INTERACTION BETWEEN RIVER ECOLOGY AND LOCAL COMMUNITIES IN THE TAMAKOSHI RIVER BASIN, NEPAL

By Uttam Sagar Shrestha

INTERACTION BETWEEN RIVER ECOLOGY AND LOCAL COMMUNITIES IN THE TAMAKOSHI RIVER BASIN, NEPAL

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LETTER OF RECOMMENDATION

We certify that this dissertation entitled **"Interaction between River Ecology and Local Communities in the Tama Koshi River Basin, Nepal"** was prepared by Uttam Sagar Shrestha under our guidance. We, hereby, recommend this dissertation for final examinations by the Research Committee of the Faculty of Humanities and Social Sciences, Tribhuvan University, in fulfillment of the requirements for the Degree of DOCTOR OF PHILOSOPHY in GEOGRAPHY.

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DECLARATION

I, hereby, declare that this dissertation is my own work and that it contains no materials previously published. I have not used its materials for the award of any kind and any other degree. Where other author's sources of information have been used, they have been acknowledged.

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Uttam Sagar Shrestha

Date:___________

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ABSTRACT

The study of interactions between communities and river ecology is important in Nepal where government policies are proactive towards the flow diversion from the river to produce energy without taking into account the long term consequences of its people along the local communities in Tamakoshi River, Bagmati province, Nepal

Objectives set in this study are to examine the basin hydrological characteristics; to identify the linkages between basin hydrology in overall river ecology river resources and aquatic ecology; to assess spatial and temporal variations of flow regime and their relation with aquatic ecology; to analyse relationship between flow regime and livelihood of the people living in riparian settlements; and to appraise the perception of the stakeholders regarding flow diversion environmental flow, cumulative impacts and its interaction with local communities. The study area lies between lesser Himalaya and Higher Himalaya zone from the south to the north. Administrtively, it lies in the central mountain region comprising two districts; namely Dolakha and Ramechhap.

The study methodology was based on quantitative and qualitative data collected both from primary and secondary sources. The physical data of river water flow and geo-chemical features were collected from 15 spatial locations with three seasonal variations; pre-monsoon, monsoon and post-monsoon. The socio-economic data were collected from 412 households, which are situated along the 1000 meter buffer zone of the flow regime of the Tamakoshi River. Key informants interviews/Focus group discussions along with major stakeholders were held in 8 different locations.

The relationship between the settlement and distance from the Tamakoshi was found to be positive (r=0.90) with least correlation in the Ist (0.59) and highest in the IIIrd and IVth sectors (0.88). The average distance to water source for the household is 461.30 meter.

The average household size ranges from 4.1 persons per household to 5.1 persons per household. The average income of the people of the study area is equivalent to NRs. 273,722.24 (US $2285.57), the contribution from river resources accounts 27 per cent. Overwhelmingly people are dependent on business (43.42%) followed by service (9.92%) and agriculture (3.89%). The people of different ethnic groups like Tamang, Thokar, Newar and Majhis are dependent more in the Tamakoshi River than other

ethnic groups like Brahman and Chhetri. Among ethnic groups, Majhis are economically, socially, religiously and culturally dependent on the flow regime of the Tamakoshi River. The basin is food deficit area as only 10 per cent of the households have enough cereals for the year.

There is a high correlation (+0.92) between temperature and river flow in the TRB. Spatially, the flow starts from 19.88m^3/s in Lapche to 258.76 m^3/s in Tribeni during 2015. During the monsoon, it is increased by 123 per cent and the index value of pre-monsoon is less than post monsoon. The total availability of the water in the basin is equivalent to 7. 47134x$10^{10}m^2$/s. The power of the river is highest in the first sector which ranges from 26.8 to 333.73 nTu and lowest in the fourth sector which ranges from 64.33 nTu to -3.33nTu.

The relationship between annual precipitation and runoff data of the last 30 years showed a low correlation (r=0.21). Results of depth and sinuosity played a significant role in the river flow and resource materials than other variables like, slope, distance and width of the river. The size of the boulders during the monsoon turns out to be double than the size in the pre-monsoon and post monsoon. The relationship between the current river power and its cumulative distance is negatively correlated (-0.22).

The river has deposited river materials like sand and boulders in different places. The minimum deposit of 39,850 m^3 is found in Lamabagar and maximum of 133, 153m^3/s is found in Masantaari. The lowest percentage of sand is found in the first sector which amounts to 20 percent and the highest percentage is found in the fourth sector which amounts to be 90 percent.

The water flow of the Tamakoshi River follows more angles in the Ist sector and IVth sectors than in the remaining sectors. The water quality is drinkable and suitable for aquatic habitat with alkaline in nature almost all sectors except some portion in the IIIrd sector.

In the cold and warm water local, short and long distance migratory fishes are available. The number of species increases as one move from the Ist sector to the IVth sector. Majority of fishes are found in the pre- and post-monsoon than the monsoon season.

More than 50 per cent of the people are in favor of diversion of flow from sector Ist to IIIrd and 23.73 per cent are against it and 26.27% are unaware about it. They have expected more energy, development activities and getting financial share of the hydropower projects. However, there are significant barriers on long-term ecological disruption.

The diversion portion from the Upper Tamakoshi to Tamakoshi IVth represents 40 per cent of the total stretch of the Tamakosh River. It will create a dry zone near to the 60 settlements along the Tamakoshi River. The value of interaction (ecological products and values - religious/spiritual values, water supply, sand gravel extraction, fishing, etc.) matrix between settlement and flow is highest in the third section (66; 6540) and the lowest in the Ist sector (49; 2870).

The study supports the conclusion that this situation could lead to the fragmentation of river. As a result the river gradient, sinuosity fish abode and size of boulders will be affected.

The ultimate effect will be on livelihood and ecological system of the riparian communities. A basin strategy with clear policy, plan, and program should be formulated to address need of riparian communities and for ecological conservation. Thus, this study recommends to undertake the further study of river flow which affects the life of people of different ethnic groups like Majhi, Thokar, Newar, Surel, Sunuwar, etc. The existing framework law and modality of the flow diversion needs to be revisited. Along with this policy framework of e-flow in HPP 1992, EPA 2019 and EPR 2020 needs to be revisited.

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ACRONYMS AND ABBREVIATIONS

ANN	Artificial Natural Network
BM	Bhimeshwor Municipality
CBO	Community Based Organization
CBS	Central Bureau of Statistics
CDG	Central Department of Geography
CIA	Cumulative Impact Assessent
CIs	Cumulative Impacts
CPUE	Catch Fish Per-unit Effort
DADO	District Agriculture Development Office
DCC	District Coordination Committee
DDC	District Development Committee
DFO	District Forest Office
DHM	Department of Hydrology and Meteorology
DN	Digital Number
Do	Dissolve Oxygen
DS	Descriptive Statistics
DSCO	District Soil Conservation Office
DSCWM	Department of Soio Conservation and Watershed Management
EA	Environmental Assessment
e-flow	Ecological Flow/Environmental Flow
EIA	Environmental Impact Assessment
EMP	Environment Management Plan
EPA	Environmental Protection Act
EPR	Environmental Protection Regulations
ERDAS	Earth Resources Data Analysis System
ESRI	Environmental Systems Research Institute
FDI	Foreign Direct Investment
FGD	Focus Group Discussion
FYP	Five-Year Plan
GBK	Gandaki River Basin
GCAP	Gaurishankar Conservation Area Project
GDP	Gross Domestic Product

GIS	Geographical Information System
GoN	Government of Nepal
GPS	Global Positioning System
HH	Horizontal Height/ Household
HEC-RAS	Hydrologic Engineering Centre River Analysis System
HMG	His Majesty's Government of Nepal
ICIMOD	International Centre for Integrated Mountain Research and Development
IEE	Initial Environmental Examinations
IM	Interaction Matrix
IWMI	International Water Management Institute
JKC	Jhiku Khola Catchment
JVS/GWP	Jal Viduyat Sanstha/ Global Water Partnership
KII	Key Informant Interview
KHEP	Khimti Hydro Electric Project
LRMP	Land Resource Mapping Project
masl	Mean Average Sea Level
MBT	Main Boundary Thrust
MCDA	Multi-criteria Decsion Analysis
MCT	Main Central Thrust
MDG	Millenium Development Goals
MEA	Millennium Ecosystem Assessment
MM	Manthali Municipality
MoFALD	Ministry of Federal Affairs and Local Development
MWSP	Melamchi Water Supply Project
NGO	Non-Governmental Organization
NPC	National Planning Commission
NWQI	National Water Quality Index (Nepal)
RCC	River Continnium Concept
RM	Rural Municipality
RS	Remote Sensing
SDG	Sustainable Development Goals
SEA	Strategic Environmental Assessment

SES	Socio-economic Study
SLA	Sustainable Livelihood Approach
SPSS	Statistical Package for the Social Science
T.U.	Tribhuvan University
TDS	Total Dissolve Solids
TRB	Tamakoshi River Basin
UTHP	Upper Tamakoshi Hydropower Project
VDC	Village Development Committee
VH	Vertical Height
WWF	World Wildlife Fund
YKC	Yarsha Khola Catchment

CHAPTER I
INTRODUCTION

1.1 Background

Rivers have long been used by human settlements for different purposes, which range from drinking water, irrigation to industrial uses. "Most of civilizations have grown from pre-historic to historic periods; the interaction between the natural environment and human activities has led to changes of distribution and geographical spatial distance between human settlements and rivers, resulting is regional heterogeneity based on the influence of climate, water resources and urbanization (Fang and Jawitz, 2019). Therefore, the most of world's civilizations have been originated along river basins (Menarguez and Holgado, 2014), allowing human settlements to interact and thereby developing co-evolutionary processes and it has created an internal dynamics which involves in the form of historical relationship with flow regime of river (Yu, 2010).

Seeing the importance of flow of river, the settlements from historical time to present time are located along the river basins. The flow regime of the river is the major attraction directly or indirectly and maintains different river ecological systems (geomorphic system, aquatic system, riparian and terrestrial system) along with it. The system also produces different types of products such as air, water, fish, boulders, and sand aggregates. It has maintained the food chain system through vertical, horizontal and lateral connections. The relationship between major basin and minor watershed systems is also based on it.

The settlement along the river flow regime receives different types of ecological system free of cost which assists them to maintain their livelihood. But now governments and other organization have shown in the use of the river flow regime to produce hydropower for energy production. Later on, people started to use river for transportation purposes or water highway. The most of the settlements even early up to 19th century tend to be located nearby river sides. But the intervention of hydropower production through dam construction in 1882 in Fox River (USA) added the mile stone of using water sources from river. The trend which started from Europe soon spread in other parts of the world. At a present 17 percent of the energy of the world is produced from the river. Similarly, there are 60,000 dam in the world and it obstructed 100 billion m^3/tons of sediment in the world to flow from river to sea (Lovegren, 2019).

In Nepal there are 124 hydroelectric dams in operation, 310 projects have licenced and 244 HPP are in construction stage (Rauniar, 2022). The undergoing activities have increased the supply of electricity in one hand and obstructed the free flow of river on the other hand. The policy of the government like Fifteen five year Plan (2019/020 to 2023/024) of Nepal and Hydroelectricity Act and Policy (2001) is to increase the energy production to raise the Gross Domestic Product (GDP) and poverty reduction. These activities have over looked the characteristics of basin hydrology, its linkages with river ecology, e.g. hydrological condition, river resources, aquatic conditions, interactions between the bio-physical phenomena with riparian settlements, perceptions of local people to the whole basin ecosystem. They are unaware about geographical consequences of flow in general and ecological flow regime particularly. The problem of dewatering zone in spatial and temporal context has been increasing each year and settlements along the river have been facing different types of problems.

As a remedial measure, the concept of Environmental flow (e-flow) was introduced which is relatively a new practice, especially in developing countries such as Nepal. The most common practice for setting e-flows consists of allocation a specific percentage annual of mean flow or proportion of flow derived from specific percentiles of the flow duration curve. However, e- flows should mimic the river's intra-annual variability to meet the specific ecological function at different river trophic levels and in different periods in a year, which cover the biota's life stages. The suitability of method was analyzed using the indictors of Hydrological Alterations and e-flows components. It also maintains that the riparian ecosystem's annual dynamic demand is sufficient for the health of river which has been taken as a guideline to allocate e-flows in the Kaligandaki River particularly for small hydropower plants (Suwal, Kuriqi, Huang, Delgado and Mlynski, 2020).

Similarly, Environmental Protection Act (2019) and implementation of Environmental Protection Regulations (2020) and further amendments of these acts and environmental protection guidelines also approved that the release of flow regime

10% enough to maintain river ecology, hydrological system & its interaction with local communities along the river.

The river ecology is a natural system comprising of three systems: terrestrial system (flow, temperature of water, slope, depth width, etc.), biological system (chemical factors, DO, pH, EC, TDS, alkalinity, algae, aquatic moss, Zooplankton, fishes, tortoise, etc.) and socio-ecologic system (people, settlements, livelihoods etc.). Biotic factors of the river are regulated by physical factors. The terrestrial animals from human beings to the wild animal depend on it. The river hydrology has operated and maintained these systems within which different food chain and food web are existed in river basin.

The flow dimension involves both technology and policy at the point of entry into the outlet. This is an issue of an ongoing scientific discussion. The challenges of how to improve river ecology and protection of the river health is a major concern of policy and its implementation which has been somehow addressed in the European countries including USA, India and China (Kar Mishra, 2014). These issues were raised in the Mahakali River for the first time and now spread in other river basins of Nepal.

In Nepal, information about the flow regime, its ecological importance and interactive relationships between river ecological services and people is scanty (Bishop, 1990; Bista, 1972). This study thus intends to explore and analyze the interactive relationships between river ecology and local communities in the Tamakoshi River Basin of Nepal. In addition, the study also focuses on the discussion of its use for livelihod, basic hydrological chracteristics, linkage between river resoruces and local communities. The impact of e-flow remains on over all river ecology and perception towards the whole system. The study also focuses on the analysis of livelihood activities of the riparian people, geochemical characteristics of the aquatic river ecology, and threats to the water flow of the river.

1.2 Statements of the Problem

Interaction between physical process within a river and human activities in a riparian area are closely related. The river civilization of the history shows the importance of it.

The flow regime plays an important role in the conservation of biodiversity, producing resources like stone, aggregates, and aesthetic value. It is the basis of the river water. Flow of water is livelihood of people of riparian communities, revenue generation to local/provincial government conducting geometric process, operation of aquatic ecosystem and exercising river bio-geochemical cycle. Similarly, it also increases moisture or wetness along the river course. Due to this many first ecology along the river course provides different types of aesthetic phenomena in the river basin than other parts. In addition to forest-based products, the people also make use of the river-based products and services such as fish, edible plants, sand, pebbles, water energy (water mills) and water transportation activities.

Even at present, the local people within a limited access other activities to conditions could be seen in the river ecology. Although hydrologic, geomorphic, and biological processes in headwaters systems have been studied for the last 50 years and much knowledge related to these systems is available (Hack and Goodlett, 1960; Hewlett and Hibbert, 1967). The role of headwater streams within the watershed and the linkages from headwater to downstream systems and literal interactions with settlement are poorly understood (Takashi, Sidle and Richardson, 2002).

In these contexts, the relationship between human beings and environment in the river basin has been studied with a spatial as well as temporal change (Saxena, 1999). Recently, a study on environmental issues in the ecologically fragile regions like the Himalayan Mountain is becoming the central theme for geographic research and environmental inquiry. It has been seriously threatened by anthropogenic activities like development of infrastructure especially construction of hydropower projects, roads and urban development.

A number of studies have been undertaken in Nepal, which focused on development and management of environmental resources and ecology. Eckholm (1976), Sharma (1977), (Keller, 1988) briefed on the hydro ecological aspect of river basis and its changing aspect due to human activities. Similarly, Mahandhar (1989) talks about indigenous human endeavors to preserve existing ecological crisis and Thapa and Weber (1990) highlight on eco management of resource – forest water in the mountain water sheds. Shrestha (1990), Shrestha (2002), Poudel (2001), Koirala (2002) studies on geomorphic process, forest ecology, dynamics of land use and land cover. Likewise Rijal (2007), CDG (2015), Aryal, (2015) briefed on livelihood based on water resources, diversion water flow and existing rules and regulations of river flow. Balasubramanin (2019), Sada, (2017) Shah, Tachamo, Nesmann and Sharma (2008) have conducted pioneering research works on river basins, it's resource use, its impact on human beings and natural resources with focus on land, forest resources, watershed condition, river flow and national acts and rules on environment flows and resources.

The findings of these studies can be divided into four parts; i) resource use, ii) ecological aspects of resource management (land and forest) in mountain regions, iii) policy level problem, and iv) availability of compound methodology(technical and social) to investigate flow regime and its effect. The study of environmental resources at macrolevel dates back to the decades of 1970s and 1980s (Shrestha and Malla, 1981) K.C, (1992), Basnet (1992), Poudel, (2001). Secondly, the ecological aspects of resource use and carrying capacity of the history of the Pokhara and the Mountain Everest region were studied, The third one has contributed to the existing government policies of water resource management and its lacuna (Shrestha, 2017); Sada 2017.

Based on those studies, most of the earlier knowledge was focused on human activities within the watershed, policy intervention on use of fixed resources of the basin like land use, its productivity, forest resource, changes, human intervention in the watersheds etc. Knowledge on the hydrology of the river basin, resource dynamics aquatic ecology, perception on local people on the changing scenario with respect to ecological flow and its interaction with riparian settlements needs to be understood.

Nepal which has long history of using flow water for different purposes and centenary history of using water for power production need to explore such knowledge differently. The country has formulated and implemented different policies and strategies to support resource production and utilization and its support to riparian communities and the knowledge of spatial and temporal aspect of flow regime is lacking.

The provision set by EPA (1919) and EPR (2020) with respect of flow regime and its effect on bio-physical environment, communities has been raised by many scholars (Aryal, 2014; Subrannnmum, 2014). Many issues are being cropped up spatially and temporarily in such issues. The policy document does not include those aspects which led to ecological misbalance between upstream, mid stream and downstream.

In this context, the study aims to identity hydrological condition, resource generation, aquatic ecosystems, values and its interaction with riparian settlements of four sectors selecting Tamakoshi River Basin as a study area.

1.3 Research Questions

The present study will attempt to answer the following research questions:

1. What is the chracteristics of hydrology of the Tamakoshi river?
2. How spatial and temporal flow pattern are related with each other and its overall impact of river basin hydrology?
3. What is the role of basin hydrology in characterizing its overall river ecology in general and its effect on river flow in general and resources and aquatic ecology in particular?
4. How is the relationship between the river ecology and livelihood mechanism of local communities' living within the riparian zone of the river?
5. What are the perceptions of the local people on the status of river hydrology, e-flow, river base resources and overall river ecology of the area?

1.4 Objectives of the Study

The general objective of the study is to examine the interaction between river ecology and local communities in the Tamakoshi river basin of Nepal. The specific objectives are:

1. to examine characteristics of the basin hydrology in the Tamakoshi river basin,
2. to identify the linkages between basin hydrology and river resources,
3. to analyze the interaction between river ecology and local communities who live within the riparian zone of the river basin whose livelihood is based on aquatic ecology, and

4. to explore the perception of local people towards the basin hydrology, river based resources, e-flow, and overall river ecology in the Tamakoshi river basin.

1.5 Significance of the Study

Nepalese rivers originating from the Himalaya, work as a lifeline of the people residing in the riparian zone. "The Himalayan Rivers originating at the Tibetan plateau in China and flowing across the downstream countries including Nepal, India, Pakistan and Bangladesh are the essential water resources supporting the livelihood of 1.3 billion people living in the region "(Yao et al., 2012; Zhang et al., 2015).

These rivers contribute to the major portion of runoff. These are important sources of water for irrigation, river resource deposit materials and livelihood of the downstream zones. One of the focus areas of SDG is to achieve economic growth with ecological sustainability (UNDP, 2030). This study also helps in fulfilling the main objectives of SDG and overall environmental objectives of the fifteenth five years periodic plan (2019/020 – 2023/024) of Nepal. The present study is significant from the viewpoint of poverty alleviation which is one of the main hindrances to achieve the targets of sustainable development goals (UNDP, 2030).

The present study is expected to be beneficial for governments of other developing nations, private sector and development partners who are involved in the process of exploitation water resources. Moreover, it will provide an important feedback to the efforts of river basin ecological conservation and improvement in the livelihood of the local people through ecological services of the river flow.

Many studies in river basins have been carried out in Nepal. However, studies with reference to hydrological characteristics, e-flow and its long term implications in riparian communities and its implications are very limited. So, the study carried out with a holistic model of both bio-physical and socio-economic aspect which can also be applied in other river basins of Nepal.

Recommendations made in this study will be helpful to the local people for protecting their ecological benefit from the negative impact of flow regime and cascading development of hydropower resources in major river basin.

However, the need for water resource development is increasing day by day and the poor understanding of the importance of river ecology and its flow regime have face the people and government to exploit major rivers and its tributaries for power generation and other activities.

1.6 Limitations of the Study

The study has following limitations.

- The river basin starts from inside Chinese and crosses Nepal-China boarder in the north and it ends in the south as the confluence between Tamakoshi and Sunkoshi, and Tibetan boarder to Tribeni is considered for the study. Only the area within 1000 meter from the river course is included for the household survey.
- There are various number of parameters in river hydrology. Among them selected parameters are considered in the present study due to resource constraints.
- Hydrological parameters are estimated from Busti hydrological stations (No 645) established and monitored by department of hydrology and metrology, government of Nepal.
- It has not covered flood hazard, vulnerability and risk assessment.

1.7 Organization of the Study

This dissertation has been organized into nine chapters. The first chapter deals with the general background of the research and research problems, objectives, significance and limitations of the research. The second chapter discusses the literature review.

The third chapter deals with the research methodology and methods including the rationality for the selection of the study area, research design and source of data collection. It also deals with sampling procedures, data collection tools and techniques, data analysis and interpretations.

The fourth chapter provides characteristics of the study area which includes bio-physical characteristics, socio-economic characteristics and infrastructure developments in the TRB.

The fifth chapter explains about river basin hydrology in the TRB, (Spatial and Temporal), and discharges of the tributaries, water flow indexes, water availability, river power, deposits and the drainage pattern are also discussed.

The sixth chapter deals with the river, river resources and its linkages with basin hydrology in TRB. It also deals with the river sub-stratum and fish species and movement of fishes.

The seventh chapter explains interaction between river ecology and community and eight chapter discusses on the perception on flow regime, and its diversion, e-flow, and cumulative impacts.

Finally, the ninth chapter includes summary, conclusions and recommendations.

1.8 Operational Definitions

Aquatic ecology (AE): The system product, which gives the result between biotic and abiotic component within the water. The river, stream and pond are the system of aquatic ecology. Fish is indicator species of the aquatic ecological system.

Base flow: The infiltrated water may percolate deep and become ground water supply to surface streams known as ground water runoff, or it may become ground water supply to ocean which sometimes referred as the base flow or the interflow.

Dissolved Oxygen (DO): The oxygen dissolved in water (DO), which is highly transient property that fluctuates in time and space, expressed in parts per million (PPm).

Ecological Flow: Ecological flow (also referred as environmental flow) is the amount of water needed in a watercourse to maintain healthy natural ecosystems. The term is used in the context of rivers, which have been mostly dammed, or some part of the flow trapped by the dam.

Electrical Conductivity (EC): Electrical conductivity is the measurement of capacity of substance or solution to conduct electric currents.

Livelihoods: Livelihood is a means of subsistence, comprising a complex and diverse set of economic, social and physical strategies. These strategies are realized through the activities, assets and entitlements by which individuals make a living (UNDP, 1999). A rural livelihood comprises several activities, which provide food, cash and other goods to satisfy a wide variety of human needs (Chambers and Conway, 1991).

pH: pH denotes hydrogen concentration (H+) in water. It is a system to specify the degree of acidity and alkalinity of substance based on number of hydrogen ions in one liter of the solution and expressed in terms of pH $-\log_{10}$ (1/H); a pH of 7 is neutral. Below 7 is alkaline and above 7 is acidic.

Rapids and pools: Rapids are those areas which iare greatly disturbed by water across the river. Unlike waterfalls, rapids are the result of a continuous and relatively gentle slope, rather than a sudden vertical drop. The pool is a body of impounded water artificially or naturally confined above the river or natural dam.

River based resources (RBR): The resources generated from the river ecosystems like water for agriculture (irrigation, animal husbandry, industry (water mills) ecosystem services like (tourism, religious values), sand, silt, fish, and fuel woods.

River Direction: The individual line or path is basic-building block of any line pattern, and the most important measurement that we can measure is its path length (l). The length of straight- line path from an origin at (x_1, y_1) to an end –point (x_2, y_2) is given by Pythagoras theorem (Unwin 1981)as : $I_{1,2} = [(x_2-x_1)^2+(y_2-y_1)^2]^{0.5}$

River ecology (RE): River ecology is a living ecosystem of flowing water which is essential for connecting vital ecosystems with life and includes supporting elements, velocities flow for different functions of aquatic and non-aquatic life and it also provides services to human settlements.

River fragmentation: River fragmentation is defined as the interruption of a river's natural flow by dams, inter-basin transfer or water withdrawal, and is an indicator of the degree to which river have modified by human activity.

River sub-stratum: Substrate is the surface on which the river organism live. It may be inorganic, consisting of geological, materials from the catchment area such as boulders, pebbles, gravel, sand or silt, or it may be organic including fine particles, leaves, woods, moss and plants (Science Learning hub, 2022).

Seasons of the Year: The year has been divided into three hydrological seasons; monsoon (Jun.- Sept.), post-monsoon (Oct.- Jan.) and pre-monsoon (Feb.- May.)

Slope Estimation:. Slope is a variant of the ratio of vertical height (V.I) and horizontal distance (H.D.) obtained from a right angled triangle in a vertical plane (Singh, and Singh, 1993).

Stream Power (SP): Stream power is the rate of energy dissipation against the bed and banks of a river or stream per unit downstream length.

Total Dissolved Solids (TDS): It indicates mainly the various kinds of minerals present in the water.

Vector: It is a force having both magnitude and direction or a quantity having direction as well as magnitude especially as determining the position of one point in space relative to another.

CHAPTER II
REVIEW OF THE LITERATURE

The present chapter covers the review of literatures related to research issues. The first section covers the review of concepts and theories on research issues. Similarly, the second part discusses the review of empirical research related to the issues. Attempt has been made to review the government policies on basin hydrology, river ecology and livelihoods in the third section. Likewise, the fourth section identifies the research gaps for the present research. Finally, the last portion presents the conceptual framework of the study.

2.1 Concepts and Theories on the Research Issues

2.1.1 Concepts and Models

River Continuum Concept (RCC): River Continuum concept is a holsitic view of rivers, first proposed by Robin L. Vannote and others in 1980, which permits a broad zonation of river systems based on the utilization of energy through the ordely processing of organic matter by the resident biota (Preston, Durkeen, Yamahara, 2019). Upstream, the rivers receive allochthonous materials from adjacent and overhanging vegetation, supplying course particulate matters (Allaby, 1998). It is the proportions of shredders, collectors and grazers without a stream community will alter the depending on the size of river channel and relatively availability of primary production (POM and FPOM). CPOM is the sequestration of carbon in the deep ocean relies on the export of sinking particulate organic matter (POM) originating in the surface waters and its attenuation by organism that reprocess and repackage it. The FPOM concentration typically increases along with headwater channel because of biological and physical processing: CPOM/ FPOM may decrees rapidly with an increasing drainage area (Cummings & Klung, 1979). Biologically connectivity is important for species migration, habitat and refugees (Saura et al., 2019) and the flux of organic matter and nutrient. It also interacts with settlement. A river is an ecosystem itself and it starts from points where it originates and ends in the last point. River ecosystem can be conceptualized in four dimensions. Those four dimensions are illustrated in figure 2.1 showing human context and its relation with spatial and temporal dimension.

a. Longitudinal connections

Longitudinal connections occur as water, sediment, contamination, nutrients and organisms move upstream and downstream.

b. Lateral connections

Lateral connections occur as movements of energy, the matter and organism between the river channel and the adjacent flood plains. Lateral connections between the river and hill slopes also occur when a landslide delivers sediment and organic matter to the river.

c. Vertical connections

Vertical connections occur in the form of evaporation of water in the atmosphere but in other direction, the connection of water with the lower part of the stream channel is called vertical connection. Carmel River of California is an example. Willows planted along the stream could not survive without supplemental irrigation, however, because the water table had dropped below historical levels as a result of intensive regional pumping ground water (Kondolf, 2000).

d. Time dimension

Time span is critical in defining equilibrium. Equilibrium lies at the multiple interacting components within a natural system which can reach a state of stability. It also implies that if the energy or material supplied to system changes, the system will change in response (Howard, 1982).

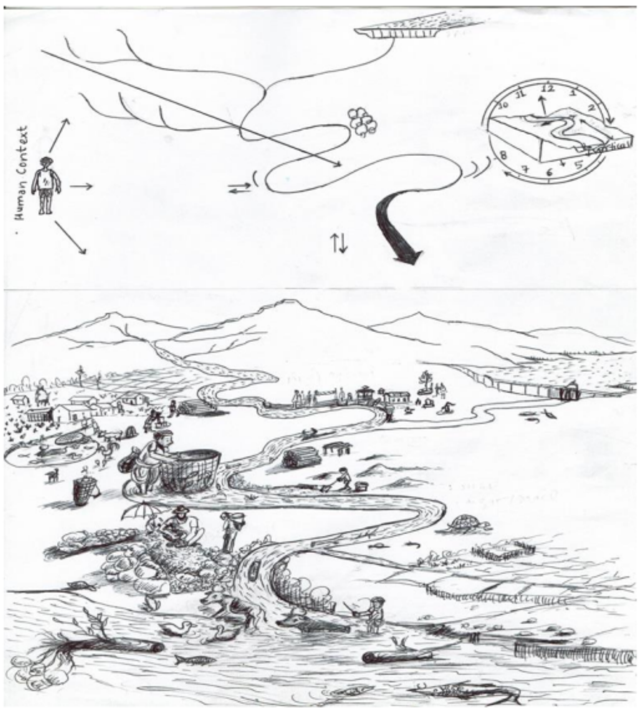


Figure 2.1: **Interaction Between Human and River Ecology**

The system has been developing in response to a dynamic pattern and process, which occurs in four dimensions which have been shown in the above diagram (Fig. 2.1). Various lotic ecology connections have been developed and they have been dealt under the following theoretical framework.

Gradient analysis: An unidirectional flow of water is one of the important features of the rivers the gradient from head waters to the lower reaches is one of the important theme of lotic ecology and it should examined. It incorporates themes like:

- Disturbances-It is most apparent in highly manmade structures like dam
- Eco-tones- They are taken as a tussling one between adjacent communities.

- Connectivity- It is relatively a new concept in ecology and lotic ecology has recently focused on it. It incorporates hydrological connectivity concept.

In analyzing a natural system Whoel (2012) is of view that the river natural system is open system which continuously exchange matter and energy with surrounding environment, which move as of gravity and controls the landscape. It can be shown through a quantitative method. But a qualitative method is broader that exhibits tendencies towards a form of stability which represents some balance between dynamic and resting forces acting on the system. A glacier or fluvial system is also most realistically considered as ecosystems that operate within a global context which is also applied in the river basin system. In contrast to a closed system, there is a constant supply and removal of matter. It exhibits a tendency towards a steady- state condition resulting from self- regulation among interacting components; a concept referred to as dynamic equilibrium.

Geomorphic transport laws applied to existing transport laws to quantify processes including mass conservation for –soil or sediment maintained landscape underlined by bed rock, sediment transport.

Bull (1991) distinguished between reaction time (before any response starts), relaxation time (system is changing), response time (reaction + relaxation time), and persistence time (the time during which system is stable and unchanged) conceptualizing changes in the natural system. Descriptions of these tendencies are sometimes called external hypotheses because they predict that a river channel will adjust to maximize or minimize a given parameter. An example of quantifying the threshold is given by Bull (1979). Stream power (Ω) can be quantified as $\Omega M= rQS$ where r= specific weight of water, Q= discharge and S= Steam gradient.

