potential source rocks in the Himalayan subthrust zone. The only measured inputs are the Swat shale (2%) TOC and Melpani Sandstone porosity (10%). The geohistory curves for both synthetic wells show rapid sedimentation and tectonic subsidence. The thermal history is constrained using a 20^{o}C/km geothermal gradient for the exterior belt, whereas for the Siwalik fold and thrust belt, a two step geothermal gradient is proposed using a 20^{o}C/km for the upper 2000 m and 23^{o}C/km below this depth. The modeled values for maturity show that the Surkhet Group lies in the mid mature oil window in the exterior belt, but for the Siwalik fold and thrust belt, the hanging-wall Paleogene wedge is in the early mature stage, whereas the footwall Paleogene wedge is in the late mature stage. Oil generation for the Swat shales started at 6.3 Ma at 3988 m depth with peak oil generation 2.4-1.3 Ma at 5435-5782 m depth in the exterior belt. However, the Siwalik fold and thrust belt modeling shows that the footwall Swat Formation has no oil generation capacity after the faulting episode, whereas it had been producing oil since about 8.5 Ma at 3800 m with main phase of oil generation at about 7 Ma at 4600 m. The hanging-wall Swat Formation has been in the early mature stage of oil generation since faulting. The timing of structural trap formation window is set to 4.1-1.8 Ma based on geological evidence from the literature. The results show that the Swat shales have the potential of generating hydrocarbon both in the exterior belt and Siwalik fold and thrust belt. Trap Formation is more or less contemporaneous with hydrocarbon generation and expulsion and timing will be highly critical in future assessments of the prospectively in this area.

Recent status of metallic mineral exploration in Nepal

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Metallic mineral exploration program had an impetus on creation of valuable databases throughout the Lesser Himalayan region in the past. The regional geochemical survey for base metals was moderately successful to identify some of the anomalous areas for prospection of base metals in the region. The efforts establish the metallic mineral scenario of the region at a glance and discovered the valuable datasets categorically showings, old workings, occurrence, occurrence old workings, subeconomic and subeconomic old workings that are cataloged. None of the metal resources have been categorized as economic deposits in the past except Phulchuaki iron deposit and Ganesh Himal lead and zinc deposit. Recent exploration activities consider these databases and generate new exploration frontiers to create national databases of the resources in which some of them need to be upgraded into economic deposits considering present conditions to re-vitalize the metallic mineral endowments of the country. Considering these facts in mind, recent exploration activities of Department of Mines and Geology (DMG) focus on the discovery of iron resource and its exploration in Nawalparasi district seems promising to upgrade it into a deposit. Similarly, ground radiometric survey using scintillation counter and gamma ray spectrometer for U and Th has been conducted in Tinbhangale, Bangabagar-Baggoth-Gorang, and northern parts of Kathmandu valley as a TC project of IAEA/DMG from 2012 to 2016 AD. The national database creation so far is encouraging to be considered for further exploration in order to upgrade the resources. The new discovery is made for the U and Th resources in the Lomanthang area of Mustang district in 2014 and follow-up work is undergoing. The prospection work and systematic exploration activities of the area along with database so far created reveal that the resource has the potential to be converted into a deposit.

State of reconstruction and recovery: achievements and future challenges

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Nepal was hit by a devastating earthquake measuring 7.6 Richter scale on 25 April 2015. The earthquake caused heavy loss of human lives and property across the difficult hilly terrain covering 31 districts of Nepal. Despite substantial delay in passing of reconstruction Act, the Government constituted a high-level national reconstruction authority (NRA) in December after nine months of the earthquake to effectively take up the mammoth task of post-earthquake recovery and reconstruction in the affected districts. NRA successfully enacted more than dozens of policy, guidelines and directives to guide re-building with resilience over the entire five year period of reconstruction. Post disaster recovery framework was formulated to guide multi-year reconstruction efforts in line with global best practices and lessons learnt in the south asian context. Central bureau of statistics under leadership of NRA completed a housing survey and damage assessment in all most affected 14 districts. The first installment was delivered to eligible beneficiaries, 2nd installment is being planned after assuring quality of foundation works in line with approved inspection guideline and building standard for resilience. Design for resilient buildings has been completed and reconstruction of school and health-post is being initiated. Similarly, reconstruction and renovation of historical monuments are underway. NRA has to play key role for guiding policies, coordination and collaboration with several institutions with implementation challenges. The major challenges are establishing NRA as a high-performing institution; resource mobilization, recent changes in grant amount, grievances management, restoring of disaster resilient housing and public infrastructures; strengthening the local level capacity; restoring and improving access to services, and environmental resilience; and restoring sustainable livelihoods for the affected communities. NRA embraces collaborative approach to ensure effective coordination and facilitation between implementing agencies, donors and earthquake affected communities. NRA is cautiously undertaking a resilient recovery approach with greater emphasis on owner driven housing and build back better principles.

Life cycle assessment of expanded polystyrene beads (EPS) based wall panel and it's comparison with brick masonry

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It is important to evaluate the environmental burdens associated with a product, process, or activity. The changes in climate would be much greater if we use the product with greater environmental impact over the product with lower impact. The objective of the study is to quantify and compare the environmental impacts associated with building material such as Expanded Polystyrene Beads (EPS) based wall panel and brick masonry. Use of the pre-fabricated panel in construction is increasing after the massive earthquake of April, 2015. Life cycle assessment (LCA), one of the tools to determine the environment impacts of product during production, usage, and disposal phase is used. This work evaluated and compared the environmental impacts, such as global warming, acidification and eutrophication; associated with the production of pre-fabricated EPS based wall panels with respect to the brick masonry. LCA was conducted by compiling the relevant inventory data i.e. the emission factors from published reports. The quantification of the raw materials was done taking a case of a panel industry in Nepal and the total emissions were calculated. Brick wall of 4-inch is usually replaced by 50 mm sandwich panel. During the production phase of brick for 4-inch brick wall of area 15 ft^2 and 50 mm sandwich panel of area 15 ft^2, CO_2 emission is 3.82 kg and 0.40 kg, SO_2 emission is 0.0055 kg and 0.0008 kg and PO4 emission is 0.0045 kg and 0.0007 kg respectively. The result shows that the environmental impacts associated with the raw materials and production of brick are much greater than that of pre-fabricated EPS panel. Hence, it is environmentally advantageous to construct building walls using EPS panel than that to construct with brick. This study shows that choice of sustainable construction materials can minimize the environmental impacts, especially impacts of climate change by reducing the green house gas emissions.

Geotechnical investigation of Seto Gumba, Chandragiri-8, Kathmandu, Nepal

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This geotechnical engineering investigation has been carried out at Ramkot-8, Nagarjun municipality, Kathmandu to investigate the subsurface geological conditions. A total of 5 drill holes, designated as borehole No. 1, 2, 3, 4 and 5 were made up to 15 m below the existing ground surface. Standard penetration test (SPT) and direct cone penetration test (DCPT) have been carried out at appropriate depths in each borehole. Laboratory tests were immediately performed after the soil samples from each borehole arrived at the laboratory. A rotary core drilling using mechanical system was used during the investigation. Core drilling was carried out as per ASTM designation D 2113-83. The core size was NX size (52 mm) with hole diameter of 76 mm. The core barrel was double tube swivel type with retrievable inner tube. The drilling was carried out by using HX and NX casing. Geologically the area lies in the Lesser Himalayan succession of central Nepal. According to engineering and environmental geological map of Kathmandu valley by DMG (1998) the area belongs to Chandragiri Formation. From borehole log data's it was found that upper portion of the soil strata consists of red colored residual soil and lower portion consists of boulder mix soil. Boulders are mainly composed of limestone. Ground water table was not encountered up to the depth of drilling. Taking consideration of various geotechnical factors, isolated square foundation is appropriate for the area. From geo-technical point of view, the proposed building foundation could be constructed with proper design. The recommended net allowable bearing capacity of soils for 1.5 m x 1.5 m Square foundation at boreholes 5 (BH#5) at a 1.5 m and 2.5 m below general ground is 121 KN/m^2 and 148 KN/m^2 respectively.

Climate change and its economical impact in hydropower of Nepal

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Climate change is not only an issue of international concern but also a concern of community of Nepal especially indigenous people, women and children. Because of the seasonal variation in rainfall, a number of run-of-river hydro plants do not operate and cannot meet the energy demand of the country at present, and therefore load shedding has become a major issue. Power outages will be continued for the next 3-4 years (NEA 2012) as demand is projected to exceed supply (with load shedding projected at 12-14 hours per day per consumer during the dry season). Historically the agriculture sector has been affected by floods, droughts and erratic rainfall, and empirical studies indicate that around 70% of the performance of crop production can be explained by the climatic variability and temporal weather conditions (Sherchand et al. 2007). This paper presents the conceptualizing, methodology and preliminary findings of the study 'Economic Impact Assessment of Climate Change in Key Sectors in Nepal' especially in sectoral estimates of the impacts and economic costs of climate change for water (hydropower) sectors. Further describes the effects of climate change over three main time periods: Current-near term (now and next 10 years); Short-medium terms (2020-2030); and Long-term (2030-2050s). The major preliminary findings of this study will support as a source to the Government of Nepal (GoN) to make policy, legislation and institutional intervention having the assessment of losses and benefits from climate change in various geographical areas (agriculture and hydropower sectors); help strategically determine where investment are needed in the short, medium and long term to adapt to current climate variability and future climate change, and identify where mitigation opportunities can be achieved; identify where capacity development is required. It also further highlights the strategic framework that is needed to strengthen and where further studies and research are important. Based on this study, it will further recommend increasing the access to climate finance and technological support both from national revenue and global funding. In conclusion, Nepal being an immensely climate vulnerability country and primarily relying on water (hydropower) sectors, it is vital to reduce risks and vulnerabilities and optimize opportunities through framing a right policies, plans and programs and its implementation at local, regional and national levels of the country.

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Vulnerability of hydropower projects to climate change in Nepal

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Current climate variability in terms of seasonal and inter-annual water availability is a key factor in designing hydropower projects in Nepal. In addition, the power system should consist of an appropriate mix of projects to addresses the uncertainties both in water availability as well as in demand for electricity. Climate change is expected to further increase these uncertainties. Global climate models show wide variations in projected changes in future temperature and precipitation. Although the models vary in terms of magnitude of temperature rise, all 23 CMIP5 climate model projections analyzed for Nepal for the 2050s project warmer climate in the future than in the present. Temperature rise in winter months is projected to be higher than in other months. Based on average projection of 23 CMIP5 models in 2040-2059, temperature increase in monsoon months (JJAS) is expected around 2˚C in RCP 4.5 scenario and 2.6˚C in RCP 8.5 while the winter months (DJFM) show higher increase in temperature, on an average about 2.7˚C and 3.4˚C in RCP 4.5 and RCP 8.5 scenarios, respectively. Model projections are uncertain on winter precipitation but most of them agree on an increase in monsoon precipitation. The average increase in monsoon precipitation is about 7 to 11% in RCP 4.5 scenario and from 10% to 15% in RCP 8.5 scenario. There is no agreement among models regarding winter precipitation, with more than half of the models showing decrease in winter precipitation. In general, wetter and warmer monsoon and drier and warmer winter may be expected in Nepal. Models however agree on rise of extreme events with higher intensity precipitation occurring more frequently. Analytical techniques and hydrological models were used to assess the net impact of projected change in climate (precipitation and temperature) on runoff (water availability) and its variations. Lack of reliable and long-term hydro-meteorological data especially in higher elevations and across different catchment types (size, elevation, etc.) increases uncertainties on climate impacts on hydroelectric projects and sector. Available data and studies show that precipitation increases up to an elevation range of about 3000 m, after which, precipitation decreases with increase in elevation. However, precipitation data in elevations above 3000 m are very limited and there is conflicting understanding on the magnitude of precipitation in higher elevations. Changes in snow hydrology and glacier melt may impact hydro projects with substantial catchments above snow line (winter snow line of approximately 3000 m elevation and year round snow line of 5000 m elevation) but their impacts are much reduced, if any, for projects with catchments in lower elevations. Vulnerability analysis using an innovative "bottom-up" climate risk assessment methodology shows that Nepal's current hydropower system, particularly the smaller run-of-river (ROR) projects, is ill-prepared to address current variability of climate and flows. Flows in smaller, more rain-fed catchments are more variable, in terms of both inter-annual and seasonal variations. Snow fed and larger catchments on the other hand have less variable flows. Adverse impacts on water availability, frequency and magnitude of extreme events and sediment concentration due to climate change will aggravate the vulnerability of hydropower projects in terms of electricity production and adaptation costs required to mitigate these impacts. Vulnerability to expected climate change varies for hydro projects, depending on factors like location, size, type, hydrological design parameters, installed capacity and live storage (in the case of storage projects).These impacts are expected to be more pronounced in rain-fed and smaller catchments than in more snow-fed and larger catchments. Smaller projects are likely to be more affected due to climate change uncertainties as design of these projects are also based on limited data, more variable flow conditions and adverse impacts of upstream interventions.

Tunnel squeezing problem and rectification: a case study of Melamchi water supply project, Nepal

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The Nepal Himalaya lies in tectonically active region. Therefore tunneling in this region has high risks of encountering weakness zones. Often, a combination of high overburden over the tunnel alignment through weak rock mass exist which causes deformation of tunnel contours. Such deformations in many cases become such excessive that tunnel excavation and stabilization become a challenge. Large plastic deformation in tunnels is often encountered, which is termed as Tunnel Squeezing. The Melamchi Water Supply Tunnel excavated from the Sundarijal outlet also experienced similar tunnel squeezing situation. In a tunnel section of about 20m length, the tunnel contour converged excessively to such an extent that the tunnel was virtually blocked and tunneling activity had to be stopped. Stabilization of the tunnel behind squeezed section was started first so as to prevent the sections that the profile was relatively intact. The tunnel section had high overburden of more than 800m in the squeezed section and the rock mass was schistosed gneiss with parting of biotites. Moreover, ground water was also present at the tunnel crown and faces. The rock class was 5 where the applied support was steel lattice girders at 1m spacing and steel fiber reinforced shotcrete of thickness 150mm. The tunnel section was later stabilized by sequential consolidation grouting, the face was re-excavated and new support elements were provided. This paper will evaluate the squeezing phenomena of the tunnel section with respect to in-situ stress environment, rock mass condition, applied support and tunnel advancement. For this purpose, analytical and numerical evaluation will be conducted. Conclusions will be drawn on the lessons learnt and measures to be adopted to prevent squeezing and methods to rectify the same.

Seismic site effect assessment of Kathmandu metropolitan city due to Mw 7.8 Gorkha earthquake

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Gorkha earthquake MW 7.8 (2015) is the largest seismic event that Nepal has faced after 1934 earthquake. The epicenter was located near the Barpak village of Gorkha district about 77 km northwest of Kathmandu. The earthquake has caused massive damage in the form of human, socio-economic and environment losses. Different level of damage pattern was observed in Kathmandu valley. The destruction caused by the earthquake was severe in Bhaktapur, Sankhu, Bungmati, Harisiddhi, and north-east part of the valley. The areas within the Kathmandu metropolitan city (KMC) like Gongabu, Kathmandu Durbar Square, Shova-Bhagwati suffered severe damage on masonry as well as concrete structures, while civil structures in many other areas like New Baneshwor, Gaushala, Baluwatar remains intact or suffered less damage. The damages associated with 1934 Bihar-Nepal earthquake and 2015 Gorkha earthquake might be due to local effects of geology. Therefore, in this context the present study deals with the seismic site effects assessment within KMC taking ground motion of Gorkha earthquake Both non linear and equivalent linear methods of analysis have been performed using DEEPSOIL code thereby taking 58 numbers of spatially distributed deep boreholes located within KMC. The preliminary results show soil fundamental period in KMC varying in between 0.5 sec to 5.5 sec, while majority of areas have soil fundamental periods of 2.5 sec to 4.0 sec. The Peak Ground Acceleration (PGA) within KMC is estimated in between 0.05 g to 0.3g, while majority of areas have PGA in the range of 0.1g to 0.25g. The areas like Balaju, Gongabu, Kathmandu Durbar Square, Shova-Bhagwati that suffered severe damages during Gorkha earthquake are estimated with higher PGA of 0.15g, 0.27g, 0.21g, and 0.19g respectively. The low PGA values in majority of areas are consistent with the no damage areas. The Peak Spectral Acceleration (PSA) values for KMC lies in the range of 0.1g to 1.32g and the range for predominant period is in between 0.1 sec to 1.5 sec.

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Engineering aspect of Nepal earthquake 2015

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Investigations regarding geotechnical and structural aspects of damages caused by Barpak-Gorkha earthquake following by aftershocks were carried out. Though, no evidences of surface fault rupture found, massive landslides and total collapse of buildings were observed in the epicentral area. The maximum acceleration was 242 gals, spectral acceleration was 1030 gals and the effective shaking duration was found 37.3 seconds. The shaking duration is very long. The major causes of damages were construction of low strength masonry, soft storey in the ground floors, and amplification of wave in the soft soil at Kathmandu and the poor construction quality. Ground motion characteristics of this earthquake seem unique and duration is very long which demands deep insight investigation for future preparedness. The poor quality construction, making soft storey at the ground level of the buildings and insufficient investigation of geotechnical properties and weak monitoring of building codes are the main causes of losses of lives and properties. Proper plan, design and effective monitoring system should be implemented to reduce the losses in future earthquakes.

Effects of riparian vegetation on streambank erosion and bank failure processes: a case study from Kodku River, Lalitpur, Nepal

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The Kodku River, one of the tributary of the Manahara River, was studied to know the effects of riparian vegetation on stream bank erosion and bank failure processes. The river is being suffering from stream bank erosion hazards and bank failure causing great threat to the infrastructures, land and settlement areas. Thus, longitudinal and cross-sectional traverse field surveys were carried out to identify the distribution of erosion processes and riparian vegetation condition along the entire river profile. The interrelationship between riparian vegetation and bank erosion processes was diverse rather than linear. Major stream bank erosion processes were (i) sub aerial erosion which includes sheet erosion, rill erosions and gully erosions, (ii) sub- aqueous erosion which includes impinging flow erosion and parallel flow erosion and (ii) mass failure mechanism that includes shallow slip, slab failure, rotational slip and cantilever failure. Which were presented on erosion map of 1:10,000 scale. Land use change, vegetation clearance, meander migration, unconsolidated and non cohesive bank materials, human encroachment are some causes of the bank erosion. The riparian vegetation zone present in the Kodku River shows variation in width and density as well as in vegetation type and their distribution and was documented in map of scale 1:10,000. In the upstream segments Badikhel and Taukhel area, bank erosion problems and mass failure processes are less prominent because of wide and dense riparian vegetation with rich canopy and low human influence. On the other hand, the downstream segments are more susceptible to channel scouring and bank erosion due to the sparse and no vegetation and human encroachment.

