

Geological issues in the development of proposed water transfer projects in the Nepal Himalayas

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ABSTRACT

Nepal is a country with ample inland water resources, with many rivers. Being a mountainous country, it is a capsule with all the physico-chemical and bio-features of the world. It is tecto-seismically active and environmentally susceptible, with a maximum number of fresh high mountains with numerous rivers, lakes and glaciers in their circles. Being a late starter in the development process, Nepal is hurdling towards the latest technology from its primitive state. So, to solve the increasing population's water demand, potential economic activity and social benefits, water diversions projects are being introduced. Among the hundreds of kilometers of planned diversion projects, most of them lie in hills till date. But such projects are in the process of being constructed in the Himalayas. This includes water diversion in a short section of river or transferring huge mass of water from one Himalayan basin to another. The Way Rivers are exploited and new projects are designed in the Mahabharat and Chure regions are not environmentally friendly. On the other hand, young mountains may not digest the various technologies and proposals which are quite unfamiliar in the existing environment. The methods and concepts usually used in such projects are ideas from elsewhere, but not even from the practices of the rivers of our own country. Such projects may be a waste of time or money, or they may cause distortions in socioeconomic, environmental, and mountain ecology. To summarize, water diversion projects in the Himalayas are a problem with social, environmental, and technological issues. Among these issues, geological concerns and their consequences are immeasurable. Thus, this paper gives emphasis to the geological issues of water diversion in the Himalayan region, with reference to under construction and proposed projects.

Introduction

The Himalaya, with the highest number of high peaks in the world, was developed 58 million years ago after the collision of the Indian plate with the Eurasian plate. The Neoproterozoic to Ordovician (Parrish and Hodges 1996; DeCelles et al. 2000) aged higher Himalayan rocks, Proterozoic (Holland 1908; Gansser 1964) aged Lesser Himalayan rocks, and Neogene to Quaternary aged sub-Himalayan rocks form the Himalayan block. Along with the development of the Himalayan block and the monsoonal climate, river systems were also developed. After the ice age, the

monsoonal rainfall and glacier ice melt water were drained out by the rivers of the Himalayas, forming seven different river basins. While flowing from north to south, these rivers encounter higher Himalayan geology, Lesser Himalayan geology, and Sub Himalayan geology before reaching the Terai (Indo gangatic plain) plain of Nepal.

Only 72% of the country's population has access to basic water supply, and 25% of the whole population has sanitation facilities. In addition to that, 42% of the total land is irrigated by the river source and 689 MW of electricity is generated out of an estimated 72544 MW of potential electricity. Thus, for the further agumentation of the flowing river water, the government of Nepal has developed a nationwide plan to fulfill the water demand for drinking and sanitation, agriculture, electricity, transportation, and recreational purposes. Among the several plans, water diversion projects in the Nepal Himalayas are also one of them. Since the Himalaya is not only seismically active but also young and environmentally susceptible. Though several canal water transfer projects are in operation in terai, interbasin water transfer systems are not in operation in Himalayas. Even though the government is investing heavily in such projects, our country is still lagging behind in developing and running such projects. There are some geological challenges too. Thus, the present study gives the typical geological characteristic features of the Himalayas of our country and the prevailing geological issues and future issues in constructing and implementing such projects, with reference to some under construction and proposed projects.

Methodology

Few cases of water diversion and water transfer projects that are being constructed and are proposed for construction in Nepal Himalayas are selected for the study of this research. Basically the secondary data is collected with respect to the research aim and the collected data is compiled.

Water transfer history in Nepal Himalayas

For drinking and sanitation, Nepalese people primarily rely on springs, spouts, and groundwater. People rely on the monsoon rainfall for agriculture. Such dependency on seasonal rainfall results in partial or no irrigation due to the present condition of climate change and seasonal lag. The continuous power cut problem was also faced by Nepalese people from 2005 to 2018. To overcome the drinking water, irrigation, and electricity demand problems, the government of Nepal has proposed and planned several projects, including interbasin water transfer projects. The Melamchi water supply project is an interbasin water transfer project in lesser Himalayan geology that diverts 170 million litres of water per day from the Indrawati river basin to the

Bagmati river basin. This project was started in 1998 with the aim of facilitating the water demand of the increasing population of the Kathmandu valley. The Bheri Babai Diversion Multipurpose Project (BBDMP), located in western sub Himalayan geology, aims to transfer 40m³/s of water from the Bheri river in the Karnali Basin to the Babai river in the Babai basin. This project aims to irrigate 60,000 ha of agricultural land in western Nepal and produce 48 MW of electricity. Likewise, the surface canals like the Sunsari Morang irrigation project, Sikta project, Bagmati irrigation project, and Rani Jamara irrigation project are surface water transfer projects in operation for irrigation. Prior to these, the Koshi Western Canal, Rampur Tar Irrigation Project, Kankai Irrigation Project, Khageri Irrigation Project, Bagmati Irrigation Project, Banganga Irrigation Project were in operation for irrigation.