The critical power (Ω_1) is the stream power that is necessary to transport the sediment supplied to the stream. The threshold of critical power is equal to 1. When the ratio exceeds 1, the stream has greater power than needed to transport the available sediment, the extra power is used to erode the stream bed. Sensitivity involves the system's response to external influences in terms of either spatial variation in the ability of land forms to change or susceptibility of a system to disturbance (Allison and Thomas, 1993).

Whiting and Stamm (1995) have emphasized the importance of channel network structure to understand the longitudinal variation in the sediment movement and aquatic environment. The flow starts from zero ordered basin to more than five ordered basin. The headwater is characterized with more water and ice accumulation. Stream water temperature, and water chemistry in headwater are closely related with soil structure and bed rock structure. The fracture in hill slope, and zero order basins are its characteristics. The changing valley configuration channel gradient and material types also modify sediment transportation from headwater to downstream (Whiting and Braddely, 1993, Nakamura et al., 2000).

The sediment movement may be controlled by channel gradient, tributary junction angle, and reach constraints (Benda and Cunday, 1990, Nanakumura et al., 2020). Intermittent channels reach also disrupt this connectivity. The headwater hyporheic zones are smaller and their nutrient exchange is less than in downstream (Ward and Standord 1983). Changes in channel morphology from confined headwater system to broad and meandering channel in downstream system may affect interaction between riparian and ecosystems, as well as habitat types (Ward and Standornd, 1983) because of isolated nature in the area and most of them are undisturbed.

The stream chemistry and headwater are closely related within the soil, structure of bed rock hill slope and zero order basin. The chemical composition of water changes with valley configuration, channel gradient and material type also modify the sediment transportation from headwater to downstream (Whiting and Baddedy; 1993, Nakamura et al., 2000).

The abrupt changes in channel gradient and valley width may cause sediment deposit including terrace and debris fans. The tributary junction between headwater and larger channels are very important as network nodes for regulating materials flows and biological process in watersheds and have unique hydrologic, geomorphic and biological attributes. Heterogeneity of water, sediment and woody debris movements are higher at tributary junctions than in the other parts. Downstream assemble in network systems between riparian and stream ecosystem as well as habitat types (Ward and Sanford, 1983).

The channel geometry at tributary junctions varies, depending on sediment and flow regimes from headwater system and their degree of synchronization. Scour, pools and gravel bars typically form along tributary flow margins, depending on junction angles (Bristow et al. 1993). Hydrologic and geomorphic variability at tributary confluence also influences habitat types (pools size and distribution as well as sub-starta type) and biological processes in the area of the junction. Connectivity of headwater stream to downstream reaches affect both the cumulative and dispersed nature of materials transport process within the watershed system.

Spatial and temporal variations of river in headwater system are critical factors, which affect dynamics of stream ecosystems heterogeneity of riparian, riverine landscape and settlements in channel network. Bioclimatic factors like riparian structure, precipitation, discharge drainage density, angle, vectors are important for river ecological system. Two general process related studies within headwater system are ; hydro geomorphic and biological processes from hill slope to stream channels (Richardson, 1992). It is a better understanding of functional linkages among wood, sediment, nutrients and water in headwater is needed to address relevant ecosystem process.

Ecology and management of downstream zones have been extensively studied and applied in the context of stream restoration during the past 10 years (Naiman and Decampus 1990). However, the role of headwater system has recently attracted more attention with respect to conservation, restoration, and management of downstream reaches**.** Consequently, management of headwater streams and riparian zones is important, and there are benefits to be considered in the linkages between headwater and downstream systems. Hydrologic, geomorphic, and biological processes in and along hill slopes, zero–order basins, river channels and second-order channels characterize headwater systems in relevance. Processes are tightly linked between hill slopes and channels and from terrestrial to aquatic environments.

The expansion of hydrology by active areas are riparian zones, zero –order basins, bogs during periods of increasing wetness increases the probability of mass movement and many headwater tributaries flow into downstream reaches which affect hydrologic, geomorphic and biological process and attributes in downstream reaches of channel network . Temporal variations of disturbance in flow regimes and riparian succession in headwater tributaries alter the physical and biological conditions of the channels , as well as in pure incoming material (sediments, invertebrates and detritus), which in turn modifies food waves and their productivity in downstream reaches (Naiman and Decampus 1990).

Connectivity of headwaters system to downstream reaches both the cumulative and dispersed nature of material transport process within watershed systems. Spatial and temporal variation of processes in headwaters affects the dynamics of stream ecosystems, as well as heterogeneity of riparian and riverine landscape in a channel network.

Two general types of studies are needed to understand headwater processes and downstream linkages. Process related studies within headwater stream are essential. Despite the progress in elucidating hydromorphic (Sidle et al., 2000 and biological (Richard, 1992, Wallsce et al., 1999) process from hill slope to stream channels, a better understanding of the functional linkages among woods, sediment and nutrients, and water in headwater system is needed to address the relevant ecosystem process. It is also necessary to evaluate the influence of headwater process on downstream systems (Benda and Dunne 1997b, Wipfli and Gregovich 2002). The connectivity of headwaters to downstream reaches must be evaluated in future studies

a. Unit hydrograph theory

Sherman (1932) propounded a theory on the unit hydrograph. He has defined it as "the hydrograph of surface resulting from a relative short, intense, called unit storm. The run off hydrograph may be "made up" of runoff that is generated as flow through the soil (Cited in Tarboton, 2003).

A unit hydrograph shows temporal change in flow or discharge per unit of run off from excess precipitation. It also shows how the law of stream will be affected over time by addition of one unit of runoff. Thus module offers a through introduction to the use of unit hydrograph and application of unit hydrograph in flood prediction. Thorough use of rich illustrations, animations and interactions, this module explains key terminologies like assumptions and outcomes. The steps in creation of a unit hydrograph examine the issue of surrounding applications of unit hydrograph theory and discuss important considerations for forecasters. It is based on time, lag concentration, rising limb, recession limb (falling limb) peak flow, time to peak (rise time) recession curve, separation and base flow. The methodology depends on stream data, regulation; SCS fitted distributions and geomorphic idea (Adeyi, Adigun, Onyeocha, Okeke, 2020).

The key points are precipitation excess of one inch, spread uniformly- over spaced-even over the watershed , uniformly in time- the excess rate is constant over the time interval and there is given duration. Duration of unit hydrograph is based on following three stages.

i. The storm is fairly uniform in nature which runs through the basin.

ii. Secondly the storm is considered to be relatively constant.

iii. The storm should produce at least excess precipitation, which makes one inch. Compare to other model based on HEC- RAS (Hydrologic Engineering Center River Analysis system), this is simple and easy to compute. The unit of intensity can be conveniently applied in other units.

The main problem in our country is unavailability of real time data on intensity of rainfall in the basin. However, this theory is based mainly on the rainfall, catchment and discharge data. So the theory is simple and has been applied for the present research.

b. River model

The cycle of erosion propounded by W. M. Davis in 1889 was fundamental concept of cycle of erosion. According to Davis the landform development would occur in the course of erosion sedimentation and deposition work. Bone River can be taken as an exmaple. The land formation evolution is based on the combined interaction between structure of rocks, the aging of land formation changes (process) and stages in the sequences of landform change already reach at a particular time. In another works, the cycle is divided into youth, mature and old stage. In the youth stage the stream occupy steep sided V-shape valley, more cutting of slopes are appeared. In the old stage,, corrosion or erosion is high and the power is less and only deposition takes place in wide river valley. The flow of river water is sluggish and regions become almost plain. According to Davis, land form development would occur due to up-liftment of land. Taking an example of river, Davis classified the development of land form into three stages- youth, mature and old. Erosion and deposition are two important aspects where human population gets benefit from deposition in the old stage of landform. But it is very slow process in total stages.

According to Moss (1998), the model stream lies in uniform geological terrain. It is most erosive in its headwaters where the boulders left from a previous stage create an uneven or turbulent flow over a rough stream bottom. As the downward erosion of the stream bed continues, the slope is reduced and the stream's ability to erode its bed declines. The slope flattens until it becomes nearly horizontal at its base level when the stream (then usually called a river, but there is no absolute distinction) meets the sea. In its downstream, the water movement becomes turbulent with pockets of finer sediment which can be deposited among rocks and persists even during floods. The size of the downstream channel increases as more water flows through. However, it does not usually increase in cross-sectional area at the same rate as does in the area of catchment, for it is determined by the erosiveness of high floods, whose effects are muted downstream. It accommodates by meandering, thus increasing its length and capacity.

Paradoxically, in the model stream, the average current speed may increase in downstream to accommodate the greater discharge. The less turbulent flow in the lower reaches, however, means a greater range of velocities over the cross-sectional area. These include very low speeds in contact with the bed and very high speeds in the mid water at the centre of the channel. The mean velocity is found at around 0.8 of the total depth in the centre of the channel. The turbulent, foaming water in the headwaters may have temporarily higher speeds, as it whirls in flood, but its average speed, largely a function of the base flow, is generally lower than that downstream.

Accommodation of the channel to the moving water leads to patterns in the deposits of gravels and sands. The riffles may form as bars at the outsides of bends, while the pools may be more or less continuous in the centre of the channel and on the inside of bends. These features provide different habitats for stream organisms.

In its lowest reaches, the channel may increase its storage capacity by winding across a flood-plain to accommodate the greater of its normal flows. The channel moves as the river erodes soil from the outside of its bends (meanders) and deposits it on the inside.

The model stream thus falls in orderly progression from uplands to the sea but does not exist. And management by man - the creation of dams, the alteration of the channel itself in the interests of flood control has upset any smooth change downstream. The model river, nonetheless, has value as a framework on which to base studies of river ecology.

The chemistry of the base flow may be different (greater concentrations of ions) from the flow because of its longer contact with the soil and rock. The flood flow, in contrast, may carry organic debris, such as leaf litter, and more solid particles eroded from the land. The flood flow passes downstream as a pulse. It may move fast, carrying suspended clays and fine organic debris, gravels and sand with it. At times of very high flood, it may cover large boulders, eroding the valley sides and the stream channel. The deep, narrow valleys of many upland streams have been cut in this way. The relatively meager base flow moves fast enough only to carry very fine particles, so that, in dry weather, beds of sand and gravel are left along with the larger rocks and boulders.

Several key ecological theories contribute to spatial ecology and guide empirical investigation in the fields and laboratories. Ecologists have used these theories to develop and refine our understanding of implication of spatial variation for ecological processes.

It shows that the size of natural area has a positive relation with occupancy of the species who live in that area. The species richness is tightly linked to the habitat area. The major cause of decrease in the number of species is the decrease of habitat area.

A simple mathematical relationship describes changes in the channel with increasing discharge. Thus, if Q is discharge, W is width, D is mean depth and U is velocity:

$W = aQ^b$ ……………………………… (1)

$D = cQ^f$ ……………………………..…. (2)

$U = kQ^m$……………………………… (3)

The groups of constants, a, c and k and b, f and m, must each add up to 1, because Q is equal to WDU. There is thus a degree of compensation among width, depth and velocity.

These formulae describe dramatic changes, as catchment area and its consequent discharge increase. In general, the rate of increase of width is greater than that of depth, while velocity increases least rapidly.

c. Settlement model

Chisholm (1966) has suggested a model dealing with the relationship of settlements of the resource of its territory along Weber's (1909) line of approach. According to him, proximity (nearness) to sources of drinking water, arable land, fuel, grazing land, building materials, farmland, geographical location, market centers and ravage of malaria and flood havoc are other factors that deserve the location of settlements. "Chisholm inverts his analyses to treat settlement pattern as the dependent variables proposing that settlement will locate themselves so as to minimize transport cost or travel time- raises the issue of how settlers weight various resources and how frequently they access these resources. In his hypothetical illustration, Chisholm assigned weight to landscape features; water (10), arable land (5), grazing land (3), fuel (3) and building materials (5) (Stone, 1996).

The central place theory of Walter Christaller (1933) was concerned with the way the setlements evolve and spread out. The fundamental concept of central place theory is principle of centralization and principle of hierarchy.

These principles serve as basis for settlement hierarchy of the present study. It considers not only the selected principles of centradity which are necssary to understand spatial organization both in space and time (i.e. static relations), also the development proces are time (i.e. dynamic process) changing due to change in flow regime in different time sequence. By learning the mechanisms of impacts as induced by FDI in river HPP, this approach allows consideration of wide range of influences out of the real world experience and were substanntial judgement of protection intended by policy guidelines i.e. nromative targets.

d. Determinism and Interaction Theory

The interaction theory came up with win- win situation in the sense that the resource should be used wisely which is called sustainable approach. While exploiting the resource, use of technology should also consider the limiting factor of the resource generation of the earth's capacity. The basis of this concept is fundamental for the use of flow resource in the present study. The over exploitation of resource by using technology through private and public sector is not good for maintaining the ecological system of the river basin.

The possibilism is a view of the environment as a range of opportunities from which the individual may choose. The theory also provides the range of choice may be limited by the environment, but allows choices to be made, rather thinking on deterministic lines. Human action is combined response to natural environment interacting with technological advance of society under the reference. Accordingly, Tennessee River Valley Project was initiated in USA for the first time by Tennessee River Valley Authority, USA. In the river valley the use of resource is rising on the one hand at the same time the judicious use of the resource is coming on the other hand and pressure is being buiot up to maintain the ecological balance with development activities. The concept is also applied in the present study of the development activities in the Tamakoshi river basin.

Determination says that man is entirely under the influence of nature. However, possibilism believes that man is never free from the influence of the environment but there is room for the efforts of man, such as technology, attitude and, habit and value of human which influence man’s action and brings the physical environment. So, it’s obvious that both facto (man & nature) are equally important to move and influence each other. “People & their environment are inseparable” (Peet, 1998).

Among the other dichotomies, dualism in environmental determinism and possibility are the dominant one. It is not the physical environment that influences the man but also the human efforts have to be considered. People and their environment are inseparable (Singh, 2007) “Egypt is the gift of Nile” - Physical environment influence the livelihood of men climate –cold climate is horse for man and mule for livelihood.

Warm climate – steppe region provides the room for nomads but growing grass and nomads is becoming life. Climate situation influence the livelihood of man, diet (Hartshorne, 1939).

Most environmentalists take a possibilism rather than the environmentalism. However, the role of environmental is still there. But it is not easy to measure the influence of environment on man as the complexity of the environment is interconnected and one cannot separate another from deterministic or environmentalists. The major effect of the environmental is climate. Aristotle believed that people of the cold climate were brave but deficient in thought while the people of warm climate were rich in thought but they lack sprit (Pradhan and Pradhan, 2006). However, man can make change in these climates with modern technology and scientific device. But these only operate indoors on a small scale and attempts to effect on modifications to the climate are very limited. Despite the technology, man is still depend on the physical environmental for all his materials and needs and desire. The nature of the dependence varies from society to society, form primary societies to modern societies. More than half of the world's labor force is employed in the primary industries of farming, fishing, forestry, mining upon which physical environment thus dominant influence. Three main types of change can be identified and they affect man in quite different ways, having both positive and negative effect on human actively. i) long – term regular change which includes silting of rivers and maintaining the fertility of flood plains from agriuculture and settlements are depending on it. ii) Short regular change which includes seasonal change that regulates a cycle of agricultural season. iii) Rapid unpredictable change which includes the earthquake, hurricanes, floods etc. However, man has extended his dominance in almost all parts of the earth (Pradhan & Pradhan, 2006).

Woo (1976) in his research work on the "Hydrology of drainage basin in Canadian High Arc" tried to explore the characteristics of permafrost melting, artic stream flow and water balance in the artic site.

Woo tried to look on the issue in annual water balance of Mc Master Basin level taking variables like rainfall, runoff, evapotranspiration and storage change. His methodology was based on water balance equation (Qm=Q+QH+QE+QR). He has also looked on snow melting and water movement through pack, basin snow melt, permafrost hydrology, surface process, active layer process, channel hydrology, break process etc. However, his study focused on the different kind of process acting in the high artic drainage basin. Moreover, researcher has also looked upon the roles played by the energy balance, the uneven snow cover and permafrost at shallow depth.

Woo found that long polar winters cause snow cover which makes substantial energy loss. Snow melts begins in the late May or June. Over three-quarter of annual discharge is released during the melting period, but occasional high –for events are also produced by summer rainstorm. About 80 percent flow occurs during summer period from May/June to September/October. In total precipitation 70 percent precipitation contributes to basin run-off showing that 10 percent goes on underground water surface (i.e. ground water).

It further assess that more works must be done to enable an appropriate application of existing hydrological concept to the Artic and formulate models to the polar region. An assessment of basin evapotranspiration and slope runoff requires an appraisal of spatial distribution of snow.

e. River ecology

Thapa (1988) has tried surface modeling of Alkali watershed under reclamation. Water movement is the main component of ecological system operation in the river basin. Water logging is the main cause of soil salinity affecting crop grown in the cultivated area. It will not only affect the water flow and ecology in the existing stage, but also the possible cause of excessive fragmentation will affect the crop production and non-crop production will rise.

The use of river is vital and becoming life sustain in the river valley (both alkalinity and salinity) of soils adversely affect the crop grown. In the long run such soils are used for agricultural purposes. The development of hydropower projects and other activity cease the river flow and will change the whole system.

The interaction between flow of water and settlement would come into fault with other uses of water. So, researcher tries to analyse the interaction between flow of water and cropping pattern. Interaction between components is low in low flow area. Similarly, biophysical interaction is also low and crop production, animal grazing and aquatic life are because of reduced flow. These things are especially in danger during the winter season than summer season.

2.1.2 Empirical research on the issues

a. Basin hydrology

Thapa and Weber (1990) have carried out a research on managing mountain watershed of the upper Pokhara. They have demonstrated that watersheds at high altitude include head water areas which are particularly vulnerable to environmental degradation due to their weak rock formation, steep slope, gradients and unique vegetation cover. Yield of the paddy production in this area is generally poor, mainly due to low availability of water and the toxic effect during the dry season. With construction of Seti Hydropower Project, the existing flow is disturbed and it affected the paddy cultivation in the watershed. They conclude that the twin objectives of maintaining a sustainable ecological balance and economic development cannot be achieved by subsistence farming system.

K. C. (1992) has carried out a research on the different aspect namely environmental stress on basic needs. It is a study on Begnas Tal – Rupa Tal watershed area of the Pokhara valley. His approach is based on basic needs approach. The consumption pattern of people of settlements along the watershed has been worsening for the last 30 years.

Basnet (1992) also mentions about the worsening balance between environmental resources and population growth up to 1970's the balance was maintained due to expansion of cultivated land into forest and shrub land. He concluded that if the train continues, the growing population will outnumber the resource as postulated by Malthus in 1779.

Shrestha (1990) has carried out a study on geomorphology on Seti Watershed and surrounding areas of the Annapurna Region. He observes that the mass wasting is the main cause of watershed degradation. It is due to heavy rainfall, which ranges from 3600 mm to 6000 mm in the high altitude above 1000 meter from the sea level. Moreover, different types of rock in the upper region have also contributed to this. Multifarious hazardous incidents in the area can be attributed to heavy hailstorm, rainstorm and thunderstorm. Apart from terrace farming practices, tourism, forestry, and animal husbandry are the common for livelihood in this area. A total of 172.69 km^2 have been affected by the landslide which accounts for 9.56 percent of the watershed area. About 387 km^2 areas are covered by Madi and 6.1 percent for under landslide and 772.31 km^2 area is under the Seti Gandaki basin. Out of total almost two percent (1.97 per cent) is covered by landslide. The researcher concluded that natural hazard is the main cause of watershed degradation.

Dahal, Shrestha, Tuitui & Ojha (2018) in their study on "Temporal changes in precipitation and temperature and their implication on stream flow of Roshi river, Central Nepal" have analyzed the temporal trend of temperature, precipitation and extreme indices of wet and dry season and observed temporal pattern of stream flow in Roshi area. The objectives were to investigate spatial and temporal variations in precipitation as well as moisture indices related to flow regime. They analyze temporal stream flow trend of the Roshi River based on the available data (1971-2014), and assess the linkages between river discharge and precipitation parameters in the Roshi river watershed, The study Methods of the study is based on the regression analysis using Mann –Kendall Test to test the hydrological changes and its linkages with precipitation indices.

The seasonal analysis is based on three seasons namely pre-monsoon, monsoon and post-monsoon. The Pearson correlation is used to determine the flow and precipitation parameter and distribution of floads also calculated with help of slope. They have found that the area has been warmed up an average $0.030C^0$ per year and has seen a significant decline in precipitation. The dry spell is represented by the maximum length of dry spell (CDD) and the wet spell by the number of heavy days rainfall (R5D) and the precipitation intensity in wet spell (SPP) has diminish significantly. The recent changes in precipitation have affected the stream flow of the Roshi River. The decreasing availability of water is likely to have severe consequences for water flow in the area.

Vaidya and Sharma (2014) have compared the the temperature and precipitation data from 1988 to 2007 for Kyanging station in the Langtang Valley and from 1999 to 2002 in Kafani basin of India. The PDD model is used to estimate the discharge in two glacierized river basins. The result showed a positive trend with a pronounced inter-annual variability. The observed annual temperature data for the Kafni River basin from 1919 to 2002 also show a positive trend (0.012^0C year^{-1}) but precipitation showed a negative trend (-8.25 mm year^{-1}). In Langtang the projected temperature shows an increasing trend of 0.0150 C year^{-1}) and projected precipitation a slight negative trend of -1.903 mm per year. The projected trends were positive for both temperature (0;033^o C year^{-1}) and precipitation(18.50 mm per year^{-1}) in the Kafni basin. The Mann Kendall tests were used to test the significance of the precipitation and temperature. Neither trend was statistically significance at 95 percent nor was it in the confidence level.

The precipitation is expected to decrease in both wet and dry seasons in the Langtang River basin and increase in the Kafni River basin, the projected discharge of water from 2010 A.D. to 2050 A.D. showed an overall positive trend in both river basins, although it will decrease after 2040 in the Kafni basin. The contribution of snow melts to the discharge from the Langtang River basin was nearly equal to the contribution of rainfall base flow. In the Kafni River basin, rainfall/ base flow contributed a more proportion of discharge than did snow melt.

b. Watershed and their characteristics

Poudyal (2001) has explained that watershed is considered as a biophysical entity and it regulates most of the human and physical actions within the boundary through stream network system. The researcher has analyzed the management issues of the Himalayan watershed based on the micro level evidences about population resources as a limiting factor. The study area is characterized by weak physical factors and it is the result of natural calamities. The farmland itself is quite poor. However, it has found that the people are engaged in farming activities in such area. The available ratio of farmland to total population is quite low and there is a large area of forest land and the benefit from forest the area has been insignificant and the estimated carrying capacity of forest area is quite high because population is quite low and outmigration is high. Researcher has also found an inverse relationship between remittances and investment on the farmland.

Khanal (2002) is of opinion that population increase leads to changes in the overall land use pattern. More changes took place over 30 years from 1950 and 1980 than in the past 150 years (between 1700 and 1850). Major processes of the change during this period were the expansion of cultivated land and human settlement by clearing forest, draining of wasteland and irrigation of grassland. His findings show that improvement in global accessibility and increase in commodity demand in urban areas in the nineteenth century has stimulated the extensive burst of land clearing and conversion. He has also explained the changes in the land use due to the bio-geographical, demographic and economic factors. Environmental hazards such as landslides, debris flows, floods, drought, diseases and pests and forest fire have also appeared in the study area, which have changed the use of land and its cover.

Chapagain (2011) has discussed on the causes of natural and anthropogenic changes of the Dhunikhola watershed. The local people were active to manage canals and even riverside to protect and irrigate farm land of the watershed. However, special events of natural cloud burst from July 19 to 20 in 1993 caused reduction in the water level and it also affected local participation in the water resource management. The action has changed overall situation of water resource management. As a result, people have changed the cropping pattern from cash crop like onion and vegetable to dry crops like bean and lentils. Even the local farmers also sent their children to foreign employment to support livelihood. Moreover, the water sources of the village also have changed after the construction of road section between Kathmandu to Naubise.

Alam (2016) has agreed that in the new context, India may contemplate departing from the existing framework for resolving disputes over each of its trans-national rivers. Large-scale modifications in the natural flows of these rivers in the upstream as well as downstream countries can greatly undermine ecological problems of different neighboring countries. When China constructs reservoirs in the upstream in Brahmaputra, it will affect both countries. The proposed modifications in trans-national rivers have put to test India’s established strategies of dealing with trans-national river disputes. In this new context, the strategic community and academia have to reflect upon the emerging contours of India’s trans-national river strategies. The contributing delay in resolving these disputes for long may harm India’s relations with its neighbors, particularly with Bangladesh which wishes to develop its own water resources on a long-term basis.

The Central Department of Geography (2015), Tribhuvan University has studied on the channel morphology and its changing aspects in Rapti Basin of the Kulekhani area. The study deals with the transfer of water from one river basin to another and its consequences in the recipient and giver basin. The research found that the geomorphic process like raising water flood, river levels and unpredicted water flows are the consequences for the recipient basin while the more problem of dewatering in agriculture and socio-religious practice are found in the giver basin. Moreover, it deals with the socio-economic consequences of the Kulekhani dewatering zone, and Rapti zone. The problem of less water in dewatering zone, more flood and associated features of geomorphologic consequences are observed in dewatering zone.

Singh (2016) has argued that surface water, ground water and rainfall are the main three sources of water in Punjab. From these sources, the total available water is about 3.13 m. ham per annum. However, the total demand of water is about 4.40 m ham per annum. Thus, there is 1.27 m. ham water deficit in Punjab. Because of continuous exploitation of ground water, presently more than 80 per cent of the total blocks have been over exploited and declared as dark blocks. The overall position of the water crop diversification, promotion of improved irrigation methods, artificial recharge of ground water and ban on higher water consuming trees are suggested for sustainable development of the water balance in the state.

Hasna & Kumar (2016) have tried to identify the scope of reducing disparities in different river basins by transferring water from the surplus basins to the deficit basins. They have also recommended inter-linkages between settlements and river flow without disturbing the environment and ecology. While some river basins have vast catchment area and carry enormous quantity of water but others are small and have comparatively less quantity of water. Keeping these and many more problems in mind, the idea of inter linking rivers through inter-basin linkages or through national grid system should mooted. But there are many problems especially in the settlements and ecological areas. However, this couldn't be materialized because of ecological problem.

Mishra et al., (2014) have conducted a research on natural flow of river in the Gandaki River Basin (GBK) using modes data. The objective of the study is to know the trend analysis of flow with respect to change in temperature and snow cover. They showed that with increase in temperature and decrease in winter precipitation, a significant negative trend in snow-covered area has been identified in the last decade in the Himalayas. In their study, a non-linear autoregressive exogenous model namely an Artificial Natural Network (ANN), was deployed to assess the snow cover in the Kaligandaki River Basin for the next 30 years. The result shows a reduction from 9 percent to 46 percent of snow cover in different elevation zones during study time periods from 2011 to 2014. The height from 4700 m to 5200 m elevation zone is the most affected area and the area higher than 5200 m is the least affected. However, it is clear from the analysis that the seasonal in the Kaligandaki is the climate change.

Jal Vyuddut Sanstha (JVS)/ Global Water Partnership (GWP) (2016) carried out research on e- flow in the Modi Khola. The study examined watershed in central Nepal. It was carried out in down stream of Modikhola Hydropower dam site. The study analyzed the hydrological flow of river obtained from primary and secondary data and it compirses the flow of water flow between different seasons. The release of minimum flow above 10 per cent complies with the existing policy and provisions. But it equally difficult to know the quantity of water flow required maintaining downstream ecosystem functioning as science based research in Nepal could be considered low or "non" including water requirement of and aquatic species (plant and animal) in the river system. The study also reported that there is no reporting an amount of water requirement of water release from the project system operations. The study found that operation of hydropower of Modi Khola has no minimum water release despite it was proposed in EIA and IEE report, except for wet (monsoon) season.

Dongol, Mertz, Dhakal and Dangol (2005) have compared low flow characteristics of the Jhiku Khola catchment (JKC) and Yarsha Khola catchment (YKC) for better understanding and future water management. Different low flow parameters including, rainfall, discharge, runoff, low flow frequencies, base flow index and low flow index were analyzed and compared. Between two catchments YKC has good water potential than JKC. The JKC has a limited potential for developing and possesses more challenge for managing water resources. Population growth along with agriculture intensification is the cause of more water demand for more food production. Shortages of water, mainly for irrigation and drinking are major issues in the area. During the rainy monsoon season there is a lot of rain and water everywhere but most of the remaining time is dry causing scarcity of water. This is the main challenge for water management in the middle mountain area.

c. River ecology

Koirala (2002) is of opinion that the forest area under the mountain region is under pressure due to increasing demand within the landscape. In many areas uncontrolled tourism is a major threat which is reflected in the habitat degradation, and biodiversity depletion. His study is based on two VDCs: Tamaphok and Madmulkhark of the Sankshwasabha district. The objective of the study is to analyse the energy flow in the agricultural eco-system from agriculture to forest and other sector. He has found out nine steps in agricultural practice from swing to harvesting system. For betterment of production, people use fertilizer like NPK and K and other chemical in soil. The soil need natural as well as artificial supplement. In mechanical support petrol and diesel are used but as a human support it uses from excreta as well as manuring the soil. He found that there are 27 economic value that support the the livelihood there. The energy efficiency in the Mountain region is lower than lower altitude. So the efficiency of the energy is very low.

Due to decrease in the forest area the birds and animals which reside in the trekking area has also decreased which in turn affect the people which are dependent on them as well as sources of income or food. The third effect is on environment. Because of decrease of birds, their habitat, the number of the people who visit forest visiting has also decreased. The main tourist doesn't harm the environment but the corresponding number of porters guide put much pressure in the forest of the area. More damage is observed on the trekking trail than other parts. There is lower degradation in the area where local people use forest. Thus, over extraction of resource due to excessive number of tourist related activities has degraded ecological systems – forest, water, etc.

Stevens (1989) has highlighted the ecological condition of the Sherpa settlements which have undergone a substantial change within the last half century following the introduction of tourism related activities in the high altitude. The ecological system that prevailed in the past did not last long. His research is about way of life. He explores how Sherpa not only survive but thrive in a difficult environment – how they cope with constraints of life on the roof of the world and exploit the unique opportunities of their mountain realm. The research is about the cultural persistence. The Mount Everest area becomes a major international tourist attraction on average of cultural practices. More than 8,000 mountaineers and trekking tourist now visit the region per year. They bring with them new opportunities for local development from which the Sherpas have been benefitted from profit as well as new environmental and cultural impacts.

Manandhar (1988) has has carried out a study on mid hills of Nepal with an objective to understand human interaction with natural environment, to understand the constraints and opportunities for improvement of agricultural and to contribute to the debt on 'eco- crisis by adding the perspective of local population. The methodology adopted is based on observation, questionnaire survey, FGD in three ethnic groups- Chitre (Tamang village), Siudeni (Brahman-Chhetri village) and Balami (Newar village). She concluded that the theory on "Mountain Environmental Degradation" is based on the observation of neglecting local knowledge. She has worked on the area where Man and Biosphere (MAB) have worked for the environmental degradation. On the basis of the previous premises and theories where she has tried to prove propound theory of the potential eco-crisis.

Cultivaton on steep slopes is not necessarily damaging at all times. The tradition of making terraces in hilly and mountainous terrain for agricultural purpose provides good protection if done with sufficient care (As cited in Manandhar, 1989).

Eckholm (1975) came forward and blamed the worlds mostly poor and their population growth forcing farmers with traditional agricultural technology onto ever steeper slopes and are associated with pristine environment. In the same way, "the poor are damaging the environment even more than the rich" In the meantime, a theory of Himalayan Environmental degradation was developed by a group of settlements (the vicious circles as referred by Ives and Messerli, 1989) and was populrized by the Nobel Laurite Rudyard Kipling.