Landslide hazards and risk in Nepal: an inventory of events and analysis of impacts from 1971 to 2014

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In Nepal, landslide is considered a major obstacles for the development causing high level of economic loss and huge number of fatalities per year, but there is lack of adequate comprehensive data that can figure out and support quantitatively. In this paper, the DesInventar database which is only comprehensive and adequate database for disaster inventory and impact analysis for Nepal has been analyzed for the period of 1971-2014 AD. The analysis shows that the number of deaths due to landslide is 4,938 which is 15% among the total deaths (33,770) due to disaster in Nepal in between 1971-2014. Besides this, 602,906 numbers affected, 670 numbers of missing, 1,843 numbers of injured, 3,060 numbers of evacuated people with 53,297 numbers of destroyed or damaged houses were reported. 22,580 (Ha) of farming and forest land and 10,816 livestock has been lost. 283 educational sectors, 18 medical sectors and 385,319 roads and routes have been either destroyed or damaged with 1,191,009,424 of economic losses during the 44 years due to landslides in Nepal. The database suggests that there is a high level of variability in the occurrence of landslides from year to year. The smallest number of deaths occurred in 2005, when only 17 fatalities were recorded, whereas the largest number was 455 in 2002. Regarding the geography of Nepal and the landslide records for 44 years, the hilly region is the most affected area by landslides however the landslides are the widespread problems in Nepal. It is not necessary that higher number of landslide records should have higher deaths. The Dhading district has highest 5% of landslide records but Sindhupalchok district has highest 9% of human fatalities. There is highest number of landslide records and human casualties during June, July and August which suggests extreme rainfall during monsoon season is the major causes of landslide records and fatalities in Nepal.

Landslide inventory, susceptibility mapping and recommendation of the mitigation measures in Nuwakot district

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Nepal earthquake of 25th April 2015 and subsequent big aftershocks impacted people, land and water resources significantly. Following the devastating earthquake, land and water management has become one of the primary focuses of the Government of Nepal as these resources are foundations of people's livelihood and prosperity. The weakened, cracked, and destabilized slopes and surfaces due to the earthquake become even more susceptible to landslides that can be aggravated due to rainfall and inappropriate anthropogenic activities. Due to the devastating earthquake, 31 districts of Nepal out of 75 were affected with 14 being severely affected resulted huge loss of human life, property and ecosystem services. These 14 districts were categorized as severely hit and crisis hit districts by the post disaster need assessment (PDNA) carried out by Government of Nepal. Nuwakot district is one of the severely hit districts. In order to reduce vulnerability and/or threat of potential landslide disasters and protect local people, infrastructures, land and water resources from potential landslide disasters, identification of the most susceptible slopes as well as treatment and mitigation of the most critical landslides deemed essential. With the initiation and financial support of WWF/Hariyo Ban Program and overall guidance of Department of Soil Conservation and Watershed Management, and field support of District Soil Conservation Office Nuwakot, a district wise study was carried out on "Landslide inventory, susceptibility mapping and recommendation of the mitigation measures" in 2016. The study has identified the landslides and its imapct areas within different village development committees (VDCs) of Nuwakot district. It has defined the type and criticality of landslides with feasibility of treatment. Landslide susceptibility mapping within the VDCs and sub-watersheds of the district was carried out with the index of different causative factors and bivariate analysis. Furthermore, the mitigation measures for the urgent and treatable landslides are purposed with the tentative estimation of the cost and prioritized them based on the social, environmental and economic criteria. Out of 542 landslides identified, 105 landslides were studied in detail based on social and physical risk. Location of the landslide, geological condition, threat to human settlement, urgency and feasibility of treatment and mitigation measures were focused in the study. The tentative cost for the mitigation measures of prioritized 46 landslides was estimated as NRs 79,931,094.48 to implement multi year plan. The study showed that the northern part of the district is more susceptible to landslides and consequent disaster. VDCs like Bhalche, Ghyangphedi, Salme, Urleni, Kimtang, Lachyang, Ralukadevi are more susceptible to the landslides in Nuwakot district. The study has recommended for treatment of urgent and treatable landslides with higher risk to settlement in priority basis.

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Possible geological sources of arsenic in groundwater of Terai plain of Nepal Himalaya

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Arsenic in groundwater of Terai districts of Nepal is recognized and documented as a serious health problem. Some potential sites of six Terai districts: Rupandehi, Nawalparasi, Parsa, Bara, Rautahat and Sarlahi are selected for the present study. The main objective of the study was to assess the possible primary geological sources of arsenic in groundwater. For that groundwater from the existing wells of different depth, river water, river bed as well as aquifer sediments were systematically collected and analyzed. Possible arsenic containing rocks, minerals and few hot spring water from the Sub Himalaya, Lesser Himalaya, Higher Himalaya and Tibetan Tethys zone were also collected and analyzed. The arsenic concentration in each water sample was determined in the field by ENPHO Arsenic Test Kit, following the recommended procedures. For laboratory analysis, selected water samples as well as rocks, sediments, minerals and hot water were collected and preserved according to the mostly adopted procedure and total arsenic concentration was detected by using Atomic Absorption Spectrometry in ENPHO laboratory. Mineralogical association and texture in aquifer sediments were studied under binocular microscope at the laboratory of Central Department of Geology, Tribhuvan University, Kirtipur. In total, about 400 water samples in the field, 100 water samples in the lab, 100 aquifer sediments, 50 rocks and minerals were analyzed for the present purpose. An attempt was also made to study the seasonal variation of arsenic in groundwater. After this study, several primary sources of arsenic have been identified from the country. Result showed that the sediments having abundant ferruginous concretions and ferruginous coatings are rich in arsenic and these materials can be considered as the immediate sources of arsenic in groundwater.

Formation of Bis Hajari tal, a wetland in Chitwan district, central Nepal

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It had been said that Bis Hajari tal and associated lakes were extended after the construction of Khageri canal. The study aims on providing clues on the hydrogeological relationship of wetland with the canal. Relevant maps and well logs from different organizations were collected and geophysical studies, auguring and questionnaires survey methods were applied on field. ERT profiles were carried out to understand the link between the lake and canal. The questionnaires survey and map study had indicated the formation of lake after the construction of Khageri canal. Before the construction of canal, there was a non-perennial stream instead of lake. The lake had formed precisely in that location simply by damming its own channel. The source of the water is the annual precipitation. The geophysical studies and the auguring indicate very low or the negligible amount of seepage from lake to canal. The silty or clayey sand at the side and floor of the channel supported to retain the water in the lake.

Rock support design for underground structures combining existing rock mass classifications and support systems

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Underground structures are constructed to sustain safely for long period, so it requires supports to obtain adequate stability. The type and function of support vary according to a wide range of factors apart from geological considerations depending upon different underground structures, so there are different support solutions. Several rock mass classifications and support systems have been developed so far to design rock support for underground structures. Rock mass classification systems are frequently used as tools for support design. The main objective of systems is to quantify different engineering properties of rock mass in relation to excavation size, stress and orientation of discontinuities for recommending adequate rock support. Regardless of the immense effort made by various scientists, existing support systems have their advantages as well as limitations. An attempt has been made to design underground excavation support categories, combining various rock mass classifications and support systems. The Rock Mass Rating (RMR) by Bieniawski (1989), the Rock Structure Rating (RSR) by Wickham, Tiedemann and Skinner (1972), the New Austrian Tunnelling Method (NATM 1965), the Q system by Nick Barton, Reidar Lien and Johny Lunde of the Norwegian Geotechnical Institute (1974-2015) and Rock Mass Index (RMi) by Palmström (1995-2000) have been combined to design the rock support categories based on engineering rock mass properties in relation to the excavation size, block size, exerted stress, orientation of discontinuities and ground water. The Q and RMi system have been used to estimate shotcrete thickness, rock bolt length and spacing. The RMR and RSR system has been used to quantify the steel sets. The NATM has been used to define temporary support. The rock support design have already been used (Q-value has been adopted for rating rock mass and support categories during excavation) in underground structures of few hydropower projects in Nepal.

Lithostratigraphy and non-metallic mineral resources in the Sundar Bajar - Besi Shahar area, Lamjung district, western Nepal

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This research was conducted at the Sundar Bajar-Besi Shahar area of Lamjung district, western Nepal to access the lithostratigraphy and non-metallic mineral resources. Detailed geological mapping and petrographic analysis were carried out. The stratigraphic units proposed by Stöcklin and Bhattarai (1977) and Stöcklin (1980) were used to establish the lithostratigraphy of the present area. The research area lies in the Lesser Himalayan unit, the Nawakot Group and it comprises the Kuncha Formation, Fagfog Quartzite, Dandagaon Phyllite, Nourpul Formation, Dhading Dolomite and Benighat Slate. The Kuncha Formation is the oldest and the Benighat Slate is the youngest unit. The Kuncha Formation consists of green to dark grey pellitic and light grey coloured psammatic schist with pronounced NNE mineral lineation. The Fagfog Quartzite consists of the white, medium to coarse grained ortho-quartzite with occasional ripple-marks. The Dandagaon Phyllite consists of green to grey coloured garnetiferious pellitic and psammatic schist. The Nourpul Formation is divided into two members namely the Purebesi Quartzite consisting of white to pink, laminated quartzite with ripple marks and pellitic and psammatic schists consist of interfoliated pellitic and psammatic schists of dark grey to light grey colour, along with thin beds of metabasite. The Dhading Dolomite comprises of laminated white to bluish grey coarsely crystalline dolomitic marble. The overlying Benighat Slate consists of black schist with quartzite partings and calcareous schist. However, the grade of metamorphism is quite higher in the present area than in the type locality. They are mainly slates, phyllites, quartzites and dolomites but in the study area, they are changed into schists, foliated quartzites and dolomitic marbles. However, the formation boundaries and younging direction are easily distinguishable. Lateral variation in thickness is observed in the Fagfog Quartzite and the Dhading Dolomite. Decorative stone, gemstone and construction materials are the non-metallic mineral resources present in the area. Decorative stone consists of quartzite, coloured schists and dolomitic marbles. Gemstone consists of garnet. Construction materials consist of terrace deposits, river bed materials, and natural bed materials. Detail exploration and systematic mining of these resources can uplift economic development of the area and also the nation.

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Geomorphological and geological comparison of susceptibility parameters for rainfall and co-seismic landslides: a case study of Sunkoshi River catchment in central Nepal

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The 2015 Gorkha earthquake triggered thousands of landslides and rockfalls distributed mainly in and nearby the seismogenic fault. Here, a comparative study of geomorphological and geological susceptibility parameters for pre-2015 Gorkha earthquake mainly rainfall triggered landslides and post-earthquake co-seismic landslides is made in a major river catchment (Sunkoshi), in central Nepal. Absolute elevation, slope, aspect, curvature and relative elevation (defined as percentage vertical distance of a point from nearest river/creek to the slope ridge/summit) which are derived from ASTER Global Digital Elevation Model of 30*30 meters, comprise the geomorphological susceptibility parameters whereas the lithology derived from geological formation map comprise the geological susceptibility parameter. A polygon based inventory of the co-seismic landslides triggered by the earthquake and pre-earthquake landslides (which mainly seem to be rainfall triggered) has been prepared in Google Earth using the updated satellite image immediately after the Gorkha earthquake and comparisons with the historical images available. This inventory is analysed with the DEM derivatives and lithology in GIS environment. The study area is in a major river catchment (Sunkoshi) of 5220 km^2 area which also experienced high seismic shaking during the 2015 Gorkha earthquake in central Nepal. However, as the landslides were mostly distributed in lower part of the catchment comprising the hanging wall of the seismogenic fault and in area below the snow-line, so, the area of analysis (AoA) is an approximate convex hull of 3631 square kilometres in lower part of the catchment. 322 Pre-earthquake landslides with total area 4.5 km^2 and 8575 co-seismic landslides with total area 21.2 km^2 have been found and analysed with landslide area as the abundance proxy variable. Comparison is done on the basis of percentage of area of each parameter class in the AoA and the total percentage area of pre- and post- earthquake landslides falling in each parameter classes. The pre- earthquake landslides show distinct parameter peaks with sharp kinks in the graphs while the co-seismic landslides show a much uniform but directive and mild peaks pattern. Landslides occurrence preferential conditions have been analysed in both the cases and parameter thresholds been identified. This study shows the response of high seismic shaking (induced by the 2015 Gorkha earthquake) towards the slope behaviour in the rugged and fragile mountainous formations of the Nepal Himalaya. It provides important considerations to be made to generate landslide susceptibility and hazard maps by considering both earthquake and rainfall triggered landslides for similar seismo-topographic regions.

Investigation of karst features in the Kusma area of Parbat district using electrical resistivity tomography and ground penetrating radar

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This research illustrates the application of geophysical method to detect karst features in the Kusma area, Parbat district. The Kusma area is covered by at least three levels of very thick river terraces. The upper (oldest) and middle terraces are composed of matrix-supported calcareous conglomerate with angular clasts of various sizes and shapes. They are of about 200 m thick. The lower (youngest) terrace represented recent fluvial deposit is about 20 m thick. Kart characterized by the sinkholes, caves, sinking valleys, pinnacle rock heads and karrens are found in the middle terrace. Two-dimensional (2D) Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR) survey was carried out in the present study in order to locate the subsurface karsatic features such as voids or cavities. The study demonstrates that the ERT survey can be effectively applied to reflect and differentiate superficial soil, clay, weathered rocks, compact of intact rocks, and air filled karstic features. The GPR method was also found to be an effective technique for the identification of subsurface features.

Quaternary geology, karst landforms and subsidence hazard in the Kusma area, western Nepal: results of preliminary investigations

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Present study was carried out in the Kusma area, western Nepal Lesser Himalaya. The main objectives of ths research were to study the Quaternary river terrace deposit and karst landforms in the area. Detailed geological study of the Quaternary river terrace was carried out for understanding the lithology, thickness and spatial distribution of the terraces. The Quaternary river terraces are distributed in Kusma, Balewa, Chuwa, Gizan, and Katuwachaupari areas. The terraces can be divided into three formations according to their relative ages. The highest (oldest) terrace is found at Godam, Mathillo Gijan, Balewa and upper part of Katuwachaupari. It is named as the Godam Formation because it is well-exposed at Godam area. It is about 200 m thick and composed of matrix-supported calcareous conglomerate with angular clasts of various sizes and shapes. The boulder size reaches up to about 2 m diameter. The middle terrace is found at Kusma, Katuwachaupari, Chuwa and Tallo Gizan areas. This terrrace is named as Gupteshwor Formation because it is well-exposed at the Gupteshwor area. It is also about 200 m thick conglomerate deposits composed of matrix-supported calcareous conglomerate with angular to sub-angular clast of various sizes and shapes. The youngest and lowest terrace level is represented by the river bed, consisting of the loose gravel and sand deposits. The Godam and Gupteshowor Formations are characterized by widespread occurrences of karst landforms. The karst landfoms are represented by the sinkholes, caves, sinking valleys, pinnacle rock heads and karrens. The karst landforms were probably formed due to the dissolution of calcite-cemented conglomerate by the percolation of surface water through sediment pores. Recent and old sinkhole and subsidence features are observed throughout the area. These are posing threat to the infrastructures development in the area.

Geological and geotechnical investigation of the Myagdi Khola hydropower project, Myagdi district, mid-western Nepal

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The Myagdi Khola hydropower project is 54 MW (proposed) with the design discharge of 7.65 m^3/s and design gross head of 560 m. It is located at Kibang VDC in Myagdi district, mid western development region of Nepal. The study is concerned with geological and engineering geological study of the Myagdi Khola hydropower project and also evaluates the support system along the tunnel alignment on the basis of RMR and Q-system and compares the predicted rock mass and estimated support on the basis of surface mapping with actually encounter rock mass and installed support after excavation. Geologically, the project area consists of the rocks of the Higher Himalayan and Lesser Himalayan rocks of the Jajarkot Nappe. The Jajarkot Nappe has thrusted to the south over the low-grade metasedimentary rocks that belong to Lower Nawakot Group. In the project area, the exposed rocks of the Higher Himalayan Crystallines are composed mainly of medium- to high-grade metamorphic consisting of light grey colored, coarsely crystalline, medium to thick bedded banded gneiss. Towards the south, the crystallines are thrusted over the Lesser Himalayan rocks, of the Upper Nawakot Group along the Main Central Thrust. The Upper Nawakot Group rocks consists of dark grey colored, medium to coarsely crystalline quartzitic phyllite and dark grey-black slate. They are interbedded and repeated frequently. The headworks site seems to be fairly suitable for the weir structures at elevation of 2411 m. The weir axis across the Myagdi River is located near Dobankharka. Banded gneiss is exposed at the barrage site at the river level on both the banks. Feeder tunnel is located on flat alluvial terraces on the left bank of the Myagdi Khola and bed rock. Desander is proposed as an underground structure due to the unsuitability on surface. The headrace tunnel is 5656 m long having inverted-D shaped with 3 m diameter. Common rock type along the headrace tunnel is gneiss, quartzitic, phyllite and slate. The gneiss proportion predominant in headworks area and decreases towards south and completely absent in surge shaft and penstock alignment. Surge shaft is located on steep slope and rocky terrain of slate and phyllite having 8 m diameter. The vertical shaft passed through the black slate and phyllite rock. The penstock pipe passes through bed rock (slate and phyllite), alluvium, colluvium, residual soil, colluvium deposits. The semi-surface power house lies on the lower alluvial terrace and flood plain. The tailrace canal runs through the recent flood plain deposits. Main Central Thrust (MCT) is the major structure in the study area along the stream near Bhainsekharka. The average RMR-value of rock mass along the headwork area is 68 which can be categorized as a Class-II type with description of good rock and that of desander is 57 indicating as Class-III (fair rock). Rock Mass Rating (RMR) value of the rock along the head race tunnel ranges the rating value of 58 to 62. This value indicates that the rock mass can be categorized as a Class-III type and Class-II type with description of fair rock and good rock. Weakness zones (shear bands) are observed along the tunnel section mainly around the stream having thickness of 2 to 5 meters.