River Basin of the Himalayas

The Nepal Himalayas typically consist of twelve river basins (figure 1). The river basins extend from the northern higher Himalayan peaks to the southern terai plains. Surface runoff from these basins accounts for approximately 72% of the monsoon rainfall, with a total catchment area of approximately 181000 sq. km, of which about 33600 sq. km is in Tibet (Sharma 1997). The rivers from the higher Himalayas are north to south trending. In addition to that, the fault system and the thrusts have controlled some rivers, changing the trend to an east to west direction. The rivers like Sunkoshi and Tamor are east-to-west trending in some places. The Arun and Kaligandaki rivers also flow from south to north in some places due to structural control.

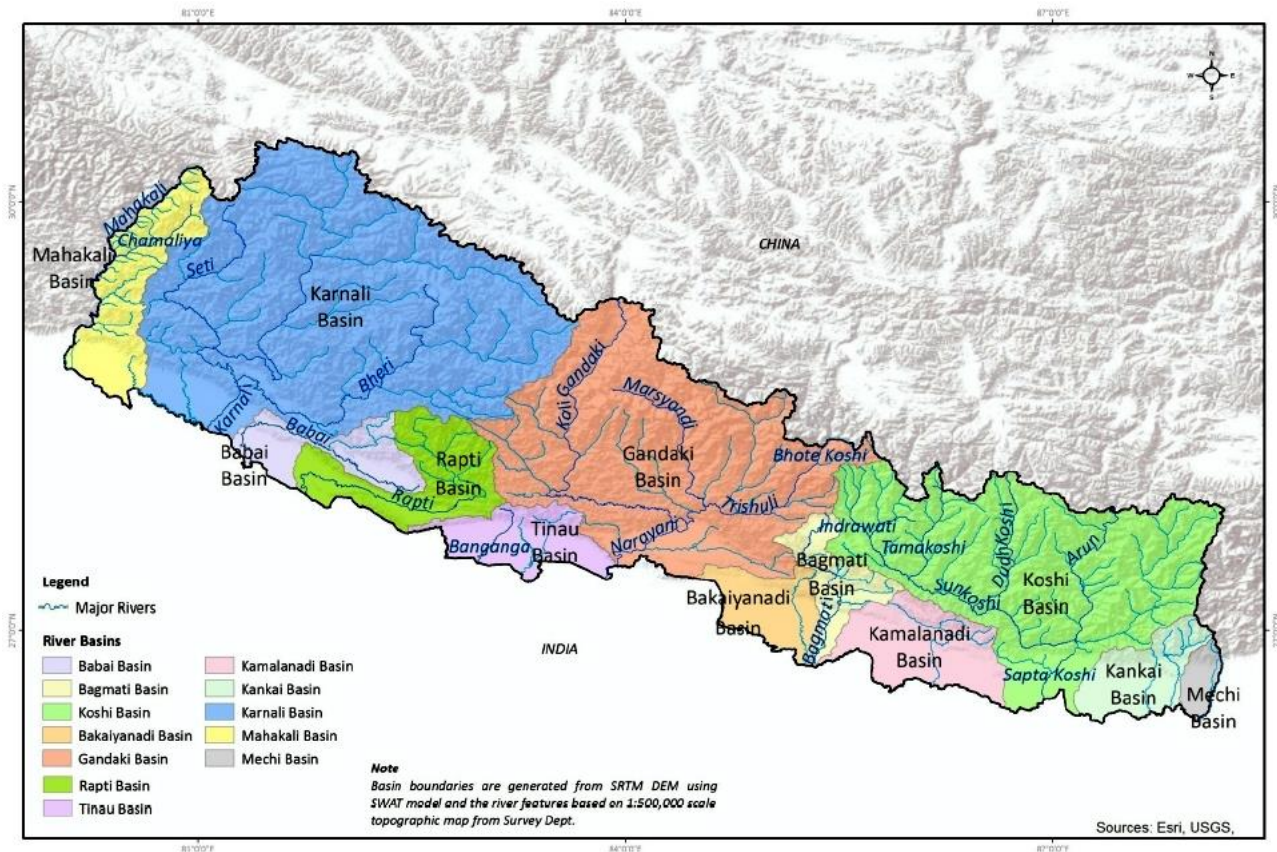


Figure 1: The river basins of Nepal (WECS 2019)