Rijal (2006) has carried out two researches. One is related with use of water resources on livelihood in the Modikhola watershed and the second is related with precipitation and temperature on the climate change. He observed that livelihood status of the Modikhola watershed is entirely based on the Modi River. The water of the river is commonly used for, irrigation, household chores, power plant use, fishing, workshop operation and cultural activities. He further opines that the use of water for hydropower has not only contributed in human health but has also decreased women drudgery. Similarly, use of water has a significant role in promotion of tourism industry in the form of restaurant, and hotels and even pilgrimages. The water is also used for illegal liquor preparation and washing buffaloes and other animals. In his second study, he has shown the increased volume of water discharge in the Modi Khola is due to the increasing precipitation and temperature which has caused the climate change.

The conclusion had been drawn based on the sampling of selected communities and focus group discussions. The study area was divided into upper and lower parts on the basis of dam site of the Modikhola Hydroelectric Project.

Suwal (2020) viewed that the climate change is one of the biggest crises facing by humanity globally. A similar problem has been faced by people of Manthali of Tamakoshi river basin. Arid and Semi-arid regions are particularly vulnerable to climate change in the following fields: agriculture, land resources, water resources, food production and socio-economic issues. It is suspected that the global agricultural production could face reduction 3 percent by the year of 2080 even if basic adaptive measures (e.g. changing crop types) would have been taken. The lower basin of Tamakoshi river lies at semi-arid region Manthali. The whole southern part of Manthali depicts either barren or dry bush with grass deominated (Shrestha, 2014). The change in climate parameters created through different scenario due to climate change are likely to have large impact in this area. This is the cause of decreasing trend of water flow in the Tamakoshi River.

Litvinov and Golovanov (2004) are of opinion that geo-ecological consideration should be considered while making large dams. The government usually constructs such dams for fulfilling multiple uses of water resources. But in long run, the system brings changes in local water regimes and environmental conditions in the surroundings of reservoirs. They have also emphasized on the need of research to deal with rigid regulation of natural environment, its characteristics, intensification of shallow water areas intensification of oxygen deficiency and methane formation. The vegetation also shows different behavior during its high water period (1957-62, 1977-92) and low water flow periods (1963-1976 and 1993). They have found decline in ecological diversity in Rybionsky reservoirs (1953-2000). All activities make different chain of fish migration. Biogeochemical indication, aquatic ecosystem with

Hg, Cd, Pb, Cu, Zu As, Co, Ni, Mn, and Fe is essential. For this, better understanding of ecological condition, flow regime, its local and other aspects are important for practical solutions. Within this, the chain reaction of cascading process must be carried out for better understanding of the system of nature.

Balasubramanin (2019) is of opinion that the river provides the total ecological services to people from fiber to food. In addition to natural water bodies, artificial reservoirs and dams are constructed to preserve fresh water. He concluded that the aquatic biodiversity is a primary concept in environmental analysis, which encompasses most of the freshwater ecosystems including lake, pond, rivers and streams, ground waters and wetlands. Aquatic ecosystems also provide a home to many species including the phytoplankton, zooplanktons aquatic, insects, fish, birds, mammals and others. Many riverside settlements depend on the ecological fruits from the river.

Sada (2017) has explained that one reason behind degradation of river ecosystem is negligence to address the ecological issue in the infrastructure planning. The clause number 6.1.1 of Nepal Hydropower Development Policy 2001 states that hydropower operators must release at least 10 per cent of minimum monthly average discharge of the river as e-flows. But, most of hydropower operators are not compiling with the provision releasing by even 10 per cent. The context of environmental flow is more important to prevent dispute over water resource among upper-and lower riparian federal states. Conflicts intensifies due to water resources are inevitable if the government is not pro-active in the river basin, planning management or else Nepal will also face the same problems of India is now facing. There are disputes between Maharashtra and Andre Pradesh over Godavari River and between Tamil Nadua and Karnataka over the Kavery River.

Shah, Tachamo, Nesmann and Sharma (2008) have highlighted that e-flow is essential for maintaining the ecological system, to preserve the aquatic system and continue supply of ecological services to the community or riparian settlement. Rivers are lifeline of the catchment and support different types of ecological system. In order to preserve aquatic biodiversity and supply of natural ecosystem services, e-flow releases must be an integral part of the water resource development plan. Only sound science based techniques can help balance both maintenance and functioning of ecosystem services. In this regard, aquatic biota based assessment technique could provide meaningful framework to evaluate impacts of changes in the hydrological regimes which is related with river health. The outcome showed that our understanding on the relationship between flow regimes to ensure sustainability of water resource development without harming river ecosystem services and its health and services to riparian settlements are poor.

Kumari (2016) has also published an article on "Flood Ecology in Saran district: Challenges Ahead in India." The Saran district is confronted with a number of problems i.e. flood, drought, water-logging, non-consolidation of land, lack of irrigation facilities, depleted roads, perpetual water logging, and micro-nutrient deficiencies. Due to heavy rainfall in the catchment area, siltation in the riverbed, acute erosion in river course and over toppling of the river course create a furious situation in the district. Due to flood they have lost not only lives and property but also the process of development has been hurdled. Buildings are collapsed, crops are damaged, animals died and drinking water polluted. She recommends that the proper needs assessment should be done and town planning should be introduced in the plain area, which will make the area less vulnerable to flooding.

Shrestha (2015a) has examined the perception of use of water flow and its interaction with the local community in the Tamakoshi Rives Basin of the central mountain region. The study provides that there is a good relationship between the use of water flow and riparian settlements. The river has been used by the fishing community, extraction of sand, soil and stones by the contractors and some people even expect shares of the hydropower projects of then issues capital. Majority of them are unaware about the long run ecological disruption. If the present trend of using flow continues in future; many settlements from the upper part to middle part of the basin will have to face problems of water shortage.

Sharma, Banjade, Bhandari (2007) have examined the impact of the Khimti Hydropower Project (60 MW) on the ecological status of the Khimti River on fisherman's livelihood using the multi-habitat assessment technique and the household survey. The result showed that most devastating impact on the ecological status of river is observed at the time of de-silting basins. A separate study on the temporal and spatial scale of impact caused on fishes and aquatic life is strongly recommended.

Shrestha (2013) carried out research in the Kaligandaki River. She is of opinion that the total available of fish species in Nepal is 228. The total number of fish species reported from Kaligandaki River before and after the construction of hydrodam has decreased from 22 to 12 species. The structure of a dam fragments and it isolates upstream from downstream obstructing the migratory root of long and mid-range fish species. The formation of reservoir alters the lotic environment to lentic and creates dewater zones affecting the fish species.

Shrestha (2007) is of opinion that the water quality of the Manahara River has deteriorated as it moves from the source to the mouth, which stretches out for 30 kms. The important biological and physical parameters of his study were total *coliforms*, macro invertebrates, sechhi disc, transparency, mean depth, discharge, and electric conductivity and dissolved oxygen. His study shows that the river water is less polluted in monsoon due to higher flow of water than pre and post monsoon. The river water is nearly in pristine condition with high species diversity of micro invertebrates in upstream near Salinadi, Sankhu and less species diversity of micro-invertebrates have been found in the middle. The high species diversity is nearly disappeared when it reaches Sinamangal near Kathmandu.

Scot, Thibault, Arscott & Tockmen (2015) have published a report namely "Emerging concept in contemporary – River ecology" in Europe. They are of opinion that the intermittent rivers have a dominant role in making Meta hydrology and Meta community. The flow of water has been affected by increasing dryness in the climate as well as abstraction of water upstream. Historically, ecologists have neglected the study on the temporary river. Therefore, it needs to be supported by new models. They have also propounded the three models. The first model concerns connectivity between habitat patches. Meta community and Meta population are applicable in temporary rivers. The second model predicts that large-scale bio-diversity varies as a function of aquatic and terrestrial patched dynamics and water-level fluctuations. The third model represents temporary rivers as longitudinal, punctuated and biogeochemical reactors.

Bruckerhoff, Leasure and Magulick (2011) have used spatial correlation in different types of flow regimes in Ozark-Quachita: Interior Highlands of Arkansan, USA. They have concluded that the ecological flow is still in dilemma and more work should be done to reach conclusion of the real meaning is a top management priority in stream management to sustain the aquatic life. It is very hard to establish relationship between the flow regime and environmental flow ecology. This relationship varies on the spatial and temporal base. They have used the tools like mixed moving average, autocorrelation and stream network. They have also opined that further work is needed to understand why flow-ecology relationship varies across the classified flow regimes and why this relationship may not fit for predictions based on life-history. Flow-ecology relationship may therefore be confounded by spatial structure inherent in flow régime classification and the biological data.

d. Livelihood pattern

From 1950's to 1970's various approaches all over the world have been adopted to ensure trickle down the fruits of the development to the poor people living in developing countries. The approaches are: basic needs, community development, integrated rural development (IRD) and participatory development (Rajbansi, 2009). However, none of these approaches could individually impact the lives of the people at large because they ignored the basic principles of livelihood like people centre, holistic, dynamics, built on strength and macro-micro link. Sustainable development has, become the buzz word of development thinking over the last three decades. It can be defined as a process which aims to create "an ecologically and economically sustainable, socially equitable society" (Diesendorf and Hamilton, 1997:87). Thus, an important question arises in the interpretation of sustainable development is that of multi-disciplinarily. A significant trend over the past five centuries has been the change in the use and ownership of natural resources from local use to non-local use mainly industrial and commercial uses (Shrestha, 2016). Consequently natural resources were exploited in an unsustainable manner for an economic gain only. In the second half of the 20th century the negative impact of human activity on physical environment of industrial countries is a big concern. By 1990 it also becomes a major debate in developing countries too (UN, 2008).

Dixit (2007) pointed out that the environment also contributed to the civilization of Indus China world culture and religion, climate principle determine of culture. Culture is an inclusive term which has language religion and agriculture. Sample and ratzel religions are not free from the influence of environment likewise, the determination relies more as physical geography but the possibility relies more as human geography. Physical environment determines the nature of type of settlement, engagement, trade and agriculture.

Fang (2018) in his research on the livelihood has shown that the relationship between livelihood risk and corresponding livelihood capital always complex. He is of opinion that the importance of financial and physical capitals may be obvious. The human and social capital also has emerged as important variables in livelihood. Social cohesion, community networks, equitable gender relations and participation on social origination, all considered positive expression of social capital, lay important roles corresponding to the livelihood risk. The commonly – used classification of livelihood capital comprises five categories – human capital, physical capital, natural capital , financial capital and social capital – as outlined in the following. In this analysis, a six category is called informal capital.

Table 2.1: ***Relationship Between Biophysical, Capital and Livelihood***

Types of Livelihood Capitals	Definition	Corresponding Livelihood
Human Capital	Personal development ability, including education level, technical competence and health status.	Health
Natural Capital	As the basis of human survival, environmental conditions in which farmers engaged in a agricultural production activities are including soil quality, shortage of water resources.	Environmental
Physical Capital	Assists that are used in the economic production process, such as some agricultural machinery.	
Social Capital	The social network is formed by people who have a common interest, generally, it can be understood as trust, cooperation and participation in various associations.	Social
Financial capital	The money is used for purchasing productive financial capital materials or consumer goods including personal credit	Financial risk
Information capital	Access to date information is required for people to make decisions in pursuit of their livelihood objectives	Information and connectivity

Source: Fang Yi Su (2018), Udouy Saikai, Ianm M. Hay

Sen (2000) has provided the useful key to interpreting the linkages between risk and mobility in analyzing livelihood strategy. Livelihood choices are based on individual capacities to access human, social, physical, and natural resources, but are part of complex well-being strategies defined at the level of more or less large households. The options concretely available to individual and households are constrained by social and environmental factors: legal and political frameworks, economic dynamics, cultural specifications and ecosystem features determined whether people are allowed or denied access to capital and opportunities and denied the boundaries of the choices they have currently available.

Wang and Gao (2020) are of view that the settlement- river relationship is a co-evolutionary interactive complex system. They have reviewed the relationship of settlements of the different basins of the world. Therefore, it is conductive to investigate both coupling and adaptive mechanism within the built up environment and the transition of river region environments from dynamic and systematic perspective. Their view will provide the framework for conserving human wisdom regarding water and river management and preserving river related cultural heritage (Wang and Gao, 2020).

Abebe, et al. (2020) viewed that the sustainable development of water resources retaining same amount of natural flow regime water bodies to project and maintain aquatic ecosystem health and the human livelihoods and well-being depend upon them. Although assessment of e-flow is now occurring globally, limited studies have been carried out in Ethiopian highlands especially studies to understand responses and flow–ecological relationship. The studies found that there is decrease in both low flow and high flow, which is attributed to the expansion of pump irrigation, catchment interventions and rainfall variability. The flow reduction results in early disconnection of flood plain wetland from the river, which in turn affects breeding cycle of migratory fishes. Hence the Gumera River an associate wetlands need restoration of ecologically relevant flows (large flood, small flood high flood, pulses, low flows and extreme low-flow) to reserve the deterioration of aquatic ecosystem in the river – water and lake interconnections.

Shrestha (2017) in his study of bio-diversity resources to livelihood of Lamabagar VDC has observed that livelihood of the local people are totally dependent on the biodiversity resources like fire wood, timber, fodder and forage for household consumption and animal husbandry. Moreover, these resources are also used as raw materials for local industries. Out of total households in the study area the share of biodiversity resources turns out to be 22 per cent. However, these resources are at risk due to infrastructure development works like roads and hydropower projects.

Shrestha (2011) while carrying out a study on the livelihood pattern of Majhi community along the Tamakoshi River has also discussed about the livelihood pattern of Majhi community in the Tamakoshi River Basin. The livelihood of Majhi community on the fishing activities has been decreased due course of time. In the past this community adopted fishing as the main occupation but now it has become a secondary occupation. They are mostly engaged in non-fishing activities like wage labour within the district and outside Dolakha and Ramechhap districts. They are also engaged in farm activities but production from the farm activities are not enough to support a year round.

Sharma (2005) has concluded that many researchers have studied in different aspects the Bagmati and it is the most extracted river in Nepal followed by River Kaligandaki. The Bagmati River has been one of the most polluted river due to varied anthropogenic activities of which discharge of untreated sewage and extraction of sand and boulders. The extraction works in various places along the Bagmati River has spoiled its ecological system. Other uses of river are washing of vegetables, carpet washing and drinking water. It is recommended to conduct a detailed research on this aspect.

Pandey and Bharati (2017) have opined that rivers are certainly the source of secure water, energy and food for millions of people. They are also the source of freshwater ecosystem as well as a part natural beauty and the hydrological cycle. Any water resources development plan should therefore aim at balancing various functions of rivers. Securing water is not only the means of providing sustainable access to adequate quantities and acceptable quality of water but also ensuring health of human being and ecosystem. The central focus of all those principles is on balancing the demands by achieving societal objectives under a wide range of plausible futures. The key questions of balancing human and environmental needs of water and understanding trade-offs between various forms of water resources development scenarios in the Western Nepal is still questionable. They are of opinion that sound knowledge, and different model approaches, and integrated policies are needed to quantify the e-flow guidelines in the country.

Shrestha (2016) has assessed the over use of energy from the Tamakoshi River of Nepal which has affected the processes and services of the ecosystem. He further emphasizes that after opening up of the river of Nepal for energy hydropower generation numbers of foreign and Nepalese companies are setup in Nepal for investment in hydropower projects. Many companies have been issued licenses to generate hydropower in a single river. This activity has challenged the government, local people and river health. Activities like flow of water, its provisioning services to local people, cultural heritage and livelihood of local people are not given due priority. The basin has a capacity of producing 2000 MW of hydropower and 24 different companies have applied for interruption of the river flow to produce hydropower. Local people and even high level officials are unaware about the cumulative impact of such activities. These issues are to be addressed by the strategic level as soon as possible.

Lal (2016) is of opinion that one of the important challenges facing the world today is increasing stress on surface water resource in light of demographic, economic and other aspects. He showed that the monetized societal benefits from quantifying monetary values of ecosystem services outstrip other cost. Based on study of USA and Rwanda, he concludes that societal costs can have significant effects towards realizing multiple land and water related cost-benefits arising from flood control infrastructure and other development projects.

Bala (2014) has carried out a research namely "Environmental and physio-cultural perspectives towards the challenges of river Ganga at Varanasi". The objective of the study is to investigate water ecology of Ganga River. She has also shown that unplanned urbanization, industrialization and over exploitation of natural resources are the main causes of water quality degradation of Ganga River in Varanasi, India. It is a holy a city with population of one million people that many tourists visits the place to have a “holy dip” in the Ganges for *moksha* and rinse their sins release of around 200 million liters of untreated human sewer into the river each day, leads to large concentrations of fecal coliform of bacteria in the water. In the upstream of

Varanasi's Ghats, there are 60,000 fecal coli form bacteria per 100 ml which is more than 120 times higher compared to the official standard. So the water is very much contaminated. In the ranking of Polluted Rivers the Ganges was ranked as the fifth most polluted river in the world in 2007. Pollution threatens not only humans, but also more than 140 fish species, 90 amphibian species and the endangered Ganges river dolphin. The Ganga Action Plan, an environmental initiative to clean up the river, has been a major failure due to corruption, lack of technical expertise, poor environmental planning, and lack of support from religious authorities.

Pokharel (2013) has assessed people's perception about wetlands in Jhapa and Morang districts'. Activities like rapid population growth and over exploitation of resources, and development activities have been contributing to the degradation of wetlands and their resources in terms of frequency, coverage, quality and availability. The wetlands which are far from the market centre and settlements are less disturbed than the wetlands nearby the market centers and settlements. So shrinking rate of the Kechana wetland is the lowest during the past forty years. Therefore, there is a need of in-depth studies representing different geographical regions so as to understand the status and dynamics of wetlands and their resources in the country.

Uprety (2013) is of opinion that policies, strategies, and legal instruments are to be formulated and implemented for conservation of biodiversity and environmental resources. The basic question is how to operationalize the impact assessment for biodiversity conservation. The Ramasr convention provides ample opportunities to expand initiatives for biodiversity conservation through environmental assessment but the process is lagging behind in our context.

Dutta (2014) has surveyed the Ganga river and its tributaries flowing through Haridwar, part of the Himalayan foothill region. Several evidences, including satellite data (LISS-III & LISS-IV image), topographic data, GPS data, sediment logical data, subsurface structural information and hydrological data were used to understand the mechanism of aggrading channel characteristics and associated fluvial hazards like flood, stream bank erosion, and soil erosion. Except the Ganga River and Solani, all tributaries are non-perennial type of streams. Rivers are characterized with rapid sedimentation of boulders, pebbles and sand, Channel shifting and avulsion are evident characteristics of drainages in the Himalayan foothill region. However, the mode and magnitude of sedimentation, shifting and avulsion depend on a number of geomorphic, hydrologic and geological factors including tectonics.

Jha and Belbase (2013) have discussed the relstionship between different types of acts directly related to the environment. It has also analyzed Forest Nationalization Act (1957 A.D) and National Wetland Policy (2012 A.D.). They have also discussed on provisions of EPA (1996) and EPR (1997), National Wetland Policy (2012) which have laid emphasis on the proper implementation of the policy for ecological conservation. There are many reasons for inadequate outcomes of environmental management efforts, but major ones are political instability and poor governance. The executive and legislature need to give more priority to human and financial resources in order to ensure effective implementation of environmental policy.

Thakur, Gozzolz, Peel, Fisher & Kidd (2009) are of opinion that transformative learning is essential to establish features of environmental planning, management and assessment. They have explored the extent to which strategic environmental assessment (SEA) can facilitate learning at an organization and individual level, and ultimately, achieve effectiveness. It is based on the assumption that SEA effectiveness can be achieved only if plan, policy and programmes are oriented towards the improvement in decision-making process and implementation. The research indicates that, three countries namely German, Italy and France have developed distinct approaches to SEA to improve the learning outcomes of SEA as efforts to differentiate between skills and knowledge needed to improve its learning outcomes. Furthermore research work is needed to improve SEA's learning outcomes and enhance EA, SEA and its application.

Khadka and Khanal, (2008) have studied impact of EMP in ecological condition in the river basin of the Melamchi. In accordance with the Environmental Protection Regulation of Nepal (1997), the Melamchi Water Supply Project (MWSP) has undergone an EIA during the stage of feasibility study of the proposed project. They have raised ecological concerns in the EIA. They have also developed Environmental Management Plan (EMP) to address environmental compliance and other issues with participation of the local people. They have also provided some lessons to learn on the modalities of addressing the demands and grievances of the local people concerning environmental management and flow regime.

Gaurav Integrated Development Association (2004) while examining the river ecology of Sunkoshi and Indrawoti. The study has reported their different types of fishes are found in Dolalghat (Sunkoshi River) and 22 species of fishes are found in the Indrawati River. Similarly, majority of fishing livelihood is associated with Majhi people of the Sunkoshi and Indrawoti River. However, sand extraction and dewatering at several places have threatened both fish diversity and the livelihood of Majhi people.

Ranjit (2002) has found that Asala (*schizothora*) is a very common and dominant fish species found in the river from Tatopani to Dolalghat. He has listed a total of 18 cold-water species with updated nomenclature and systematic position. The prospect of ranching Mahaseer (Tor spp) has been reported by Shrestha (2002) in the running waters of Nepal.

Shrestha (2002) has described problems and mitigation measures of cold-water fisheries development in Nepal. He has highlighted economic prospectus of cold-water fishes for self-employment and income generating opportunities for poor fish farmers. He has reported that 31 species of fishes are found in the Koshi River System. Similarly, he has discovered 69 species of fish belonging to 9 groups and 19 families that are found in the Narayani River system in 2001.

Cooper and Canter (1997) have studied the cumulative impact of EA based on a questionnaire survey of EIA practitioners in the United States of America. The geographical boundaries (spatial boundaries), life cycle considerations (temporal boundaries), and recognition of all projects in the study area (past, present, and future) are becoming more important issues in the current EIA process (Swick 1994). As more consideration is directed to cumulative impacts (CIs) and cumulative impact assessment (CIA) within the EIA process, it has been realized that minimal guidance is available on a variety of substantive issues. Because the focus was on substantive issues rather than administrative requirements, the results should have applicability to CIA requirements within the EIA process of many countries. Moreover, bilateral and multilateral aid agencies, international organizations, and lending institutions have financial capital also complied with EIA guidelines to award projects and lending activities.

Gautam (1990) has conducted a research namely "Ecology and Pollution of Mountain Waters: A Case Study of Bhagarathi River." The study area covers from Uttar Kaski to Deo Prag. The variables used for the study are temperature, salt, COD, BOD, turbidity and conductivity. He has also observed that BOD and COD increase from upstream to downstream which indicates the impact of anthropogenic activities in the downstream. All the nutrients are recorded higher during the winter, which is attributed to the low filtering capacity because of low flow and high human activities in the downstream.

Similarly, pollution in the river is caused by anthropogenic and more human activities in the downstream. The biochemical use of water and water standards mentioned in this study are also very useful (Gautam, 1990).

Shrestha (1988) has extensively studied the resource endowment; its implication in the Tinau Watershed of Palpa district. He is of opinion that there are two sources of water namely surface and ground water. Most of the rivers are originated from the Mahabharat and Siwalik ranges and there are no rivers in this district with perennial sources from the Himalaya. Most of people in the rural areas depend on the sources like river, pond and spring for washing, animals, and irrigation. At the outlet of the Tinau watershed the water of the Tinau Khola has been diverted from 2 km long stretch for producing hydropower with a capacity of 1000 kw and distributed to the surrounding villages. Similarly, unscientific land use practices and cultivation of more marginal land by people have posed severe problems in the area like soil erosion, and other environmental resources. So he is of opinions that a long term plan is needed to preserve the environment of the watershed (Shrestha, 1988).

Maburajuza, Tumwesigye, Otim, Akurut, Mutikanga (2022) have published an article namely "Water Flow and downstream effect in the South Uganda." He concludes that the increasing number of reservoirs in the world in the name of hydroelectric have enhanced the use of energy which have benefited governments and companies. He opines that, there is problem in the upstream but the problem in the downstream is more serious than the upstream. In many cases even people who have been living in the areas since historical time have to change their livelihood and even in some cases, they have to migrate to other places. Citing an example of the Owens dam of Uganda, he explains that the construction of the dam outlet of Lake Victoria has not made any changes on the local hydrological regime but it has changed the whole aquatic ecosystem. He has also observed that the exploitation of hydraulic head in the name of cascading system of dam river basin may impact on the local area.

Mujapuria and Shrestha (1968) have studied aquatic ecology of fresh water of Kathmandu valley with reference to fish production, marketing management and conservation. Similarly, other works on the fish ecology were carried out by Budhathoki and Sapkota (2018), Wazir Singh Larka, Uttam Kumar Sarkar, Rupali Sani Kumar, Ajaya Pandey, Om Gusain (2010) in different parts of Nepal and India. However, they focused on the production part of the river ecology. Likewise, Shrestha (1966) has studied fresh water of the Tadi River Shrestha and Shrestha (2015) have studied fresh water ecology for practical purposes like fish farming in different parts of the river basin of Tadi and Trishuli River.

Hamilton (1822) was the first person to provide an idea of descriptive ecology of the Himalayan fishes by writing a book on it namely "River Fishes in Gange and Nepal". In this book there are descriptions of 269 species of fish from different water systems of Nepal and India.

Nepal (2014) in his doctoral dissertation entitled "Upstream-downstream linkages of hydrological Process in the Himalayan region" attempts to explore the issue of relation between ecological support of stream to the riparian people in the Dudha Khoshi and Sunkoshi river basin and lives and livelihoods for millions of people living downstream. The study has used hydrological and bio-physical data to establish this relation.

The analysis is based on time series data analysis for spatial and temporal change and data on the average temperature, precipitation and discharge. The trend analysis, precipitation, and discharge were carried out using a non-parametric Mann-Kendall (MK) test (Mann, 1945). In this test Hydrological system, Leopold matrix was used to analyzes the magnitude, extent and duration of specific issues of the proposed project,

The future scenario of the e- flow was analyzed to assess the cumulative impact of hydrology in the basin. The other attention was given to understand how the communities might be affected by existing system of change in hydrology of the lean water flow.

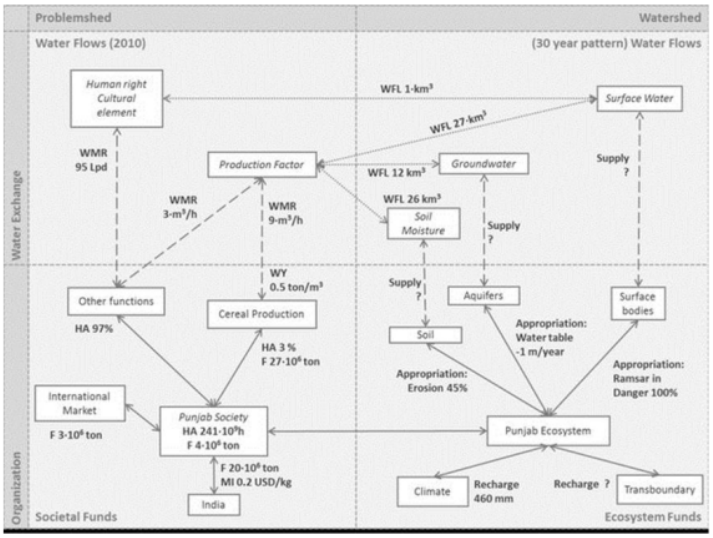
The PRECIS data during pre- monsoon, monsoon and post –monsoon replicated the seasonal pattern of precipitation and temperature changed. The temperature and precipitation of the Koshi River basin is presumed to increase by 4^0C or 14 per cent by the end of the 21 century (Nepal 2014). From modeling results, the basin's discharge will increase mostly during the monsoon season. Due to an increase in temperature evapotranspiration will be increased. Similarly, the snow line will shift to higher altitude areas which will decrease the snow melt contribution. This will reduce the snow-storage capacity of the basin, and the streak is likely to be shifted in types from a melt-dominated river to a 'rain-dominated river". The study also emphasized on the strategic plan of the basin level project implementation for inter country benefit of Nepal and India. The government of Nepal started to prepare the bigger project like Saptakoshi High Dam Multipurpose project for Saptakoshi Hydrop dam purpose.

Gurnell, Moggridge, MC Gregor, Goslain and Jones (2008) have carried out study on "A Baseline Appraisal of Water Dependent Ecosystem Services " based on DESKOTA methodology. They are of opinion that livelihood system is based on water ecosystem and its is linked with various components; hydrology, climate, precipitation, ground water etc. However, due to change in climatic scenario many ecological services have changed. Among various activities anthropogenic activities are of major factor for changing the water dependent ecosystem. They emphasized that if this changes goes on the further it will fragment the ecosystem. So they stress on need to understanding proper interaction between different components- ecology, hydrology, ground water recharge etc.

Gomi, Roy and Richardson (2002) have researched on" Understanding process and downstream linkages of headwater systems in general system. The objective of the study is to review the characteristics of the difference between headwater and large water systems in terms of interaction between the headwaters and downstream system. The interdisciplinary approach was used to analyze the inter-linkages between headwater and downstream by using hydrologic, geomorphic and biological variables. They are of opinion that the linkages between headwater and downstream are important in the context of all three variables like geomorphology, hydrology and biology. The paper shows the inter-linkage among the angle, deposit, slope, depth and power. The understanding of the spatial and temporal variations of hydrologic, geomorphic and biological processes in headwater systems is the key to comprehending the dirthy and heterogeneity of the riparian and riverine ecosystems.

The process from the headwaters to the downstream systems is often discontinued because of change in valley width, tributary junctions, angle, sub-strata size and channel gradient (Benda and Cundy, 1990, Ward and Stanfor, 1995. The equilibrium concept of geomorphology (Leopoled, et all 1964) which demonstrates the relationship between the sediment supply and transport lead to the development of geomorphic perspective fluvial process in continuum from the upstream to the downstream.

Madrid-Lopez and Giampietro (2015) in their work on "The water metabolism of socio-ecological systems: They are of view that the natural water cycle and anthropogenic activities have been related in broad concept of Global Water partnership (GWP, 2005; Hoffer, 2010). The objectives of their work are to make explicit the reasons that hinder the inclusion of water in metabolism studies and to create an intellectual space where the fields of metabolism studies and SE-hydrology can converge. Water metabolism and socio- ecological system are interacted. The metabolism lacks a comprehensive analysis of socio-ecosystem dynamics (Golubic, 2012). The socio- metabolism is intricate with ecosystem metabolism. This is a geo-physical exchange between physical and social mechanism. The methods developed in SE-hydrology for the assessment of coupled water-human systems have been influenced by the water balances of traditional hydrology as well as by the flow assessment of metabolism studies (relation B in figure 2.2).



Source: Madrid-Lopez & Gaimpietro (2015).

Figure 2.2: **The water metabolism of SES based on and example from Indian Punjab (2015)**

A- Society is fundamental to energy flow.

B- Energy and materials are exchangeable. An important output is bio-physical flows.

C- Ecosystem with materials flow (Odium). Ecosystem moves from one system to another

D- A structural organization lies between societal system and ecological system.

Societal and ecosystem metabolism are considered differently but they are strongly interrelated and connected processes. They also include societal metabolism studies. During industrial revolution the exploitation of fossil fuel was deeply associated with swift social change which is uni-directional and reverse. Unlike fossils resource the water is multidimensional resource that does not change its molecular composition. Indeed a certain mass of water can first be used for moving turbine e-flow in a society then for maintaining the life of the riparian plants in the ecosystem, the earth behaves as a self-regulatory system composed of physical, chemical, biological, human components (GWP, 2005). The system is composed of two problems namely watershed problems and problemshed problems.

The watershed problem domain provides the external view of social- ecological metabolism. In this domain, water is considered as a fund, structural component of ecosystem that contributes to expression of its identifying that which must be conserved. The level defined in this domain takes into account fund such as the riparian's plant, river flow pattern or different besides and sub basins.

The problemshed domain offers the internal view of the metabolism pattern of the socio-economic pattern. In this domain the level of analysis are regular phenomena taking into account the societal functions. These functions include energy transformation, food production and impact. In this domain water is considered as a flow that contributes the stability of society.

Using an example of the hydropower project the water under to move turbine will be analyzed at level s-I. Once it flows back to the river, its availability for other societal work and environment use, this hasn't effect the flowing "backward to upper level of the representation."