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Soil bioengineering techniques for road side slope stabilization in the mid-hill region of Nepal

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Landslides and road blockades on the highways and rural areas are a common issue in the context of Nepal. In combined with floods, landslides are the second biggest disaster-related killer in Nepal. The main causes of landslides in Nepal are steep slopes, combined with loose material and excessive rainfall during monsoons. The Nepal earthquake 2015 which killed thousands led to 2780 number of landslides which exacerbate cutting into hillsides, disturbing natural drainage systems and inappropriate land use. Road construction particularly in the mid-hills of Nepal is both considered as a complex and difficult task. The conventional engineering approaches to road construction are generally being followed in the mid-hills of Nepal. Experience has revealed that such approaches alone are proved to be less than satisfactory. In addition, they do not adequately take into account environmental considerations which should be taken into. Analysis of this subject matter indicates that it requires both the conventional engineering wisdom as well as the techniques used in soil bioengineering measures. Soil bioengineering is relatively a new terminology in soil conservation activity however, Nepal has been using for centuries plants and modern engineering to combat the landslides and protect surrounding environment that regularly plague the nation. The Hariyo Ban Program through WWF Nepal has identified some sites and initiated immediate actions through soil bioengineering measures to maintain and stabilize many slopes that have been badly affected and triggered by 2015 earthquake. The soil bio-engineering work completed in Phewa catchment area, Kaski was one of the first pilot demonstration sites by Hariyo Ban for stabilizing the slope, avoiding the road blockade and safeguarding the settlements on the top of the hill. The other demonstration sites in earthquake affected districts viz. Gorkha, Dhading and Rasuwa are also completed and the bioengineering interventions has grown to be very effective as time passes and can be easily maintained. Different local species were used in soil bioengineering techniques such as in palisades, brush layering, fascines and bamboo crib wall. The combination of some small scale simple civil engineering with application of these techniques has shown good results in the project areas. The close cooperation and involvement of local communities also made possible for a successful establishment of soil bioengineering approach in four districts. Still, there is an urgent need to introduce soil bioengineering in many parts of rural districts in Nepal for more resilient to future earthquakes and other disasters.

Structural configuration and stability status of Malekhu landslide, Malekhu area, central Nepal

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About 1 km upstream from the Malekhu Bridge of the Prithvi Highway in Malekhu, central Nepal, a huge, old and complex landslide was found. The western part of the landslide was reactivated and there were rock toppling and wedge sliding. Two unpaved roads, one from the crown of the landslide and the other from the toe of the landslide extend from Malekhu Bazar towards the remote villages in the south. The toe of the landslide is the right cut bank of the Malekhu Khola. Since, vehicular movement places landslides into vibration, and near bank stress tends to erode the toe of the landslide, the stability of the landslide is questionable. The objectives of this study were to investigate structural configuration and stability status of the landslide. For this, a detailed engineering geomorphological map and engineering geological map in 1:500 scales were produced applying Ushikata Tracon S-25 surveying equipments. Geomechanical properties of rocks were assessed for Rock Mass Rating (RMR) and discontinuity and kinematic analyses were undertaken for Slope Mass Rating (SMR). These field measured attributes along with study of rocks and failed debris, the filed assessed engineering geomorphology of the landslide and its activities were considered to come into recognition of landslide type, mechanism, and stability status. The landslide area is composed of metamorphic rocks of siliceous dolomite and phyllite of the Malekhu Limestone, and quartzite, schist and amphibolite of the Robang Formation. It shows two distinct slopes; an original hillslope and an altered hillslope. The original hillslope is characterized by original topography in the sense that it has not been actively involved in erosion and slope movement, and therefore contains convex types of slopes with well vegetation. The altered slope is characterized mainly by very steep rocky slope with scarps, failed debris and the portion of the cut slope on the uphill side of the road. Other landforms of the landslide area include river valley, spurs, foodplain and terrace, etc. The crown and toe are located at elevation of 429 m and 361 m, respectively whereas width of the landslide is about more than 800 m. Major portion of the landslide has experienced toppling and is distributed in the extreme right and the left flanks. The central portion of the landslide shows active wedge failure. Few gullies of different dimensions, 5-10 m wide and 3-5 m depth were also observed. Tension cracks were found on the crown of the landslide.The toppled blocks had rotated from its right side up position to the current position by 36 degrees. The bed dip direction had also rotated about 31 degrees from the major dip direction of toppling. The rotation probably occurred during sliding of the toppled blocks. The nature of toppling is a flexure toppling of passive mode. The landslide is complex and old in which the wedge failure is reactivated during the April 2015 earthquake in Nepal. Currently, the wedge failure is active. The RMR of the rock masses of the landslide area shows fair rock to good rock categories. The SMR shows that the vicinities of the landslide ranges from completely unstable to completely stable. At the right side of the landslide the rock is completely stable, at the middle part the rock is partially stable to complete unstable, at right side the landslide is partially stable to stable. The kinematic analysis shows that the toppling is stable whereas sliding of the toppled blocks and wedge failure modes are unstable due to presence of potential wedges. There is a possibility of failure along the SW direction. Tectonic activity at the Mahabharat Thrust just about 1 km south of the landslide and earthquake activity are triggering causes while valley rebound and adverse discontinuity conditions in the rock masses seem to be major causes of the landslides. Since the road extends along the crown of the landslide and if the failure regresses, the landslide may affect not only the road but also some houses and a community water tank at the right portion of the crown. Possible removal of the toe of the landslides during flash flooding of the Malekhu Khola may also add threat to the stability of the landslide. Therefore, it is urgent to stabilize and mitigate the Malekhu Landslide.

Seismic refraction survey of Budhi Gandaki hydropower project, central Nepal

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The Budhi Gandaki hydropower Project is one of the ambitious project which aims to generate 1200 MW electricity located on the Budhi Gandaki River covering the parts of Gorkha and Dhading districts. Major structure such as power house and dam axis lies on the Dhading Dolomite and Nourpul Formation respectively. Seismic refraction survey conducted at this project along seven profiles has revealed the important information of the sub-surface materials. Similarly the rock mass classification on the test tunnels penetrated along the dam axis shows variation of rock class. Seismic refraction survey had revealed the major three velocity layers. The topmost soil with little pebbles, second the alluvial layer with boulders and third layer of consolidated rock. In some cases highly crushed rock, soil and alluvium show similar behavior with compressional wave. The rock layer is not monotonous rather consist of mixed lithology of quartzite, phyllite and dolomite. Due to the fact the velocity through all the profiles are not equal but similar. The seismic result was verified by the drilling in the area. Compressional wave (P-wave) velocity has shown different behavior with different materials. These velocities are used to calculate the geotechnical parameters of the materials such as UCS, moisture content, porosity, density and friction angle using the empirical formulas and correlated with the laboratory results. Tunnel quality index (Q) can be computed from the p-wave velocity and vice versa. It has been proven within this study that it is possible to predict rock-mass classes and other geotechnical parameters out of high resolution seismic data with high accuracy. This ultimately replaces the surficial prediction of the rock mass properties and other geotechnical parameters of the sub surface materials.

Gorkha earthquake 2015: socio-economic impacts, lessons learned and way forward

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Nepal is prone to various types of disasters such as: earthquakes, floods, landslides, fires, epidemics, avalanches, windstorms, hailstorms, lightning, glacier lake outburst floods, droughts and extreme weather events. Among all these disasters – earthquake is the most scary and damaging. The effects of a disaster, whether natural or human induced, are often far reaching. In addition to the natural factors, the losses from disasters are increasing due to the human activities and absence of proactive legislations. Fundamentally, the weak structures have been found as the major cause of infrastructure collapse in earthquakes. This emphasizes the need for strict compliance of town planning bye-laws and earthquake resistant building codes. Thus, proactive disaster management legislation focusing on disaster preparedness is necessary. This paper analyses the critical gaps responsible for emphasizing the seismic risk and of factors that would contribute towards seismic risk reduction to enable various stakeholders to address the critical areas for improving seismic safety in Nepal and other earthquake prone countries. Additionally, this paper aims to pinpoint the deficiencies in disaster management system in Nepal with reference to the devastating earthquake of 25 April 2015 and suggest appropriate policy and advanced technical measures.

Factors controlling variation in composition and texture of the sediments from Malekhu River, central Nepal

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The sixth order Malekhu River is being studied to identify factors affecting composition and texture of the river bed sediments to understand provenance and processes of sedimentation. Malekhu River is contributed by three major tributaries as 5th order Khani Khola, 4th order Dumling Khola and 4th order Aap Khola. A cross-sectional study was carried out along ten different stations from upstream to downstream along Malekhu River. To understand the sedimentation process, mapping of depositional features and erosional features in a scale of 1:10,000 was done. Wolman pebble count method (Wolman 1954 modified by Rosgen 1996) and sieve analysis of sediments was done. Various statistical parameters were calculated for the determination composition, texture and maturity of channel sediments of both Malekhu River and its major tributaries. Grab samples of sand sized particles were taken to the lab for the petrographic study to find out the major composition. Textural studies of both fine and coarse grained sediments were carried out to observe the effect of fluvial process on texture. The study was conducted to evaluate the role of lithology in determining the composition of sediments derived from a mixed metamorphic and sedimentary source terrain belonging to different geological formation. It is observed that the composition of channel sediment and sand sized sediment varies in accordance with the source area lithologies. Sorting of the sediments in Malekhu River was found to be extremely poor to moderately poor and grain size slightly increases downstream. Sorting and size of channel sediment is affected by the human influences and extraction of bed material from river bed. Roundness has slightly increased from upstream to downstream and is affected by the tributaries and anthropogenic factors. The lithology, tributaries, anthropogenic factors affect composition, texture and amount of channel sediments of main river system.

Approach by DMG aftermath of 2015 Gorkha earthquake

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Gorkha earthquake struck Nepal at 11:56 a.m. NST on 25th April, 2015, with the magnitude of Mw 7.8 (ML 7.6) and epicenter was at Barpak, Gorkha, approximately 78 km northwest from Kathmandu at the depth of 15 km. The main shock was followed by thousands of aftershocks including Mw 6.6 and Mw 6.7 within 24 hours and Mw 7.3 on 12th may 2015. This earthquake took lives of around 9,000 people and more than 23,000 people were injured. Aftermath of 2015 Gorkha earthquake, Department of Mines and Geology (DMG) accomplished multiple tasks from locating the earthquakes to conducting the detailed geological assessment for the safe and planned relocation of settlements. National Seismological Center (NSC) is continuously monitoring the earthquake before and after the Gorkha earthquake. Its effort during the time of crisis had been a psychological appease for our people. DMG in collaboration with various institutions like DASE (Department Analyses Surveillance Environment)/France, CALTECH (California Institute of Technology), EOS (Earth Observatory Singapore) and with JICA (Japan International Cooperation Agency) conducting various researches regarding microseismicity, macroseismicity, strong ground motion, crustal deformation and seismic hazard assessment. A survey was carried out in the Kathmandu valley to collect necessary data to assign the intensity of the 25th April 2015 Gorkha earthquake. A map of intensity distribution of Gorkha earthquake has been prepared based on data collected from field observation as well as incorporating the response of local people regarding the effects of the shaking on the certain key features on the ground that are typical to the standard of Modern Mercalli intensity scale. The result of the study shows that the intensity of the earthquake inside the Kathmandu valley falls broadly into the three major categories: MMI-VI (strong), MMI-VII (very strong) and MMI-VIII (severe). Maximum intensity has been observed on the northern and north-western parts of the valley. In general, maximum effect has been noticed on topographically high lands, at the break of the hill slopes and in proximity of the existing river valleys. The rapid geological assessment was conducted to assess vulnerability of the settlement area in the 18 earthquake affected districts in two phases. Based on recommendation from these studies, the Nepal government took the decision on 2072.03.15 to relocate the vulnerable settlements which is being implemented by the ministry of urban development. After the rapid geological assessment, 475 settlements were considered to be in high risk of earthquake induced geo-hazards and among them 193 settlements had been relocated immediately considering the threat of upcoming disasters. As per the annual program of the DMG and in collaboration with National Reconstruction Authority (NRA), DMG conducted detailed geological assessment in 9 earthquake affected districts of central and eastern Nepal. The main aim of investigation was to categorize earthquake affected settlements into 3 major categories i.e. safe, unsafe and under the risk of manageable geo-hazards. Field study comprises of detailed study of the targeted settlements from geological hazard perspective by filling up standard data collection sheet drafted by DMG and approved by expert committee from NRA which included the Assessment of geological, geomorphological, engineering geological, geotechnical, and pertinent social parameters. Total 117 settlements were surveyed out of which 57 settlements were reported as unsafe with proper recommendation for relocation .

Spring inventory in Khar area, Darchula district, far western Nepal

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Springs are the interface of surface water and sub-surface water. In hilly region they are only the source of drinking water, water for domestic uses and water for agricultural uses. Springs are the main source of water for maintaining stream flow which are used for irrigation and for micro-hydroelectricity production. Study area lies in the Khar VDC of Darchula district, far-western Nepal. It belongs to the Api-Nampa conservation area and is a hilly region where springs are only the sources of drinking water and water for domestic purposes. Although springs are widely used in this area, but their condition is not known. Therefore, this study was focused to know conditions of springs in the study area. The study was done with spring inventories just before monsoon of 2015 by measuring spring discharge and in-situ hydrogeochemical parameters like Electric Conductivity (EC), Dissolved Oxygen (DO) and pH and geological information of the surrounding area of springs were collected. The study area consists of 49 perennial springs. Depression spring and fracture spring are the type of springs present in the study area, whereas, the maximum numbers of springs are concentrated in the altitude range of 1600 m to 2000 m. However, springs distribution is almost equal in dip slope and anti-dip slope. All spring water samples were alkaline in nature, their EC value and DO values were in the range of 222 to 546 micro Simen/cm and 5.35 to 7.7 mg/l, respectively. This study presents how geology controls the distributions and lithological dependence of hydrogeochemical parameters of springs.

Soft sediments deformation structure in Sunakothi Formation: implication for draining of paleo-Kathmandu lake

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Kathmandu is one of the Quaternary intermontane basin in the central Nepal Himalaya. It is bounded by many faults on both southern and northern margins. The basin is filled by Plio-Pliestocene terrestrial deposits. Sedimentary characteristic indicate four types of unconsolidated succession are clearly identified within the basin. These are before lake succession, during lake succession, draining stage lake succession and fluvial succession. Late Pleistocene aged Sunakothi Formation crops out along the southern part of the basin. It is a typical fluviolacustrine delta succession that extended from 1390 m in the southern margin to nearly 1300 m toward center of the basin. It is composed of poorly consolidated sand, gravelly sand, siltstone and mud. Various soft-sediment deformation structures occur in the formation, especially in fine- to medium grained sands, silts and mud, load structures, flame structures, clastic dikes (sand dike), disturbed layers, laminated convolute beds, slumps and synsedimentary faulting. The deformation mechanism and driving force for the soft-sediment deformation are related essentially to gravitational instability, dewatering, liquefaction-liquidization, and brittle deformation. Field data and the wide lateral extent of the structures as well as regional geological data show that most of the deformation is related to seismicity and the structures are interpreted as seismites. Many researchers have studied seismites in different sedimentary environments. In addition, there have also been experimental studies undertaken by various authors within the different sedimentary basin. Soft-sediments deformation structure (SSDS) are mainly considered to be part of the initial diagenetic changes of the sediments and include: Slump structure which occurred on the slope like delta-front area, dewatering structures which occurred by the processes of upward escape of water commonly due to loading, load structures which occurred due to density contrasts between sand and underlying wet mud. The existence of seismites in the Sunakothi Formation is evidence of continuing tectonic activity in the study area during the late Pleistocene and is a main factor for draining of the paleo-Kathmandu lake water. Hence, in this paper I present these structures on the basis of different criteria and key to interpret the causes of draining of the lake water.

Detection of non linear response using the main shock and it's aftershocks of the 2015 Gorkha earthquake recorded at DMG, KATNP and KTP sites in the Kathmandu valley, Nepal

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We have tested the occurrence of non-linear behavior of soil at the DMG and KATNP sites in the Kathmandu valley filled by thick sediments using the accelerograms of the main shock and its aftershocks during the 2015 Gorkha, earthquake Nepal. The DMG accelerometric station is installed on the surface at the concrete slab of the single-storey office building in Lainchaur whereas; the KATNP accelerometric station is installed inside the American Recreation Center Building at Kantipath. We calculated the horizontal to vertical spectral ratios of S-waves part of the earthquake records (S-H/V) which is expected to provide information about the ground response. Then we calculated the degree of non-linearity (NDL) (Noguchi and Sasatani 2008) for the main shock and its aftershocks at DMG, KATNP in the frequency range from 1 Hz to 10 Hz. It is found that DNL of the main shock record clearly differs from those of the aftershocks records at both of these stations. The PGA-DNL plot shows that the main shock runs off from the trend formed by the aftershock records. Furthermore, the KTP strong motion records observed in the ground floor of the four storey building in Kirtipur Municipality are used as a reference motion to test the deamplification with the surface records at DMG and KATNP. The clear deamplification has been observed in main shock both at DMG and KATNP sites. Based on the above study we guess that non-linear behavior took place during the main shock of the 2015 Gorkha earthquake, in the Kathmandu valley.