Geology of Nepal Himalaya

The continent-continent collision has given rise to the peculiar Himalayas and several structures. Among the total length of 2400km, the Nepal Himalayan range covers 870km of length. It is geologically diversified, from the tallest mountainous terrain to plain terai. Thus, geologically, it can be divided into five tectonic zones from north to south: the Tibetan Tethys, the Higher Himalaya, Lesser Himalaya, Sub Himalaya, or Siwaliks, and the Terai (Figure 2 and 3).

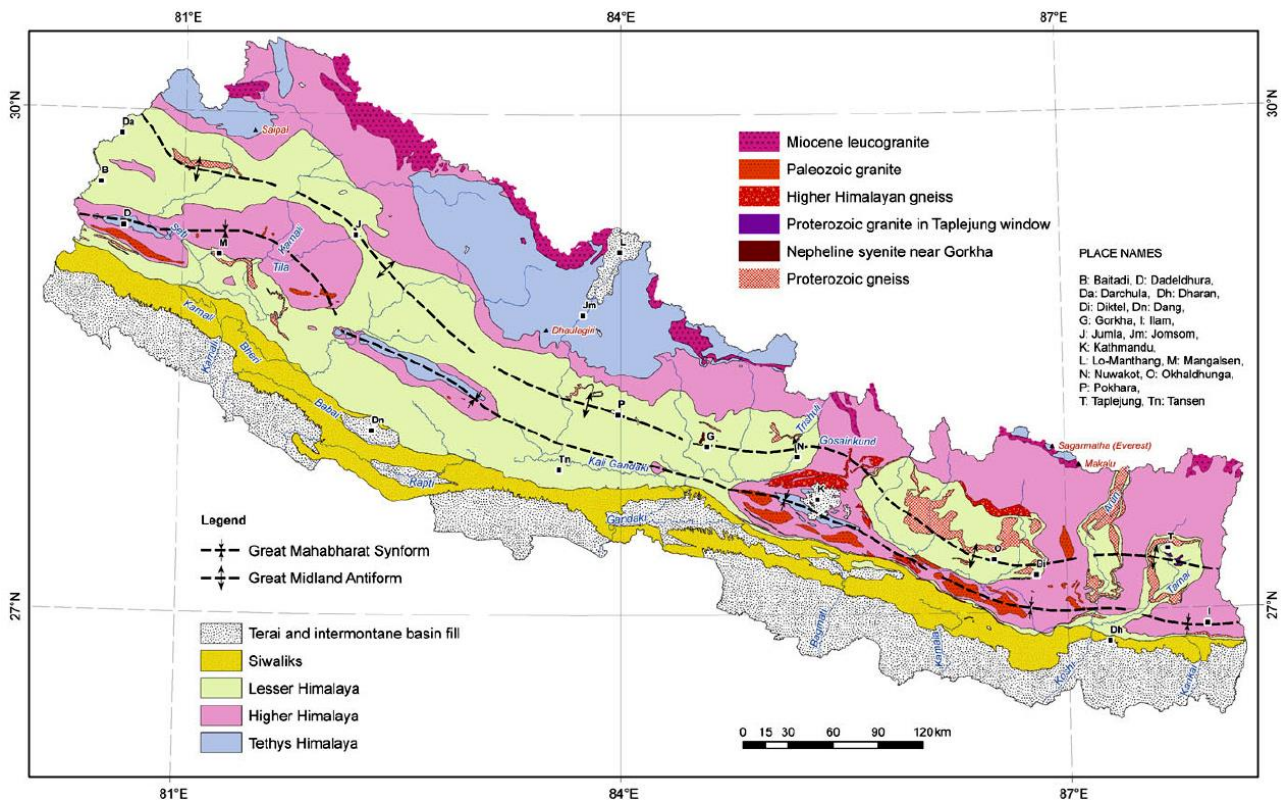


Figure 2: Simplified geological map of Nepal. Source Compiled from Tater et al. (1983), Shrestha and Shrestha (1984), ESCAP (1993), Amatya and Jnawali (1994)