Delima and Morersidik (2018) have studied the integration of human ecology and sustainable development in the city of Balam, Indonesia. They are of view that human ecology with environment is the most important component of sustainable development which is based on the three-pillar; economic, social and ecological. The economic power raises the cost of environmental degradation. The inclosing of human approach is the most important. Without fulfilling the basic needs (water, food, shelter and energy), the sustainability cannot be achieved.

The study has used Likert method of qualitative data of human ecology and sustainable development, which rank from one to five, The services on the health related activities were the main component of the study of Balm city. The pre-requisite on the healthy service is good health, housing condition, water availability, good livelihood and employment. The study emphasized on the development of strategic plan for streamlining the ecological integration. However, fluctuations in terms of individuals, population as well and environmental conditions are highly influential. The study warned possible ecological disaster of coastal area due to lack of strategic plan in the city of Balan.

2.2 Government of Nepal Policies on Water and Environment

The federal constitution of Nepal (2015) has classified the fundamental rights of the Nepali citizens under 41 groups and among them rights regarding clean environment has been provisioned in the 38th group. The citizens are not only guaranteed about clean and healthy environment but also to protect them from environmental pollution and degradation. The constitution also has a provision to strike a balance between development projects and environmental degradation. In the 4th part of the constitution directive principles have been provisioned and in the H part there is a provision of conservation, promotion and utilization of natural resources. Schedules from 5 to 9 of the constitution have delegated the powers to the provincial and local governments to protect, promote and use of available natural resources in an environment friendly, and sustainable way. Accordingly, the government has enacted many laws to implement these constitutional provisions.

Khanal and Bhatta (2013) are of view that a separate policy on environment is felt needed after adoption of National Environmental Policy Act in USA in 1970 and Nepal also followed the path and enacted Environmental Protection Act (1996) and Environmental Protection Rule(1997) as well as sectoral policy, laws and guidelines. Following the enactment of EPA and EPR it became mandatory to work as per EIA findings in every development projects. They have also mentioned that the provisions of SEA have not been complied by the government institutions at the local level and federal levels. So, they have recommended incorporating SEA policy to improve the implementation system in Nepal.

Aryal (2014) is of opinion that the Hydropower Policy of 1992 was introduced for amendment in the policies of the water resource sector of the Nepal government. The policy seeks to conserve resources and protect environment of the river basin in sustainable manner. It has adopted environmental assessment processes and techniques for achieving sustainable development goals. However, the policy does not give any reference to other principles of sustainable development such as ecosystem approach to watershed management, conservation of indigenous techniques, aquatic diversity including endemic, rare, endangered species, and their habitat. For the smooth working of the ecological system of the river basin, each and every hydropower project should ensure the release of at least monthly 10 per cent of the existing water flow of the river after constructing dams for power generation. Neither in the current environmental legislation, nor in the EIA/ IEE practice and guidelines there is no mention of clear process and procedures for e-flows. Moreover, there has not been standard procedure to fix the minimum environmental release for maintaining river aesthetics.

The Water Resource Act (1992) was enacted on 17 December 1992. It is expedient to make arrangement for rational utilization, conservation, management and development of water resources in Nepal. It has envisioned to use surface water, underground water or in whatsoever form. It also laid emphasis on legal arrangements for determining beneficial uses of water resources, preventing environmental and other hazardous effects and keeping water resources free from pollution.

The Hydropower Development Policy (2001) states in its article 5.7 their contribution shall be made to environment protection by developing hydropower as an alternative to the biomass and thermal energy.

The Aquatic Life Protection Act (1997) was enacted on 20th February 1997 which provides legislative protection for the habitats of aquatic species. It obliges to carry out different activities to minimize the adverse impact on aquatic life, which includes,

- construction of a fish ladder at the dam site to ensure the movement of fish and
- provision of punishment is there for those who work with the intent of catching or killing aquatic life

The National Environment Policy (2019) was endorsed by the Nepal government to control pollution, manage waste and promotes greenery to ensure citizens right to live in a fair and healthy environment. The policy was framed to guide the implementation of environmental related laws and other thematic areas as per Nepal's international commitment. It also seeks collaboration among all concerned government agencies and non-governmental organization on environmental management activities.

Environmental law is drawn upon from and influenced by principles of environmentalism: including ecology, conservation stewardship, and responsibility. Environmental law is hence to prevent any form of negative externality (Bothe, 1980)

Ministry of Local Development (2010 Ref. 1413) on Dhunga (Stone and Sand Extraction) Provision Circulated by Cabinet. A per EPA (1997) EPR (1997) the daily extraction of sand and gravel up to 300 m^3 need IEE but for more than 300 m^3 they will need to conduct EIA prior to mining sand and gravel from river or streams. Mines Act (1956) attracts this provision and Department of Mines and Geology is an authorized agency for issuing license. However, in 2017 the government decides to make separate decision for this.

As per the decision taken by the Nepal Government on 2 May, 2017 the Ministry of Federal Affairs and Local Development (MoFALD) isresponsible to direct the District Coordination Committee (DCC) on how to manage extraction, sale and export of river product like sand, pebbles and stones and to designate quarries collection sites, quantity and procedures for extraction of river products.

A monitoring committee led by the Chief District Office of the district in question fixes the maximum price of river products, including stones, pebbles and sand, for the district on the basis of extraction cost and the distance between the excavation sites and the market. The price may differ from place to place depending on the total extraction cost.

District Coordination Comittee shall have a bank account in which the amount received from the sale of construction materials can be deposited. No expenditure can be incurred from the account and it can not be shared with any expenditure for purpose of distribution of local levels on. The government is required to spend 10% of its revenue to restore ecological balance of the river corridor.

Nepal started its planned development effort in 1956 and it was the Eighth Plan (1992-1997), which incorporated environmental considerations as a separate chapter and also infused environmental concerns in its sectoral objectives and policy enunciation. It emphasized the need to internalize the environmental impact assessment (EIA) system, improve legislative measures and conserve natural resources. The process has been in diferent plan from the Eighth plan to the fifteen five year plan.

The main objective of the 15th five-year plan (2019-2024) (NPC, 2019) is to achieve prosperity, self-reliance and socialism oriented and happy Nepali economy. It has adopted sustainable development goal (SDG) as its main agenda to be achieved by the year 2030. It aims to increase per capital income of Nepali people up to US$ 12,100.

The vision of the plan is to make environment pure, clear and green. For achieving this mission, the plan has adopted different strategies. The government plan has focused on pure flow of natural water, biodiversity conservation and climate change. The policy of the government will be implemented on an international pact and convention in which Nepal is a partner for the national, regional and international issues in conservation of environment (NPC, 2019).

2.3 The Research Gaps

The gap in underdtanding interaction between river ecology and local communities has been found out at several levels. At the basin hydrological level, very few studies have been carried out on spatial and temporal study of the flow regime. The hydrological studies are separately carried out but integration of hydrology with other aspect is lacking. This has been due to the lack of proper study on the spatial and temporal level of the flow regime, its relation with sub-watershed and overall basin.

The level of study is temperature and preipitaion change, climatic changes and its effect on local people some of the hydrological regime and it consequences is not satisfactory. As a result, the people by affected flow regime of the basin are not in good in condition, which is well observed in the basin. The overall study of the hydrology, and its product resources in the basin is not properly mentioned. Furthermore, the livelihood of the people of the riparian area is associated with flow regime, its product resources is another important aspect of the river basin, which is interacted by flow regime.

The perception level of the study is concentrated in sporadic level, no basin level perception is captured in the academic field. The development and academic level of study has not focused on riparian settlements marginalized, unprivileged and economically backward groups (KC, 1991; Thapa and Weber, 1990; Basnet, 1992; Koriala, 2002; Stevens, 1989; Manandhar, 1988; Rijal, 2006; Balasubramnin, 2019)

a. Research gaps on basin hydrology

The basin hydrology is described for technical aspects only (Woo, 2010; KC, 1992; Shrestha, 1990; Poudel, 2001; Mishra, Tripathi and Babel, 014; JVS/GWP, 2016; Dongol, Mertz, Dhakal and Dangol, 2005; Suwal, 2010; Dahal, Shrestha, Tuitai and Ojha, 2018). The hydrology is described in terms of its potentiality of hydropower, irrigation in the lower basin, and sedimentation process at macro level. The collection of appropriate information requires collaboration of interdisciplinary aspects of hydrology, geomorphology, biology and socioeconomic which are found to be scanty.

b. Research gaps on river ecology

Research has been carried out river basin biology, in fish species, fish habits and relation with biotic phenomena. But interaction of aquatic ecology with changing condition of development activities and flow zone parameters are lacking. The studies on the overall system with relation of chemical composition along with the riparian communities and it condition are scanty (Hamilton,1822); Mijapuriya and Shrestha ,1968; (Nepal, 2014; Gurnell Muggridge Greager, Goulson and Jones, 2008).

Hyporheic process may be enhanced at the junction because of the accumulation and exchange of material. But this subject has not been studied (Richer et al., 1996). The connectivity of headwater to downstream reaches must be evaluated in further studies to understand cumulative effects of changes in headwaters.

Two general types of studies are needed to understand headwater processes and downstream linkages. Process –related studies within headwater stream are essential. Despite the progress in elucidating hydromorphic (Sidle et al; 2000) and biological (Richard, 1992; Wallsce et al., 1999) process from hill slope to stream channels, a better understanding of the functional linkages among woods, sediment and nutrients, and water in headwater system is needed to address the relevant ecosystem process. Water metabolism and socio- ecological systems are interacted (Sidle et al; 2000). Moreover, the metabolism lacks a comprehensive analysis of socio-ecosystem dynamics (Golubic, 2012).

c. Research gaps river resource, livelihood and interaction with local communities'

Several studies carried out by Sada, (2017); Khadka and Khanal, (2008); Alam, (2016) and they have emphasized that the flow of river have been interrupted in different parts of the world for water supply to urban, making high dam for hydropower and irrigating farmland. Likewise, other studies like Poudel, (2001); Weber & Thapa (1989); K. C., (1992); Shrestha, (1990); Rijal, (2006) have emphasized on resources of watershed management within the last two decades in major river basins for energy production. However, a detail research on the use and interaction of the riparian resources interdependence of the flow ecology, and e-flow hydrology river stretch along with river flow and its interaction is lacking. The relationship between flow of water and riparian communities, the water flow and its interaction with local communities domain not been focused in the past studies. Hence, in order to fulfill this gap the present research has been carried out.

The gaps in the river ecology and its interaction are felt at different levels from a micro study level to a higher level and their coordination and study methodology. The micro level study is concentrated in a small level and it is not intact with basin level study. The absence of the relationship between the local study in the tributary level and its association with the basin level felt necessary.

Moreover, anthropogenic activities have increased stress on ecosystems, but the full impact of habitat fragmentation requires further research. Specifically, there is need for understanding how fragmentation affects the remaining habitat and the stage at which "threshold conditions" are reached, whereby ecosystem functioning is fundamentally altered. They have emphasized on understanding of relationship between ecology and hydrology (Gurnell, Moggridge, MC Gregor, Goslain and Jones, 2008).

d. Researh gaps in water governance policy

The sector policies EPA (2019), EPR (2020), Hydropower Policy (2001) adopted same provisions of ecological flow for mmaintening basin hydrology in the river basin and, Water Resource Strategy (2002), Aquatic Life Protection Act (1997) along with other sectoral water resource related policy, principles; guidelines commit to ensure that basin hydrology, and downstream water resource user and ecological condition can not be affected through e-flow hydrology. However, these aspects are not mentioned in other policy explicitly and implemented integrated properly. The prior right (appropriation) is in vogue in Nepal. Water resource strategy has not modified the status. Hence, the mandatory needed to provide downstream hydrology, water use, ecology is not clear in action and study is not carried out yet.

The sector policies principles, guidelines commit to ensure that basin hydrology, downstream water resource user and ecological condition can not be affected through e-flow hydrology. However, these factors are not mentioned in other policy explicitly and implemented properly. The prior right (appropriation) is in vogue in Nepal. Water resource strategy has not modified the status. Hence the mandatory needed to provide downstream hydrology, water use, ecology is not clear in action and study is not carried out yet.

Exploitation of water resources are guided by neo determinism than determinism and possibilism. Neo-determinism is evident in watershed management initiatives. By assessing the limits and potential of the local hydrological system, communities can develop effective water conservation and purification strategies, promoting sustainable water usage and safeguarding ecosystems.

River ecology and riparian settlement has close interrelationship with Neo-determinisms that came with development of ecological system. Consequently, the country started to exploits the flow regime of river system in the name of economic development to supply electricity. For this, government enacted the law in the name of maintaining ecological system through ecological flow and thereby maintaining the interaction between river ecology and riparian settlements.

The present research deals with river ecology and interaction with local settlement with respect to basin hydrology, river resources generation, aquatic ecology and perception on ecological flow maintaining the balance basin hydrology. Development activities along the river basin and aspiration of local people getting capital share from hydropower is the main component of river basin. On top of that, priority of government to raise the hydropower production is the major factor for changing hydrology, river resource, river ecology (Sada 2017) all above mentioned factors. In the long run, this will be the major challenge to government and local settlements to maintain the ecological system in the river basin.

The present conceptual framework tries to link up the river ecology with riparian settlement with respect to four important aspects; river flow regime, river resource, aquatic ecology, policies and perception.

"Environmental flows maintain basin hydrology- ecology relationship for diverse taxa including lower groups of flora and fauna, fish, riparian plants and terrestrial fauna associated with different riparian vegetation. It also contribute to ecosystem functioning and provisions of ecosystem services that are crucial for human well beings. It provides basin goods and services for food security, human health and contributes local livelihoods and economic development that are essential for achieving the sustainable Development Goals of 2030, including poverty reduction (Shah, 2023).

2.4 Conceptual Framework

Based on the literature, a conceptual framework has been prepared for this study and presented in Fig 2.3. The following conceptual framework model demonstrats the river basin hydrology and its interaction with flow regime and riparian communities. The desired environmental flows maintain basic hydrology–ecology aquatic ecology fish, terrestrial fauna associated with different riparian altitudinal ripples, pools, and community. It provides basic goods and services for food security, recharge in clean air and water, and contributes to local livelihood and economic development that are essential for achieving SDG by raising livelihood.

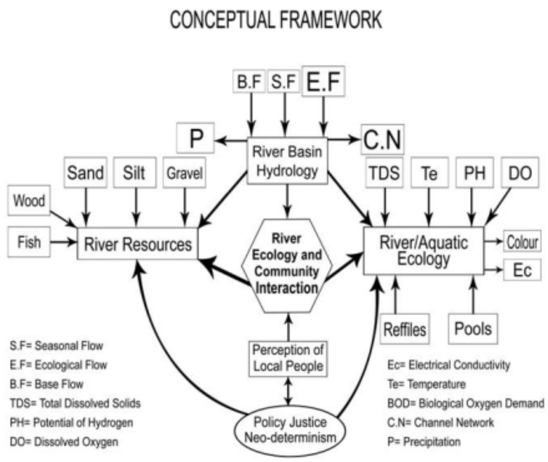


Figure 2.3: **Conceptual Framework**

Based on the review and conceptual framework developed for this study, a research design and methodology prepared which is discussed in the next chapter.

CHAPTER III
METHODOLOGY

The chapter starts with the selection of the study area, philosophical basis of the methodology adopted, sources of data, analysis of data, interpretation and ends with using indexes of the research.

3.1 Selection of Study Area

Tamakoshi River is one of the major tributaries of the Koshi river system. Moreover, it has significant role maintaining riparian settlements and river ecological system of the basin. A riparian zone with marked of buffer zone of 1000 meters on either side (east and west) of the Tamakoshi River has been defined for the study area. The other causes are; the mean distances from river to riparian communities is 416 meters ranging from 50 meter to 1600 meters; the local communities are dependent in water use highly within 1000 meter either sides. The local people regarding the issues also show the distance as the main dependent for water user than beyond 1000 meters. Presently it consists of 8 rural municipalities and two municipalities. Reasons for selecting the study area are as follows:

- Transboundary perennial river,
- High and low awareness of local people on ecological and environmental system,
- Water diversion of Upper Tamakoshi Hydropower Project with practice of e-flow by other hydropower projects- Khimti, Singati.
- Three types- pre monsson, monsoon and post-mnoonsoon of river flow control dams namely (already commissioning, ongoing and propose),

Representative water use in Tribeni in terms of socio-economic and ecological context from Bista community of Lapche to Majhi community of Tribeni.

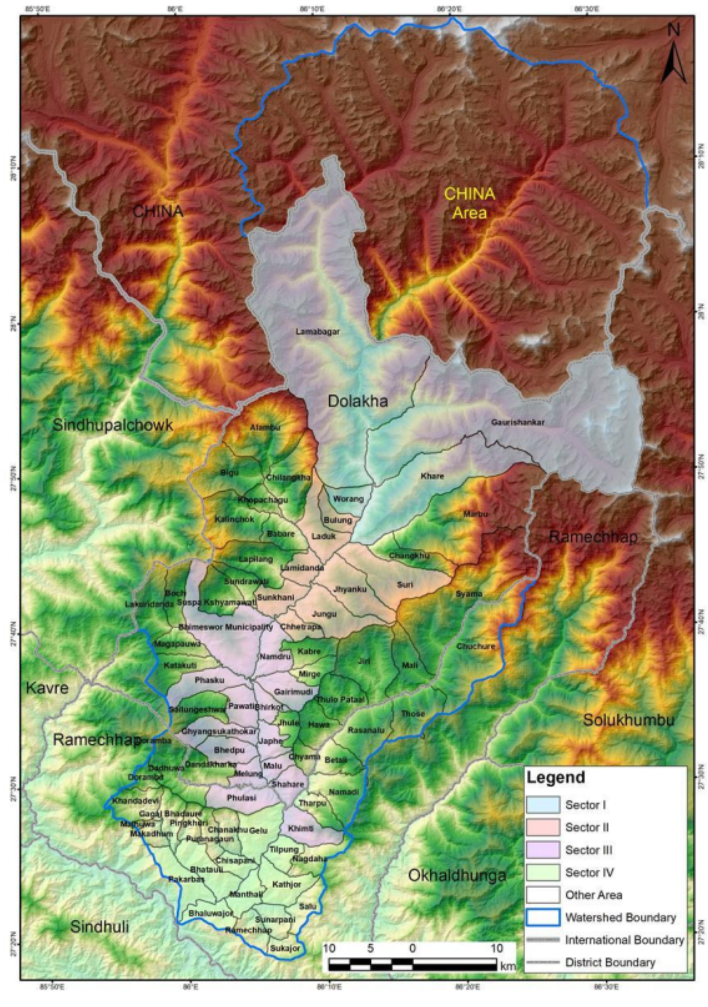


Figure 3.1: **Administrative Unit of Tamakoshi River Basin**

3.2 Philosophical Basis of the Study

Philosophy is an abstract way of thinking, which provides answers to the fundamental questions and it makes a distinction between "analytic" and 'synthetic" statements (Kuhn, 1970). Philosophy consists of framework of epistemology (theory of knowledge) and ontology (theory of existence) together with methodology. It indicates laws and forms of how information can be accumulated and arranged systematically to acquire the knowledge.

The positivism philosophical approach is a movement characterized with emphasis on science and scientific method as only the source of knowledge, making a sharp distinction between the realm of fact/data and value/culture and a strong hostility towards religion and traditional philosophy especially metaphysics and it is also called empiricism as philosophical view point that limits knowledge to facts that can be observed and to the relationship between these facts (Mark, Mathew, Guy, Marry , Michael, Lauren & James, 2017).

The present study is guided by two perspectives of knowledge: positivism and humanistic philosophy. This philosophy has supported to generalized the phenomena and its emphasized on objectivity and empirical generalizations.

This study has been carried out with knowledge of ecological phenomena of the river flow water. The applied theories in the study are hydrological theory (Sherman, 1932), river flow models (Moss, 1998), natural river system (Whoel, 2012). The adopted tools like biological use of mathematical and statistical tools, which are adapted to a new approach in the geographical concepts. Ideas of these theories and models are the sources of thought for the present research. The part of the natural flow is replaced with ecological flow. This is a paradigm shift due to technological advancement in the use of flow regime in water basins and its interaction with local communities of Nepal. The idea also attracts the theory of natural flow and its relation with local communities for long run.

Thus, positivism of this study is consisted of formal observation, flow measurement of the river, boulder size determination, sand and gravel deposit, data derived from different offices, and field survey. The knowledge of ontology and epistemology are applied. The interaction between river ecology and local communities takes positivism as research has carried out the research on his value and burdened appraise through information collected from various sources. So, the axiology is considered ladened value.

The humanistic philosophy has also been adopted in the sense that the researcher has collected qualitative data from discussions with local people, key informants, and collection of perception of people regarding hydrology of flow diversion, resource extraction (sand, gravels) and fishing activities. The locational aspect of settlement has been examined with the help of Chisholm model (1966) and Walter Christeller (1930).

The theory of deconstruction propounded by Jacques Derrida has also attracted over here (Turner, 2016). The feelings and knowledge are applied. Both positive and negative ideas are found in the form of flow regime disruption. The feelings of the people are now shattered by new idea of technology and e-flow over all condition of river basin.

The study is also related with structuralism and post structuralism. The structuralism approach has been adopted to apprehend the structure, process and pattern of flow regime and rainfall pattern. The flow pattern of river is conducted under the umbrella of "earth's interconnections between bio-physical atmospheric and certain science and other also includes human activity as driver or response to earth and environmental change" (Peet, 2011). This has been examined with the help of their feeling and the attitude towards the flow regime and its consequences. The difference of feelings and their association with river –ecology are thoroughly examined with the help of the technique like multi-criteria decision analysis (MCDA) (Kiker, 2005; Shrift, 2003).

3.3 Division of TRB into Sectors

The study area covers 106 kilometers only in Nepal, which stretches from the Chinese border to the Tribeni as the ending point to the confluence of Tamakoshi and Sunkoshi River. For the present study, spatially the river course with 1000 meter buffer zone has been divided into four spatial units and temporarily, the year has been divided into three hydrological seasons (pre-monsoon, monsoon and post-monsoon).The basin has been divided into four sectors from I to IV (Fig 3.2).

The basis of four sectors area as follows:

- Distinct of rainfall distribution (Scanty rainfall, moderate rainfall, high and low rainfall)
- Distinct pattern of population distribution in remote rural municipality, municipality from the north to the south.
- Remoteness with no road connection from Nepal side but adjoining to Tibetan Autonomious region of China, road connection with new emerging communities in one side, nodal point in the middle settlement and road connection from both Kathmandu and Terai in the southern side.

Table 3.1: ***Basin with four divisions***

Sector	Section	Area (Km^2)	Percentage
I(Upstream)	China Nepal border – Sipring Khola	745.74	27.62
II (Mid-stream Upper)	Sipring – Dolti Khola	625.59	23.16
III (Mid-stream Lower)	Dolti- Tilpung Khola	1024.38	37.94
IV(Downstream)	Tilpung – Tribeni Khola	304.02	11.26
		2699.73	100.00

Source: Field Survey, 2014/015

Sector I (Upstream): China-Nepal border to Sipring Khola

This sector starts from the China-Nepal border in the north to Sipring Khola in the south. The sector is characterized by V shape velley of the River Tamakosohi. Out of total streatch from Kathmandu to Lamabagar, the road from Jagat near Sipring Khola to Lamabagar comes under the section. Presently Bigu and Gaurishankar Rural Municipality fall under this sector. The communities like Lapche, Lumang, Lamabagar, Khare and Jagat are major locations of the sector (Fig. 3.2).

Sector II (Mid-stream Upper): Sipring Khola to Dolti Khola

This sector is located between Sipring Khola in the North to Dolti khola in the South. The initial area of the valley is steep but comparatively wide after Singati. Communities like Jhangreli, Singati Bazar, Pikhuti bazaar, Baguwa, and Kasheri lie in the sector. Presently Bigu Rural Municipality,Gaurishankar Rural Municipality and Baiteshwor Rural Municipality fall under this sector.

Sector III (Mid-stream Lower): Dolti Khola to Tilpung Khola

This sector is located between Dolti Khola in the north to Tilpung Khola in the south. It is one of the biggest sectors in the river basin. The Municipality of Bhimeshwore with then 13 VDC falls in the category. Presently Bhimeshwor Municipality, Sailung Rural Municipality, Melung Rural Municipality, Baiteshwor Rural Municipaity and Tamakoshi Rural Municipality fall under this category. The communities under the area are Nagdaha, Nyagal, Nayapool, Phasku, Bhirkot, Malu, Saharetaar and Khimtibensi.

Sector IV (Down Stream): Tilpung Khola to Tribeni Confluence

This sector is located between Tilpung Khola in the north to Tribeni in the south. The river flows relatively flat over here and river has made a broad valley in the southern part. Presently Manthali Municipality and Likhu Rural Municipality covers this area. Tilpung, Panthali, Kathajhor Manthali, Mugitaar and Bhautali are major communities of the sector (Fig. 3.2).

Figure 3.2: Sector division with buffer zone settlements of TRB

3.4 Sampling Design

The sampling design for the river hydrology (major and tributaries) coefficient of tributaries, direction and dimension, resources river geo-ecological conditions i.e. river geo-ecology, derived from the field survey are presented in Table 3.4 and Fig 3.3. Similarly, settlements selected for household survey are presented in Fig 3.4.

3.4.1 Measurement of Physical Parameter of River Networking

Sector	Major river	Tributary	Boulder and sand	Geo-ecology	River sub-stratum
I	Lapchi	Rolwaling	Lamabagar	Lamabagar	Lamabagar
	Lamabgar	Bhaisa	Bhaisa	Rolwaling	Gongar
	Gonger	Gonger	Gonger	Gonger	Sipring
II	Suri	Khare	Sungati	Jagat	Bhorle
	Singati	Singati	Pikhuti	Singati	Singati
	Gumkhola	Gumukhola	Gumkhola	Gumkhola	Gumkhola
III	Nagdaha	Dolti	Nagdaha	Dolti	Dolti
	Nayapool	Andheri	Bhanga	Nayapool	Charange
	Malu	Charange	Charange	Gopi	Malu
	Milti	Gopi	Gopi	Milti	Milti
	Khimti	Milti	Dholi	Andheri	Khimti
IV	Chisapani	Khimti	Chisapani	Chisapani	Chisapani
	Manthali	Mahadev	Kunaure	Kunauri	Kunaure
	Masantari	Ranajhor	Masantara	Manthai	Bhatauli
	Tribeni	Bhatauli	Tribeni	Tribeni	Tribeni

Tributary – location of sample flow measured in the confluence of the Tamakoshi river with the tributary joining from the both sides.

Boulder and sand- location of sample site measuring volume of stone, sand, pebbles.

Geo-ecology – location of sample where six chemical properties of Tamakoshi river were collected.

River substratum – Observed location of sites under the Tamakoshi river.

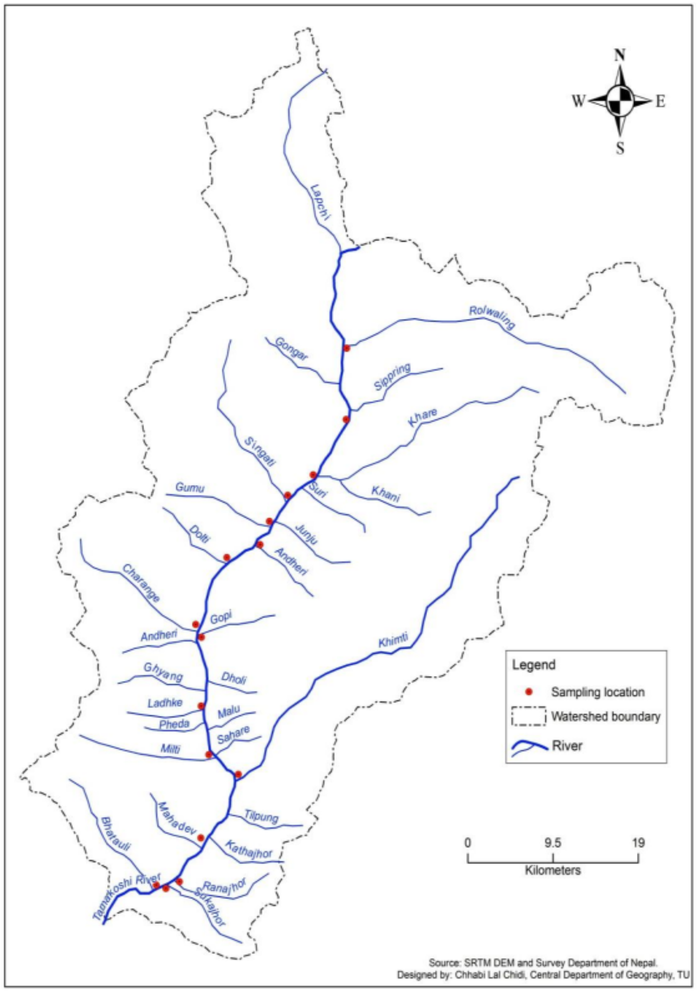


Figure 3.3: **Sampling site for Physical Parameter**

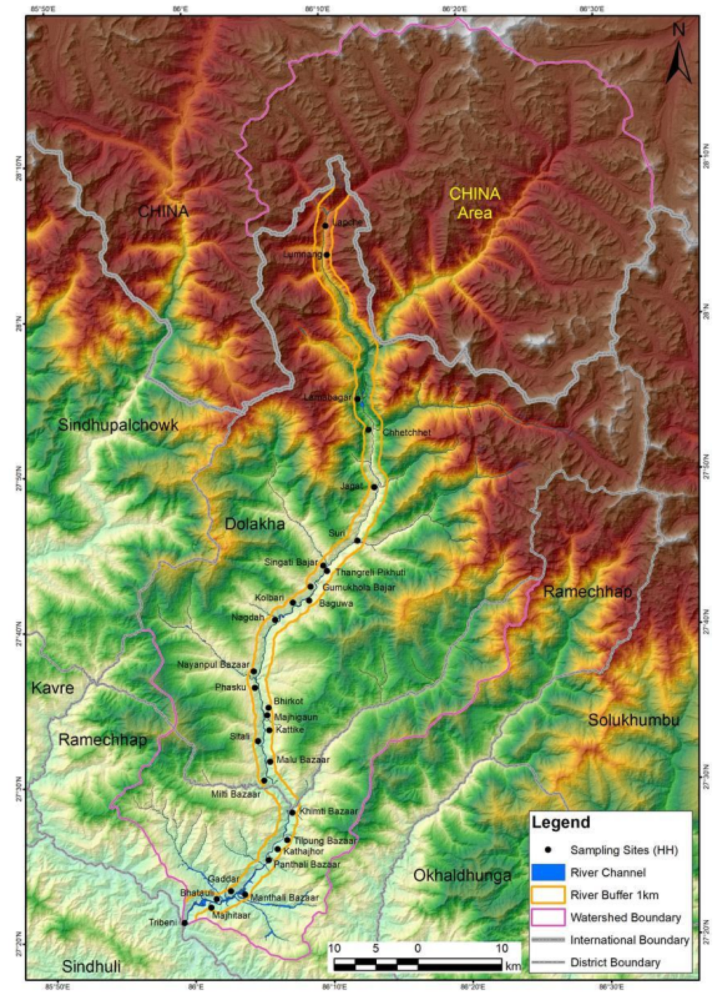


Figure 3.4: **Sampling Settlements for Household Survey**

3.5 Sources of Data

Both primary and secondary sources of data have been collected for this study.

3.5.1 Secondary Data

Spatial units are prepared by using the Arc GIS software and ERDASdas imagine software. For the analytic purpose of the study the Satellite data and image processing – Bird's Eye View and topographical sheets (no 27860, (1:50,000); 278605, 5B, 5A, 5B, 5C, 5D, 09A, 9B, 9C and 2785 12D (1: 25,000), are used. The source of data are from REDD, Department of Forest and Soil Conservation, Nepal GIS Project and Department of Survey. Similarly data published by district line agency offices like District Development Offices, District Forest office, and District Soil Conservation and Watershed Management office of Dolakha and Remcehhap are other sources of information.