Geology of Tapa-Murkuti area, northeast Dang with special reference to limestone deposits

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The geology of the study area comprises of the rocks of Daban Supergroup which is separated by the Botechaur Thrust from the underlying Siwalik in the south. The Daban Supergroup is divided into the Gwar Group and the Tosh Group where the latter is resting disconformably on the former. Among these two groups, upper three formations of the Gwar Group are named as the Dhorbang Khola Formation, the Sirchaur Formation and the Ranibas Formation. On the other hand, the Tosh Group consists of Sattim and the Dubring Formations. The Tapa limestone deposit is located in the Ranibas Formation. The deposit lies at the northern closure of the Tapa Syncline. The area is tightly folded. The Tapa deposit consists of finely crystalline and siliceous limestone. The X-ray diffraction shows the proportion composition of calcite and silica where the calcite content is a bit higher. The average content of CaO and MgO in the limestone determined by total analysis of 20 channel sample reveals up to 47% and 3% respectively. Geologically, reserve of the Tapa limestone deposits is 38 million tons (MT) (Block A). The mining loss and transportation loss is estimated about 20%. This deposit can support 1500 tons per day (TPD) cement plant up to 48 years. For a 1500 TPD cement plant run, the mining parameters are taken as: the bench height of 5 m, bench width of 15 m, working bench slope of 60º and ultimate pit slope of 70º. The mine development and extraction of limestone is proposed taking into consideration of economic and environmental constrains.

Hydrogeological characteristics of bedrock aquifer of Kathmandu valley

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More than 40% of total civil water supply in Kathmandu valley comes from groundwater resource. The aquifers used for extracting ground water are mainly composed of fluvio lacustrine sediments, weathered and fractured bedrock and mixture of these two. The water quality varies depending upon the aquifer material from where it is drawn. The lithological data of more than 100 deep tube wells that hit the bedrock in Kathmandu valley, pump test and water quality data of some of these tube wells were collected from different sources. These data were processed and analyzed to study the hydrogeological characteristics of bedrock aquifers in the valley. The study shows there is large area covered by weathered fractured bedrock beneath the thick fluvio lacustrine sediments. These bedrock show high slope and are exposed in the nearby protruding hills and rim of the valley. This condition facilitates regular recharging of such aquifers, which in turn recharges sediment aquifer which are in contact with it depending upon the hydraulic gradient. The yield of these aquifers are somewhat constant with time. The bedrock aquifers has extensive areal extension at the base of the sediment. The thickness reaches even to 100 m. The yield is also very good and can serve for long term water demand of the valley.

Landslides and threat to the infrastructures case study of hydropower projects, Rasuwa, Nepal

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Landslide is common land forming process in the Himalayas. However, there are natural or human induced causal factors behind the acceleration of landslides and eventually increase the disaster events. The April 2015 earthquake followed by the monsoon has caused many landslides all over the area from Syanga to Okhaldhunga in central part of Nepal. Rasuwa District is one of the most most affected districts in terms of landslides. After the earthquake, many people were temporarily migrated, still not able to return to their village fearing landslides during monsoon season. Many lifelines and infrastructures were damaged (e.g. road, bridge, water supply system, hydropower, etc) due to the earthquake induced landslides and following monsoonal events. An effort was made to investigate the impact of landslide on different hydropower (e.g. UT-3A (60MW), UT-1 (216MW), MKSHP (5MW), Rashuwagadi and Sanjen projects which are under construction) projects. Over the area damage of the built up infrastructures and threat to the project components were analyzed to evaluate the project sites and further geo-risks to the project. The are covering the project sites is extended in about 40km long stretches where more than 250 major landslides were mapped, out of which 90% are earthquake induced and 10% were old landslides. However, monsoon has significant impact over the landslides and was now extended higher up hills releasing huge amount of sediments in the river valley area. GIS based WOE model was used to prepare landslide susceptibility map of the region, which was followed by Kinamatic Analysis all along the project road alignment. The kinematic analysis does not show significant instability of the road slope indicating that the unstable parts were move either during the earthquake or during monsoonal rain. The most important thing to be noticed was that much part of the landslide area was still not accessible and thus not able to perform specific analysis of each landslide. Use of Drone might be effective in order to evaluate the slope stability and mapped the landslides in the region.

Numerical simulation of centrifuge tests with considering dependency of bulk modulus of soil void on degree of saturation and confining pressure

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To evaluate the effectiveness of "desaturation by air injection technique" as a liquefaction countermeasure for foundation soil layer, centrifuge test was carried out in the laboratory. The mechanical properties of the soil in the saturated and the desaturated zone was exactly the same with an exception of degree of saturation. Having been the mixture of water and air, the pore in the desaturated model had significantly lower bulk modulus as compared with that of the saturated. In this study, an attempt was made to numerically simulate the centrifuge model with effective stress analysis (LIQCA-2D) by changing the bulk modulus of the pore fluid. It was found that analytical results were quite comparable with the test results for both saturated and desaturated model. This suggests that effects of soil desaturation can be successfully simulated by effective stress analysis with considering the dependency of the bulk modulus of void on degree of saturation and confining pressure.

Main streamlining environmental assessment in infrastructure development projects in Nepal

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Construction of roads, hydropower projects, irrigation canals, and water supply and sanitation facilities are one of the major ongoing infrastructure development projects in Nepal. The developmental projects could bring adverse impacts on natural resources and ultimately on socio-economic dimensions, if such activities are not regulated or controlled through appropriate planning, study of alternatives and proper design. Environmental Assessment (EA) process has, therefore emerged as an instrument to charter a new course of development action which insures environmental protection and human development. EA is the systematic process by which the effects of a proposed project or other human action on the environment are evaluated, producing a set of recommendations which serves as influential input to the design of the project. EA is based upon the three values and principles which will ensure effective implementation at the project level and they are: Sustainability- the EA process will result in environmental safeguards, Integrity- the EA process will conform to agreed standards, and Utility- the EA process will provide balanced, credible information for decision making. Government of Nepal (GoN) has enacted Environmental Protection Act (EPA-1997) and Environmental Protection Rules (EPR-1998) as a major step to safeguard environment from the adverse impacts of developmental activities. Since then, various initiatives have been taken place in Nepal to integrate environmental aspects in the development plans, policies and infrastructure developments projects to achieve the sustainable development goals. EPA-1998 has established Environmental Assessment (EA) is one of the major instruments to streamline the developmental activities environmentally sound and sustainable. The EPA requires that an EA either in the form of an Initial Environmental Examination (IEE) or an Environmental Impact Assessment (EIA) shall be carried out for all proposed projects which meet the criteria listed in Schedules 1 and 2 in the EPR-97. Moreover, the National EIA guidelines 1993 for Nepal were drafted, tested and finalized through a participatory approach. Within the broad framework of the National EIA guidelines for the forestry and industry sectors were prepared and endorsed by the government in 1995. Besides these, the bilateral and multilateral donors have developed EA guidelines which Nepal is required to follow in projects funded by them. Similarly, EPA empowers the government to issue any kind of standards to promote environmental management in Nepal. GoN and several sectoral agencies have developed environmental standards and guidelines for effluents, vehicle emissions and pesticide residues. EA processes often includes consideration of socio-economic and cultural conditions as well as the biophysical environment. However, the need to assess a project in terms of preserving the social fabric, assisting the poor and disadvantaged groups, addressing gender issues and generally ensuring that targeted groups receive the intended project benefits have become increasingly important in Nepal and other developing countries. The fragility of Nepalese mountains and the fertility of diverse farmland are heavily impacted not only by infrastructure developments but also land- use changes. Moreover, the recent trends in developing the infrastructures include a mandatory inclusion of environmental and social attributes. Thus, assessment of both environmental and social aspects is important while developing infrastructures. In this context, EA process studies the adverse impacts of the project activities, performs analysis on project alternatives and proposes different measures to minimize the impacts of projects and maximize the benefits of the project in order to enhance the sustainability of the projects goals. In order to ensure the implementation of environmental mitigation and protection measures, EA process ensures preparation of an Environmental Management Plan (EMP). The proposed EMP includes plan for the implementation of the mitigation measures, environmental monitoring and a proposal for environmental auditing. Furthermore, an Environmental Unit is often established for the effective implementation of the project insuring environmental soundness, social acceptance, technically and economically evenhanded. This paper would provide state-of-the-art information on the current policies and practices of EA implementation in Nepal. Few case studies, examples and bottlenecks in the process have been illustrated.

GIS-based weighted overlay model to determine the best locations for the artificial recharge of groundwater in the southern part of the Kathmandu valley within the Kodku watershed

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Kathmandu valley has been suffering from the lack of fresh water resources for quite a long time. With the increasing day by day population, this problem is only going to get bigger. This study aims on finding the best location for the artificial recharge of groundwater in the southern part of the Kathmandu within the Kodku watershed. Kodku Khola is a tributary of the Manahara Khola with the watershed area of 35.67 km^2. Thematic layers including slope, distance to residential area, distance to road, landuse, geology, precipitation, distance to treatment plant and distance to production well were prepared in the GIS environments. These layers were classified, provided with their respective influence percentage or weight and finally integrated in the GIS environments. A suitability map including several classes was prepared using the weighted overlay model in GIS. The study showed that the southern portion of the Kodku Khola watershed is most suitable for the artificial recharge. This model is a simple and time efficient approach and can also be used in other places with the parameters selected according to the prevailing conditions.

Study of geological setting and the semi-precious stones in the Marsyangdi valley from Khudi to Tal, western Nepal

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The study area covers the northern part of Besi Shahar along the Marsyangdi valley around the Khudi-Tal area. The total aerial coverage of the study area is about the 300 sq. km. The study focuses mainly on the geological setting of the area, petrographical details, grade of metamorphism and distribution of the semi-precious stones within the Khudi-Tal area. The lithological unit of Lesser Himalayan terrains and Higher Himalayan terrains are found in the study area. The lithological units of the Lesser Himalayan terrain from bottom to top are pelitic schist, white quartzite and schist, metacarbonates, graphitic schist and laminated white quartzites and garnet schist. The lithological units of the Higher Himalayan terrain from bottom to top are Kyanite gneiss, Banded gneiss and quartzite, Banded gneiss-I, Kyanite-garnet gneiss and Banded gneiss-II. The rock units of the Lesser Himalaya are correlated with the stratigraphy of the Upper part of the Nawakot Group (Stöcklin and Bhattarai 1977, Stöcklin 1980). The rock units of the Higher Himalaya are equivalent to the Formation-I of Le Fort (1975). The regional scale structure of the area is Main Central Thrust (MCT) and other meso-scale structures are meso-scopic fold, foliation, lineation, quartz veins and boudins. The mineral assemblage and modal composition were studied in thin sections. In the study area, mineral assemblages in Lesser Himalaya are Grt+Bt+Ms+Plg+Qtz and that in the Higher Himalaya are Ky+Grt+Ms+Bt+Fel+Qtz. The isograd map of the Khudi-Tal area consists of garnet isograd zone in the southern part towards the Khudi area and kyanite isograd zone in the northern part towards the Tal area. The Khudi-Tal area lies in the thrust zone of the MCT. The area is rich in the distribution of the semi-precious stone of different quality. The garnet and kyanite are the main varieties of semi-precious stones found in this area. The physical properties of the semi-precious stones with the geological setting are emphasized in this study. Two varieties of the garnet namely reddish brown and pink garnet are found in the different lithological units of the Lesser Himalaya and Higher Himalaya. Light to dark blue variety of kyanite with two sets of cleavage is found in the different lithological units of Higher Himalaya. Some of the semi-precious stones observed in the study area can be used as gemstone. However, most of them are of industrial grade.

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Detection of buried ice in the moraine dam of Imja glacier using electrical resistivity tomography

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Glacier Lake Outburst Flood (GLOF) is one of the potential disaster in Nepal. A very few work is carried out to study the geophysical condition of such moraine dams in Nepal in the past. The Imja glacial lake is considered as one of the fastest growing glacial lake with high risk of GLOF. The internal structure of moraine dams, especially the distribution of buried ice blocks and permafrost materials is one of the key factors in assessing potential GLOF risk. Subsurface conditions of the moraine material such as location of buried ices, seepage areas and material distribution were considered to be surveyed in detail. The geophysical study of moraine dam was carried out by using dipole–dipole array of electrical resistivity method. The study presents the results regarding the use of electrical resistivity surveys in the assessment of the subsurface buried glacier ice and permafrost zones within the dam of the Imja glacier lake. The interpretation of resistivity data at end moraine of Imja glacial lake is based not only on specific resistivity values, but also with field observations and previous studies. The maximum depth of information obtained from the modeling is about 25 m and; highest and lowest values of resistivity ranges from 117 Ωm to 2682240 Ωm. The result shows distribution of major subsurface materials from lowest resistivity value to highest resistivity values are saturated moraine, dead ice and frozen moraine. The distribution of dead buried ice in moraine dam is found heterogeneous. The minimum and maximum depth of dead ice from surface is about 0 m to 20 m at various locations.

Geological study from Sundar Bajar to Besi Shahar area, Lamjung district, western Nepal

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The present study is focused on geology, structures, petrography and metamorphism of the Sundar Bajar to Besi Shahar area, a part of Lamjung district, western Nepal. This area lacks the geological study in medium and large scale. The area lies in the Lesser Himalayan terrain consisting of low to medium grade metamorphic rocks. Geological study shows that, the lithological unit of this area are equivalent to the higher metamorphic grade from the autochthonous unit of the Lesser Himalaya of central Nepal and can be correlated with Kuncha Formation, Fagfog Quartzite, Dandagaon Phyllite, Nourpul Formation, Dhading Dolomites of Lower Nawakot Group and Benighat Slates of Upper Nawakot Group of Nawakot Complex. It is represented by low to medium grade metamorphic rocks like schist, marble and quartzite. Regional structure includes the northern limb of the Gorkha-Kuncha Anticlinorium and area vicinity to the MCT. The axis of the Anticlinorium passes from the southern part of study area. The average trend of the local fold axis and mineral lineation is NNE-SSW with gentle plunge. Petrographic study reveals the two metamorphic zones in the study area; biotite zone and garnet zone. The metamorphic zones are inverted with biotite zone in the stratigraphically lower part and garnet zone in the upper part. The isograd boundary is oblique to the lithological boundary. The lithological units belong to green schist and epidote-amphibolite facies, which indicates that the main metamorphic event is younger than the development of foliation. Foliation map from south to north shows almost no change in foliation pattern. Crenulation fold formed by the crenulation of the pelitic mineral becomes indistinct at the vicinity of the MCT zone. Porphyroblast of both syntectonic and postectonic overgrowth are found.

Geology of the area between Abu Khaireni to Tal, Lamjung and Manang districts, western Nepal

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The study area covers the part of the Marsyangdi River basin, lies in the Lamjung and Manag district, western Nepal. The detailed geological mapping was carried out in Abu Khaireni-Tal area based on stratigraphic units proposed by the Stöcklin and Bhattarai (1977) to reveal the geological setting and lithostratigraphy of the area. The study shows that the geologically area lies in the two tectonic units; Lesser Himalayan unit and Higher Himalayan unit. The area also includes the axis of Gorkha-Kuncha Anticlinorium which is supposed to be a counterpart of Mahabharat Synclinorium in the central Nepal. The rocks in the southern limb of the anticlinorium are metamorphosed relatively at low grade than in the northern limb. The rocks of the area between the Abu Khaireni to the Besi Shahar area are well compared with the lithostratigraphy given by the Stöcklin and Bhattarai (1977). However, there are several discrepancies to compare the rocks of the area between Besi Shahar to Tal area with Stöcklin and Bhattrai (1977). The Higher Himalayan unit consists of Formation I. Three different lithological units within this formation were distinguished and they are Kyanite-Gneiss, Banded Gneiss and Kyanite-Garnet Gneiss. The boundary of the upper MCT is traced on the basis of change in lithology from schist of Lesser Himalayan unit to the gneiss of Higher Himalayan unit and high grade of metamorphism. The information for the location of lower MCT is still inadequate because of the lack of the base map of same scale in the boundary region and complex geological setting. Fold axis of local folds and mineral lineation in the area shows the general trend towards the NNE to SSW and gentle plunge.

Study of suspended sediment and its mineral content analysis with impact on hydropower design: a case study of Rahughat hydroelectric project

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Rahughat hydroelectric project (RGHEP) is a peaking run of river (PROR) project with the installed capacity of 40 MW. The suspended sediment study was carried out in 2008 and 2015 AD. The present study is concentrated on the study carried out in 2015 AD. The suspended sediment samples were collected in the headworks site and its analysis was carried out. Concentration analysis, particle size distribution (PSD) analysis and mineral content analysis were carried out. The minimum and maximum sediment concentration is 54 PPM and 3759 PPM respectively. The particle size distribution analysis shows that 52% of the suspended sediment contained sand fraction and 48% is fine sediments. The mineral content analysis shows presence of quartz, feldspar, mica, kyanite, garnet, carbonates, chlorite, clay and some fragments of shale, phyllite and slate with few unidentified sediments. The proposed desander in RGHEP is designed to settle particles of size 0.2 mm and above. The sediments lesser than 0.2 mm size that reaches to the turbine may affect the turbine material through erosion.

Characteristics of landslide in Nepal Himalaya

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Landslide is one of the main natural hazards in Nepal Himalaya due to intricate topography, fragile geology, and extreme events (earthquake, cloudburst). The landslides are causing loss of life and property every year especially during the summer monsoon season (water-induced disaster of July 1993, 2014 Jure landslide etc.) or earthquake events (e.g. 2015 Gorkha earthquake). It is very important to characterize the landslides in terms of inter-correlated factors. An analysis of various factors (pre-disposing and triggering) based on field evidences and geospatial techniques indicated that the rugged topography and fragile geology play vital role for the occurrence of landslides in Nepal. The landslide probability generally influenced by slope gradient and a case study in the central Nepal showed that predominant occurrences of landslides are found in slope angle range from 25 to 35 degrees in case of rainfall-triggered whereas greater than 35 degrees in earthquake-induced slides (tend to occur in steeper slopes and higher elevated region). Hillslope orientation is another topographic factor and shows a strong inheritance from bedrock structure, especially by bedding or metamorphic foliation because the orientation of hillslope indirectly affects the landslide occurrence. The landslides in Nepal are densely distributed in close proximity to the major thrusts/faults or linear feature formed by competent and incompetent strata. When excavations are made into slopes with upward inclined strata, potential planes of weakness can be exposed and day lighting the cut slopes. Many dip-slope failures undergo strain incompatibility between materials of contrasting permeability or stiffness, such as sandstone and mudstone. Such dip-slopes will fail due to surcharge of slope with unkeyed fill and excavating toe of slope for engineering works. Many landslides in mountain hill-slopes are originating as planar slides at initiation point and converted into debris slide to flow which generally moves in down-slope with high velocity. Foliations dipping back into slope or vertically stratified strata often undergo massive toppling failures along the inclined joints and intersections of joints lead to wedge failure. Among the factors contributing landslides, human intervention is also the dynamic factor because a number of landslides occurred along the highways or road corridors or excavations. The road is considered to increase the probability of landslides in hilly terrains as a result of undercutting and the application of surcharges and thus, landslides are highly localized along the major highways as well as in recently expanding rural roads that significantly increases the losses and damages. Conclusively, the landslides in Nepal Himalaya are because of the complex interplay of various factors (lithology, geological structures, slope geometry, rainfall or earthquake) which is crucial for the hazard and risk evaluation and implementation of mitigation measures.