These zones are separated by three major thrusts: the Main Central Thrust (MCT), the Main Boundary Thrusts (MBT), and the Main Frontal Thrusts (MFT). The Tibetan Tethys zone consists of Paleozoic to mesozoic aged sedimentary rocks in the northernmost part of the country which are heavily folded and faulted. It consists of the inner Himalayan valleys of Thakkhola and Langu. The rocks of this zone are horizontally bedded and are soft to medium. As this zone lies north of the Higher Himalayan range, there is low monsoon rainfall. But due to its high altitude, regular snowfalls take place, resulting in the freezing and thawing of rocks. The main Himalayan range, known as the higher Himalaya, includes Mount Everest, which has an altitude range of 3000m to 8848m and is composed of metamorphic rocks such as gneiss, schist, and phyllite. The rocks of this zone are hard and steep and lie between the South Tibetan Detachment System (STDS) in the north and the Main Central Thrust (MCT) in the south. The freezing and thawing action is prevalent in this zone and major eroding glaciers form u-shaped valleys. The lesser Himalayas zone consists of paleozoic and Mesozoic rocks that are exposed between the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT). This zone is highly disturbed

and overturned folds, faults, and thrust sheets are common in this zone. The most common rock types in the lesser Himalaya are slate, phyllite, sandstones, limestones, dolomites, are common. In addition to that, in some places, lesser himilayan gneiss can also be seen. The Sub Himalayan rock consists of Tertiary (Middle Miocene to early Pleistocene) sedimentary rocks with fining up sequence. Mostly, the Lesser Himalayan rock consists of mudstone, sandstone, and conglomerate beds extending between the Himalayan Frontal Thrust (HFT) and the Main Boundary Thrust (MBT). The terai (indo-gangatic plain) consists of a quaternary deposit of sand, gravel, and pebbles. It ends up to the Main Frontal Thrust (MFT) giving rise to the sub-Himalayan rocks.

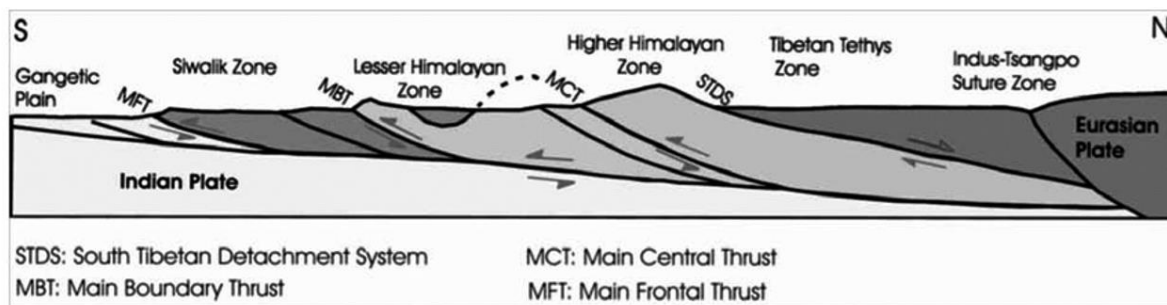


Figure 3: Generalised geological section of Himalaya (after Harris & Whalley, 2001)

Geological issues

Nepal is rich in surface water resources, and for the augmentation of these resources, water diversion is to be done in the Himalayas. The diversion of huge volumes of water to the desired location to meet the aims and objectives is impossible without the construction of mega structures like dams, tunnels, and underground caverns. Geology plays a dominant role in the construction of water diversion projects. Since the geology of the Nepal Himalaya is variable and unstable due to folded, faulted, and thrust rock sequences, construction of such projects without considering such challenges results in not only a loss of investment but also a toll on life and property. The young and mobile Himalayan zones thus have different geological challenges such as: a) poor rock mass quality, b) highly weathered, fractured, faulted and folded rocks, c) stress overloading in rock mass, d) influence of groundwater, e) seismic influence, and f) geological hazards, which are discussed below.