Data regarding climate, hydrology and flow of 35 years are collected from the nearest hydrological station of DHM (Busti station, No.635). The collected data are analyzed to find out changes in the rainfall from stations of Manthali, Melung, Nagdaha, China, and temperature from Jiri station and the flow regime from Biusti station of DHM. Statistical tools like variance, correlation and regression and statistical significance tests are also used to find out the relationship between the flow, precipitation, temperature, slope width, sand and gravel depositon, and angle and river power.

Data published by the Central Bureau of Statistics on total number of households, and population structure are used for socio economic analysis. Likewise, data published by Department of Hydrology and Meteorology (DHM) and Khimti Hydropower Projectd and Upper Tamakosh Hydropower Projet are also used for physical part of the research. Mathematical tools (Singh and Singh, 1993; Unwin, 1981; Gupta, & Pundir, 2013; Chitrakar, 2014) have been used to explain the river flow, river direction, river slope, and river width and river profile. Published and unpublished policy documents and other relevant information are used to discuss the history of settlements. Periodic Plans, Acts and Rules, as well as policies, legal documents of information related to environment published by the local and national bodies are used as valuable source for the study.

3.5.2 Primary Data

The study is based on primary data collection from the field during the study period. To collect necessary primary data from the field, methods like pigmy meter, interview with questionnaire, observations, key informant interview (KII) and focus group discussions (FGD) are used. Moreover, geological and geographical data are also used. Likewise, policy issues are also discussed during the focus group discussion. All these methods have been used to verify the data collected from different methods .

The reconnaissance survey in the field was conducted from April 7 to 17 April 2014 from Lapchi to Triveni. During the reconnaissance survey following data were generated: flow regimes along the river, comparison of hydrological difference of various spatial units, analysis of locational differentiation of settlements along the riparian zone, explanation of the geo-hydrological variation associated with local units. Then the successive two months visit from July 18 to August 7th 2015 and another visit from October 8th to 15th December 2015 were made to collect the pre-monsoon, monsoon and post monsoon flow in the basin.

a. Flow rate: The flow pattern differs from one season to another season. For sampling, 15 locations are selected for flow data collection. This is enough as it represents a flow in every 7.5 kilometer because the geo-chemical parameter of the aquatic variable changes only after 10 km (Shrestha, 2007). Description of each survey so far carried out is given below.

Two students each from CDES (TU) and SchEMS (PU) were trained to measure the water flow of the Tamakoshi River in the pre- monsoon, monsoon and post monsoon. The velocity of water was measured thirce in these locations. The mean flow was derived by measuring the water flow in the said locations. The flow of the tributaries of Tamakoshi River is measured by using pigmy meter (Photo 1).

In order to study deposits of sand and gravel in the Tamakoshi River, 15 different river sites have been selected and data are collected using measurement of map and depth by asking local people nearby community and measuring by local people. The total quantity of the sand, pebbles and gravel has been measured through general formula: L× W× D; where L= length of the area, W= Width of the area and D= Depth of the area (Photo 2).

b. Boulder size (BS): Boulder size distribution has been collected through quadrate. The quadrate was conducted in 15 different locations along the river stretch. Each quadrate is in the size of 1mx1m and a total of at least 30 different types of stone are collected. The length, breadth, and height of the stone are measured using measuring tape to find out the total volume and weight of the stone. The floating wood was seen in several places and the estimation estimation was made in the respective locations.

c. River water chemical: For aquatic parameters, samples are collected from 15 locations from the Tamakoshi River in the times of pre-monsoon, monsoon and post monsoon to trace out quality of water. The sampling was collected in the morning (8;00 am -10:00am) and evening (4: 00pm -6:00pm) during the survey period (photo 3). Various parameter and tools that are used for this purpose are presented in Table 3.2.

Table 3.2: ***Water Sample Parameters of the Present Study***

S.N	Water Quality Parameter	Methods /Tools
1	pH	pH meter (Portable)
2	Electrical Conductivity	Conductivity meter (Portable)
3	Total Dissolved Solids	TDS Meter (Portable)
4	Temperature	Thermometer
5	Dissolved Oxygen	DO meter (Portable Oxygen meter)
6	Biological oxygen demand	BOD meter (Portable Oxygen meter)

Source: Field visit, 2014

d. Household survey: Households representing from the representative settlements of selected then VDCs' and municipalities adjacent to the Tamakoshi River flow have been selected. The CBS data of the 2011 have been used as sample frame for the survey work. The household is sample unit and household heads are respondent for resource use and perception about the water flow (photo 5, Appendix II, III).

The then thirty local units ten RMS and two municipalities) comprising population of 30,358, households were taken as study area of the Tamakoshi River Basin. To ensure representativeness of the household/ population from VDCs/ Municipality, a sample size was selected by using the following formula (Daniel and Terrel, 1995):

$$n = \frac{Z^2 P(1-P)}{e^2}$$

Where,

n= sample size

Z= the value of the standard variance

P= proportion of success event

e= the precision level

There is 95 percent confidence level with an allowable error of 4 percent. There is a 20 percent proportion of success chance. The required sample size for the household survey is 390 households. However, when it is allotted to different strata it comes to 412 households. This sample size is considered to be optimal. The sector is divided by adapting Neymen, Nxn%/100 (Parel, 1966).The proportion of sample households based on the sector wise households of the basin are assigned as Table 3.3.

Table 3.3: ***Sample Households***

Sector	Total Household	Sample Household	Percentage
I	1,558	40	9.7
II	6507	100	24.27
III	15,861	212	51.45
IV	10,886	60	14.56
Total	34,812	412	100.00

Source: Based on the results of populyion census 2011 published by CBS.

After deciding total units of the sample from each sector, the size of population for interview has been determined by taking into account the central limit theorem. As per the rule of thumb, if the size of sample is 30 or more, the distribution becomes normal and statistical test can be performed (Daniel and Terrell, 1995). The sample households selected randomly and presented in Appendix I.

3.6 Methods and Tools of Primary Data

3.6.1 River Hydrology

a. Discharge: The flow has been measured on the basis of area- velocity method. The total discharge (Q) is calculated by the method of mid-sections as follows (Subramanya, 2019).

$$Q = \sum_{t=1}^{N-1} \Delta Qi$$

Where,

Qi = discharge in the i[th] segment.

The figure 3.3 shown below is considered where the cross-section of a river is divided into N segments by N-1 vertical. The velocity averaged over the vertical at each section is known. Then,

Q $=\Sigma\Delta Q_j + \Delta Q_{n-1}$ Where,

$\Delta Q_1 = \bar{v}_1 . \Delta A_1$; $\Delta Q_{n-1} = \bar{v} A_{n-1}$ and j = 2 to (N-2)

Discharge except for 1[st] and last segment;

$\Delta Q_1 = \Delta A_j \text{ x } V_j$

= (depth at the j[th] segment) × ($\frac{1}{2}$ width to the left + $\frac{1}{2}$ width to right) x (average velocity at j[th] vertical)

$= yj \times (\frac{wj}{2} + \frac{wj+1}{2}) \times vj$

For, j = 2 to (N-2).

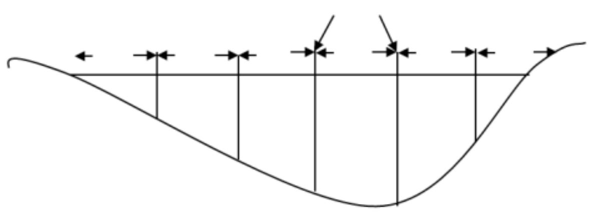


Figure 3.5: **Stream cross section**

The slope of the river course on toposheet is calculated using formula or<= tan^{-1}(P/B)

3.6.2 Observation

Observation is a tool for primary data collection and is systematic way of watching and listening a phenomenon (Kumar, 2011). The observation sheet was designed for soliciting the macro level information of location of village on public facilities and infrastructure, ethnicity rapids and pools. Similarly, land use, livelihood, their activities etc. were also observed. Likewise, places of fish abode, its migrating places were also observed and observation of the local market area of the study was also done temporarily and spatially in the basin. The observation sheet is attached in Appendix II.

River substratum, fish species and fishing community: The observation of the stretch was made first in the approachable sites with under water camera, (canon zoom lens 5x15, 50.260 mm 1394.8mm) and the stretches in the non-accessible sites have been calculated from the topographical and aerial photographs.

The diversity of the fish species has been identified from the interview with the local people with a scheduled questionnaire. To get the density of the fish species picture, other methods such as electro- fishing is also used. However, the density is also measured based on cast net and a kind of fishing net called *laharo passo* to calculate of the size of the catch fish per unit effort (CPUE).

3.6.3 Household Survey

General Information about family and its socio-economic structure was collected. The questionnaire section concentrates on household information which starts from location of the communities to attachment of the property like – locality, family structure, ownership, cereal crops production, drinking water, religion and food security (Photo 5). The questionnaire like family dependent on Tamakoshi, involvement of people on water related activities and its perceptions, involvement in gravel and sand extraction and grazing in nearby river side, etc. were other part of question. Detail of the household questionnaire is presented on Appendix - II

Key Informant Interview (KII)

Discussions were held with district line office like then DDC, DFO, DSCO and local VDC's. They were briefed about the topics related to existing activities and proposed plan of the riparian zone of the Tamakoshi River along the river course. Moreover, the most of the major problems of strategies adopted by the local government policies were also discussed with key informants.

3.6.4 Focus Group Discussion (FGD)

Informants have been selected on the basis of their expertise and experiences. In-depth discussions about the flow regime, resource use, livelihood of the local people, were discussed. Eight focus group discussions (FGD) were carried out at least two from each sector compirsing 6-8 persons from 2071/02/02 to 2072/06/28. The detail is mentioned below Table 3.4:

Table 3.4: ***FGD Locations***

S.N	Locations	Settlements	No of participants	District
I	Lamabagar	Lamabagar, Jagat	20	Dolakha
II	Lamidanda, Sunkhani	Singati, Gumukhola	37	Dolakha
III	Bhimeshwore Municipality	Charnage,Malukhola	40	Dolakha
IV	Manthali municipality	Akase Manthali	18	Ramechhap
Total			115	

Source: Field survey, 2014/2015

Local people, teachers, development workers and representative from offices of the district offices like District Forest Office, District Soil Conservation and Watershed Management and Planning Units of then District Development Committee were involved (Photo 5). The discussions focused on the existing condition of watershed, resource extraction, dependence of local people on the river resources, people's perception towards hydropower projects, and e-flow with cumulative impact on the flow regime. A standard checklist was developed to conduct the focus group discussion, which is attached herewith in Appendix - II.

The number of people participated in interaction range from 20 in Lamabagar to 40 in Charange. The size of interaction with people was small in Lamabagar and

Tribeni due to the size of settlement within buffer zone were small. The list of persons presented in FGD are presented in Appendix II.

During the interaction, the participants were briefed about the objectives of the study and issues to be discussed were sorted out. Deliberations were noted in the diary. The other information such as household size, their income, livelihood, literacy, etc. which was not covered by the household questionnaire was also sought during interaction in the field. The study adopted sectorial methods for generation of quantitative and qualitative data. The method adopted in this research is presented in methodological framework (Fig 3.6). Each of the methods and data generalized are analysed and the processing of data are generalized in fourth coming sections.

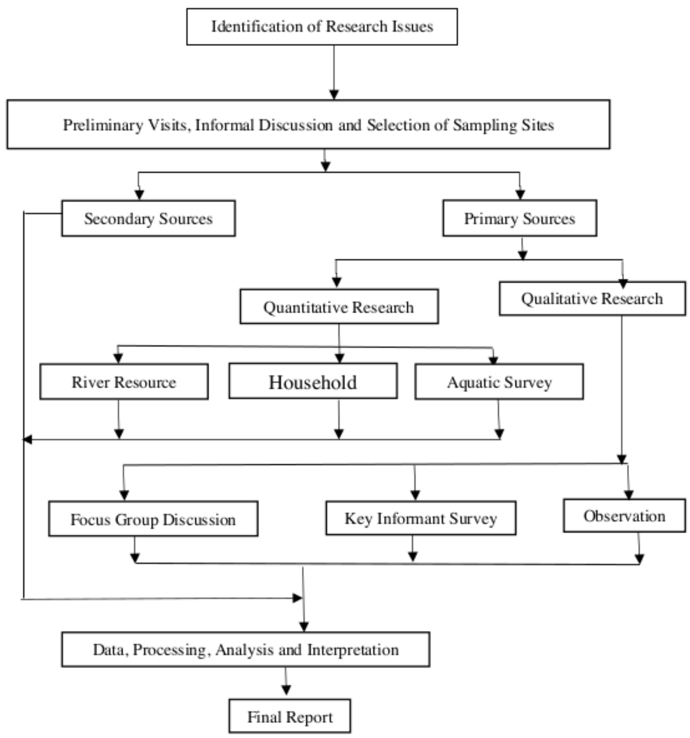


Figure 3.6: **Methodological Framework**

3.7 Processing and Analysis of Data

3.7.1 River Hydrology Data

Statistical tools like correlation and regression were used to show the relationship between temperature and water flow, rainfall and water flow and sediment concentration in the bank of river. Annual and seasonal discharge of the stream flow was calculated using index value. The relation between precipitation and discharge of water of rivers was analyzed using Pearson's correlation. The seasonal analysis was based on the three seasons of the year: Pre-monsoon, monsoon and post- monsoon. The slope estimation of the river was analysed through vertical height versus horizontal height (VH/HH) (Singh 1996).

The direction and vector have been done through the methods of path description, vector and trigonometric ratios (Unwin, 1981 & Gupta, Malik & Pundir, 2013). This has been done to find out further effect of cumulative impact and changes in the main flow of the Tamakoshi river. The power of stream was analyzed using formula given by Bull (1979). The flow routing and level calculated using HACRAS method and unit flow graph.

The sector wise spatial and temporal flows with respect to distance and discharge have been calculated by using correlation and regression. The data is based of topographic sheet, data received from field survey and interpolation of available flow data. Moreover, the contributions from the sector specific tributaries are also mentioned in terms of R^2 value.

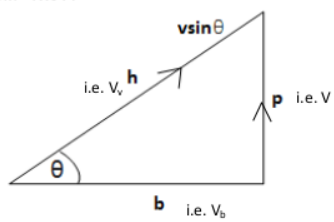
3.7.2 Index Value and Trigonometric Function

To get the knowledge about the spatial and temporal flow regime of the Tamakoshi River, flow data were collected from 15 locations. From the data seasonal availability of the total water volume and spatial index flow were calculated. Similar indices were also used to assess the volume of river deposits. Index numbers were used to find out the changes in the magnitude of phenomena for time and places.

The path is the fundamental aspect of the flow pattern of the river. The fundamental characteristic of an Eluceidean Schem is that the well-known Pythagoras theorem holds true in any right angled triangle l=la+lb. It follows that the straight- line distance between the points 1 and 2 can be found from their spatial co-ordinates. The topographical features of slope and direction were computed from the equation suggested by the Singh and Singh, (1996); Unwin (1981), for the study. The power of the stream is calculated from the field flow data and specific weight of the water. Stream power is given by - W = pgqs/b, where

p = density of water ($1000 kg/m^3$)
g = acceleration due to gravity
q = discharge
w = stream unit power
b = width of channel (Bagnold, 1966).

For the present study, latitude N 27^0 $40'$ 00" and longitude of E 86^0 05' 00" have been marked in the toposheet as an origin and the mark has been transformed into map scale of 1cm=3.8km. The path description (chain encoding) with origin (O); and ending (e) and distance bearing were measured in the toposheet. The measured data were transformed into trigonometric rations; $0\text{-}90^0$, $90^0\text{-}180^0$; $180^0\text{-}270^0$; $270^0\text{-}360^0$ with cosine, cosin +. sign and tangent (Unwin, 1981).

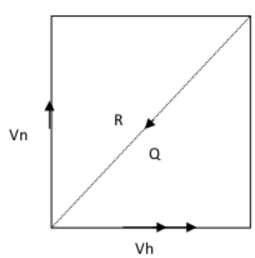


Sin θ= $\frac{p}{h}$ i.e. $\frac{V}{V_v}$

Cos θ = $\frac{b}{h}$ .e. $\frac{V_b}{V_v}$

Tan θ = $\frac{p}{b}$ .e. $\frac{V}{V_b}$

Tan $^{-1}$ θ = $\frac{b}{p}$ .e. $\frac{V_b}{V}$



$V = V_v \sin\theta$

Cosθ = $\frac{V_b}{V_v}$ Sin θ = $\frac{V}{V_v}$ Tan θ = $\frac{V}{V_b}$

θR = Tan $\frac{V_1}{Vh_1}$

Figure 3.7: **Trigonometric Diagram**

3.7.3 Geochemical Data

The required parameters like pH, EC, TDS, Temperature, and DO was measured and analyzed with help of table provided by aquatic ecologist (Shrestha and Shrestha, 2019, DWQI, 2005).

3.7.4 Socio-economic and Livelihood Related Data

Analysis of socio economic and livelihood data are analysed using percentage and graph and related statistical tools: mean and standard deviation.

3.7.5 Descriptive Statistics (DS)

The descriptive statistics was used to analyze the qualitative data. The analyzed data were used to compare the general significance of household data of the basin and its relationship with various physical, chemical parameter of river water and aquatic data.

The household information collected from the settlements was calculated in excel and divided into four sectors- 1, II, III and IV. Likewise, information on land ownership, food situation, cropping pattern and livelihood were gathered from questionnaire, the FGD and KII. The information have been presented in tables and bar charts. The data on the socio-economic variables (sex, education, occupation and livestock) are analyzed through descriptive statistics.

3.7.6 Correlation, Regression and Interaction Matrix (IM)

One of the main objectives of the present study is to analyze chracteristics of the basin hydrological, ecological flow regime and perception of the local people on the flow regime in the basin. So ecological flow was identified in terms of physical attributes in the river flow and socio economic data were derived from the household survey.

Correlation is a statistical tool with the help of which one can determine relation between two variables. It shows the association of two variables and accompanied by change in one variable leads to change another variables flow regime with rainfall is an exmaple. Similarly, regression is a statistical tool with the help of which one can estimate or predict the unknown value of the one variable from the known value of any other variables (eg. flow and deposition of sediment).

3.7.7 Spatial Data Derivation and Interpretation

The Geographic Information System (GIS) was used to analyze the spatial data of the basin. The spatial data units are related with administrative boundary, land use/land cover and the settlements. ArcGIS Desktop and ERDAS imagine were used to enter and analyze the map of land use and land cover. The land use/ cover of 1996 was derived from Department of Survey (DoS) map and compared the data with the land use/of data of ICIMOD along the river corridor. Overlay of different layers of maps were done and analysed on descriptive ways at different physical as well as socio-economic characteristics on spatial context.

3.8 Data Analysis

3.8.1 Characteristics of Basin Hydrology

The characteristics of basin hydrology have been analyzed through index value, coefficient of flow, correlation and regression and key statistical results were tested with scattered diagram.

3.8.2 Interaction Model Between River Ecology and Local Community

Community interactions have been analyzed with the help of Leopold matrix (Canter 1996). After collecting the people's perception on the flow water, a checklist of 15 parameters has been provided to them requested to rank them accordingly to their importance for the development and conservation of the basin with respect to flow Tamakoshi River. Similarly, Leopold matrix is a qualitative environmental assessment method pioneered in 1971. The interactions are filled into indicate the magnitude (from -10 to +10) and importance (from 1 to 10) of the impact of each activity on each environmental factor (Canter, 1996).

3.8.3 Perception of Local People Towards Basin Hydrology, Ecological Flow and River Ecology

For analysis of interaction impact, itself is an alternate process. Multi Criteria Decision Analysis (MCDA) model is taken into consideration (Kiker, 2005); Shrift (2003). The interaction of impact ranges from 0-10 and are categorized into magnitude (low, medium and high), extent (site specific, local and regional and duration (short, medium and long term).. The figure has been divided into three categories High (60), Medium (20) and Low (05) (NPC, 1993). Aquatic habitat and chemical composition are also combined with this analysis.

The popular method is 'component interaction matrix', which considers only environmental setting of an area. A major advantage of this technique of analysis is that it can assist the fraught task of identifying indirect impact within physical environmental systems and food chain (Selmen, 2000; NPC, 1993; Khadka, Mathema & Shrestha 2012; McEachern, Khadka, Rautainen & Shrestha, 1996). Based on the prescribed methodology in this chapter, the study area follows succeeding part.

CHAPTER IV

THE STUDY AREA

This chapter outlines the geography of the study area including its bio-physical characteristics, socio-economic characteristics and infrastructural development in the study area. Brief description of the characteristics of the study area is presented below:

4.1 The Biophysical Characteristics

Bio physical is characterizing the interaction of biophysical species with the physical environment (Khadka, Gorzula, Joshi, Guragain and Mathema, 2013).

4.1.1 Location

Located in the central mountain region of Nepal (Figure 4.1), the Tamakoshi River Basin consists of two types of relief features in terms of elevation, namely high Himalayas and lesser Himalayas, according to the physiographic divisions of Nepal (Burathoky, 1968). The elevation of the terrain rises from 380 meters at the confluence point of the Sunkoshi River and the Tamakoshi River to the south as high as 7,117 m (Mt. Gaurishankar) to the north (Figure 4.2).

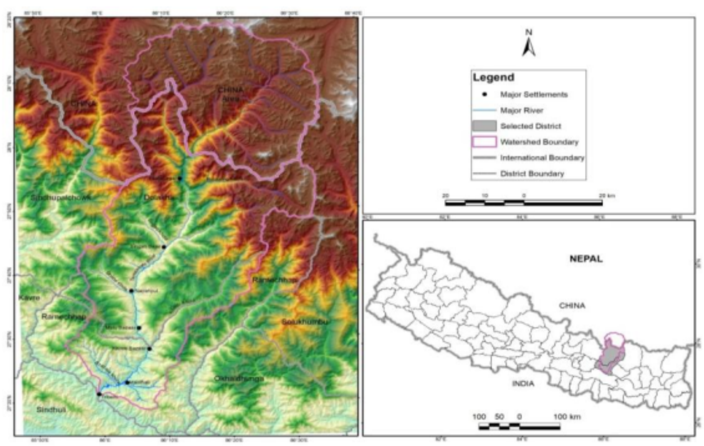
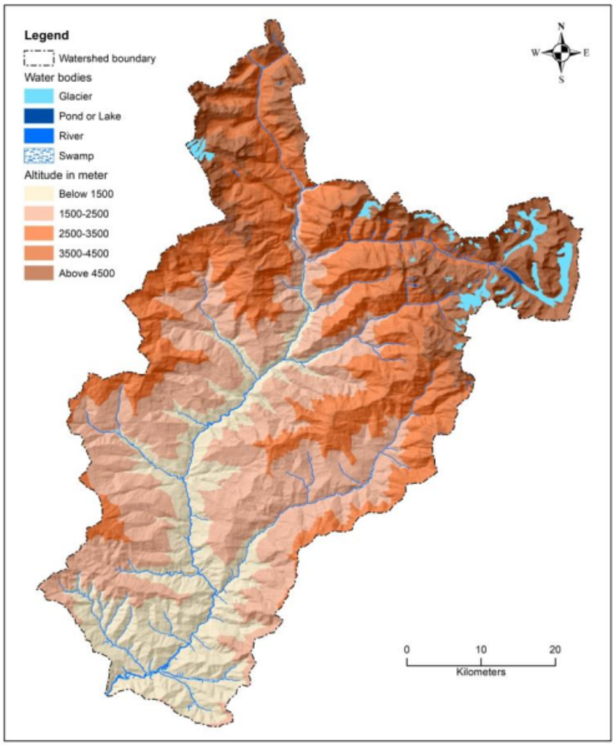


Figure 4.1: **Location of the Tamakoshi River Basin, Nepal**

The basin in Nepal has been extending from the Nepal - China boarder. The Tibetan (China) border is in the north to the confluence, locally known as ‘Tribenighat’ in the south. The Tamakoshi is the main river and 72 feeder streams join the basin. The basin has a total area of 2700 km^2 in Nepal side and out of total area of waterh 50 per cent lays in the Tibetan Autonomous Region of China (DHM, 2011).

For the study, a buffer zone of 1000 meters on either side (east and west) of the Tamakoshi River has been defined (Figure 4.1). Presently, ten local administrative units which account eight rural municipalities and two municipalities are located in the study area. The estimated number of households of the basin were 34,812 (with a mean household size of 5.5 persons), consisting of various castes and ethnic groups, such as Janajatis (ethnic), Bahun-Chhetri, and Dalits. The Lamosangu-Jiri Road passing through the basin is the main thoroughfare, which connects with the Araniko highway at Khadichaur linking Kathmandu Valley with Tibet. The Araniko or Kodari highway was built in 1966 and is the country’s second oldest highway.

Geographically, the study area extends from 27^{o} 19' 00" North to 28^{o} 10' 00" North latitude and 85^{0} 30' 00" East to 86^{0} 30' 00" East longitude. It’s surrounded by the Tibetan Autonomous region of the People's Republic of China in the North, Sindhuli district in the south, Okhaldhunga district in the east, and Sindhupalanchowk district in the West.



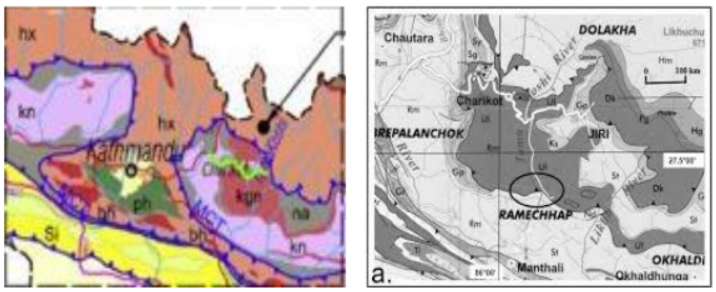
Source : DoS

Figure 4.2: **Relief Feature of TRB**

4.1.2 Geology

The study area lies between low height Himalaya and high Himalaya zone which run from the south to the north. The Main Boundary Thrust (MBT) is approximately located 45 km south and MCT is located 35km north from the district headquarters Charikot of Dolkha district that is located in middle sector.

The northern part of the basin is geologically composed of gneiss, slate, dolomite and phyllite, and southern area consists of recent alluvial deposits, old alluvium terrace, colluviums and quartzite phylite with inter –bedded schist and gneiss rock. The gneiss was well exposed along the Tamakoshi and its tributaries from Chyadu river to Bhatauli river (Shrestha, 2016) The geological composition of the study area is presented in the Fig 4.3 (a) and enarged map of the area is presented in Fig 4.3 (b).



Scale 1.4 cm= 45km

Source: Department of Mines and Geology

a) Geology of the study area **b) Enlarge map of geology**

Figure 4.3: **Geology of Study Area**

4.1.3 Topography

Two distinct physiographic regions (mountains and mid-hills) and several fertile river valleys are found in the area. The broad view of regional geological structure is shown in Fig 4.3 a) and project geology in fig b)

The topographical division of the basin has been divided into10 divisions at an interval of 500 meter. The larger area fall under above 5000m (14.76%) followed by 3001-3500 meter (14.13%). The proportion under 500 meter in the basin is (0.23%) the least one

4.1.4 Climate and Hydrology

The bioclimatic condition of the area consists of climatic from sub-tropical to tundra type of climate. The sub-tropical type of climate is found in altitude below 1200 meter, warm temperate between 1200- 2100 meter, cool temperate between 2100-3,300 meter, alpine between 3,300 to 5,000 and tundra above 5,000 meters (LRMP 1986).

The study area exhibits three types of climatic conditions from sub-tropical to severe cold. The southern part of the basin particularly Manthali and the surrounding area is characterized by sub-tropical climate. In summer season, it is very hot in the day time. The middle part of basin particularly Dolkha and surrounding area exhibits warm temperate climate. The upper part of the basin is characterized by cold temperate climate. The maximum and minimum temperatures recorded at the upper part (Lamabagar, 1940 masl) of the basin were at 28^{0} Celsius and-7 ^{O} Celsius respectively (DHM, 2015).

4.1.5 Vegetation

Generally, the sub-tropical evergreen forest is found mainly in lower part of the area like Manthali and Tribeni including nearby hills up to the height 1,200 meters. Likewise, deciduous monsoon forest is prevailed between 1,200 to 21,00 meters, evergreen coniferous forest from 2100 to 3,300 meters, alpine forest from 3,300 to 5,000 meters and cold desert vegetation is confined above than 5,000 meters.

4.1.6 Land Use

The total area of basin of the study area is 2700 sq. Km (within Nepal boarder side only) with about 19 per cent cultivated land and 37 percent bush land. The remaining area is covered by forest, snow and settlements, rocks and water bodies. The overall picture of the land use pattern of basin and river corridor is presented in Figure, 4.4 4.5 and and Fig 4.6 respectively. However, the land use along with the corridor 100 meters, buffer is presented in Table 4.1.

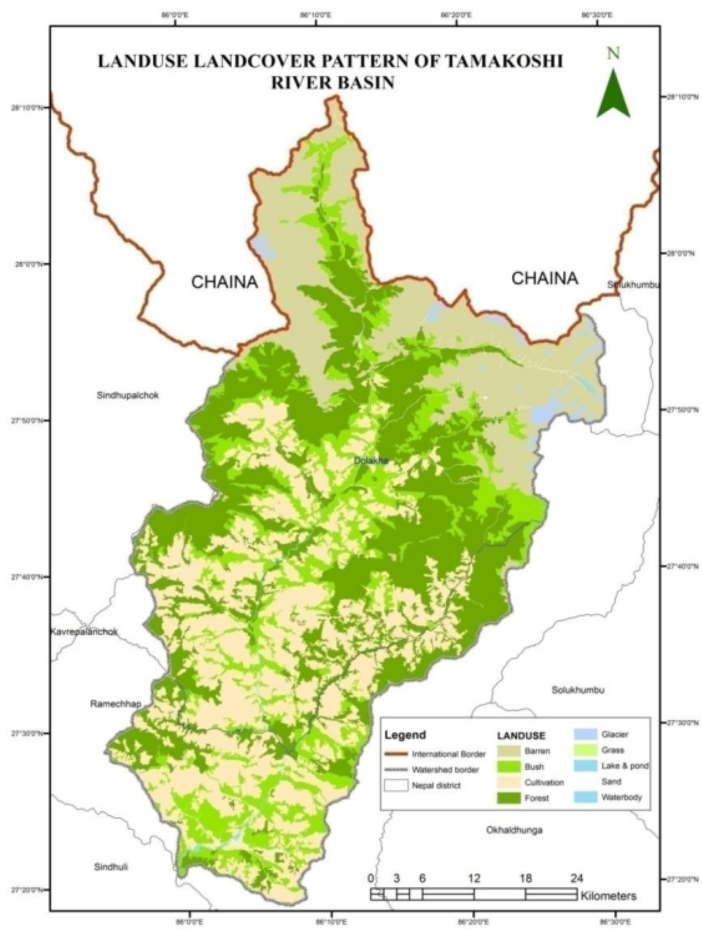


Figure 4.4: **Overall Land Use of the TRB**

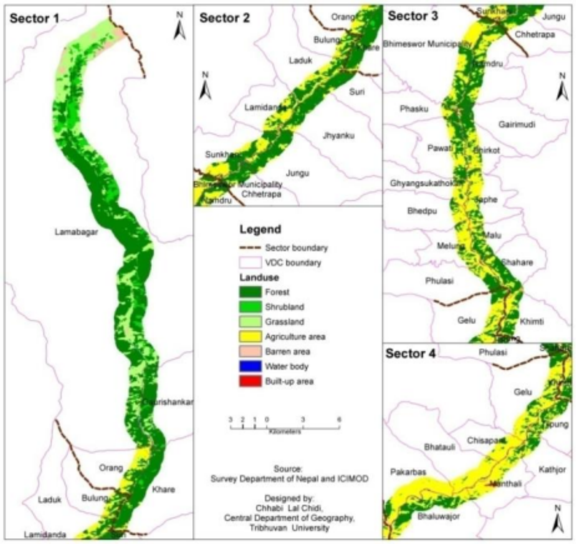


Figure 4.5: **Sector Specific Land Use**

Table 4.1: ***Existing Land Use Along Riparian Zone***

S.N	Land Use Sector	Area (Km²)	Percentage	I	II	III	IV
1	Forest	86.35	39.25	10.7	11.3	9.6	7.7
2	Grass Land	29.29	13.31	5.14	3.19	2.52	2.46
3	Bush/Shrub	10.10	4.59	3.42	0.89	0.22	0.06
4	Agriultural Land	88.35	40.16	6.00	14.00	38.10	42.00
5	Blarren Land	3.48	1.80	1.06	0.06	0.01	0.67
6	Water	2-17	0.98	0.14	0.10	0.29	0.47
7	Buitl Up area	0.19	0.08	-	-	-	0.08
	Total (km²)	219.95	100.00	91.98	31.73	54.08	42.02
Total				41.82	14.43	45.59	19.13

Source: Satellite Image processing and GIS and Field Survey and Shrestha 2014

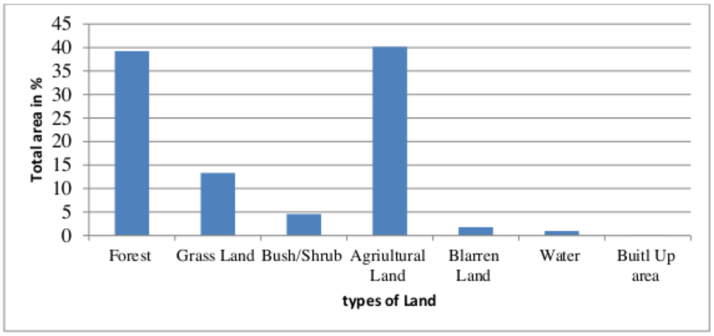


Figure 4.6: **Existing Land Uses Along Riparian Zone**

From the table 4.1 and Fig 4.6 it has been clear that the total area along the river basin is 219.99 km^2. Agricultural land has covered 40.16 percent of the total area followed by forest land 39.25 percent. The forest land occupies the highest per cents (11.3 %) in the IInd sector and agricultural land in the IV sector 42.00 per cent (Table 4.1, Fig 4.5 and 5.6).