Landslide mechanics and management issues in Nepal

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The loss due to landslides and related problems in the Himalayan region alone constitutes about 30% of the world's total landslide-related damage value which is extensively within Nepal. About 300 people are dying, millions of rupees is losing, and about 12.9% of the total development expenditure is spending on response and recovery activities. Many national and international researches are ongoing, technological innovations are developing, however; what exactly is the landslide occurrence mechanism in different ecological regions of Nepal, is still matter of concern. The features of driving and resisting forces operating on slopes like cohesion, internal friction angle of the soil, rock, land use pattern, forested and non forested landscape and many other underlying factors are making the mechanism complex. In the same landscape, slope stability analysis using deterministic model (safety factor calculation), and linear weight age methods have shown the landscape susceptibility status different. It is estimated that about 5000 slope failures per year is noticed throughout the country. However, the great Gorkha earthquake has triggered many landslides. Department of Soil Conservation and Watershed Management is one of the responsible government institutions for managing the landslides. Annually about 1000 numbers of landslides are requesting from different communities (required treatment budget is about 2000.00 million rupees). After the occurrence of earthquake, about 1103 numbers of landslides were reported from 11 districts alone. However; due to budget availability, and human resource capacity, less than 20 % of the problem is addressed so far. Many government and non government institutions are working in landslide hazard management, however, coordinating and cooperative efforts are lacking significantly. Landslide management is an interdisciplinary science, and it is becoming to bring the different scientist and practitioners into a common platform through an national level institution. Due to the growing national severity caused due to landslides, a national level " Landslide Management Centre" is becoming essential.

Landslide susceptibility mapping of Triyuga watershed using analytical hierarchy process (AHP)

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Siwalik also called Churia in Nepal, is youngest low altitude mountain in Himalayan range. It is mainly composed of unconsolidated alternating bands of mudstone, sandstone and conglomerate. Heavy rainfall in Siwalik make the mudstone saturated and gets washed away leaving behind the overhanging sandstone which gets disintegrated and makes the Siwalik susceptible to landslide. The Triyuga watershed that is considered for this study lies dominantly within the Siwalik, comprising the total area of 992 sq. km and with the elevation range from 120 m to 2000 m. Most part of study area lies in Uadaypur and partly in Saptari district and some part in Sunsari district of Nepal. The objective of this study is to prepare landslide susceptible map using the analytical hierarchy process (AHP). In this method, the weightage of the causative factors and their classes are calculated and integrated. AHP is multi criteria decision making analysis which can also be used when qualitative and quantitative aspects of decision are to be considered. It is based on three principles, namely decomposition, comparative judgment and synthesis of priorities. Slope, aspect, drainage density, land use, geology, rainfall and distance to road are the causative factors considered to prepare susceptible map. The data from topographic map, satellite imageries and field investigation were used in the study. Each factor was divided into the required classes and weightage of each factor and their classes has been found by pairwise comparison using AHP. Weightage of each factor and their classes has been integrated and final susceptible map is prepared in GIS. Susceptible map is classified using natural breaks into very low, low, moderate, high and very high susceptible classes. Landslide inventory within study area prepared using satellite image and google earth is compared with the resulting susceptibility map for the validation of work. It has been found that very high susceptible zone covers about 5.89% (58.29 sq. km) of the study area. The susceptibility map well represents the field condition, suggesting that the AHP method can be used in preparing the landslide susceptibility map in the Nepalese terrain.

Landuse assessment in central Terai of Nepal: a case study of Bardibas municipality of Mahottari district

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Land is one of the important and precious natural resources of the earth surface. The contribution of agriculture to national economy is gradually decreasing from 40 percent at 1980 to 32 percent and is further going down. According to land use policy 2017 the Government of Nepal had outlined 11 zones. This paper is the outcome of National Landuse Project (NLUP) and Land Resource Mapping Project database of Mahottari District. Geographic Information System (ArcGIS 10.3) and Remote Sensing software are used for mapping and results. To prepare land use, intensive ground field verification of recent high resolution satellite image WorldView-2 and Google images were used for enhancing interpretation. The Bardibas municipality is foot hill of the Siwalik range and junction of Mahendra highway and BP highway. Urbanization process is very rapid. The total area of this municipality is about 175.3 sq. km (Department of Survey) and total population is 37048 (CBS 2011). The population density is 211 Person per sq. km (611 Person per sq. km without forest). The largest area of this municipality is forest which is about 58% and agriculture land is about 24% and one percent area is covered by residential area. Two type soil order Inceptisols and Entisols with the major soil great groups Dystrustepts, Haplanthrepts, Humustepts, Plagganthrepts, Ustipsamments are found in the study area.

Nepal in need of a geological research center and geological council

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In a writ petition filed by this author, the Supreme Court of Nepal has directed the government of Nepal on September 9, 2015 to establish a geological research center and a geological council. This order by the Supreme Court is believed to have a far-reaching consequence considering the fragile geological structure of Nepal. In the same writ petition the court has directed the Government of Nepal to install earthquake early warning system. The general public can be warned about the quake via radio, television, and mobile phones. Court believes that even a warning issued few seconds earlier makes the public alert; warns hospitals, airports and other emergency service providers to be ready to deal with emergency situations. In the recent devastating earthquake that hit Nepal, different geologists had different analysis and voices that confused and misled the public. Headlines such as "be relieved for next 80 years now" in leading media were also seen, which allowed the public to refuse in adopting safety measures as it made them understand that no mega earthquakes will be faced again in the near future. However, the 7.8 Richter scale's earthquake that hit on 12 May proved their claiming to be completely wrong. Considering these bitter experiences, there is a strong need of geological council that assesses the qualification and competency of the geologists to award them the respective license required for geological practices. Similarly, if Nepal had a well functioning research center to conduct various studies and gather relevant information, the public would be disseminated with correct and appropriate information and they could be better guided in taking proper decisions. Let's hope the geologists of Nepal can play a vital role in pressing the Government of Nepal to respect the decision of the court.

Geological mapping and petrographic analysis with reference to the Tertiary sequence of the Malikarjun area, Darchula district, far western Nepal

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Geological mapping was carried out in a part of the Darchula and Baitadi districts, far western Nepal between Darchula Khalanga and Gokuleshwar in a scale of 1:25,000. Present study is mainly focused on lithology, petrography and metamorphism. The rocks of this area belong to the autochthonous zone of the Lesser Himalaya. It is divided into two sub- units as the Parchuni Crystalline Unit and Bajhang Metasedimentary Unit. The rocks the of whole investigated area are divided into four units as (1) Miocene beds (Suntar Formation), (2) black slate with rare thin dolomite bands, (3) dolomite with slate bands and (4) quartzite with metabasic and phyllite. The units belong to low grade metamorphic rocks contain quartz, feldspar, biotite, muscovite, chlorite and hornblende. The rocks are represented by schist, quartzite, phyllite, dolomite, slate, metasandstone, metabasic, sandstone and shale. Petrographic studies of rocks reveal that there exists two metamorphic zones in the study area and they are chlorite zone and biotite zone. In the Miocene beds, there are two thin coal seams and whole sequence is fining upward. These beds also consist of fine sandstone to pebbly sandstone, conglomerate and various colored shales. The Crystalline Unit and Metasedimentery Unit are separated by the Parchuni Thrust. The thrust passes from southwest and northeast of Gokuleshwar Bajar and it appears a few kilometers north of Khalanga. There exists another south-dipping thrust, which is named as that Malikarjun Thrust and separates the sedimentary rocks from metamorphic rocks. The Suntar Formation disconformably lies above the dolomite to the north. The study area also consists of a regional anticline and a syncline, and they passes through Dallekh Dhar and Gokuleshwar Bajar respectively.The different lithotectonic units of study area are correlated with the Kumaon area. The present study shows that the rocks of study area are similar to those of the Kumaon Lesser Himalaya.

Land use change detection of Kaski district using remote sensing

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The study was focused on detecting the land use changes in Kaski district of Western Development Region (WDR) over a period of 32 years since 1984 by using remote sensing and visual interpretation techniques. This study was mainly focused on conversion of agricultural cultivated land to urban/ peri-urban or forest to agriculture land etc. Land use classification was done by using supervised classification from satellite image (LANDSAT 8TM) and visual interpretation was done using Google earth to validate the study area. The main emphasis given on changes in agricultural land to urban and forest area which is depicted with help of land use change matrix. The percentage change in agricultural land was 24.30141% to 19.66982% whereas percentage change in urban area resulted as 0.368% to 1.836% and change in forest resulted as 38.62466% to 41.33457% respectively. However; interestingly the forest area have increased over past 32 years in this district. The change in population growth rate of Kaski district is 2.01%. The population in 1981 was 2,21,272 where as in 1991 it was 2,92,945, Simultaneously, in 2001 population of this district was 3,80,527 and 2011 was 4,92,098. Similarly, the projected population in 2016 is 5,43,767. The changes in land use study is substantial important to draw the potential effects associated with future changes as well as also associated with changes in vegetation driven by atmospheric CO_2 concentration, effects on climatic changes as well as changes in anthropogenic land use. The changes in land use and their detection plays a pivotal role in land use zoning decisions, water availability, integrated land and water management decisions, risk assessment and natural disaster management etc.

Generation of synthetic ground motion

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Earthquake time histories are required for the dynamic analysis of structures, response spectrum or time histories analysis, in order to calculate the structural responses. It has been the general practice that structures are designed based on the artificial time history considering the worst case scenario not on the real time history. Also due to the lack of sufficient and accurate earthquake records, generation of artificial ground motion is necessary. The main target of this work is to generate artificial earthquake time histories which are compatible with real earthquakes. In many cases, response spectra are given. Thus, most of the artificial time histories are generated from the given response spectra. Obtaining the response spectrum from a given time history is straightforward. However, the procedure for generating artificial time histories from a given response spectrum is difficult and complex to understand. Thus, this study presents a simple frequency-domain method for generating a time history from a given response spectrum. In the present work, Barpak earthquake records are taken and response spectra are generated using three attenuation relationships given by Youngs et al. (1997), Gregor et al. (2002) and Kanno et al. (2006). Different weightage is given to these attenuation relations. Each of the response spectral values are multiplied by weightage and summed up to obtain the final weighted average response spectrum. This response spectrum is considered as target response spectrum. A MATLAB program is used to generate the synthetic ground motion. Random waves are generated based on probability density function from envelope function for earthquake duration. These waves are modified until the simulated and target spectrum are in permissible error. Maximum value of acceleration time history after fifth iteration is 225 gal at 16 sec. which is nearly equal to the 230 gal for the real earthquake. Shape of acceleration time histories may completely vary for real earthquake and simulated earthquake since the amplitude and nature of simulated earthquake depends totally on the target spectrum. However the maximum amplitude of acceleration in both cases are almost equal.

Building damage patterns during April 25, 2015 Gorkha earthquake in Nepal and "Baliyo Ghar" program for technical support in earthquake reconstruction

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The April 25, 2015 Gorkha earthquake of magnitude 7.8 in Nepal damaged about seven-hundred thousand buildings. The main typology of buildings in the affected area are stone masonry with mud mortar, some buildings with stone and brick masonry with cement/sand mortar and few reinforced concrete buildings with masonry infill. Among the damaged buildings, about 96% of the buildings were masonry and about 4% reinforced concrete buildings with masonry infill. This study conducted detail damage assessment of over one hundred fifty thousand buildings of different type of Masonry and Reinforced Concrete (RC) buildings in Nepal. First, the buildings were classified to different structural types like adobe, stone in mud, brick in mud, stone in cement, brick in cement, wood, bamboo, RC and others. Other important parameters like type of floors and roofs and occupancy of the buildings were noted before starting the detail damage assessment in structural elements. In the wake of the April 25 earthquake and its subsequent aftershocks, the GoN has identified the huge need and demand of trained human resources to complete its goal of "Building Back Safer". The Housing Reconstruction Technical Assistance Program (Baliyo Ghar) program is an initiative to support the government's goal by providing technical support on a wide range of activities implemented by NSET with financial support from USAID. The objective of the program is to ensure disaster- resilient construction of houses through awareness, training, demonstration and support on code compliance. The program duration is for five years from October 01, 2015 to September 30, 2016. The Baliyo Ghar is implemented in 3 districts (Dolakha, Dhading, and Nuwakot) out of the 14 most-affected districts are planned for the implementation of all program activities. Further, within the selected districts, approximately one-third of total VDCs are selected for VDC level / grass roots level program activities. Remaining VDCs are supported indirectly through supporting other partner organizations with the technical and training guidance from NSET. This paper discusses the damage assessment results and the Baliyo Ghar program achievements, lessons learned and challenges on building resilient communities through safer reconstruction.

Geotechnical investigation of soil at sinkhole damage site in Pokhara, Nepal

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Numerous sinkholes have been forming since November 2013, in the Armala area of Pokhara valley, central Nepal, posing serious threat to local residents. In order to provide measures aimed at reducing sinkhole risk, new insights into the sinkhole cause and features is crucial. This paper reports the results obtained from multiple surveys conducted in 2015 and 2016 by the authors in Armala area. The surveys carried out in the sinkhole affected area were Standard Penetration Test (SPT), Dynamic Cone Penetration Test (DCPT), surface wave exploration, UAV image interpretation and salt tracer test. All the results are presented in this paper. The results obtained from borehole and standard penetration test indicates that the cavities were generating in the clayey silt layer about 7.5 to 10 m depth below ground surface. The drill barrel passes without any obstruction in this part (7.5 to 10 m depth) of the soil. The thickness of the clayey silt layer were not demarcated yet. By means of S-wave explorations the layer with cavities were identified and the result were cross checked with borehole data. The UAV images shows the trend of the recent sinkhole formation process is shifted from eastern side to western side. Though the main cause of the sinkhole has identified as ground water flow, a salt tracer test was carried out in the study area to identify the route but the exact route of the ground water has not yet been made for the sinkhole.

Geological investigation of river terraces and assessment of sinkhole hazard in the Armala area, Pokhara, Kaski Nepal

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Pokhara is one of the most naturally beautiful cities in the world with a unique geological setting. The valley is filled with the Quaternary sediments and occurs as distinct terraces and fan deposits. The sedimentary deposits of the Pokhara valley overlie the schist, phyllites, metasandstones and quartzite of the Kuncha Formation and lies in the core of the Gorkha-Kuncha Anticlinorium. The calcareous nature of sediments is dominant in each level of terrace and creates the serious geological hazards like caving, subsidence, erosion, deep gorges, sinkholes and landslide. Present study was carried out in the Armala area covering a part of the Quaternary sediments of the Pokhara valley. The study is focused on depositional environment and mechanism of sinkhole formation in the area. Geophysical and geotechnical methods are also used to identify the subsurface geology of major sinkholes hazard area in Armala or Kali Khola valley. The boreholes, seismic, and Dynamic Cone Penetration Test (DCPT) logs indicate that the Armala is filled with sediments of Phewa Formation. The Phewa Formation is covered by the recent flood deposits of Kali Khola. The zone between 5-10 m depth is occupied by loose calcareous silt. The silt is non-cohesive and very much susceptible to piping when groundwater moves through the pores. It helps in formation of cavities below the recent gravel deposited by the Kali Khola. The overburden made up of loose gravel easily subsides to form sink hole. The compositional difference in layered sediments, piping, dissolution of calcareous clayey silt, high infiltration rate, easy groundwater flow and deepening of Kali Khola in Phewa Formation sediments are the major possible causes of sinkhole in Armala area.

Assessment of groundwater contamination due to waste dumping in the Bagmati River bank, Kathmandu, Nepal

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The study is the primary assessment showing the impact on nearby groundwater sources due to waste dumping in the bank of river Bagmati (Teku-Dhobighat section) and its vulnerability, indicating towards an immediate need of counter measures to be taken. The groundwater samples were collected from the wells nearby the river (farthest 50 meters away from the bank) and analyzed (only inorganic contaminants). Totally 43 samples were collected, 6 being surface water samples, rest the groundwater samples. On-site measurements were carried out and 50 ml samples each were collected, from September 7-17, 2014. Organic samples were not measured incurring errors due to loss of contamination on the way of being transported by airplane. The same water which was staple two decades ago now is not suitable, even for the laundry purpose. Despite of the clay lithology (black clay~ Kalimati) in most of the section, contamination has been transported toward the groundwater from the site of disposal. The major contaminants being Fe (0.03-29.54 mg/l), nitrate (0.01-27.62 mg/l), ammonium (0.01-6.87 mg/l), arsenic (0.02-17.74 mg/l) along with sodium and chloride. Some of the figures are above the legal limits of WHO. Agriculture practice, animal husbandry, etc can also be other source of contamination.

Climate change impact on glaciers in the Langtang and Imja sub-basins of Nepal from late 70s to 2010

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Increase in glacier number and decrease in glacier area are perceived significantly in recent decades in Nepal. The glaciers are one of the key indicators of climate change. In order to understand the impact of climate change on glaciers a repeat decadal glacier inventory since 1980s based on landsat images were carried out in the Langtang and Imja valleys. The recent glacier outlines were delineated semi-automatically from the images using object based image classification (obic) in Definien Developer. The glacier outlines of other decades were obtained by manual editing on the glacier polygons of semi-automatically derived glaciers polygons by overlaying separately on the images of respective years. The result shows that the glacier area has been decreased by 26% in Langtang valley in the period 1976-2009 and 28% in Imja valley in the period 1979-2010. The lowest elevation of glaciers has been shifted upward by 50 m and 115 m in Imja and Langtang valley respectively. The annual mean temperature from 1988 to 2008 was found to be 4.2°C and 0.3°C in Langtang valley and Imja valley respectively. The rate of temperature rise in this period was 0.116°C yr^{-1} and 0.09°C yr^{-1} in Langtang valley and Imja valley respectively. The rise of mean decadal and annual mean temperature in Langtang and Imja valleys is one of the key factor of shrinking and retreating of glaciers.