The rock mass quality in the Himalayan region varies greatly from completely weathered to completely fresh depending on the influence of faults, thrusts, and shear band influence. Himalayan rocks vary greatly in strength due to different factors. Mineral grain orientation, bedding, and foliation plane of the Himalayas have made them highly directional concerning strength and deformability, resulting in the incompetency of the rocks (Panthi, 2006). As already mentioned, the Himalayan rockmass consists of an interbanding of weak and strong rock beds. As a result, the weaker parts do not have self-supporting capacity, resulting in the squeezing of the tunnels. Such incompetencies of the rock may result in problems while damming water and constructing water conveying tunnels.

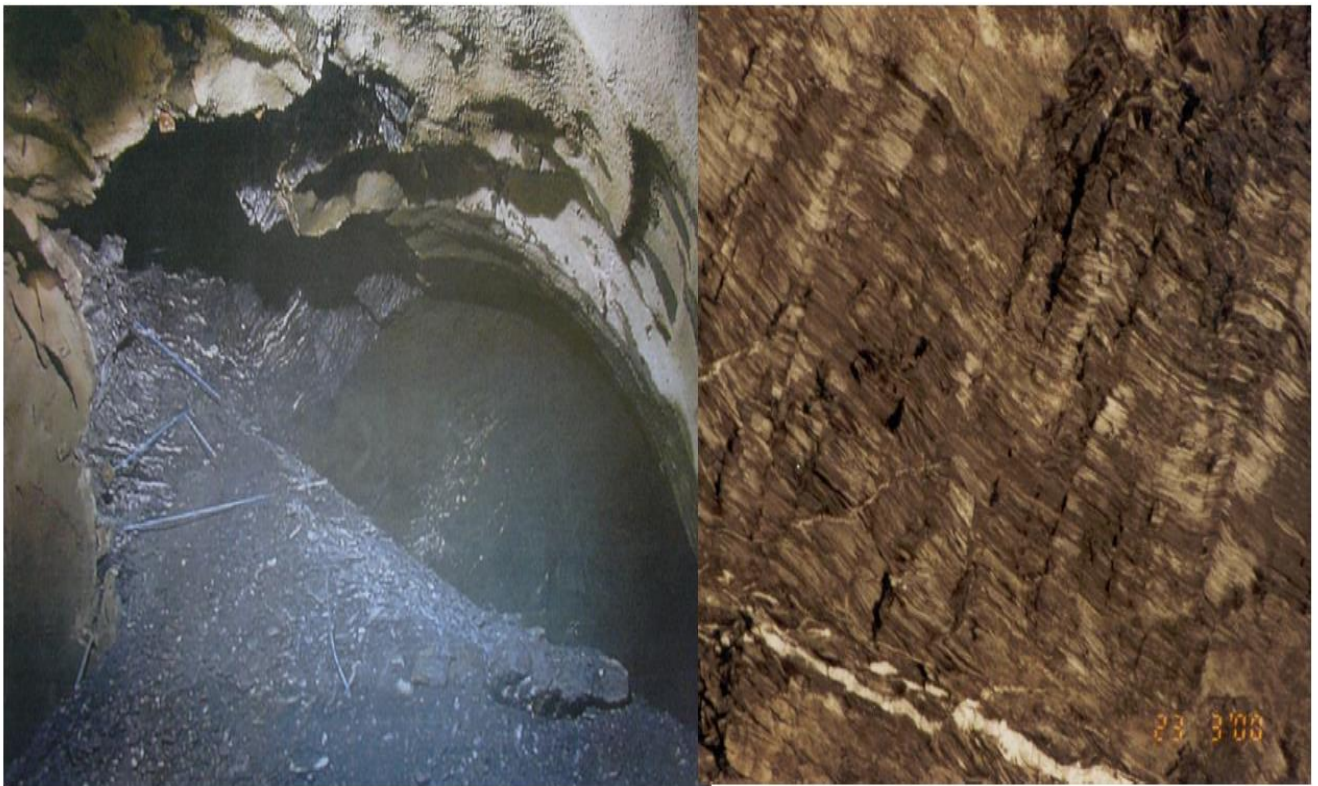


Figure 4: Headrace tunnel collapse at kaligandaki A hydroelectric project and rock mass at tunnel face (Photo: Impregilo SpA, 2000)



Figure 5: Weathered exposed rock mass at higher Himalaya section.

The Himalayan rocks are weathered by physical, mechanical, and biological processes. Since the young Himalayan block is under continuous pressure, causing the rockmass to fold and fracture. This fractured under the action of flowing water, and the freezing and thawing of ice causes the rockmass to weather. Initially fractured rock with weakness zones intensifies further mechanical and biological processes of weathering. The degree of weathering, in some cases, is so intense that it can reach more than 100m below the surface, resulting in the immediate tunnel collapse during excavation and water inflow and leakage into the tunnels, as in the Khimti Hydropower Project (Panthi, 2006).