The percentage of area covered by forest has decreased from 58 percent to 27 percent between 1992 to 2019. However, the arable land has increased from 2.1 per cent to 6.8 per cent (Shrestha, 2014).

However, the overall study of the area comprises 219.95 km^2 within buffer of 1000 meter and this represents 8.15 percentage of the area of the basin. The land use pattern of the buffer area differs from the picture of the total basin. Within the corridor area, the highest percentage of the area is occupied by agricultural land, followed by forest and the least percentage is covered by built up area (Fig 4.6).

4.2 Settlements, Demography and Socio-economic Characteristics

4.2.1 Settlements

There are many rural settlements on the banks of the Tamakoshi River. Some of them have developed small market centers after the road construction. Later, the growth of the market settlements is found to be influenced by the development of infrastructure such as roads, bridges, irrigation and hydropower (Appendix III c). Recently market settlements are developed in Lamabagar, Singati, Nayapool, Malu, Milti, Khimti, Tilpung, and Manthali.

Most of these settlements along the roads are in linear form, while traditional towns are in the semi-circular and oval forms. The population sizes of Singati, Nayapool, Khimti, Manthali settlements ranged approximately from 100 to 5,000. The settlements within buffer zone of 1000 meter each in the either side of the river channel of Tamskoshi fall under the study. The settlements start from Lapchi in the north to Tribeni in the south.

There are 65 ripairan settlements in the study area and on an average each settlement is 415 meter far from the Tamakoshi river. After the construction of road in 1981, the economic activities and physical expansion of Charikot grew rapidly and the physical expansion of Dolakha as well. Next was the Manthali which lies in the downstream of the basin. This settlement has been connected by the feeder road with Khurkot along with the Banepa-Bardibas highway. The highway links the central hill including Kathmandu Valley with the Tarai in the south.

Before the devleopment infrastructure (road, hydro power) was constructed the settlement was concentrted in the lower altitude and along the river where agricultural production was more favourable. The river flow and road alignment follow from north to south. Consequently, the settlements and populaiton density grew in the same pattern.

The general description of settlements as per-sector is presented below:

Sector I: Settlements in this sector is sparcely distributed. Lapchi (4250 m) and Lumang (3650 m) are located in the highest altitude of the basin (Figure 4.7). Except settlement of Lamabagar (1940m), other settlements are located on bank of the Tamakosh River. The Lamabagar, Gonger, Jagat and Bhorle are main settlements and are located in the edge of the Tamakoshir river or road side up to Upper Tamakoshi Hydripower Project (Figure 4.7). The settlements are consisted of less than than 40 households (Appendix III C).

1

The Tamang is the dominant ethnic group, followed by other ethnic groups such as Sherpa, Newar, Chhetri and Kami. The Tamangs and Newars lived in the bazaars along the river, while the Sherpas used to live in the higher altitude villages.

Sector II :. The setltments in this sector are more compact than the first sector. Settlements are concentrated in relatively wide valley or in the river flow direction. The two main settlements are Singati and Gumukhola, which are also confluence of Singati and Gumukhola River. The Upper Tamakoshi Hydropower Power Projet (UTHP) is the main cause for development of linear settments along the road side. The number of households range from the minimum of 50 to maximum of 200 in the settlemnt. These settlements are also the hub center for trading with northern area of Nepal and sector is hub centre of northern economic centre.

The dominating ethnic/caste groups are Chhetri-Brahman, Tamang, and Newar. Thangmi, Jirel and Surel are the marginalized ethnic groups.

Sector III: The size of the settlement ranges from 100 household to more than 300 households. The main settlements are Nagdaha, Nayapool, Malu, Milti, Devitaar, Kirnetaar and Khimtitaar (Fig. 4.9, Photo 13).

The Chhetri, Brahman, Newar, Tamang, Magar, Sarki and Kami are major ethnic groups in the sector alongwith Nagdaha, Nyagal and Nayapool are inhabited by Newar and Tamang.

Sector IV: The main settlements in this part are Chisapani, Tilpung bensi, Jakhantaar, Bandry, Manthali, Mugitaar, Kanauri, Tilpung, Gelu, Panthali, Goddar Masantari and Bhalujhorare, Bhatauli, Rajgaon (Fig. 4.10, Photo 12).

Major people are Chhetri, Majhi and Newar.

4.2.2 Demography

The population of the study area is 40,000 with growth rate of 1.75% per year. It covers 34.8% of the total population of Dolakha and Ramechhap districts. The total sample size households of the study area are 412 with total population size of 2060. There are 48 per cent female and 52 per cent male. According to the age structure, 34 percent people belong to the below 15 years of age and 45 percent people are belonged to the age group of 15-49 years which is economically active population. The figure is followed by age group 15-59 which 57 per cent. So, the size of dependent population is 42 percent. The figures are presented in Table 4.2

Table 4.2: ***Population Structure***

Age group	I	II	III	IV	Total HH
Total Sample HH	40	100	212	60	412
Total Populationn	184	449	1045	280	1958
Growth Rate (2001-2011)	-1.79	-10.04	-10.96	-7.45	-7.56
Population Density (Pop/km^2)	56	162	370	201	197
Household size (2011)	4.61	4.49	4.93	4.67	4.67
Broad age group (%)					
0-14 years	28.2	33.5	36.64	41.29	34.90
15-59 years	63.2	59	56.92	50.32	57.36
>60 Years	8.7	7.66	7.42	7.61	7.84

Source: Field Survey, 2014

There are two municipalites in the study area namely Bhimeshwor and Manthali Municipality. These municipalities have a direct bearing on the economic activities of the study area.

The growth of population is observed mostly along with the road corridor between the north and southern section of the Tamakoshi River basin. The development of Upper Tamakoshi Hydropower Project has facilitated access to the road network. As a result, the growth of population along with the road nearby the hydropower sites has raise higher than other parts like Singati, Lamabagar and Khimti.

The population gravity point of the TRB is also concentrated along with the road and flow regime side and north southward to the road and north which can be taken as the growth of Manthali community. The growth is concentrated along the HPP/road axis. The most booming centers without doubt after Charikot are either Singati or Manthali.

The highest density (with more than 430 persons/km^2) is observed in Manthali municipality (Sector IV) followed by Bhimeshwore with more than 300 persons/km^2 in sector III. The lowest population density is observed in Lapchi, Lumnang and Simigaun (less than 20 persons/Km^2).

Figure 4.7: **Major Settlements of Sector I**

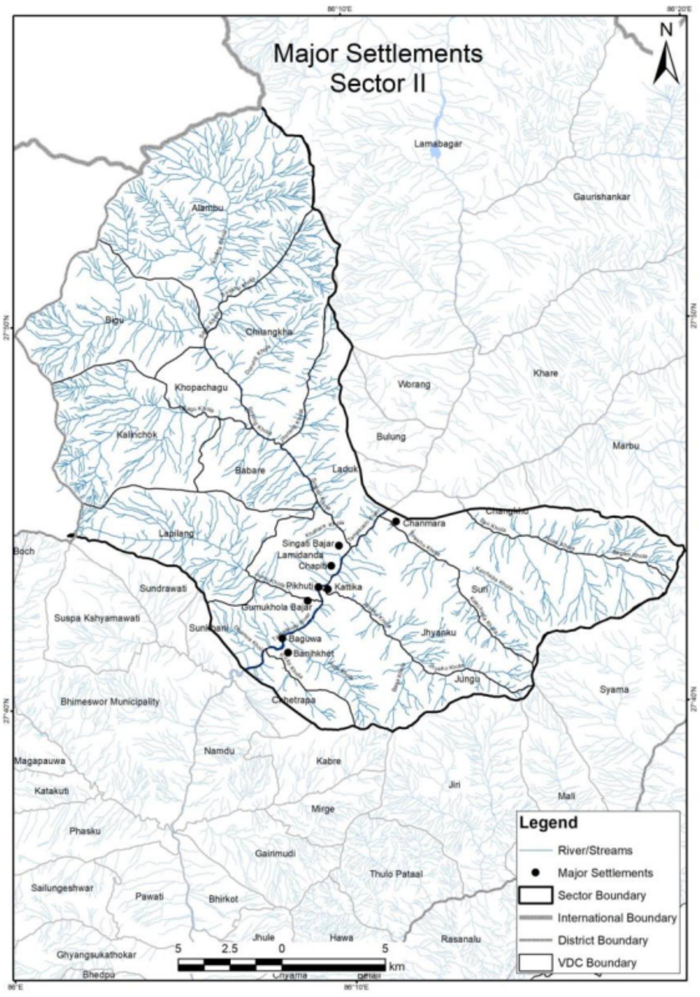


Figure 4.8: **Major Settlements of Sector II**

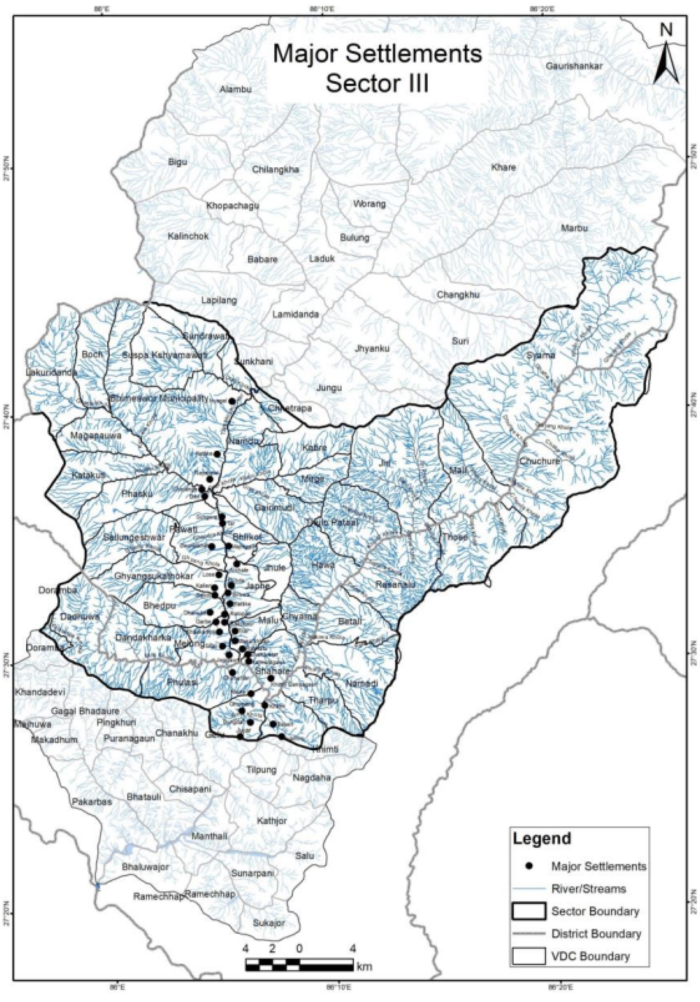


Figure 4.9: **Major Settlements of Sector III.**

Figure 4.10: **Major Settlements of Sector IV**

4.2.3 Socio-economic Activities

Economic activities paly a significant role in livelihood of the local people. The people belonged to the age between 15-60 yearsof age are considered as economically active population and are involved in occupations. A detail description of the sector-wise occupation is presented in Table 4.3:

Table 4.3: ***The Occupational Categories (Percentage of People)***

S.N	Sectors	Agriculture	Services	Trade	Study	Not stated
1	I	37.53	4.95	4.31	18.29	34.90
2	II	27.93	5.81	19.03	35.29	12.51
3	III	42.48	6.19	8.99	26.30	16.03
4	IV	52.12	14.07	4.50	22.51	6.75

Source: Field Survey, 2014/15.

It is evident from the Table 4.3 that the highest number of people is involved in agriculture and service in the sector Ist and sector IVth, trade is more prevalent in the sector IInd. Agriculture is the main occupation of households in the settlements along the River Tamakoshi, but that only is not the source of livelihood of 412 households. However, the settlements of the business centres like Lamabagar, Singati and Manthali have also adopted business as the major forms of economic activities.

The average land holding size with 0-5 ropani (0.12ha) is enough for livelihood of average family size of study area.

So the land holding pattern in the study area is divided into five categories; less than 0-.25 ha, 0.25-0.5 ha, 0.5-0.75 ha and 0.75-1.0 ha and more than 1.0 hectare. None of the farmers have land holding sizes more than 3.5 ha (70 ropani). It is felt that the nearly three-quarter of the surveyed households have holding smaller than 0.25 hectare. The mean size of land holding in the basin is 0.9 ha. of which 16.0% is Khet i.e irrigated crop land, 80.8% is Bari land (unirrigated crop land) and 3.21 % is *Khar Ba*ri. By caste/ethnicity, nearly three quarter of Majhi, Tamang and Sunuwar have land holding less than 0.25 ha. Compared to them with Brahman, Chhetri and Newar own larger land holding size compared to others.

The average production of crops of paddy, wheat, potatoes, maize is highest in the sector IIIrd and sector I st is followed by sector IV. The dominant crop area in the valley is maize followed by paddy, wheat and buckwheat. The contribution to the livelihood of the local people from these crops is more along the river valley from Nagdaha downwards.

In the basin only 31.55 per cent households are found food sufficienty for a year from their production among the sample household showing a problem of food security in the study area. Around one third (28%) have only food sufficiency for less than three months. However, 10 per cent of household from the IIIrd sector export cereal grain to other parts of the district.

In the animal husbandary goat farming is seen highest in all sectors of the basin. The average number of livestock per household (cow/ox) is 2.5, 3.2, 7.6 .98 and 13.8 live stocks per household in sectors Ist, IInd, IIIrd and IVth respectively. However, other farming activities are also found and they are of small in the size and owned by certain caste/ethnic group, like Magar, Gurung, Sunuwar and Majhi. They earns around Rs. 5, 000 per year. From the sample survey it has been found that people living in the riparian zone use the river side as grazing land. The average income of the household per month is equivalent to NRs. 22, 810. Majority of portion of the income is derived from business followed by agriculture. Business in terms of Trekking, tourism and mountaineering are also popular among the people and forms the 3rd category. The percentage of the people accounts almost 35 percent.

The agriculture profession also includes the population involved in agriculture labor, fishing and lumbering. Off-time is being utilized in the labour jobs in the local market centre (Bhorle, Singati, Gumukhola, Nayapool, Malu, Khimti, Manthali), district headquarters.

4.3 Infrastructure and Services

4.3.1 Drinking Water

Drinking water is distriuted properly in the study area. In the rural area, public taps are distributed in the market area. A system of providing taps to every household has been properly managed. This kind of situation is found in the II and III sectors. In the III and IV sectors of the basin, people use water from stream and spring for drinking and household purpose in many settlments.

4.3.2 Sanitation and Health Facilities

People have realized that the toilet facility as a basic necessity for healthy and social life. A considerable number of households (45%) of the study area have their permanent toilets and 55% are using make shift high toilet. Similarly, only 17.5% households have toilets attached to their building and the rest 82.5% households have constructed their toilets detached from their houses. From the field survey, the percentage of people used toilet in the sector 1st is 36% and 65% having only temporary toilet. Similarly the percentage of people using toilet in the sector IInd, IIIrd and IVth turns out to be 54%, 43.8% and 45.7% respectively.

Diseases such as fever, cholera, jaundice, cough and diarrhea are common in the study area. The field survey shows that almost 52 per cent of the households are free from any types of illness. It is also revealed that 27.3 %, 24.6 % 18.8% 4.0% 19.7% and 1.9% and 14.5 % of the population suffer from tuberculosis, stomach ache, diarrhea, dysentery, hysteria, fever and skin diseases respectively.

Among the various methods of treatment, 41.6 % consult doctor, 4.1% use healers (*Baidya*), 5.0 per cent use Dhami and Jhankri. Remaining 50% use local health posts and services of pharmacy. After earthquake, most of the health posts are sufficient from the medicine and health personnel.

4.3.3 Education Facilities

Education is basis for occupation. The overall literacy rate is (for population of 5 years of age and above) has increased from 46.1 in 2001 to 49 per cent in 2011. The male literacy rate (64%) is comparatively higher than the female literacy rate (30%). The overall education level is presented in table 4.4.

Table 4.4: ***Levels of Education (percentage of people above 5 years of age)***

S.N.	Sector	Below SLC	SLC	Intermediate	Bachelor	Masters
1	I	56.86	21.56	17.64	3.92	0.00
2	II	76.24	8.47	4.38	2.54	8.35
3	III	81.01	9.28	5.96	3.14	0.53
4	IV	75.35	9.64	11.07	2.5	1.42

Source: Field Survey, 2014/015.

It is evident from the Table 4.4 that overall literacy rate in the sector Ist is less than 45 per cent. Similarly, about 57 percent have not completed their school leaving examinations (previously it was called matriculation and now it is called SEE). Likewise, the persons who haven't completed Matriculation, in the IInd, IIIrd and IVth sectors are accounted to 76.24%, 81.01% and 75.35% respectively. The percentage of completing Master's degree is nil in the Ist sector. Similar percentage is found 8.3%, 0.5% and 1.4 in the sector IInd, IIIrd and IVth respectively (Table 4.4).

The settlements like Nayapool, Khimti, Manthali, Singati, Bhorle, Ratmate have a close connection to the district headquarter and capital city. Hence, increasing interaction with the urban areas has a positive impact on status of these rural people.

4.3.4 Transportation Facilities

The Silk Road in the Tibet region was one of the oldest traditional highways used for facilitating exchange of livestock across large geographical distance and topographically challenging landscapes (Warmuth 2013). A section of the Silk Road was passing through the north to the south of Lapchi, Dolkha district. This route was connected to China from the south along Tamakoshi River. The historical documents show that the trade relation between India and China was flourished during historical times such as the Lichhavi (circa 400-750) and the Malla (circa 1201-1779) periods through the major towns of the basin that continued till the early twentieth century (Detail described in Section 4.2.1).

4.4 River Based Livelihood

4.4.1 Fishing

The people of the riparian communities in the sector IIIrd and IVth have received more benefits in terms of abundance and varieties of ecological services (fish, snail) from the aquatic ecosystem than those living on the sector Ist and IIrd. The communities dealing with fish in the basin include diverse ethnic groups, such as the Majhi, Thokar, Tamang, Thami, Magar, Bhujel and Newars. Of these, the Majhis with population about 300 (15 percent of sample household) people are the only group to earn livelihood from fishing; four-fifths of them live in the sector IVth . The survey revealed that full time and part time incomes turn out to be NRs. 60,000 and 38,000 respectively accrued from fishing are people of other castes, such as the Chhetri-Brahmin are also engaged in this activity but numbers are nominal. However, fishing remains a seasonal activity throughout the year, except for cold (December/January) and dry months (April) when it cannot be practiced. But, for a few fishermen, the confluence sites locally known as 'Ghats' provides a the-year round support. The fishermen prefer fishing in the tributaries to the Tamakoshi itself because it is easier and they offer a rich habitat for the fish population. According to local Majhis, the suitable time for catching fish in the IIIrd and IVth sectors is from 11 am to 1 pm in winter and after 4 pm during the summer due to warm temperature of water. The demand for fresh local river fish has increased in recent years due to rapidly growing catering services, such as restaurants and hotels in several market towns along with the highway. Each fishermen used to harvest 7 to 8 kg of fish per day by using nets and hooks, locally known as 'Lahare Paso'. The fishermen used to make their nets from the fiber of the Allo plant i.e. Himalayan giant nettle (*Giradianai diversifolia*) available in the near-by jungles and along the river banks. This has significant implications to fishermen, mainly the Majhis who are part of the river ecology. According to them, there exists an interactive relationship between the river flow system and fish species. They are well aware of the relationships between types of fish and the river flow regime. The species of snow trout (*Schizothorax macrophthalmus*) is found in cold water its habitat is the upstream and Jalkapoor is found in the warm water and its habitates concentrates in the down stream area. According to the local fishermen, a fish can be mature and weighs 2½ kg within 6 months while its life expectancy is only three years. The Majhis are fishing in a sustainable way in the sense that they are aware of fish behavior and its habitat, temporal cycle and spatial distribution. It is most important that their fishing method appears to be environmentally friendly, without disturbing their habitat. However, fishing does not provide a year-round employment to most of the Majhis living in the downstream area. They are forced to find other seasonal jobs, such as in agriculture, labourer and in the ferryboat service for the local inhabitants and cross across the Tamakoshi River.

The river ecology is important for fish. Both fish species and their composition vary from one river to another, according to physical attributes such as direction, transparency, surface water temperature, river substratum, water colour and availability of sun light. They require at least a 20 km stretch of flowing water for healthy growth. Asala, common snow trout (Schizothorax richardsonii) the dominant species of the Tamakoshi River, need clean running highly oxygenated water. So do water purifying insects like *Ghunghi* or *Sankhe* *(water snail)*. Once the water is polluted, these animals will slowly disappear.

The flow regime is essential for a functioning of aquatic ecological system in the rivers. Flow regime, fisheries, the fauna of river banks, and the land based living organisms are closely interrelated, including local insects, birds, monkeys, tigers and other animals. Any obstruction to the flow of the river will disturb the safe and natural movement of medium and long distance migratory fishes. Small mammals and reptiles, which cannot cross the river, can move from one area to another. Such activities fragment the flow ecosystem, which in turn will reduce the size and population of habitat and abundance of fish species.

Finally, the marginalized people of the riparian communities have enjoyed more benefits from the ecological services than other communities, including the Mājhis (Manthali area) and other indigenous people such as the Sherpa and Surel (Ist sector). They are deprived of managing, conserving and decision making concerning the river water and its resources on which their livelihood directly or indirectly depends. It is therefore essential to carefully consider the exploitation of the river water in order to maintain a sustainable balance of water chemistry by appreciating the use of the indigenous communities' traditional knowledge in the Tamakoshi River Basin for the future.

4.4.2 Other Resources

Resourcrs such as sand and gravel in the Tamakoshi river beds are the sources of livelihood of 15 per cent people in the basin. There are about twenty five places in which local people depend on sand and stone mining for their livelihood. During field survey it has been revealed that local women are collecting stone and boulders from the river at the time of flooding. They also collect stones and boulders from river bed and grinding them to make *Gitties* (gravels) (Photo, 4). It was reported that they sell the concrete/gravels to contractors and earn Rs. 3,000-5,000 per month per people. Such activities are observed in Nayapool, Charange, Barbise, Malu and Milti. The boulders were extracted from Charange and downwards part of the Ranjhor Khola too.

During the field survey, it was seen that some contractors extracted sand, stones by using excavators while some people extracted sand only. Five groups of people from Bhalujhor were observed in Manthalil, two groups in Akase, near Airport and one group near the bridge. They mine sand and sell to local market charging at cost of Rs. 100 per sack. One of the tile factories was established in Kirnetaar which used sand from the river (Detail about sand and stone mining is presented in in chapter V & VII).

4.5 Settlement Model and Hierarchy

The location aspect of settlements in the TRB is examined with the help of ideal five variables necessary river resources, drinking water, arable land, grazing land and geographical locations. Respondents are requested to rank the assign value in five order based on assigned values and their socre are sum up. The assigned values were examined throught the number provided by Chisholm 1966.

The highest value is found in the sector IVth with 18 points. It is followed by 17.9; 14.7 and 9.6 in sector III and II and I respectively. Among these settlements, highest value is found in the Nagdaha (22) and lowest in Suridovan/ Gongar (9.5) in the 1st sector (Annex IIIe).

Access to sources of drinking water and availability of arable land are another factors for growth and development of the settlements in hill areas of Nepal.

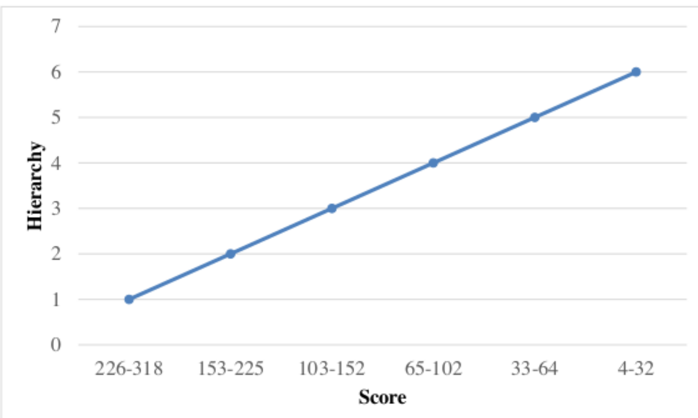
In Nepal, the settlements pattern also defines the livelihood. The settlements of the Himalayan region are scattered, the settlements in Terai or plain land in general, are clustered. However, settlements of mid hill, in most cases are dispersed and isolated. In hill of Nepal and middle mountain regions, the settlements are located in the terrace land as well. The proverb given by the local people on this is as follows:

"*Banmuntira Ghar, Ghar muntira Kulo and Kulo muntira Khet and tesko taltire Koshi ra chota kootha baser khane ra goth harne*"

The English translaton goes like this:

In hill area, settlements are concentrated on area where there is forest in the upper part, followed by kitchen garden in backyard and behind the settlement is canal (*kulo*) and it is followed by agricultural the land and the ending part is river. Generally, the house is of two storeys with sizable of number livestock's' in the cowshed. However, the settlements of riparian zone are mostly clustered or aligned in the direction of river flow.

Similarly, the higher score settlements are found very few than lower order settlements. The number of higharchy settlement increases from the sector I[st] to sector IVth. The computed value shows that there are settlement (Manthali) with score value between 22-318, 3 (Singati, Nayapool, Kirnitaar) in score between 153-225; 9 in 103-152; 12 in 65-102; 15 in 33-64 and 25 in 4-32 secore (Figure 4.11 and Appendix IIIa).



Score based on Groeli and Griesbaum (1988a).

Figure 4.11: **Settlement Hierarchy**

Similar studies have been reported in other parts of the globe. These include Shadan of China (Libang, Xiaodang, Yayatian, Yongi, Chen, 2017; Kosiniki, Elan 1985; Nair, 2003) and similar studies was carried out in Gang river valley of India and also in the Netherlands. (Rai, Majhi, 2014; Shrestha, 2011, 2015, 2017, Russel, 1992, Primack, Pudel, Bhattari 2013; Awasthi and Singh, 2015). The situation is found in the other river basins of Nepal like Trishuli river basin, Koshi river basin and Gandaki river basin (IFC, 2020).

4.6 Chapter Summary

The settlements are distributed along the north south corridor roads, market centers, and hydrographic network of the Tamakoshi river and hydropower areas. The sector IV of riparian settlement is dominated by Majhi caste, sector I by Sherpa (Bista) and Sector II and III by hill castes/ethnic groups like Chhetri, Tamang, Brahman and Newar. The entire livelihoods are associated with trekking/tourism and mountaineering in the Ist sector, business and agriculture with livestock in the IInd and IIIrd sector and farming with extraction of river resources in the IVth sector.

The literacy rate and educational attainment of Lamabagar is found to be lowest and these rates are found highest in Singati, Charange and Manthali (more than 70%) showing influence of transportation and connectivity with district headquarters and concentration of educational institutes. The people holding agriculture is found more than 40 per cent. The proportion of trade is found almost same.

Similarly, the production of cereal grains are raised from the sector IInd. The productivity of the cereal crop is found to be highest in the IIIrd and the IVth sectors. The livelihood depending in agriculture in the sector Ist to the sector IV accounts from 37.53% to 52.12%. Similarly, the productivity of wheat, pulses, mustard potatoes are highest in the sector IIIrd. The goat and sheep accounting 73.93% are major livestock in the sector Ist and they account for 47% in the sector IVth. The study area is food deficit area except some parts of the sector and IIIrd situation of the sector IVth is not so bad.

From the field survey it has been found that fifty places of area dependent in sand mining for their livelihood and they earn NRs. 3000-5,000 per month from sand mining. The other sources of income are manual labour, remittances and fishing activities. The mean income is equivalent to NRs. 22,810. Out of this, the business accounts 43.42 %. Since the area fall under the trade route and major trail of the south and north, the percentage income turns out to be higher in business. River side grazing and sources of water along with arable land is the major attraction of settlements in

Nepal. The modes of the settlement show that the highest value is found in the sector IVth followed by sector IInd which accounts 17.9 percent.

The highest population growth rate is observed in Lamabagar, Orang (4.13%), followed by Nayapool, Kirne, and Singati. These places are either market centres as well as centres located in the Tamakosh River. The places of Sahare, Singati and Lamabagar have a lot of people from other parts of the country due to hydropower project. After discussion of the study area, the hydrological condition is presented in the next section.

CHAPTER V

HYDROLOGY IN TAMAKOSHI RIVER BASIN

The chapter discusses characteristics of basin hydrology, the flow pattern (spatial and temporal) dimension and its relation with sediment deposit and boulder size distribution.

5.1 Water Flow Pattern in Tamakoshi River

A water flow pattern is a state which implies availablility of water for ecosystems and human to use. The pattern of water is defined as a flow in the river basin available for a temporal and spatial area for a year. Measurements were carried out constantly of two years (2014/2015) during April for pre-monsoon, August for monsoon and November for the post –monsoon flow. The average flow of each locations for two years period were recorded and the measurement of mean discharge of fifteen locations of 2014/2015 is presented in Table 5.1.