Assessment of Kahphuche glacial lake expansion and potential impact in Kaski, Tanahun and Lamjung district, Nepal: using geospatial tools

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This study analyzes the temporal trend of the Kahphuche glacier lake from 1990 to 2016 using multi-temporal satellite imagery to explore the glaciological and climatic causes of lake expansion, assess socio-ecological vulnerability, and explore possible risk mitigation measures. The Kahphuche lake in Kaski district in Nepal has increased perceptibly in size over the last one and a half decades, and it continues to expand. From a bathymetric survey the area of the lake is 10.40 hectares, volume is 1,886,300 m3, average depth is 20.37 m, and maximum depth is 37 m. The discharge rate of water from the lake is 3.1 m^3/s. There is a positive correlation between rising temperature and volume of lake water, with a rapid increase between 2005 and 2010. After 2010, the increase in water volume and temperature continued but more slowly. The study found that the glacial lake is not likely to burst in the near future as it is dammed by a 348 m wide moraine dam. However, a glacial lake outburst flood (GLOF) may occur if there is an avalanche or rock-fall, or seismic disturbance. The hazard map prepared by this study includes the downstream areas up to 200 m from the main stem of the river, separated into 50,100 and 200 m intervals. The areas lying within a 50 m distance on both sides of the river, and up to 5 m above the river run-off surface, are the most vulnerable in monsoon season. The economic analysis estimates the potential cost of property damage and loss in the vulnerable areas from a GLOF could be USD 46.87 million in upper Madi, USD 2.02 million in Middle Madi and USD 10.23 million in lower Madi.

The study of Kakani-Okharpauwa area hard rock aquifer based on hydrogeological and geophysical approach

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The geology of Kakani-Okharpauwa area consists of rocks such as gneiss, metasandstone and schists of pre-Cambrian to Cambrian age. The lithology, tectonics and discontinuities of this area can contribute to the high well yield in these types of rocks. These factors also play a vital role in controlling the groundwater flow and distribution. This area is developing as a centre for trout farming and recreational area, with consequent increasing demands on water supplies. Improved utilization of the spring water resource of the area is a possible solution to address these demands. This study aims to understand the behavior of the groundwater in hard rock by developing hydrogeological map that may assist in the future to manage the springs and aquifers. Methods used in this study include hydrogeological mapping, geophysical survey and spring discharge measurement. A revised geological mapping was made with the two Electrical Resistivity Surveys for the correlation between hydrogeology and geophysical method. Groundwater discharge as springs and seepages is common in Kakani- Okharpauwa area. Spring discharge may occur directly from the fracture and conduits in the gneissic zone. Recharge is the result of infiltration of local precipitation, and the greatest potential for recharge occurs in the ridges of Kakani which is the weathered zone. The result shows that the hard rock of the study area has good potential of groundwater.

Evolution of fluvial systems and geochemistry of the Neogene Siwalik Group, Khutia Khola section, far western Nepal Himalaya

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This study focuses on the fluvial systems and geochemical variations of the Lower and Middle Siwalik in the Khutia Khola section of Far-western Nepal. The results are compared with the equivalent sediments of the adjacent Karnali River section, which are known to have been deposited by the large paleo-Karnali River system. The river deposits in these two sections are important records of tectonism and climatic change in the western part of the Nepal Himalaya, and the local variation of these key processes during middle to late Miocene times. Depositional facies description from the Khutia Khola section show same sequences of facies associations that are recognized in other Siwalik sections in Nepal Himalaya, namely; fine-grained meandering river system (FA1), flood-flow dominated meandering river system (FA2), deep (FA3) and shallow (FA4) sandy braided river systems, from the oldest to youngest. FA1-2 corresponds to the Lower Siwalik, and FA3-4 to the Middle Siwalik. Muddy facies are more common in the Khutia Khola section than in other Lower Siwalik sections in Nepal. Most of FA1-2 is composed of red paleosols. Lateral accretion patterns are typical in meandering river deposits and are commonly observed in FA1-2 but the top of each laterally-accreted packet is marked by a rooted horizon with mud drapes. Calcite nodules tend to be more abundant in the upper part of each single channel sandstone succession, with increments in nodule size. This type of channel fill is uncommon in FA1. A fluvial channel deposit represented by sandstone beds up to 3m thick is dominant in FA2. Sometimes channel deposits with frequent mud drapes are observed. These characteristics suggest that the most of the channels are of ephemeral stream origin. A thicker fluvial channel deposits (ca. 5m) representing perennial stream origin, which are characterized by parallel stratification, antidune stratification, and trough cross-stratification, indicating the predominance of upper flow regime sedimentary structures are less frequent in FA1-2. The FA2 interval contains more frequent flood-related deposits. A couplet of sandstone (sst: up to 10 cm) and mudstone (mst: up to 0.1 cm) in a sst-mst alternation records inundation and desiccation events, respectively. Most of these sst-mst alternations are interpreted as being of seasonal lake origin and are frequently observed in FA2. Frequency of thick sandstone beds of braided stream origin is less in the FA3-4 intervals than in the Karnali River section. These facies characteristics suggest that small river deposits are predominant within the Khutia Khola section. The timing of the appearance of FA2 is crucial for determining the timing of increase in precipitation due to monsoon intensification and sediment supply increment associated with tectonic uplift. FA2 appears at around 13.5 Ma in the Khutia Khola section which corresponds with the adjacent Karnali River section. Changes in geochemical indices including provenance, sorting effect, and intensity of weathering are well synchronized with the changes in depositional facies. Comparable provenance indices suggest the same source for the Karnali River and Khutia Khola sediments. Stratigraphic ratio plots show more intense weathering, uniform source, and greater sorting fractionation in the meandering river systems. Systematic upward changes in elemental ratios reflect change in fluvial style in the Lower to Middle Siwaliks, from meandering to braided river systems. Collectively, the dominance of the finer sediments and thinner sandstone units than in the neighboring Siwalik successions indicate that the Khutia Khola section was deposited by small river system and located at the western margin of the paleo-Karnali River system or may represent the interfluve setting of major river systems. The timing of appearance of FA2 in the Khutia Khola and the Karnali River sections are same, as noted above. This implies increased discharge and enhanced erosion from the frontal part of the Himalaya at around 13.5 Ma in the Far-western Nepal Himalaya which is earlier than the central and eastern Nepal Himalaya. Similarly, there is no significant variation on the record of monsoon intensification between small river system and the large river system in the Siwalik Group.

Fluvial morphology and dynamics of the Godavari Khola southeast Kathmandu, central Nepal

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The Godavari Khola flows from the south to the north and contributes the Hanumante Khola, which is one of important tributaries of the Bagmati River, flowing from the eastern part of the Kathmandu Basin. The Godavari Khola is among the three prominent tributaries flowing from the south to the north in the Kathmandu Basin. Recently, the Godavari Khola has been suffering from human encroachments due to rapid urbanization. Studying nature and dynamics of the stream is an important work if the stream has to be made less affected and well managed. The present study aims to establish fluvial morphology and stability status of the Godavari Khola. For these purposes, the watershed was analysed for morphometric parameters and planform fluvial morphology, and thirteen representative segments were surveyed from upstream to downstream of the Godavari Khola for recording and analysing sediment properties, stream cross-sections and profiles, and hydraulic parameters. Using the planform characteristics, hydraulic parameters and stream sediment size distribution, the stream segments were classified into stream types. The stream's aggrading degrading potential was analysed using morpho-hydraulic parameters and sediment size distribution of channel and bar. The Godavari Khola is a fifth order stream, the two upstream segments of which flow over the bedrocks, and then the rest of the downstream segments flow over the fluvio-lacustrine sediments in a wide alluvial valley. The segments are classified into six kinds such as 'C4'-, 'C5'-, 'B3'-, 'B4'-, 'E4'- and 'F4'-type streams. The upstream segments are of 'B4'-, 'B3'- and 'F4'-types which show entrenched, steep, gravel to cobble grade streams. The downstream segments are of 'C4'-, 'C5'-, 'E4'- and 'F4'-types showing non-entrenched to low entrenched streams with gentle slopes, high sinuosity and gravel to sand grade bed materials. The two of the segments lying in extremely upstream and the two in extremely downstream portions of the Godavari Khola before confluencing with the Hanumante Khola show degrading condition whereas the remaining nine segments show the aggrading condition. Because of the huge width/depth ratio in majority of the downstream channels, the streams are laterally unstable in this segment of the Godavari Khola.

Site investigations: importance and challenges for hydropower development in Nepal Himalaya

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There is tendency to blame to geology, most of georisks faced during tunnelling, saying due to fragile geology and worse geological conditions although site investigation is not in acceptable level. The blame would never been given directly to geology, if there had been proper site investigations and predicted georisks for different ground conditions to tackle the risks. Structures of hydropower, particularly underground, have uncertainties of georisks. Georisks are major cost driven factor and site investigation is the only means to identify georisks. The site investigation assists to acquire properties of ground and hydrogeology to visualise and predict behaviour of ground for designing and construction of structures. It helps to select suitable layout, estimate design parameters, reduce georisks, assess project cost, evaluate constructability, plan construction activities and prepare tender documents. Similarly, site investigation can also save project cost by either tackling the problem before hand or relocating major structures in safe ground. The degree of accuracy in predicting geological conditions, evaluation, and interpretation of rock mass quality are directly proportional to intensity and quality of site investigation. Therefore, thorough and convincing site investigation is very essential to identify and predict reliable rock mass and soil conditions prior to the actual construction that can minimize project cost significantly. In Nepal Himalaya, effective site investigation is a challenge due to mountainous terrain, lack of access, limited site investigation equipment, lack of rock testing, lack of in situ testing and skilled manpower. In addition, areas of high cover over the tunnel exceeds 400 m, are the most difficult for tunnel site investigation in mountainous terrain. Practice of rock mass prediction for underground structures mainly relies on geological mapping in Nepal. In Nepal, general practice of site investigation for hydro structures is very limited. Most of underground projects in Nepal Himalaya experienced georisks due to lack of site investigations. There were many case studies of underground structures of hydro projects suffered due to lack of site investigations. For instance, Khimti-I hydropower project can be considered for case study. Khimti project suffered from several overbreaks, rock squeezing and drastic change in predicted rock mass quality during construction. Main reason was lack of site investigation to identify problematic tectonised schist bands, faults and shear zones. Few centimetres to 50 m thick weak tectonised schist bands were not identified which were causes of major georisks. Therefore contractor were not prepared for georisks surprises during construction. As a result 11 major overbreaks and rock squeezing had to overcome with project delayed and increased amount in rock support. Similarly, advantage of site investigation in study phase was highlighted from Tamakoshi-3 hydroelectric project's tunnel. Site investigation added advantages in finalisation of size of tunnel and selection of alignment. In feasibility study, capacity of the project was 880 MW with 11 m diameter headrace tunnel. Site investigation identified weak tectonised schist bands and severe rock squeezing was predicted for 11 m diameter tunnel. Additional site investigation such as 3D over coring in situ stress test, uniaxial compressive strength, Poisson's ratio, Young's modulus were carried out for further analysis. To tackle the expected severe rock squeezing, further study was carried out by focusing on the maximum constructible tunnel size, orientation and excavation method to optimise squeezing, and suitable rock support design. After numerical modelling, maximum constructible size of tunnel in full face tectonised schist band was found to be 9 m with a modified horse shoe shaped tunnel. Hence, it was decided to adopt 9 m diameter headrace tunnel. As a result, the project capacity was decreased to 650 MW. In addition, the tunnel was passing through major plunging syncline fold comprising the thick tectonised schist bands at core and crossing old landslides. 2D electric resistivity tomography geophysical investigation was carried out to confirm the thickness and orientation of the tectonised schist bands and soil cover in landslide crossings. Rock squeezing, overbreak and water ingress georisks are predicted. The tunnel alignment was realigned to dodge the schist band in syncline core and shear zones based on the 2D Electric Resistivity Tomography investigation results. Likewise, tunnel excavation by TBM was also studied but there was big concern to tackle severe rock squeezing driving through the tectonised schist.

3D-ERT survey of the army post area, Langtang village, Rasuwa

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One of the devastating signatures of the Mw 7.8, 2015 Gorkha earthquake is still evident as a huge, desertified, grey cover of debris in the Langtang village. The snow avalanche followed by heavy debris flow after the earthquake completely ruined the village including the army post, claiming hundreds of lives and property. More than hundreds of civilians and ten army personnel are still missing in the area. This work was done as per request and logistic support of the Nepal army. The main purpose of this work is to investigate the subsurface anomalies so as to identify any object of public and military interest in regard to the missing people. Further, the work is aimed to characterize geomorphological phenomenon triggered by the 2015 Gorkha earthquake. To fulfill the objective, 3D-Electrical Resistivity Tomography (3D-ERT) survey was deployed as the geophysical tool for subsurface investigation. Further sedimentological and geomorphological study was carried out to understand the ongoing surface processes in the area as well as to gather geological information important to interpret the geophysical results. The fieldwork was carried out during 28 May to 3 June, 2016. SYSCAL R1 PLUS SWITCH 48 was used for ERT data acquisition. Active geomorphological agents particularly surface and subsurface inflow of water on the hill slope, continuous erosion of soil by the Langtang Khola, is responsible for continuous modification of topography in the area revealed from 3D-ERT as well as geomorphological and sedimentological studies. Different geophysical anomalies, identified in different locations are verified in different pits where plant roots, boulders and ground water table are obtained at the proposed depth. 3D-ERT findings along with the spatial distribution of boulders suggest very small probability of finding any object of military and public interest particularly in the army post area.

Comprehensive inventory of glacial lakes of five major river basins in the Hindu Kush Himalaya

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The Hindu Kush Himalayan (HKH) region has experienced numerous Glacial Lake Outburst Floods (GLOFs) and some of them are with trans-boundary impacts. Climate change had a major role in the substantial increase in number and size of glacial lakes to the category of potentially dangerous. So, the risk of GLOF is likely to increase in the future. For assessing and managing the increasing risk of GLOF, it is necessary to have an understanding of the distribution and dynamics of glacial lakes. This study attempted to prepare an inventory of glacial lakes in the HKH region. We have mapped and classified the glacial lakes using the Landsat images of 2004 to 2007. Firstly, the water bodies were automatically delineated using the NDWI ratio with the threshold values between -0.6 and -0.9. The final glacial lake polygon data was prepared by manually editing by overlaying on the Landsat images and cross checking in the high resolution images in Google Earth. This inventory includes all the lakes in front of and on or adjacent to a glacier. A total of 25,658 glacial lakes with an area ≥ 0.003 sq. km. were mapped. Brahmaputra River basin has the highest number of glacial lakes followed by Indus, Ganges, Amu Darya and Irrawaddy. Majority of glacial lakes are erosional type (59.3%) followed by moraine dammed (32%) and ice dammed lake (4.7%). The size of glacial lakes are comparatively larger in Indus and Ganga basins and smaller in Irrawaddy river basin. The smaller lakes (>0.05 sq. km.) comprises 78% of total number of lakes. Majority of glacial lakes (58.8%) are located in elevation zone between 4000-5000 m and 33% between 5000-6000 m. More than 44% of mapped lakes are glacier fed. With the existing physical parameters the glacial lakes can be further analyze to identify the potentially dangerous glacial lakes. So, it is hoped that this inventory would provide the basis for identification of potentially dangerous lakes to reduce the GLOF risk in the HKH region as a whole.

Geological controls on landslides of Sub-Himalayan region

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Genetically formed by the very weak, fragile and youngest rocks of the Himalaya, and lying in the most dynamic area within the Himalaya, Sub- Himalayan Region (Siwaliks) is exposed to various types of slope instabilities and landslide hazard. To address the issues of soil conservation in effective way, the President Chure-Tarai Madhesh Conservation Development Board (PCTMCDB), Government of Nepal have enacted collaboration research programme with Central Department of Environmental Science, Tribhuvan University. The study area includes the sub Himalayan region of the Makawanpur, Bara, Rautahat, Sindhuli, Sarlahi, Mahottari, Dhanusha, Udayapur, Siraha and Saptari districts and research based on detailed field investigation and landslide mapping besides any laboratory analysis of rock and soil. Geologically, The Sub- Himalayan region lies between the Lesser Himalaya in the north and Terai in the south and are lying within two major geological structures namely Main Frontal Thrust (MFT) in the south and the Main Boundary Thrust (MBT) in the north (Gansser 1964). The rocks of the Siwalik are grouped into three geological formations. The Lower Siwalik consists of variegated mudstone and fine to medium grained sandstones. The Middle Siwalik consists of coarse-grained, "Pepper and Salt" sandstone, mudstone, shale and pebbly sandstone. The Upper Siwalik consists of the boulder-cobble conglomerate. The landslides are highly influenced by the geology in terms of the processes, mechanism size and numbers of landslides. Granular flow, debris fall and gully erosion are dominant in Upper Siwalik. Vertical and overhanging slopes of conglomerates or the differently graded gravels are common features that control the landslide process in this area. High grade of weathering in mudstones of Lower Siwalik indicate gully erosion, earth slides, mudflow and debris flow as the dominant processes in this geological formation. The Middle Siwalik mostly consists of massive sandstone alternating with incompetent mudstone layers signifying differential weathering and the processes such as rock slides and rock falls.

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2D-SRT survey for road slope management: a case study in Trongsa area, Bhutan

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Road slope management is very crucial for sustainable development and maintenance of road in mountainous terrain. During the construction of a road in such terrain, slope instabilities are major problems which significantly affect the time and cost of the project. In this regard, JICA funded a pilot project for road slope management in Bhutan along Punakha-Trongsa highway and proposed 2D-Seismic Refraction Tomography (2D-SRT) survey for subsurface geological and geotechnical exploration of hill slopes in Banglapogto and Thomang Cliff area of Trrongsa Zongkhag. 2D-SRT survey was done along four profiles: one in Banglapogto and three in Thomang cliff area A 24 channel seismograph system: GEODE-24 by Geometrics, USA was used for data acquisition. For signal generation explosive was used at the interval of 25 m along each profile. The offset distance between geophones was set to 5 m. One (vertical) component geophones with frequency of 14.5 Hz was used to record the data. In Banglapogto area, surface observations show thick residual soil while in Thomang cliff area hill slope exhibit thick colluvium deposits. 2D-SRT results show bedrocks at depths less than 4 m at Banglapogto while in Thomang Cliff area at depths between 5 m and 40 m. Further in Thomang Cliff area, a passive southeast dipping slip surface is inferred at the depth of 5 to 13 m. These results from 2D-SRT are well verified by core drilling at different locations. This study hence shows the importance of 2D-SRT as a powerful indirect method for slope management in mountainous terrain.