Faults and thrust zones are the weak zones that create further challenges in the construction of water diverting structures. Water-diversion tunnels and dams are typically built in the higher Himalayan, lesser Himalayan, and subhimalayan rocks, all of which are highly sheared and deformed. These structures should either pass through them or be constructed near them. Such fault and thrust zones may result in a tunnel squeezing problem, subsidence of the reservoir, and cracking and subsidence of the dam. The perfect example of tunnelling squeezing is in Kaligandakai Haderace tunnel and Chameliya head race tunnel. In the case of the Kali Gandaki headrace tunnel, more than 50 centimeters of horizontal convergence occurred at the overburden of approximately 450 meters of Himalayan phyllite (Panthi 2006). The Chameliya Hydroelectric Project (CHEP) lies in the lesser Himalayan zone of Nepal in which dark grey slates, grey calcareous slates, sandstones, and dolomitic limestone are found. The HRT alignment has two faults, one at about 900m and the other at about 2750m from the desanding basin. In the tunnel section from 3100m to 3900m in the

CHEP project, squeezing and collapse problems were recorded.



Figure 6: Tunnel squeezing a Modi pressure tunnel and kaligandaki headrace tunnel (Photo: Impregilo SpA, 1989)



Figure 7: Severe squeezing and collapse of Chameliya Hydroelectric Project (CHEP)

Leaks are common in water-diverting structures such as dams and tunnels. Since the Himalayan rock masses are highly weathered, faulted, and fractured, they show high permeability, resulting in the loss or addition of groundwater. Damming and tunnelling for water diversion in such a rock mass is always challenging. The high risk of losing valuable water due to leakage is not acceptable, so identification of the groundwater table and appropriate treatment is necessary to avoid the loss. On the other hand, heavy ingress of water hampers the tunnel's excavation speed and induces excavation face stability.

Conclusion

Himalayan country like Nepal has both challenges and opportunities in the water resource sector. Since a large volume of current-bearing river water that can be used for drinking, irrigation, and hydropower generation is being lost each day. Balancing the water-scarce area with the water available basin via diversion structures is more challenging from various aspects. The geological challenges create great uncertainties in project execution that can lengthen the cost and time. So prior to that, a proper

geological investigation is to be conducted so that the proper design of structures can be made without any loss. The Himalayan geology is fragile and young; therefore such a project is to be constructed with care and caution.

References

- Amatya KM, Jnawali BM (1994) Geological map of Nepal, Scale: 1:1,000,000. Department of Mines and Geology, International Centre for Integrated Mountain Development, Carl Duisberg Gesellschaft e. V., and United Nations Environment Programme
- Gansser A (1964) Geology of the Himalayas. Interscience, New York, 289 pp
- Harris, N., & Whalley, J. (2001). Mountain Building, Block 4, The Open University, U.K., PP. 165
- Holland TH (1908) On the occurrence of striated boulders in the Blaini Formation of Simla, with a discussion of the geological age of the beds. Rec Geol Surv India XXXVII(part 1):129–135 (with one plate)
- Himal Hydro (HH). 2001. Construction report. *Modi Khola hydroelectric project*. Nepal.
- Himal Power Limited. 1995. Project definition report. *Khimti I hydropower project*: Nepal
- Panthi, K.K. (2006) Analysis of engineering geological uncertainties related to tunneling in Himalayan rock mass conditions, Doctoral Thesis, Norwegian University of Science and Technology
- Parrish RR, Hodges KV (1996) Isotopic constraints on the age and provenance of the Lesser and Greater Himalayan sequences, Nepalese Himalaya. Geol Soc Am Bull 108:904–911 Parrish RR, Gough SJ, Searle MP, Waters DJ (2006) Plate velocity exhumation of ultrahigh-pressure eclogites in the Pakistan Himalaya. Geology 34:989–992
- Sharma CK. (1977) River Systems of Nepal. S. Sharma, Kathmandu, Nepal
- Tater JM, Shrestha SB, Shrestha JN (1983) Geological map of Western Central Nepal. Scale: 1:250,000. Department of Mines and Geology, Kathmandu
- WECS (2019) Assessment of Hydropower Potential of Nepal