Table 5.1: ***Water Flow in Tamakoshi River 2014/2015***

(in m^3/s)

S. N	Location	Distance (km)	Watershed (km^2)	Pre-monsoon flow (m^3/s)	Monsoon flow (m^3/s)	Post-monsoon flow (m^3/s)	Average (m^3/s)
1	Lapche	0	189	5.53	44.96	9.15	19.88
2	Lamabagar	9	194	21.95	85.15	40.19	49.10
3	Gongar	22	403.7	25.14	150.22	74.14	83.17
4	Suri	31	156.2	25.89	301.25	80.9	136.01
5	Singati	38	262.1	26.96	359.99	88.82	158.59
6	Gumukhola	42.5	42.6	28.38	366.1	92.93	162.47
7	Nagdaha	51	98.4	28.39	395.43	172.48	198.77
8	Nayapool	56.5	313.5	29.23	460.39	209.32	232.98
9	Malu	69	53.1	29.96	468.27	216.46	238.23
10	Milti	74.5	69.1	30.9	478.83	228.11	245.95
11	Khimti	79.5	358	37.11	501.26	236.66	258.34
12	Chisapani	84.1	37.3	38.23	505.36	240.41	261.33
13	Manthali	91.1	60.7	37.16	506.01	240.88	261.35
14	Masantari	95.1	41	37	501.01	241.49	259.83
15	Tribeni	104.6	100.7	36.84	493.34	246.11	258.76

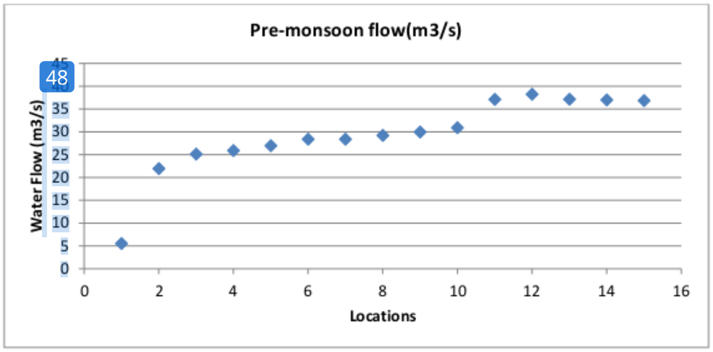


Figure 5.1a: **Pre-monsoon water flow in Tamakoshi River**

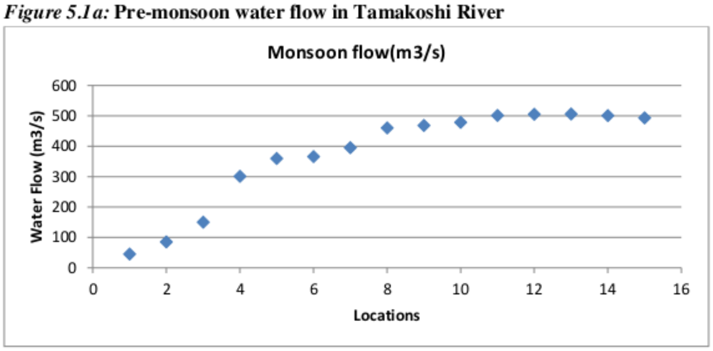


Figure 5.1b: **Post-monsoon water flow in Tamakoshi River**

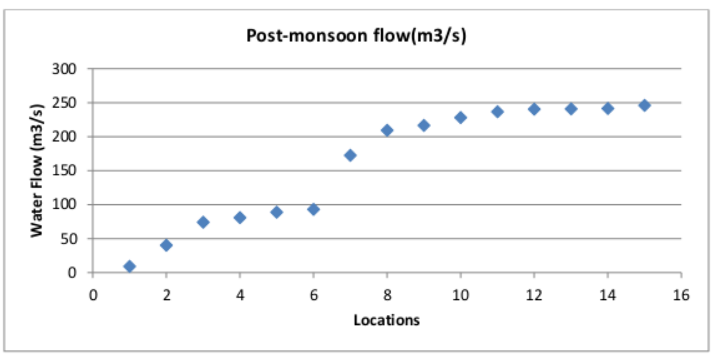


Figure 5.1c: **Pre-monsoon water flow in Tamakoshi River**

Source: Field Survey 2014/015.

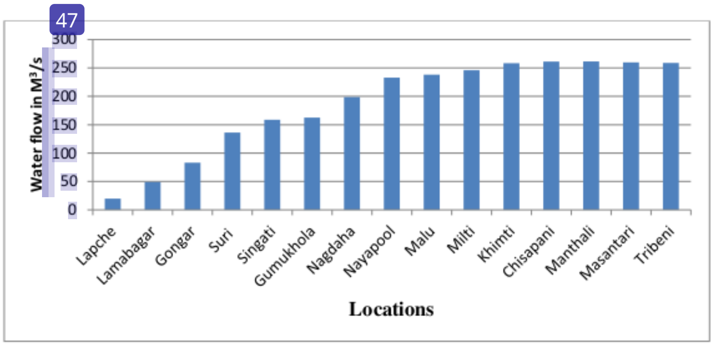


Figure 5.1d: **Spatial flow of Tamakoshi River**

Water Flow in the Sector I

It is evident from the Table 5.1 that the spatial flow of the water starts from the 19. 88m^3/s in Lapchi to 83. 18 m^3/s in Gongar. The observed pre-monsoon flow of the sector is found to be 5.53 m^3/s in Lapchi and 25.2m^3/s in Gongar site. During monsoon period, the flow is recorded at 44. 9m^3/s in Lapchi and 150.2m^3/s in Gongar (Photo 6).

Water Flow in the Sector II

The flow of water in the Suri confluence amounts to 120.1 m^3/s and in Gumukhola it is 176.7 m^3/s**.** In this sector, in the pre-monsoon a water flow of 25.8 m^3/s is recorded at Suri and 28.8 m^3/s is recoded at Gumukhola. The monsoon flow has been characterized by huge difference of flow which ranges from 301. 2m^3/s in Suri to 366.10m^3/s in Gumukhola. During the post – monsoon period flow has been recorded at 80.9 m^3/s in Suri and 92.93 m^3/s in Gumukhola.

Water Flow in the Sector III

The flow of the water starts from the 198.7 m^3/s in Nagdaha to 258.3 m^3/s in Khimti Khola confluence. The pre-monsoon flow in the section is recorded at 27.9 m^3/s in Nagdaha and it reached to 37.3m^3/s in Khimti confluence. During monsoon the recorded flow in the Nagdaha is found to be 395.43m^3/s and it is increased to 501.6m^3/s in Khimti. The post-monsoon flow varies from 172.48 m^3/s at Nagdaha to 236.66 m^3/s in Khimti.

Water Flow in the Sector IV

In the fourth sector, the measurement of flow of water is 261.33 m^3/s in Chisapani and it is increased to 258.76 m^3/s in Tribeni confluence.

The flow of water is found to be low in Tribeni because as the water flow from a narrow river to a wider area valley, its volume rate must remain constant. So, its speed decreases over the wider area (V1A1 = V2A2) (Bernoulie equation or volume flow rate of water). Moreover high perculation and evaporation due to high temperature, more river width, and geological condition and roughness of the surface which is ($Q=AR^{2/3}/n$, where v= Q/A = R2/3).

The sub-watershed along with the Tamakoshi river basin area ranges from Dholi Khola (10.5km^2) to Khimti Khola (358.00km^2). The large watersheds are concentrated in the sector Ist and smaller in the sector IVth. The distribution of flow also ranges as that of watershed distribution. "A linear reservoir unit hydrograph transfer function approach does not capture correctly the basin process that convert short memory precipitation to long memory stream flow. The degrees of multi fractility of river flow functions decreases with increasing watershed area which is depicted in Flient River Gasin in Georgia.

A major assumption of ratio method is that flow scales directly with watershed area, i.e. as watershed area increases the flow rate, increases at the same fixed rate per unit area. This means that the flow per unit area is the same at both un-gauged location and gauged reference location (Unit Hydrograph Theory).

According to Bradshaw model, the average speed or mean velocity of a river (measured in meter per second) will always increase with distance along with its channel. This is because the river tends to become deeper, wider and have a higher discharge the further downstream it moves. Similarly, as one moves along a stream in downstream, discharge increases as noted above, because waters is added in the stream from tributary streams and ground water. As discharge increases, the width, dept and average velocity of the stream increase. The gradient of the stream however decreases (Figure 5.2 & 5.3).

The pre-monsoon data reveal that the minimum flow of 38.67 m^3/s is recorded in Chisapani and maximum flow of 36.67 m^3/s recorded in Tribeni. In the monsoon the recorded flows are 505.36 m^3/s in Chisapani and 423.34 m^3/s in Tribeni. The post monsoon flow in the same locations has been recorded at 240.41 m^3/s in Chisapani and 246.11 m^3/s in Tribeni (Table 5.1, Figure 5.1, Photo 7a, 7b).

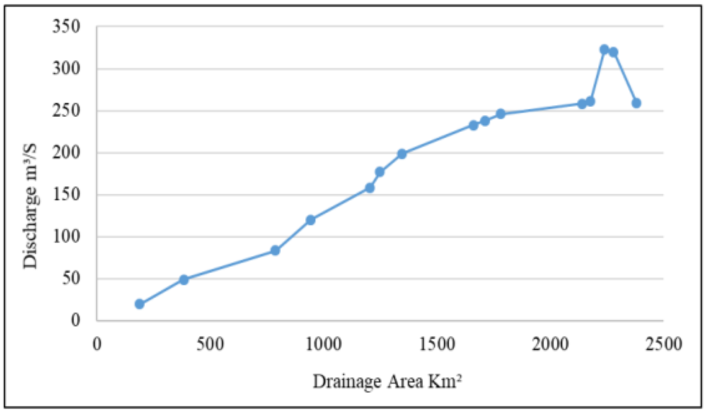


Figure 5.2**: Drainage Area and Discharge**

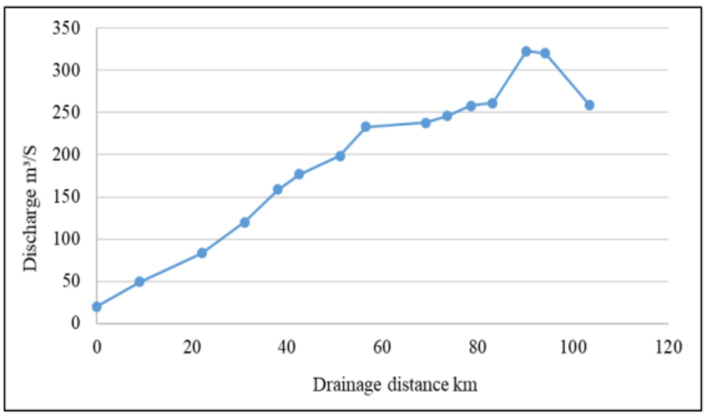
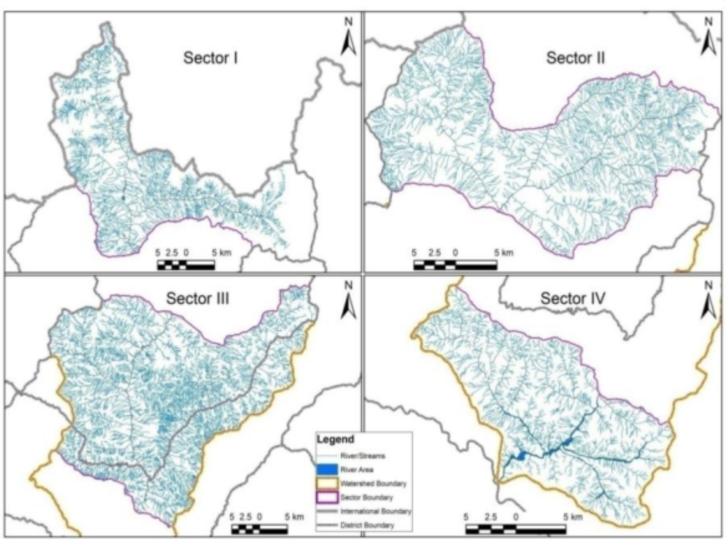


Figure 5.3**: Drainage Distance and Discharge**

Comparing the hydrological parameters, the flow rate (474.4 m^3/s), catchment area (11400 km^2) and lakes (335km^2) are more in the Kaligandaki river than the Tamakoshi river basin. However, monsoon precipation (62-90%), its contribution to the monsoon flow 10-20 times, post monsoon and seasonal flow show comparatively similar chracteristics between them.

The Kaligandaki river plays a significant role in the Gandaki river with discharege 474m^3/s which has a catchment area of 11,400 km^2. The perturbation regime is controlled by the monsoon system, which delivers 60-90 per cent of the annual precipitation in the summer monsoon flow from June to September (Hannah et al., 2005).

In response to the monsoon rainfall 55 to 80 per cent of the annual run-off occurs during June to September (Hannah et al., 2005) with high flow that are 10 - 20 times higher than the corresponding low flows in October to June (Chalise et al., 2001). High levels of rainfall give an abundant water supply (Sharma, 2005).



Source : Toposheet , Department of Survey.

Figure 5.4: **Drainage Network in Four Sector**

Compare to the large tributaries (Rolwaling, Singati, Khare Khola, Khimti) of the Tamakoshi River, the small tributaries are not suitable for estimating flows. The flow behavior of the larger tributaries is almost similar to that of the flow regime of the Tamakoshi River flow. The catchment areas of these rivers lie in the high altitude and lower rainfall. The main source of their stream flow is melting of the glacier which is true for Khare, Khimt, Singati also. The flow curve shows non-flushy shape. Contrary to the main river the flow of the tributaries are much more flashy than the main river. This shows that the nature of tributaries flow is highly variable than the main flow of tributaries.

However, the solid rock of the bedrock in the tributaries flow in the Ist sector is not reliable. The water is leaked from the boulders lines under rocks. The observation shows that each year, bed of the stream changes during monsoon. Compared to this the lower sector (II-IVth) the location of leaking flow is almost same.

The spatial flow trend of the river has been examined from alternate source of flow. The data show that the mean flows of water of Lapchi and Tribeni are 8.79 m^3/s and 182.3 m^3/s respectively. The temporal variation of the flow during pre-monsoon, monsoon and post monsoon has been recorded 32.08 m^3/s, 360.04 m^3/s and 67.76 m^3/s respectively. The figure represents 6.97 per cent, 78.43 and 14.71 per cent accordingly.

The natural flow pattern during the rainy season remains unchanged. But flow downwards the stream area from section II to IV has decreased substantially during the months of winter and spring due to use of upstream water for consumption and irrigation purposes.

5.2 Discharge of Tributaries

The discharge measuremt of tributaries flow is essential because one the main objective of the study is related to ecological flow or flow diversion of the main river. While there is water divrsion of main river for any development poject like hydropower, irrigation, it was assumed that 10 per cent release from the dam or diversion side is enough to downstream communities and remaining flow in the downstream, which is supplied by tributaries flow is enough to maintain hydrology and river ecology of the river basin. The fact is also approved by government rules and regulations. The base flow is measured at the lean flow period of the year i.e

April. The cross sections of tributary river segment are divided into various divisions and flow is measured at different depths. The measurement is carried out as an average of three measurements for each tributary and the output is averaged for the whole segment.

For the present study, seventeen tributaries have been selected for discharge measurement in the lean flow period (April, 2014) with the help of Pigmy meter (Digital counter revolution and time pre-set), model RCT 003T, current meter no 1142 and spin time was 55 seconds (Photo 1). The data acquired from the measurement of the tributaries is presented in the table 5.2 Fig. 5.5.

Table 5.2: ***Discharges of Tributaries***

Section I	Name of River	Width(m)	Discharge (Q) m^3/s	Remarks
1	Rolwaling	3.5	2.16	Nearbridge on way to Simigaon
2	Gongar	3.1	0.36	Upper part of Suspension bridge
3	Bhainse	2.1	0.11	Road side
4	Tinukhu	1.2	0.14	Road side
Section II				
5	Khare	11.7	2.12	200 meter from confluence
6	Singati	24.4	3.75	Near Singati Bazarnorth of bridge
7	GumuKhola	7.3	0.22	Gumu khola Bazar
Section III				
8	Dolti	4.3	0.39	Near Nagdaha
9	Andheri	1.5	0.02	Tamakoshi confluence
10	Charange	12.8	2.39	Upper side of Charange bazar
11	Gopi	5.25	0.59	Gopitaar
12	Milti	3.4	0.09	About 150 meterabove the confluence
13	Khimti	2.5	2.13	200 meter above motorable bridge
Section IV				
14	Mahadev	-	-	Dr near confluence with Tamakoshi
15	Ranajhor	2.5	0.68	100 metre above bridge
16	Sukajhor	-	-	Dry near confluence with Tamakoshi
17	Bhatauli	1.4	0.03	200 meter above the confluence of Bhatauli withTamakoshi

Source: Field Survey 2014, 2015

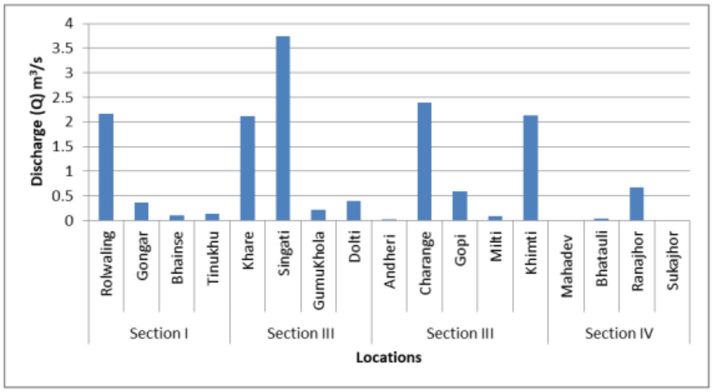


Figure 5.5: **Discharges of Tributaries at Different Locations**

From the Table 5.2 and Fig 5.4, it reveals that the Singati River (Sector II) has the highest discharge of 3.7 m^3/s. It is followed by the Charange River (Sector II) with 1.4 m^3/s. Among the tributaries, the Bhatauli River has the lowest discharge which accounts for 0.03 m^3/s (Table 5.2, Fig. 5.4, Photo 8a and 8b).

Observations at the Singati of Tamakoshi River show that the snow usually melts after the first and second week of March. The flow from Singati, Tamakoshi and Khare increases with mudflow (Sita Ram Balami and Umit Shrestha). The precipitation usually occurs in the form of cloudy moist called (*Dhumenin Nepal)* in Nepal in Lamabagar. (Discussion with Lax Sherpa, age 58 Lamabagar 2014 August 26).

5.3 Water Availability and Index

The water flow index has been calculated as the sum of flow for the year. The water flow index is presented in the Table 5.3.

For the Tamakoshi as a whole the seasonal index value shows that during pre-monsoon the flow is decreased by 91.09 % while in the post monsoon, it is decreased only by 45.36%. During monsoon, the flow is increased by 123% only as compared to overall indx in the Tamakoshi River Basin (Table 5.3, Annex IV).

There are four months (June -September) of water flow in the river during monsoon and is entirely based on the rainfall. The post-monsoon flow (October-January) is supplied by melting ice and pre-monsoon flow (February -May)is supplied by ice accumulation in the mountain. However, ice cannot melt immediately during early period after the ending the post monsoon. So the flow during the pre-monsoon time is base flow which is entirely based on the ground water accumated in the river basin , also know as base flow (BF).

The availability of water is defined as a flow of water in the river basin available for a whole year. It is a broad topic, encompassing the biophysical supply of water, demand for water and access to water. It is a state, which implies that water is available for ecosystems and human society to use (Brauman, 2015).

In the sector Ist, a total of $1.6482x10^{10}$ m^3/s of flow water is available. It covers 27.62 per cent of the total basin area. This represents 16.47 per cent of water of the total basin. As per this the order of water basins of the sub-basin ranges from 28 (Suri) to 40 (Gongar).The area covered by the sub-watersheds range from 29.00 km^2 to maximum of 199.89 km^2. Among them Lapchi is the major one with an areas of 590.00 km^2 . Similarly, the Rolwaling Khola is originated from Tsho-Rolpa glacier lake located at 4,580 amsl and other rivers are also originated either from the high Himal or from high mountain.

In the IInd sector the total water availability is equivalent to $7.499x10^9$ $m^{3/}$s and it has represented 9 % of the water of total basin. The sector is made up of 14 different sub-basins with an area of 1067.4 km^2. The order of the sub-watershed ranges from 10 in Jungu to 34 in Chilankha. The watershed in the zone is mostly concentrated in the High Mountains. Among various sub- watersheds Singati (Jhoroung and Soroung), and Khare are major ones. The area covered by the sub-watershed ranges from 9.34 km^2 to more than 230 km^2 Singati khola and Khare Khola are originated at a height of 4,587 masl and 4160 masl respectively.

In the IIIrd sector, a total of $4.9776x10^{10}$ cm^3/s water is available which represents 49.74 per cent. There are 22 sub-watersheds in this area. The total area coverage by the water is 1361.69 km^2. Except Khimti (the origin 5502 m near Gumdel) the other tributaries are originated from the lower mountain range like Dholi and Ghyangsukhathokar.

The area covered by the sub-watersheds ranges from 9.88 km^2 to 320 km^2. The sub-watersheds with the area more than 100 km^2 are the Charnwati and Khimti Khola watersheds. The Bhimeshwor sub-watershed has been ranked as the first and Shymamali has been ranked as the 22^{nd}. The best watersheds are Maryang, Jilukhola watershed and Charnawoti Khola sub- watersheds.

The total availability of water flow in the IV^{th} sector is $2.42951x10^{10}$ $m^{3/}s$. This covers 24.24 percent of the total water in the whole basin. The order of the sub watershed ranges from 10th order of Bhatauli as to 18th orde of Jakhami khola (Appendix V). Most of the sub watersheds are characterized by dry with low rainfall.

The tributaries are originated from the mid-mountain region. Among the tributaries, Bhatauli has a drainage area of 100 km^2 and remaining drainage area of the watersheds has been less than one third of Bhatauli (Fig. 5.7). The sub- watersheds in the zone are mostly concentrated in the middle mountain and are mostly dry. The area covered by the sub-watershed ranges from 9.88 km^2 to more than 120 km^2 (Fig 5.7).

It has been revealed that the flow from the first to the fourth has decreased by 43.334%, 47.92%, 33.28% and 93.68% respectively (Table 5.5).The total water availability of the basin is equal to $7.47134x10^{10}m^{3/}s$.

The coefficient of variation of the tributaries ranges from 96.66% in Gongar Khola to 99.5 % in Lapchi Khola of the first sector. The value of the Sukajhor Khola is 116.16%. The CV of the sector II and IIIrd lies between these two values.

Likewise, a seasonal index of Lapchi Khola is found to be 79.24 % and 81.31% in Khare Khola, whereas the value is 0.40% in Mahadev Khola and 6.50 % in Sukajhor Khola. The characteristics of the tributaries of the sector II and III lie between these two values.

5.4 Ecological Flow Site and Dewatering Zone

The data for the examining the river basin flow with regard to dewatering zone with e- flow are generated from toposheet, Google Earth and the field survey has been prepared for the present study (Photo 9). The sectorwise river basin with existing and planned dewatering zone is presented in Table 5.3.

Table 5.3: Existing HPP in Tamakoshi River Basin

Sector	Km	Dewatering (km)	MW	No of HPP	Lean flow period (m^3/s)	E- flow (m^3/s)	Augmented flow (m^3/s)	Deficit flow (m^3/s)
I	30	14	957	12	17.54	1.75	0.69	1.06

The existing de-watering zone of Tamskoshi river flow is 11 km from Lamabaga to Gongar. The minimum flow of the area is 17.54 and remaining flow is supplied by Rolling. Similarly the existing dewaterins zone of Singati Khkola, Suri Khola are respectively. The flow of Khimti is 11 km from Plalti to Kirnetaar.

Buddha Tamang viewed that the after damming in the upper Tamakoshi hydropower, the fishing activities is disappearing. "Catching fish these days certainly takes more luck than it used to" said 20 yeas old Tamang. Similarly, Maker Bahadur Khadka viewed that hydropower projects have turned Singati a hub centre of hydropower which is becoming a major centre of fifty major and minor hydropower projects, but it also damages the river ecology also. He remarks "the large- scale infrastructures projects have alos taken a toll on the Tamakoshi basin's rivers and river ecology."

9

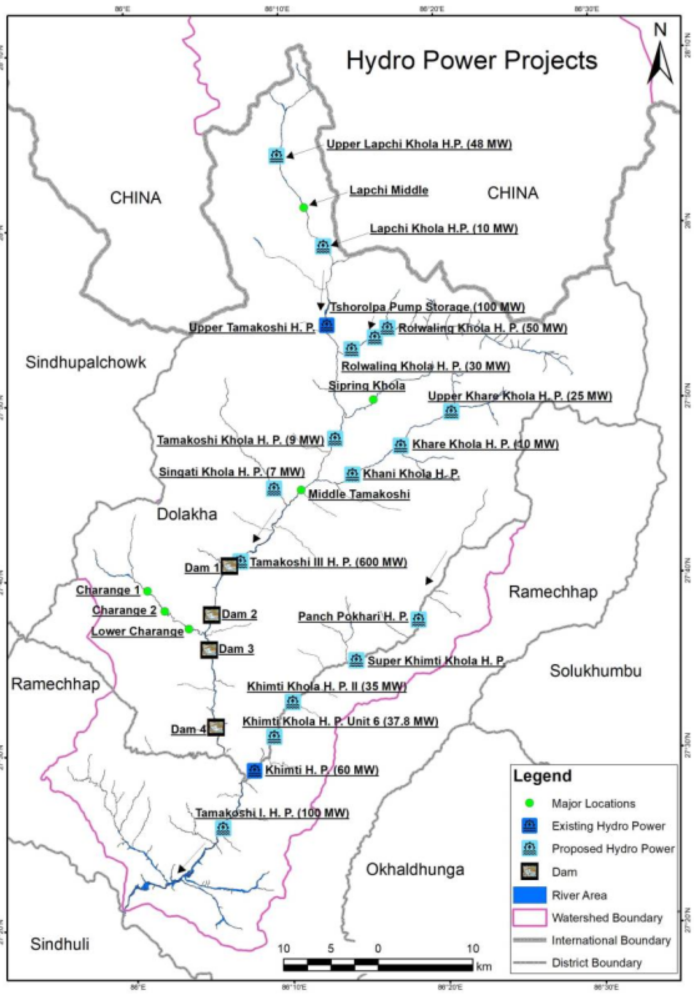
The quantity of fish in the lower section of the Singati River has decreased significantly since the construction of Singati hydropower dam. Similarly, only the common snow trout (Schizothorax macrophthalmus) caught in the Singati River. Before the river was dammed, at least five different species of fish were caught.

Table 5.4: Proposaed HPP in Tamakoshi River Basin

Sector	Km	Dewatering (km)	MW	No of HPP	Lean flow period (m^3/s)	E- flow (m^3/s)	Augmented flow (m^3/s)	Deficit flow (m^3/s)
II	25	6	30.52	6	27.04	2.70	1.61	1.09
III	32	24	1410	3	31.11	3.11	1.07	2.04
IV	23	3	110	1	37.30	3.73	0.11	3.62
Total	80	33	1550.52	10	95.45	9.54	2.79	6.75

Sorce: Field Survey, 2014, 2015 and Self- calculated

From the Table 5.4 it is evident that the number of projects in the first sector (density hpp/2.5 km) is outnumbered the hydropower projects in the fourth sector (density hpp/23km) (Fig 5.6).



Source: Field Survey, 2014/2015.

Figure 5.6: **HPP Locations in TRB**

The dewatering zone is 47 kilometer and their magnitude range from 30.52 MW in the IInd sector to 1410 MW in the third sector and most of dewatering zone lie in same sector (Table 5.4).

The lean flow, e-flow (photo 9) and augmented flow of the first sector are 17.54 m^3/s, 1.75 m^3/s and 0.69 m^3/s respectively. The deficit flow is equivalent to 1.6 m^3/s in the sector Ist. The lean flow during April of the Tribeni is found to be 36.84 m^3/s and e-flow of the sector is equal to 3.6 m^3/s and augmented flow is equal to 0.11 m^3/s and deficit flow in the sector IVth is equivalent to 3.62 m^3/s (Table 5.4). In this way the trend of deficit flow increases from the Ist sector to the IVth sector. The contribution of augmented flow is less than 2-4 per cent of the main trunk.

Table 5.5: ***Coefficient of Tributary Flow in Watershed***

Sector I	Name of tributary	Discharge (Q) m^3/A
1	Lapchi	0.01
2	Rolwaling	0.61
3	Gongar	0.02
4	Sipring	0.61
Sector II		
5	Khare	0.19
6	Singati	0.15
7	GumuKhola	0.04
8	Jhyanku	0.07
9	Andheri	0.03
Sector III		
10	Charange	0.49
11	Ladke	0.06
12	Phadke	0.05
13	Dholi	0.005
14	Gopi	0.08
15	Milti	0.05
16	Khimti	0.05
Sector IV		
17	Tilpung	0.05
18	Mahadev	-
19	Kathajhor	0.04
20	Ranajhor	0.04
21	Sukajhor	0.04
22	Bhatauli	0.04

Source: Self calculation based on based on Chitrakar, 2014, Sharma 1977

It is evident from the Table 5.5 that the contribution of the watershed more than 1 m^3/s is limited. The Khimti watershed (302 km^2), Rolwaling (224 km^2) and Singati(146.9 km^2)are bigger watersheds which contribute more than one cubic meter of water flow during the dry period (Fig 5.7).

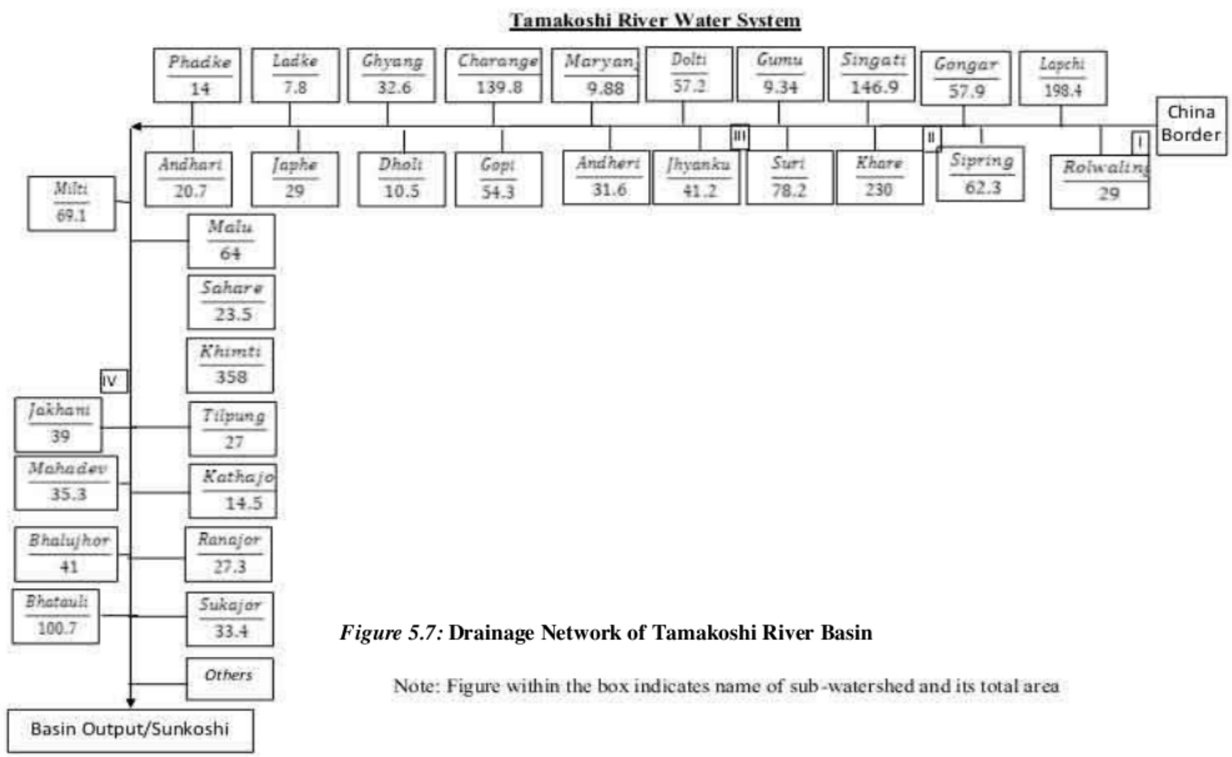


Figure 5.7: **Drainage Network of Tamakoshi River Basin**

Note: Figure within the box indicates name of sub-watershed and its total area

5.5 Distance and Discharge

The accelerated flow of water in Tamakoshi seemed lower in Tribeni and Manthali (sector IV) than earlier location due to following reasons.

a. The rainfall- runoff coefficient (R^2) is only 0.23 and t-test is significance (0.2).
b. Overall all contribution of precipitation in the IV sector is only 13 % and almost 45% of the rainfall occurred in Charikot and Nagdaha (III sector).
c. The altitude and rainfall distribution is uneven and relationship between two variables is only 0.36. The ground water extraction programs are implemented in the sector IV. The operation of two big and six small shallow tube well lead to lower the water table almost by two feet in the sector in 2014/2015 compared to 2010. It has been learnt that after operation of pumping in Manthali for the last five years the water level has reduced down by almost 1 foot (Communication with Bharat Majhi, Age 71, Manthali). The distance and flow of tributaries are found to be negatively correlated in the IVth sector, but it is found more favourable in the IIIrd sector (.99). The relation is also proved from regression equation with high slope in the Ist sector and low in IV sector. The result of regression are as follows: sector I (0.99), II (0.95), III 0.96), I (0.75). It shows that only 75 per cent is dependable in the sector IV and 25 per cent is due to other variable.