Geophysical investigation to image the signature of the 2015 Gorkha earthquake in Sinamangal area, Kathmandu Nepal

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Seismic radiation of the 2015 Gorkha earthquake entered the Kathmandu valley with an azimuth of 135^{o} from the epicenter deforming the valley sediments. Considering an average P- and S-wave velocity of 6.0 km/s and 4.0 km/s respectively the onset of P-waves in the valley were felt after 13.5s with S-P lag of 6.8s. The Kathmandu valley is comprised of fluvio-lacustrine deposit with gravel, sand, silt and clay along with few exposures of basement rocks within the sediments. The response to input seismic energy seems spatially different causing ground deformation in a systematic pattern associated with the frequency of 1Hz containing maximum power (Ghimire et al. 2016). To image the signature of such deformation pattern 2D-MASW and 2D-SRT surveys were carried out in various parts of Kathmandu valley. A 24 channel Seismograph system under the brand name of GEODE-24 was deployed with vertical component geophones of 14.0Hz and 4.5Hz for 2D-SRT and 2D-MASW respectively. This paper deals a case study from Sinamangal area where a 12-storied business complex is proposed to construct by Civil Aviation Authority of GoN. Altogether two SRT profiles and five MASW profiles were surveyed to image the subsurface deformation pattern in the area. The result reveals a southeast dipping shear zone (or slip surface) up to the depth of 5 m to 10 m ruptured by the 2015 Gorkha earthquake causing differential settlement of ground in the area. This shear zone is confirmed by drilling after the geophysical investigation. The orientation and alignment of the shear zone follow the systematic pattern of ground deformation as proposed by Ghimire et al. (2016).

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Probabilistic seismic hazard analysis of Nepal considering uniform density model

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In this study, probabilistic seismic hazard analysis for Nepal has been carried out in terms of peak ground acceleration. Detailed earthquake catalogue within the rectangular area bounded by the co-ordinates (N 25° 30' 00", E 78° 30' 00"), (N 31° 30' 00", E 89 ° 30' 00") from 1255 up to 2015 AD and new seismic and seismotectonic maps have been prepared. Five hundred twenty eight numbers of areal sources has been proposed and historical earthquakes are plotted in the map of Nepal for identifying and characterizing the seismic sources. Major controlling earthquake not addressed in BECA (1993) has used as input and three attenuation laws for subduction zone has been used to take the mean effect of them. The completeness of the data has been checked by using Stepp's procedure. The seismicity in four regions of study area has evaluated by defining 'a' and 'b' parameters of Gutenberg Richter recurrence relationship. The uniform density model has been adopted to get the hazard in terms of contour map for peak ground acceleration and the spectral accelerations for eight different time periods have been plotted for hard, medium and soft subsoil conditions for 2%, 5%, 10% and 40% probability of exceedence in 50 years period and spectral accelerations for eight different time periods.

Sediment properties and prospect for aggregate from gravelly deposits between Aaptar and Malekhu, Dhading district, central Nepal

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The Malekhu Khola is rich in sediments which are widely exposed along its banks. In recent years, river mining sites have been established and mining have been carried on to produce aggregates to meet a small portion of the market demand. Because the riverbank deposits are of heterogeneous composition, quality of the aggregate from such deposits is of main issue. This study therefore, aims to evaluate quality of river sediment to know its suitability for aggregate as raw material for various uses, and the volume of the deposit. Aggregates were evaluated for quality and quantified based on the field observation and intensive laboratory works. The samples of aggregate were analyzed for texture, composition, durability and physical and mechanical properties. The gravelly deposits were categorized into point bar deposit, older floodplain deposit and mid channel bar deposit. The major composition of the sediments was derived from metamorphosed Lesser Himalayan rocks such as quartzite, schist, marble, metasandstone, amphibolites, gneiss and granite. Most of the deposits were matrix-supported and the matrix was basically sandy. Majority of clasts showed form of bladed to disc and were generally rounded to subrounded. The sediment size ranged from granule to up to boulder but the modal size was of cobble grade. While tested for gradation, the coarse aggregates ranged from uniform to gap graded categories. In terms of shape, workability of aggregate was found satisfactory. Aggregate samples possessed low water absorption value (0.53-1.08%) and thus low effective porosity. Aggregate impact value (13.40-15.70%) and aggregate crushing value (17.50-19.67%) showed good soundness. Los Angeles abrasion value (37.00-48.40%) showed consistent hardness of each of the samples. Low range of sodium sulphate soundness value (1.37-2.16%) indicated good resistance of aggregates against chemical weathering and frosting. The aggregates were also resistant to slaking as indicated by very high range of slake durability strength index (98.67-99.72%). Comparing with the existing Nepal Standard (NS), British Standard (BS) and American Standard of Testing Material (ASTM), the studied samples were suitable for concrete structures and unbound pavements. Six different localities were considered in the study area to estimate for resource of aggregates. The dimensional attributes of the gravelly deposits were measured in the field and the total volume of the deposits was estimated to be 3.9 million cubic meter.

Implementation of national building code in municipalities of Nepal

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National building code was approved by the Government of Nepal in 2003 in a context of almost strictly non-engineered buildings. The idea behind the building code was "to move from nothing to something" with a slow movement from non-engineered to pre-engineered construction, and then from pre- engineered to engineered construction. Lalitpur sub-metropolitan city was the first to implement the code followed by Kathmandu metropolitan city and Dharan sub-metropolitan city. The pioneering municipalities in the beginning followed a step-by step approach, taking implementation one step further each year. They brought some innovative ideas which could not be thought at that time. Apart from Dharan, Vyas, Bharatpur and Dhangadi are now the leading municipalities in Nepal who have implemented the code satisfactorily. At present almost all 217 municipalities of Nepal have implemented the code but the level of implementation is different in different municipalities. This paper overviews the experience gained by the leading municipalities of Nepal in implementing Building code. It explains the different problems faced by these municipalities in the implementation stage and the steps taken to overcome such issues. It also explains how these practices have been replicated to other municipalities of Nepal and the current status of building code implementation in Nepal.

Mineral potential and exploitation status in Nepal: an overview 2016

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Nepal Himalaya is divided into five geo-tectonic zones: The Gangetic Plain, the Sub-Himalaya, the Lesser Himalaya, the Higher Himalaya and the Tethys Himalaya. Different geo-tectonic zones have been proved potential on distinct types of mineral resources. Previous extensive mineral exploration work was conducted by Department of Mines and Geology (DMG) in 1993 AD. It was published as the Atlas of Mineral Resources of the ESCAP Region, Volume 9, Geology and Mineral Resources of Nepal in cooperation with Department of Mines and Geology and UN, ESCAP Secretariat. Study showed that during early 90's Mineral based industries on production phase were 4-cement industry, 1-marble industry and 1-agri-lime industry. There were about 100 small-scale mines under exploration phase. (ESCAP 1993). Now the establishment of mineral-based industries has increased significantly. There are 122 mines under opening license and 406 mines under prospecting license on FY 072/73 BS (2016 AD). Out of these, there are 44 limestone mines on production phase and 168 mines on prospecting phase. Opening licenses are issued for 15 minerals and prospecting licenses are issued for 25 minerals (DMG 2073). Total investment in mineral exploration and geological survey program was Rs. 2,27,10,000 on eighth national plan (1990/91-1995/96) while the annual budget in mineral exploration and geological survey program for the FY 073/74 is Rs. 33,02,33,000. Total sum of revenue from mineral sector contributed to national economy was 252.2 million at 1993 and now mining and quarrying alone contributes 11,961 million in the national economy (CBS 2015). The total contribution to GDP from mineral-based industries at 1993 was 2.34%, while excluding mineral-based industry, mining and quarrying alone had contributed 0.572% to the national GDP on the FY 071/72 BS (CBS 2015). There have been substantial increases in foreign direct investment in limestone based cement industries. Apart from this, the mining leaseholders are not operating the mines to full mineral potentiality, and there is great chance to enhance the mineral industry. After, about twelve years the royalty of minerals were revised and adjusted to present value on 2072 BS. Before revision of royalty the total revenue from DMG was Rs 5,80,41,560 on FY 071/72 BS while it gets increased to 26,30,31,562 on FY 072/73 BS. Limestone mines alone contributes Rs.19,72,03,050.4 i.e. 74.94% on total revenue by DMG. This revenue excludes the contribution from mining licenses issued by District Development Committee (DDC) for general construction materials and from mineral-based industries. Exploration works and geology of Nepal show that there lays great scope of mines operation of limestone, gemstone, construction materials, decorative stone, paving stone etc. With more mines in operation and establishment of mineral industries, the country will create job opportunities to many people eventually contributing substantially to national GDP. There lies a big research gap in mineral exploration of Nepal since Higher Himalaya is still nearly virgin due to its lack of accessibility and rugged terrain. Here lies the strong potential of gemstones and rare earth elements (REE) as indicated by its geology. Hence, mineral sector welcomes great deal of extensive works which is yet to bring good news on geosciences, mining and hence to national economy of Nepal.

Reconstruction and relocation of vulnerable settlements: NRA's expectations from geoscientists

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The Mw 7.8 Gorkha Earthquake 2015 and its subsequent aftershocks severely affected hundreds of settlements across the 31 most affected districts. Based on rapid geological assessment, the Government has declared 475 villages as the most vulnerable communities. Out of the total 475 villages, 175 communities were shifted to temporary shelters immediately after the earthquake. The government has a plan to shift all the vulnerable villages (it could be more than the initially identified 475 communities) to safer sites under the government's integrated village development schemes. The idea of developing the integrated village was based on the fact that it would be easy for government to provide basic needs like drinking water, health, education, electricity, transport, etc. to general public rather than providing such services to scattered villages, many of which are located in rainfall-induced and seismic-induced landslide prone areas. But how to identify the safer sites for integrated village development was a pertinent question whose answer, acceptable to all stakeholders, was not easily available. Generally a site is considered to be safer for a settlement (re)construction if the state of geo-hazards like landslide, flooding, liquefaction, and site amplification is manageable within Nepalese context. At the same time, the site should have nearby sources of enough construction material, and drinking water along with a reliable access to other basic services like road, hospitals, electricity, schools and city centers. It has therefore been realized that safer sites of reconstruction can only be identified considering inputs from a team of professionals that includes, but not limited to, engineering geologist, geotechnical engineer, seismologist, watershed management expert, water induced disaster management engineer, infrastructure development planner. Describing the mandate-holding government departments and their state of interdepartmental coordination, this paper provides an overview of NRA's initiative to identify safer sites for community resettlement. It also highlights the geotechnical issues where geoscientists' contribution is a most to find applicable solutions.

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Application of electrical resistivity method for the assessment of groundwater potential at Panchkhal valley, Kavre, Nepal

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Groundwater is widely distributed in nature, but its occurrence and distribution is confined to certain geologic formations and structures. Hydrogeology of the area depends on the local lithology, geological structure, geomorphology and climate. Surface geophysical methods are used to measure the physical properties of the subsurface such as electrical conductivity or resistivity, dielectric permittivity, magnetic permeability, density, or acoustic velocity which are used to characterize the subsurface condition. Electrical methods are widely applicable for groundwater exploration because of the close relationship between electrical conductivity and the physical properties of aquifers. The main propose of the study was to assess the groundwater potential at Panchkhal valley, Kavre, Nepal using electrical resistivity methods. Data acquisition was carried out by resistivity meter WDJD-4 using Schlumberger configuration for vertical electrical sounding (VES) method and Wenner and Dipole-Dipole method for two dimensional electrical resistivity imaging. Data were analyzed using geophysical software IPI2Win and Res2Dinv which are used for processing and interpretation of the resistivity data. A total of four 2D ERT profiles and ten VES point were carried out in the area to map the subsurface lithology of the area. Geoelectric layers of the area were clay, silt, compact lateritic soil, sand, gravel, fractured bedrock and competent fresh basement rock. The depth of the fractured bedrock from the existing ground level ranges from 50 m to 60 m on different part of the study area. The result of 2D electrical resistivity methods was used for locating the position for VES Survey and assessing the availability of groundwater in the highly weathered and fractured rock. Result of the study was verified by drilling four deep tube wells in the area. Results from this study are useful for technical groundwater management in the area, as they clearly identified suitable borehole locations for groundwater prospecting.

First record of *Eotragus noyei* from the middle Siwalik Dhok Pathan Formation of Pakistan

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The fossil remains described in this study have been recovered during field work by the authors from the Dhok Pathan Formation in the middle Siwalik of Pakistan in December, 2015. The sample comprises maxillary and mandibular fragments along with isolated upper and lower teeth. The morphometeric analysis of the specimens led us to recognize the sample as belonging to *Eotragus noyei*, which has been considered as the smallest and the oldest bovid in the Siwalik. *Eotragus noyei* is characterized by brachydont teeth, finely rugose enamel, more inclined buccal walls of the molars and small lingual cingula. The inclination of the metaconal area has caused rotation of the metastyle in relation to the antero-posterior tooth axis and thus situated more lingually. The protocone in second upper premolar is well developed and situated posteriorly and also has an anterior lingual constriction. The metaconule in the third upper molar is smaller than the protocone. The dentition in *Eotragus noyei* is smaller in size as compared to *Eotragus sansaniensis* and *Eotragus lampangensis*. In *Eotragus noyei* the buccal walls in molars are more inclined while in *Eotragus sansaniensis* they are less inclined. The genus *Eotragus* has been reported previously in the lower and middle Siwalik of Pakistan; however the recognition of the present sample as *Eotragus noyei* has extended the range of this species from lower to the middle Siwalik of Pakistan.

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Description of Anthracotheriidae remains from the middle and upper Siwalik of Punjab, Pakistan

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In this paper new dental remains of *Merycopotamus* (Anthracotheriidae) are described. The specimens were collected during field work by the authors from the well dated fossiliferous locality "Hasnot" belonging to the Dhok Pathan Formation, and from "Tatrot" village belonging to Tatrot Formation of the Potwar Plateau, Pakistan. The stratigraphic age of the Neogene deposits around Hasnot is 7-5 Ma; whereas the age of the Tatrot Formation is from 3.4-2.6 Ma. The newly discovered material when compared with the previous records of the genus *Merycopotamus* from the Siwalik led us to identify all the three reported species of this genus from the Siwalik of Pakistan. As the sample comprises only the dental remains the identification of the specimens is solely based upon the morphometric analysis. The occlusal pattern of the upper molar in *Merycopotamus dissimilis* is different from *Merycopotamus medioximus* and *Merycopotamus nanus* in having a mesostyle fully divided, forming two prominent cusps, while mesostyle in *M. medioximus* is partly divided and small lateral crests are present on the mesostyle. A continuous loop like mesostyle is present in *Merycopotamus nanus*. The entoconid fold is present in *Merycopotamus dissimilis* on the lower molars whereas it is absent in *Merycopotamus medioximus* and *Merycopotamus nanus*. The hypoconulid in *M. dissimilis* is relatively simple but a loop like hypoconulid is present in *M. medioximus* and *M. nanus*. The results of the present findings are in line with the previous records of the genus *Merycopotamus*, with *M. nanus*, *M. medioximus* and *M. dissimilis* in the Late Miocene – Early Pliocene Dhok Pathan Formation, and *M. dissimilis* in the Late Pliocene Tatrot sediments of Pakistan.

New artiodactyl fossils from Dhok Pathan Formation of Pakistan

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The Late Miocene-Early Pliocene of Pakistan has produced a rich artiodactyl fauna. The new fossils include the cranial material of artiodactyls. The diverse material presents taxonomy of artiodactyl from the Dhok Pathan Formation of Pakistan. The assemblages of artiodactyls from the Potwar Plateau are dominated by the presence of the bovids. The taxa are consistent with a Late Miocene-Early Pliocene age of the deposits. The specimens are classified on the basis of morphometric features of the material from the Late Miocene-Early Pliocene of the Siwalik Group. This faunal list may be compared with that of other Late Miocene localities of the Siwalik. The artiodactyl remains increasingly indicate both taxonomic and adaptive diversity.

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New Bovidae fossils from upper Siwalik of Pakistan

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New Bovidae fossils are collected from the outcrops belonging to the upper Siwalik Subgroup of northern Pakistan. The recovered material comprises cranial elements including dentitions and horn-cores. The recovered specimens provide existing evidence of the large sized bovids in the Plio-Pleistocene of Pakistan. The diversity of the collected fossilized fauna is helpful in the reconstruction of the paleohabitat of the ancient animals existed in the upper Siwalik Subgroup of Pakistan.

Diagenetic effects on upper sands of lower Goru Formation of lower Cretaceous Basin block, Lower Indus Basin, Pakistan

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Khaskheli Oil Field is the first largest and most prolific oil field in Pakistan situated in the south eastern part of Lower Indus Basin in Badin area. In Lower Indus Basin, more than 12TCF gas reserves and more than 100 million barrels oil have been discovered and almost 90% oil production is from Badin area. The 60% reserves and production is only from the early Cretaceous Lower Goru sandstone. The informally named B Sand (a part of the Upper Sand, Lower Goru Formation) is the most important reservoir unit. Lithologically, the Lower Goru is predominantly a marine and marginal marine shale and silt. Within these shales and silts are a number of sandstone horizons. The spacial and temporal variations in porosity and permeability in Lower Goru sandstone horizons is a common phenomenon which has resulted numerous setbacks because the sandstone at many places have unexpectedly been found tight. That is most probably due to spacial and temporal variations in diagenesis of sandstone horizons. Despite of great interest among oil exploration and production companies in the Khaskheli Oil Field, only a small number of published studies about the Lower Goru sandstone reservoir are available. These studies are more descriptive and deal with lithology, lithofacies distribution, sequence stratigraphy, and petrophysics. Almost nothing or very little have been done to understand the diagenetic controls on the variation of porosity and permeability within this most producing and promising reservoir sands of Lower Goru Formation. However, significant potential remains untouched due to limited understanding of the distribution of reservoir, key reservoir facies, diagenesis and its effects on reservoir quality. It is general observation that diagenetic episodes are responsible for retention, generation and destruction of porosity. Keeping in view the importance of diagenesis; core samples of B sand reservoir rock of Lower Goru Formation from three wells of Badin Block were studied using thin section, XRD, and SEM techniques to investigate the diagenetic effects on reservoir characteristics. Thin section study indicates that the B sand unit is texturally and compositionally mature with quartz as the predominant mineral constituent with variable amount of feldspar and lithic minerals. The studied samples are fine to medium-grained and medium to coarse-grained in size. QFL plot indicates that majority of the samples plot into the field of quartz arenite, sub-litharenite and sub-arkose, respectively. A few of the samples plot into the litharenite and feldspathic litharenite fields because of relatively higher amount of lithics and feldspar. The feldspars are partially to completely altered into kaolinite and other clay minerals. In most of the thin sections, the corrosion of quartz was observed. Coarse-crystalline and micro-crystalline calcite is the predominant cementing material. In the diagenetic sequence, the microcrystalline is of earlier stage while the coarse spary calcite indicates late diagenetic events. Bulk rock XRD analysis also confirms that the main mineral constituents of the studied samples are quartz and calcite in variable proportions. The undulose extinction and fracturing of quartz grains indicates that the area remained under stress and the fracturing is post-depositional and therefore is the product of late diagenesis. Scanning Electron Microscopic (SEM) images at 50 micron meter size shows irregular type of fracturing within the quartz grains. This late stage fracturing of quartz has also generated various types of channels which may serve as secondary porosity. The quartz overgrowth is also seen in some samples which is the product of late stage diagenesis. The micro-crystalline cement in the form of calcite is mostly present within the pores. Based on the above results, it can be concluded that diagenesis played an important role in the alteration of B sand unit and enhanced the quality of B sand as reservoir rock by increasing the porosity due to quartz fracturing, feldspar dissolution and alteration, and quartz corrosion.

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Study on enamel hypoplasia in an artiodactyle taxon to compare stress in geological periods of the Siwalik Formations of Pakistan

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Studies on dental enamel hypoplasia have been used by different paleontologists in order to analyze the stress in extinct ungulates. The present study involves the enamel hypoplasia analysis of five Siwalik genera of family giraffidae to determine and compare stress periods in Kamlial to Pinjor Formation of the Siwalik of Pakistan. The studied fossils have an age from Early Miocene to Early Pleistocene (18.3-0.6 Ma). Enamel is the hardest tissue of body and marks of enamel hypoplasia remain unaltered even during fossilization. Enamel hypoplasia is a tooth malady which is mainly caused by the deficiency of food/nutrients. The feeding deficiency is directly linked to the physiological or environmental stress. In this study, occurrence of enamel hypoplasia has been observed in species of five out of six formations of the Siwalik. The observed enamel hypoplasia has evident that comparative intensities of stress episode in the Siwalik formation are Kamlial > Chinji > Dhok Pathan > Tatrot > Pinjor Formation. No enamel hypoplasia is observed in Nagri Formation. Rapid and irregular climate changes during 17 and 13 Ma, marked cooling after 6.5 Ma, Late Miocene species duration decrease, Plio-Pleistocene glacial cycle and 2.5 Ma transition are the major stress events of the Siwalik and are the etiological factors for observed enamel hypoplasia. These climatic, vegetational and ecological stresses during different time span of the Siwalik are responsible for migration, extinction and evolution of extinct fauna of this region.

Ambient ozone impacts on legume crop productivity by using ethylenediurea at Lahore, Pakistan

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An experiment was conducted at Institute of Agricultural Sciences (IAGS), University of the Punjab, Lahore, Pakistan to determine the effect of ambient ozone pollution on growth and yield of legume crop. Soil drench method of application of Ethylenediurea (EDU) on two cultivars of mungbean (*Vigna radiata* L. cv. NIAB-2006 and AZRI-2006) and its improving results against ambient ozone stress was checked on growth and productivity features of crop. Monthly mean O_3 concentration changed between 79.4 ppb and 105.2 ppb during the experimental period. Mungbean plants were treated with EDU by making concentrations such as 0, 200, 300, 400 and 500 ppm after 10-days break as soil drench during the whole growth period. EDU treatments affected plant growth and productivity with varying effects on cultivar, age, and EDU concentration. In this study growth and productivity was improved for NIAB-2006 and AZRI-2006 at 400 ppm EDU. Overall results on mungbean crop by applying EDU looks like a very useful to evaluating the ambient ozone consequences in Pakistan.

Seawater intrusion and its effects on agriculture in coastal parts of Thatta district Sindh, Pakistan

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Contamination of the seawater into coastal aquifers of the world is a major groundwater problem. The aquifers of the study area are shallow (1-25 ft) and severely affected by seawater intrusion due to the shortage of freshwater flow from Indus River. As a result, groundwater and soil salinity have increased to the alarmingly high levels which are badly affecting agriculture and livelihoods of the local farmers. The study area forms the southernmost parts of vast Indus deltaic plain that have been formed by gradual filling up of low lying alluvium derived from Himalaya. The texture of soil is dominated by silt loam (90%) followed by silt clay loam and clay. Topography of the area is uneven marked by depressions often waterlogged by salt water flooding, seawater intrusion and heavy monsoon rains. This area also experienced floods in 2010 and 2011 causing severe damage to crops. Total 107 groundwater samples were collected from 33 sites in 5 Tehsils of Thatta district lying at the coast of Arabian Sea. Samples were taken during post- and pre-monsoon seasons of 2011-2013. The chemical analysis of groundwater show highly variable electrical conductivity and total dissolved solids ranging between 0.63 to 10.05 dS/m and 403 to 6432 mg/l respectively indicating highly saline groundwater. The intrusion of seawater into groundwater is indicated by high Cl/HCO_3 ratio ranging between 3.7–4.9 which far exceeds the standard limit of <2.8. Plots of the water samples on Piper diagrams show that most of the water samples are dominated by Na-Cl type which further indicates the seawater intrusion in the area. Moreover, the study of these groundwater samples by stable isotopes $\delta^{18}O$ (-8.81 to – 6.23 0/00) and $\delta^{2}H$ (-60.63 and to -43.20 0/00) indicate the age of seawater intrusion in the study area as 65 years. It is the time when the damming of Indus River started in Pakistan resulting in reduced fresh water flow to Arabian Sea.

Working with NRA: reconstructing community infrastructure – building back better

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The earthquakes of 2015 in Nepal destroyed approximately 500,000 houses and caused extensive damage to additional 400,000. Community infrastructure that had been developed over decades was equally impacted, including water supply systems, access roads and trails, micro-hydro plants. To some extent, the earthquake exposed pre-existing vulnerabilities – physical, social and economic that make whole communities less resilient. Ongoing reconstruction efforts need to address these underlying vulnerabilities where possible. The humanitarian response organised by local people with the support of local and Central Government was impressive; international organisations and Governments including that of the UK contributed generously, with the UK Government's Department for International Development (DFID) providing £70 million for the emergency phase and committing a further £73m for a 6-year reconstruction programme. In consultation with the recently established National Reconstruction Authority (NRA) DFID has designed a broad spectrum of reconstruction investments including significant investments to restore critical community infrastructure; a contribution towards the housing reconstruction programme, masons training and support for people who remain displaced from devastating landslides caused by the earthquake. DFID upholds the principle of supporting the most vulnerable, who are often those with the least power and voice, and will continue to strive that no-one is left behind in ongoing reconstruction efforts. Working closely with the NRA since its inception DFID has been impressed by the tireless dedication and commitment of the Authority, despite the sometimes complex beaurocratic process that any Government navigates. NRA and DFID have collaborated closely on *mission critical* components of the reconstruction process including funding / supporting enrolment in the 11 priority rural districts; supporting geo-hazard surveys across 500 at-risk communities; expanding house damage surveys into the remaining 17 districts and ongoing technical assistance where requested. This close collaboration has given DFID a unique perspective on the strengths of the agency and areas for development and improvement. Strengths include the mandate of the organisation; the dedication and unrelenting focus on mobilising the housing reconstruction grant and masons training to enable people to reconstruct safer homes. On the other hand, DFID sees opportunity for NRA to think broader about the wider reconstruction needs, including livelihoods and equitable access to work; the opportunity to create a cross-department framework to support resettlement and durable solutions for those displaced by natural disasters; to adopt an evidence-based approach to programmes including communication on better building practices; to work in closer harmony with technical organisations – local and international.

Flood risk assessment under different scenarios on climate change, urban expansion, and economic exposure: a state-of-the-art probabilistic approach in the context of Nepal

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Flood risk assessment is crucial for Nepal, a low-income country that has been witnessing floods of high magnitudes, and where future increases in rainfall intensity, built-up areas, and economic exposure are likely. The key concepts behind a state-of-the-art approach for flood risk assessment models in the context of Nepal will be presented during the conference. In addition, the feasibility of implementing a flood risk assessment model for Nepal and the possible use of the results of this implementation will be illustrated via the study area of the upper Seti River watershed, a basin located in the Pokhara valley of the Kaski District. The study of the upper Seti River watershed is a necessary step to spur stakeholders in flood risk to develop and use much needed flood risk assessment models on Nepal to reduce the gap in knowledge and application of flood risk assessment models in the region. In fact, the monsoon rainfall has dire consequences in many places in Nepal and beyond: almost every year during the monsoon period, precipitation wreaks havoc in the agro-ecological region of the Terai in Nepal and in northern India. Ultimately, flood risk in the upper Seti River watershed will be assessed via a quantitative estimation of the direct tangible consequences of future floods. After the development, calibration, and validation of the fully-probabilistic flood risk assessment model, the model will be used to predict annual damages from future floods for both present and future conditions of rainfall, land use, and economic exposure. These predictions will allow a rigorous assessment of the risk from future floods in the upper Seti River watershed, including the testing of two hypotheses: first, flood risk for the year 2030 increases, and, second, the main drivers of this increase are the increase in economic exposure and the increase in the built-up area.

Soil liquefaction observations following the 2015 Gorkha earthquake

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The 25 April, 2015 Gorkha earthquake caused significant damage in Nepal, and within the Kathmandu valley. Notably, there were many observations of ground failure, which are important observations for the geotechnical earthquake engineering community. Notable examples of ground failure include landslides, rockfall, liquefaction, and cyclic failure of soft soils. Herein, we examine reported liquefaction cases around the Kathmandu valley. Importantly, the occurrence of liquefaction was muted, compared to what was expected based on the Kathmandu valley's depositional environment and observations from previous earthquakes. In this talk, we explore reasons for why the observed liquefaction was muted during the 2015 Gorkha earthquake and aftershocks. Also, we highlight how the geotechnical observations from the 2015 Gorkha are relevant to earthquake engineering practice worldwide. Finally, we talk about some of the other post-reconnaissance geotechnical observations, and how to use the observations to prepare better for the next earthquake.

2015 Nepal earthquake: building back greener for sustainable reconstruction and development

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The Nepal earthquake of 25 April 2015 and its aftershocks affected 31 districts in Nepal. The total estimated value of damage and loss across several sectors was over US$7 billion, a major proportion of this being housing. Nepal is witnessing massive recovery and reconstruction efforts across the country. The post-disaster needs assessment, post-earthquake rapid environmental assessment and post-disaster recovery framework outlined the high risk of environmental damage during recovery and reconstruction. Many people in Nepal are highly dependent on locally available natural resources for their wellbeing and livelihoods, and on ecosystem services to reduce risk of future disasters such as floods and landslides. Recovery and reconstruction efforts should avoid inadvertently degrading the environment, and should contribute to building back better and safer by restoring previously impaired ecosystem functions. The Hariyo Ban Program and WWF Nepal have worked across multiple sectors to promote sound environmental practices during recovery and reconstruction, including capacity building and awareness raising at multiple levels; support to government policies and guidelines; production of guidance materials; and establishment of good-practice demonstration sites. This has been done through developing partnerships across multiple sectors. The program was able to bring in practical examples from its own recovery and reconstruction efforts with partner communities in four seriously affected districts. There has been a gratifying response from government, parliamentarians, media, NGO partners and donors, and there is much recognition of the importance of incorporating sound environmental practices. However, strong leadership is required to continue this process, ensuring that awareness at higher levels is converted to good practices on the ground, with measures that are practical, cost effective and time-sensitive. This presentation outlines Nepal's experiences to date in this field, and recommendations for the way forward. it provides important insights for future disasters, both in Nepal and elsewhere.

Building with earth: earthbag technology

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In the 1980s, visionary architect Nader Khalili founded a school of architecture based on the idea that bags filled with earth could be used to create permanent structures. Sand bags had long been employed to build temporary dams, dikes and military bunkers, but it was Khalili who realized that ordinary soil could be employed to build strong, stable and lasting buildings suitable for everyday living. The walls of Earthbag structures are composed primarily of ordinary soil found at the construction site. The soil is stuffed inside polypropylene bags, which are then carefully stacked like masonry and tamped down. After a month or two, the soil inside the bags becomes as hard as brick. Barbed wire laid between the bags provides tensile strength, and serves as the mortar. Coating the walls inside and out with a thin veneer of plaster creates a smooth, pleasing appearance. The soil used in earthbag construction can come from any nearby field, and nearly all soils are suitable. There must be enough clay and moisture to bind the aggregate together but precise ratio is not necessary. A mix of 25%-30% clay, 70%-75% sand and 10% moisture is typical. Earthbag construction is now flourishing in Nepal, across a wide range of terrains and topographies. Notable for their resistance to extreme seismic events, all 55 Earthbag buildings survived Nepal's 7.8 magnitude earthquake with no structural damage. Properly maintained, Earthbag structures will stand for generations, perhaps centuries. Because Earthbag technology makes minimal use of cement, concrete, steel and timber-and the trucks and fuel needed to transport them-the building technique is also easy on the environment and doesn't deplete scarce natural resources. Earthbag technology requires less expertise and skilled labor than more traditional building methods and only the simplest of tools, cutting standard construction costs by almost half.

The Himalaya seismogenic zone: a new focus for multidisciplinary earthquake research

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The Mw 7.8 Gorkha, Nepal, earthquake that occurred on April 25 of this year was a dramatic reminder that great earthquakes are not restricted to the large seismogenic zones associated with subduction of oceanic lithosphere. The Himalayan seismogenic zone shares with its oceanic counterparts a number of fundamental questions, including:

(a) What controls the updip and downdip limits of rupture?
(b) What controls the lateral segmentation of rupture zones (and hence magnitude)?
(c) What is the role of fluids in facilitating slip and or rupture?
(d) What nucleates rupture (e.g. asperities?)?
(e) What is the role of splay faults in accommodating rupture?
(f) How can a better understanding of Himalayan rupture be translated into more cost effective preparations for the next major event in this region?

However the underthrusting of continental, as opposed to oceanic, lithosphere in the Himalayas frames these questions in a very different context:

(g) How does the greater thickness and weaker rheology of continental crust/lithosphere affect locking of the seismogenic zone?
(h) How does the different thermal structure of continental vs oceanic crust affect earthquake geodynamics?
(i) Are fluids a significant factor in intercontinental thrusting?
(j) How does the basement morphology of underthrust continental crust affect locking/creep, and how does it differ from the oceanic case?
(k) Do lithologic contrasts juxtaposed across the continental seismogenic zone play a role in the rheological behavior of the SZ in the same manner as proposed for the ocean SZ?

It remains to be established whether the Himalayan seismogenic zone has the potential for earthquakes of the greatest magnitudes (e.g. 9.0+). However, there is no question that future ruptures in this system represent a serious threat to major population centers (megacities) in the Indian subcontinent. For this reason alone the HSZ is deserving of a major new international, multidisciplinary effort.

The role of shear zones and faults within the greater Himalayan sequence, eastern Nepal

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Since the early work of Heim and Gansser (1939), it has been recognized that several laterally continuous major fault zones separate rocks of different metamorphic grade. In the 1980's one of these faults, the South Tibetan Detachment System (STDS) was identified as a normal fault rather than a contractional structure. Since that time a number of models have been proposed to explain the presence of extension in the highest Himalaya and in a convergent plate boundary setting. It is now further recognized that these models needs to consider the role of the multiple shear zones that exist between the Main Central Thrust (MCT) and the STDS. We have identified several of these shear zones within the Greater Himalayan crystalline sequence in the Khumbu region of eastern Nepal and are currently investigating their role in the mountain building story. Towards the northern part of the Greater Himalaya in this region, there is some evidence from deformation fabrics that these minor shears may have a north-south extensional component to their kinematic history, however further south the deformation is consistent with north-south shortening. Early work on one of these southern ductile shear zones revealed young (~4-9 Ma) cooling ages. The Greater Himalayan sequence is also host to brittle deformation suggesting that faulting and shearing have been active processes potentially for the past 20 Ma. While the shear zones represent regions of localized high strain, it is true that there is some degree of penetrative shear fabric across most of the Greater Himalayan sequence. Future work will be aimed at teasing out the contribution of pure shear to this fabric so that we can better quantify simple shear and displacement across the Greater Himalaya.

Coupling on the Main Frontal Thrust and magnitude of the maximum plausible earthquake in the Himalaya

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We first find the coupling pattern and rate of moment build-up on the Main Himalayan Thrust. To do this we use GPS, leveling data, InSAR and microseismicity data, and an inversion. We find that the fault is fully locked along its entire length, with no creeping segments. We then estimate the magnitude and return period of the largest plausible earthquake that could occur on the Main Himalayan Thrust (MHT). Our approach is probabilistic but takes into account the physical constraints that seismic and aseismic slip must add to match the long-term slip rate on the fault. We use the rate of moment deficit buildup found previously to place an upper bound on the average seismic rate release. We also make use of the instrumental and historical seismicity and the related Gutenberg-Richter (GR) statistics. Our method also takes into account aftershocks of the earthquakes with magnitudes larger than those in the instrumental catalog began, as the may substantially contribute to the slip budget. The method yields an estimate of the probability distribution of the magnitude and return period of the maximum possible earthquake.

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