5.6 Relationship Between Watershed and Flow

5.6.1 Trend of Temperature, Rainfall and Runoff

The brief description of trend of temperature and precipitation is presented in the following sections.

a. Temperature and precipitation: The temperature and precipitation recorded at Jiri station has been used to analyzed the tend analysis. The maximum and minimum temperature of the upper part of the basin at the north most station (referred from Index sector 1103 at Jiri) are taken as 28^0 celcius (upper limit) and -7^0 celcius at lower limit (DHM 2015).

Five years mean of yearly temperature (both maximum and minimum) of the last twenty one year's shows the increasing trend of temperature. The maximum temperature indicated 0.027 ^{0}c annual increase in maximum temperature with R^2 value of 65.7%. Similarly for minimum temperature it was found to be 0.026^0 c increase in temperature every year with R^2 value of 44.6%. From January, temperatures increase, reaching a maximum in August (35^0 celcius). Relative humidity varies between 65% and 90% (DHM, 2011).

Five years moving mean of annual precipitation of the last two decade (1992-2012) fitted well in the second degree polynomial curve with higher R^2 value i.e. 89.4% clearly indicates an average of 4.394 mm decrease in precipitation every year (Figure 5.8).

b. Rainfall- Run off

The flow data of Busti has been available since 1971. The relationship between rainfall and resulting run –off is complex and is affected by various factors like land use, catchment area and evaporation. The yearly precipitation and run off of the last three decades of Tamakoshi River has been calculated with help of a regression mode. The regression equation is: R=9.65+p124.13, where R= mean runoff (m^3/s) and P= Precipitation The correlation between two variables (rainfall and runoff) shows that there is a weak correlation (r= 0.23) between two variables.

The basin experiences the effects of the south-west monsoon flowing from the Bay of Bengal. But the area from Manthali to Sailungeshowre (sector of the IVth) experiences one type of climate. Similarly, the area from the Tilpung to Dolti another where more rainfall experience in the Suspachemawoti (2200 mm)which fall in the (IIIrd sector) similarly, from Dolti to Jamune experience less rainfall(850 mm) than Suapachemawoti (Setion III). From Jamune or Sipring upwards the monsoon hardly penetrates upper side. So, the area experiences less rainfall. However, the upper side is covered with snow throughout the year.

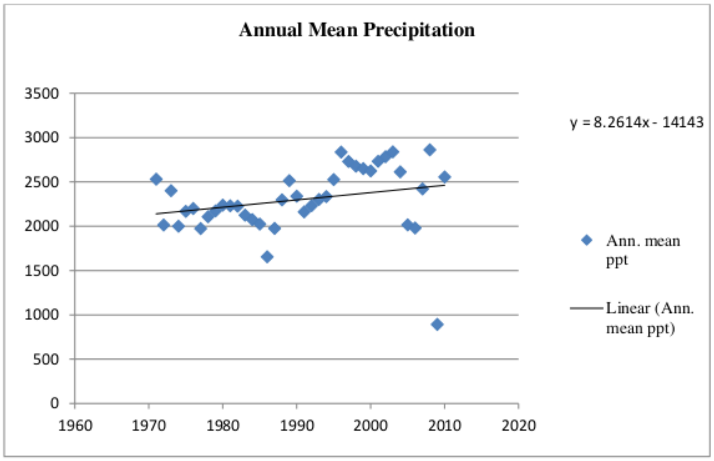


Figure 5.8: **Annual mean precipitations**

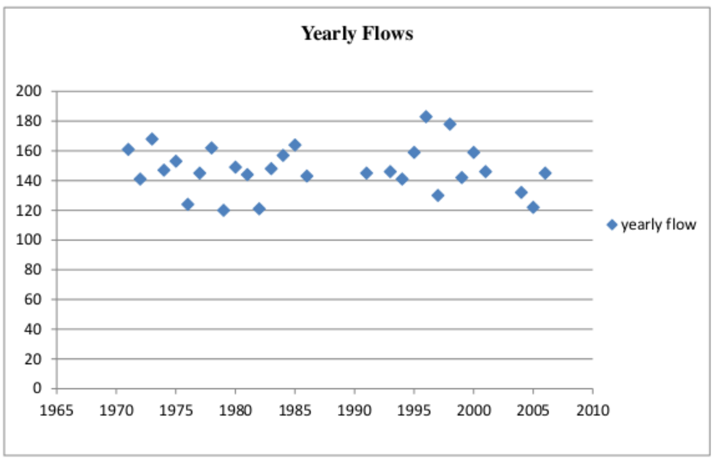


Figure 5.9: **Yearly flows**

The percentage contribution of March ranges only from 1.4 to 1.8 per cent in the most cases.

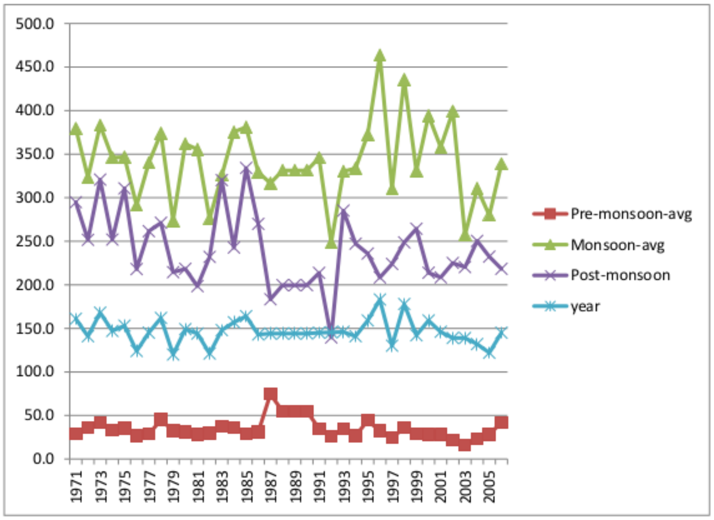


Figure 5.10: **35 Years Yearly Flows Recorded at Busti Station (DHM)**

The 35 years turns out to be 55.11. It indicates that the average yearly flow of the Busti station ranges from 121 m^3/s (1982) to maximum of 183 m^3/s (1996) in 35 years. The pre-monsoon flow ranges from maximum of 74.5 m^3/s in 1987 to minimum of 23.1 m^3/s in 2004. The post monsoon flow ranges from maximum of 80.2m^3/s in 1987 to minimum 34.9 m^3/s in 1992 (Fig. 5.11). The overall trend also shows decreasing trend. Maximum and minimum flow trend also shows the similar trend which has been presented in the following figures.

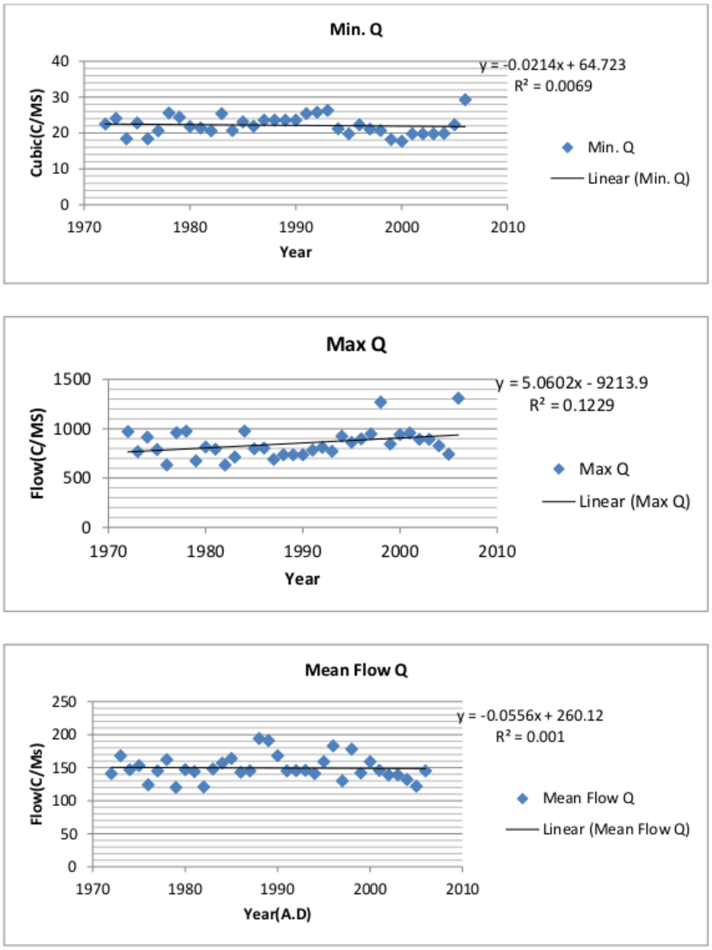


Figure 5.11: **Minimum, Maximum and Mmean Flow**

5.7 Flood Risk Assessment

A flood frequency analysis has been performed on annual basis. The maximum daily average flood values at the gauging station No 647 Busti along the Tamakoshi River. Annual maximum values are shown in Table 5.6 and in Figure 5.12.

Table 5.6: ***Maximum Daily Average Flood Values (647 Busti)***

Year	Maximum discharge (daily)	Year	Annual maximum discharge (daily average)	Year	Annual maximum discharge (daily average)	Year	Annual maximum discharge (daily average)
1970	-	1980	814	1990	-	2000	940
1971	792	1981	792	1991	783	2001	957
1972	971	1982	632	1992	811	2002	1053
1973	768	1983	713	1993	770	2003	-
1974	915	1984	976	1994	924	2004	827
1975	788	1985	796	1995	862	2005	742
1976	634	1986	803	1996	897	2006	1312
1977	960	1987	903	1997	947	2007	740
1978	975	1988	1073	1998	1267	2008	810
1979	674	1989	922	1999	845	2009	-

Soruce: DHM, 2011.

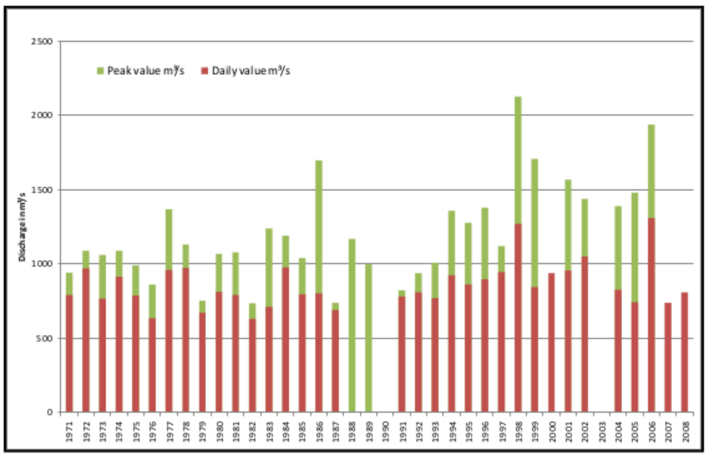


Figure 5.12: **Maximum Daily Discharge and Peak Values (647 Busti)**

The analysis has been performed using the software EKSTREM developed by The Norwegian Water Resources and Energy Directorate (NVE). Several flood frequency distribution formulae were tested and GUMBEL (EV1) was selected as giving the best fit and also one of the most conservative results. The flood with recurrence intervals was interpolated from that distribution.

From observations at the Busti Gauging Station the ratio between peak values and daily average flood values was calculated. The ratio, varies from 1.05 to 2.12. in 32 years. The mean ratio is found to be 1.41 in the study. It is used to establish peak values for the 1000 and 10000 year floods. The flood values for different return periodsare shown in Table 5.7.

Table 5.7: ***Magnitude of Flood Values at Different Recurrence Intervals***

Recurrence interval (years)	Daily mean(m^3/s)	Flood Peak (m^3/s) value
5	985	1389
10	1071	1510
20	1152	1624
50	1255	1770
100	1331	1877
200	1405	1981
500	1501	2116
1000	1572	2217
10000	1905	2686

(a) Flood routing through the Busti Station

Based on the daily mean and peak values, flood hydrographs to the Busti area with 1000 and 10000 years recurrence intervals were constructed as shown in Figure 5.13. Both these floods were routed through the sector III in the Tamakoshi to get the maximum out flows of flood. The flood routing results the 1000 year and 10000 year events are shown in Table 5.8 and Figure 5.13

Table 5.8: ***Results from Routing Floods Through Busti***

	Total inflow				Outflow				Water level in the Busti
	24 h mean		Peak value		24 h mean		Peak value		
	m^3/s	l/s·km²	m^3/s	l/s·km²	m^3/s	l/s·km²	m^3/s	l/s·km²	m a.s.l.
Q_{1000}	1572	537	2217	757	1560	532	2005	684	942.70
Q_{10000}	1905	651	2686	917	1895	647	2441	833	943.10

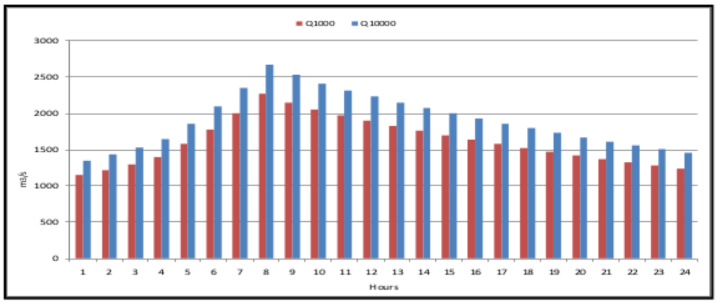


Figure 5.13: **Flood Hydrograph for the Inflow to the Busti Station (No. 645)**

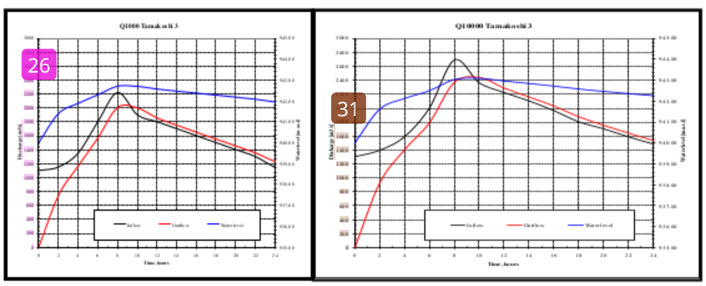


Figure 5.14: **Routing results for Q 1000 (left) and Q 10000 (right) in Busti Station**

5.8 Temporal and Spatial Discharge

The temporal/spatial pattern on the flow was observed during 2014 and 2015. It is almost the same for the pre-monsoon and post monsoon period. However, the monsoon discharge fluctuated between 2014 and 2015. The details of the sector-wise flow are presented in the Table 5.9.

Table 5.9: ***Location-wise Flow Regime***

Location	Flow pattern in 2014/2015
Lapche	The flow pattern remains almost same throughout year. However, during monsoon it raises slightly hight and and less flow during pre and post-monsoon period.
Lamabagar	The flow pattern almost remains same throughout the year. No more change is recorded in this location
Chechet Flow	The flow of the river is confined in the V shape valley and more water flows during the monsoon. The flow of water in the river is almost non-existence and is not visible during pre and post –monsoon and even monsoon the flow of the river runs through deep george.
Gongar	The flow pattern is erratic during the monsoon than in other seasons. But during the winter it does not expand
Khare	The flow during the monsoon turns out to be almost five to ten times greater than the regular flow and more water seems to be crystal when it flows through the snow cap area. When Khare joins Tamakoshi in the confluence the water colour becomes more turbid as it contact more sediment and carries different types of materials.
Singati	More erratic and torrent flow observed during the monsoon. It is more in the confluence of the two rivers. More variability is observed in 2015 than 2014.
Gumukhola	The flow over here goes smoothly in the gradient. But the flow reaches near Gumukhola bazaar too. Sometimes the flow of Gumukhola is more turbulent as it flows through higher range.
Nagdaha	The area is almost flat and the flow is no more erratic in 2014. and quiet erratic during 2015 and behaves like this due to the earthquake and flow of water almost spread to other parts of the river bank. But river rises up to nearly to the bridge during high flood. The river Dolti some times makes disruption.
Nayapool /Charange	The flow in the pre monsoon and post monsoon is almost similar but in the monsoon period the flow is torrent over here. However, sometimes the river Charange creates problems and even blocks the flow of Tamakoshi River. More waves (Chhal) were seen in the interval of 2 to 3 hours in 2015 compare to 2014.
Malu	The flow is more turbulent and wider in 2015 than 2014. More area of boulders and sand deposits are found in 2015 than in 2014.
Milti	The pattern of flow during monsoon is violent and more erratic too, but during the pre- monsoon and post monsoon the flow is almost same
Khimti	The water flow in the section is wider over here and erratic during the monsoon. But the area remains almost same during pre –monsoon and post monsoon.
Gaikhura	The water flows swiftly in the beginning and it is divided into two parts in the middle section. The direction of the water flow starts from the west to the east. The water flow is faster and swifter at this stage than other parts.
Chisapani	The f low pattern in the sector is wider and erratic during monsoon than pre-

	monsoon and post monsoon. More deposition of boulders and other materials observed during post monsoon.
Gadari	The flow in this part is controlled by the wall built up in the western part of the area. But this time the water flow has reached up to the point which is higher than the river valley. It has come up to 1/2 portion of the river valley (Communication with Suresh Majhi, Manthali). But in 2014 even the ground area of the school building was inundated.
Ranajhor	The flow of Ranajhor is more than double in 2015 compared to the year 2014. But this time it was noticed that the flow has increased on the second day of the July due to rain on the last day. The flow starts to get more slurry than liquid. The Ranajhor flow has cut in several places. In such a way that there is a big island made in the confluence between the Ranajhorkhola flow and the main Tamakoshi flow area.
Bhatauli	The flow of Bhatauli in 2015 is more than expected when it is compared in with 2014. There are several areas from where the canal has been constructed from Bhatauli. The whole Mugitaar is a gift of Bhataulikhola. The most important plain in called *Machhiphant* plain cultivated land.
Tribeni	The flow pattern in the sector covered almost 5 meter below the normal flow is wider and erratic during monsoon period but low and about 1-2 meter in pre-monsoon and post monsoon. The flow is violent and it covered more area of the valley in 2014 than in 2015. The river flowing in the Tribeni side is deeper and sided towards the west. The flow also returns back which can be seen only in the Khurkot side.

Source: Field Observation Survey 2014 and 2015

The pre-monsoon flow is used for better management of river flow materials. Similarly, the post flow regime is the first deposit of new materials of river flow. Likewise, the monsoon is the period of deposit of river materials in the river basin.

The high flow during monsoon is a sign of danger in the Ist and IInd sector but it is a gift for some communities of the sectors IIIrd and IVth. For instance, when the over flow occurs in the Tamakoshi, the Majhi community seemed quite happy and they welcome at their home. They even cross the waves of the Tamakoshi. Likewise, they try to see if there is any whirlpool to mark the deposit of sand. These are the places, which have large concentration of sand and other river resources. Different types of fish have washed dead in the riverside. Similarly, when flow rises, the nutrients are disbtributed in all courses of the river. Likewise, big fishes are also move up with high volume of water.

5.9 Direction and Dimensions of Water Flow

Dimensional analysis is an extremely valuable method in any applied science because equations must be balanced dimensionally and numerically. It can be used to check the existence of variables that have not taken into account and to recommend the appropriate correct forms of functional relationship.

The character of hydrological parameters of different sections has been derived from the calculation and the result is presented in Table 5.10.

Table 5.10: ***Flow Direction and Dimensions***

Sector/DD (km $^{km-2}$)		Elevation Range (m)	River length (km)	**Slope**	Angle (0^0)	**Width**	**Vector value**	**River Power (nTu)**
I	0.6-1.11	4000-1300	29.5	1:07-1:22	13^0-45^0	7.4-9.71	1.27-1.0	26.80-333.73
II	1.22-4.61	1300-900	25.22	1:22- 1:05	45^0-13^0	9.71-6.54	1.0-1.37	54.80-106.01
III	3.02-4.61	900-550	32.49	1:05-1:01	13^0-17^0	6.54-7.51	0.87-2.82	23.76-76.31
IV	1.11-1.66	550-440	22.17	1:02-1:01	17^0-18^0	7.51-2.52	0.6-1.27	64.33-3.30

Source: Toposheet,DoS, Nenpal scale 1:50,000 and 1:25,000. 1992, 1996 and self calculated.

DD = Drinage density

The Table 5.10 shows that the Tamakoshi river is straight in 10 places (40 per cent) and sinuous in 10 places (40 per cent) and meandering in 5 places (20 per cent). From the table and field survey it has been found that the channel is senious and and meandering near Dholi to the Ladke Khola. Among the four sectors, the sectors IInd and IIIrd have the higher drainage density than the others. It is also clear that the erosion rate is higher in the sector IInd than the Ist and IVth sector.

Moreover, there is a relationship between water flow vector (direction and angle) and river width. The flow of water in the straight direction has more velocity than flowing the river in angle (Ist sector). When the river flows in a wide valley the speed of the river breaks and velocity of water gets reduced in the IVth sector (Table 5.10). In addition as angle in the river path changes, speed gradually decreases until the angle reaches to constant over the period of time.

From the Table 5.10, it has been clear that the overall drainage density of the sector ranges from 0.62 km km to 1.22 km km and the path direction ranges from 7.40^0 to

9.71^0, slope ranges from 1.07 to 1.22 the power of the river ranges from 26.8 nTu to 333.73 nTuin the Ist sector.

In the fourth sector, the drainage density ranges between 1.11 km km^{-2} to 1.66 km -km-^{2}, the gradients of the river in the sector measure less than 3^o. The power of the river ranges from 64.33 nTu to -3.33 nTu. The mean width of the river in the sector is 128.28 m. The value of the sector II and IIIrd lie between these two sectors (Table 5.10). Compared to the first, second and third sectors, the angle and distance are similar except in Tilbung side (Appendix V & VI).

It indicates the effects of main channel curvature on the flow pattern in the river. The junction points are important in terms of flow pattern, sediment deposition, acquatic ecology and river morphology. Moreover, it also effects on vertical and travers velocity profile, water level in main channel. The changing junction angle, depth are more in the first sector and less in the IVth sector (Table 5.10, Fig 5.14). The gradient with more curve is shown in figure A to H in the Ist sector and N to Q in the IVth sector (Fig 5.15). It indicates that the flow is more sluggish in the setor sector iv than the otherr sectors.

During the field visit, the local people share the view about decline in the flow of water. The local people of Tilpung said that there is decline of yield of water resource and as a result they have to depend on the other sources of water specially pumping from the Tamakoshi river (Communication with Shyam Dahal, age 42 Panthali). Water resource has been drying up. Water resources are the major problem in the fourth sector of the study area. The local people of Bhatauli are highly affected by the decrease in water availability from the existing sources. About $3/4^{th}$ of the traditional water sources like springs/ spouts are being exhausted or its capacity has become less in comparison to the water availability two decades ago. Only about 40 per cent of the local people have the facility of a year round water supply (Communication with Suntali Majhi, Age 52, Bhatauli), and remaining time have to depend on Bhatauli and Tamakoshi river.

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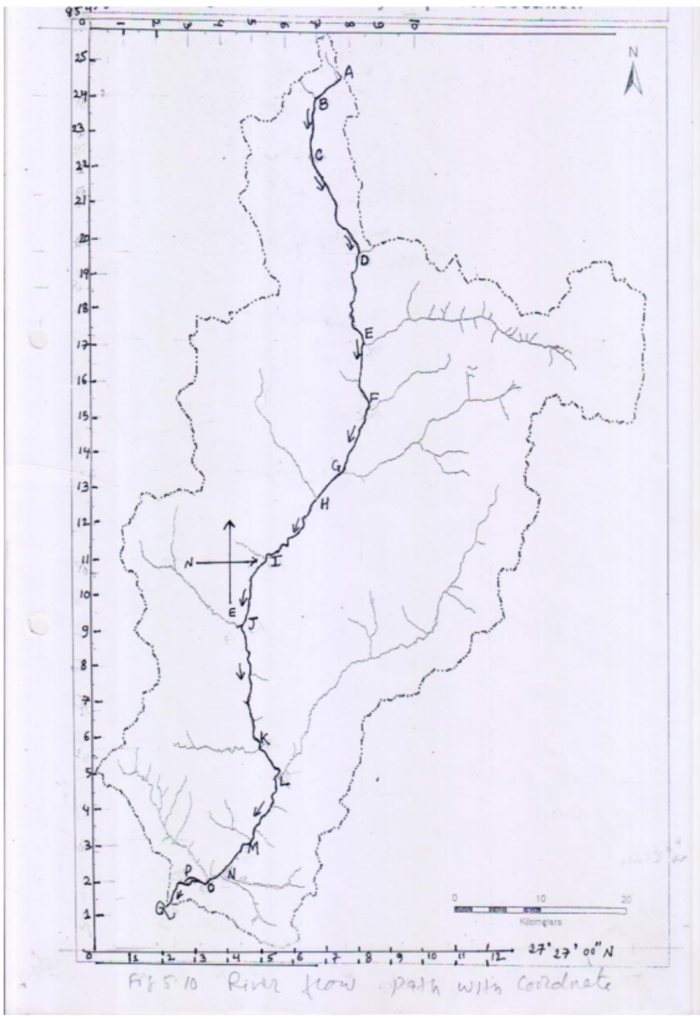
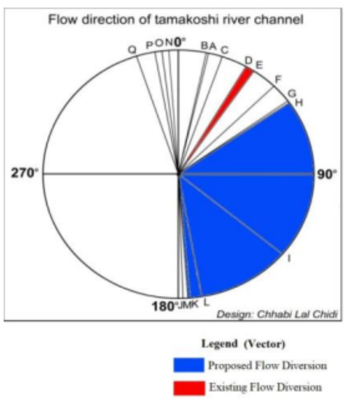


Figure 5.15: **River Flow Path with Coordinates**

To date geographers have shown a little interest in dimensional analysis, due to overload of human activities. For the present study, latitude 27^0 40' 00" and longitude of 86^0 05' 00" have been marked in the toposheet as an origin and the mark has been transformed into map scale of 1cm=3.8 km. The path description (chain encoding) with origin (O); and ending (e) and distance bearing were measured in the toposheet. The measured data were transformed into trigonometric ratios; 0-90^0, 90^0-180^0; 180^0-270^0; 270^0-360^0 with cosine, cosin + sign and tangent (Unwin, 1981).

Thus, the flow direction and angle shows that in the first stage there is a high gradient with more curve and force. It is proved by cos θ. In the IIIrd sector, there is high in the first stage and less in the end stage. The last stage (IV) is again more or less flow in its direction and more curve linear indicating less force than earlier. (Table 5.11, 5.12, figure 5.16).



$$\mathrm{Cos}\theta = \frac{b}{v},\ \sin\theta = \frac{v}{b}\ \theta = \frac{v_1}{vH_1}, \theta R = \mathrm{Tan}^{-} \frac{v_1}{vH_1},$$

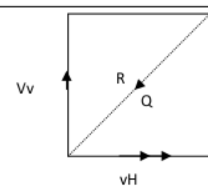


Figure 5.16: **Flow Direction of the Tamakoshi River Channel**

Table 5.11: ***Vector Summation (a)***

Quadrate	Sector Distance	Angle	Resolution		
I	A ,B, C, D, E, F, G, H,	13^0 to 55^0	V_i Sin 201.77	V_i Cos	Tan
II	I	30^0 -	3.046	-	-
III	J,K,L,M	170^0 to 180^0		- 340.99	-
IV	N, O P, Q	-4^0 to -18^0	-	-	-0.2404

$$Tan\ \theta_R = \sum v_i \sin\theta_i / \sum v_i \cos\theta_i$$

201.77/-340.99=0.59 lies on 30.610, i.e. Lamabagar location

Average vector magnitude V /n =342.36/4=85.5990.

This place is located nearby Jhyanku and Pikhuti (between Singati and Gumukhola)

Table 5.12: ***Vector Summation (b)***

Angle /Sector	I	II	III	IV
X- coordinate	159.24^0	55.01^0	-62.69^0	30.07^0
Y-Coordinate	78.93^0	52.47^0	5.85^0	-7.05^0

Source: Self calculated

5.10 River Power and Sediments

The seasonal variation of mean depth of water of the river over the period of 2 year investigation is shown in Appendix V D, Table 5.6. The mean depth of water of the river fluctuates highly at different locations like Gongar, Singati Gumukhola and Nagdaha. It generally increases and reaches maximum level in July. In August (monsoon) its depth was measured with 3.5m. mean and 1.55 m. in Nayapool (Section III) downstream (d/s) up to Karambotee. But, it reached maximum level of almost more than three meter in August in Nagdaha and Nayapool (Communication with Stalin Shrestha, Age 65, Nagdaha, Bhimeshwor Municipality-2).

For sampling data, Karl Pearson's correlation value was taken to test the significance which was found to be-.224 along with P value of test statistics t 0.329. Since, p value is (>0.5) is not significant. There is no significant relationship between current river power and cumulative distance. The correlation is observed in the IIIrd and Ivth sector only. However, there is a negative correlation between them. Hence, this situation guides us to find out the other factors which explain downstream why there is downstream downward current power from reference point. The scenario also explain from scatter plot (Fig. 5.17).

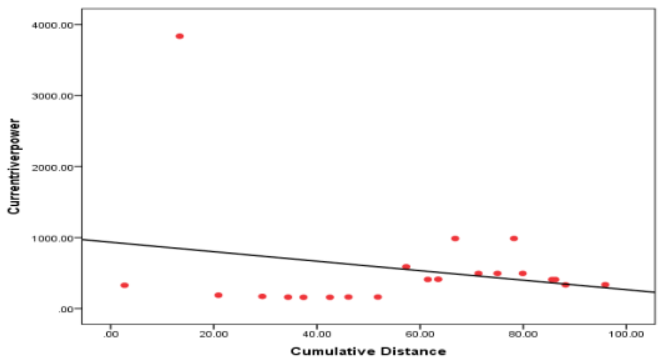


Figure 5.17: **River Power and Cumulative Distance**

The water depth played a significant role in the flow regime of the Tamakoshi River. The sinuosity ratio has a high impact on sedimentations than other variables (Appendix V D). Sand is deined as "a detrial particle smaller than a granule and larger than a silt grain having diametr in the range of 1/16 to 2 mm (Hoffferman, 1993). The stone is described as "a general term for rock that is used in construction either crushed for use as aggregate or cut into shaped blocks as dimension stone (Hoffferman, 1993) and gravel is named as "a collection of water eroded rock materials found on the beds of rivers, lakes or seas, comprising mainly rounded fragments (4-45mm in diameter) together with same finer particles or cly or sand (Buchanan 1974).

River sediments including boulders, rocks, gravels, pebbles, sand, soil and silt are freely available for use by inhabitants of the basin. The sediments resulting from land erosion are transported by the Tamakoshi River and its tributaries like the Lapchi, Gongar, Bhainsa and Chyadu Khola. The size of boulders and pebbles, the granular size of sand and silt, and the volume of those sediments generally vary as the river flows downwards and as more tributaries mix with it. Detail description of the river sediments are presented in the Table 5.13

Table 5.13: ***Deposition of Resources in the Tamakoshi***

Resources	Sector I	%	Sector II	%	Sector III	%	Sector IV	%
Sand	45,000 m^3	13.0	3,114.12 m^3	0.08	119,544.9 m^3	1.8	133,155.0m^3	6.55
Stone	222,877m^3	64.7	3,423,756 m^3	85.72	9,856,6887 m^3	97.9	1,131,607 m^3	55.69
Gravel	76,867 m^3	22.3	56,6877 m^3	14.19	866,877 m^3	0.86	766,877 m^3	37.74
Total	344744 m^3	100.0	3993747.12	100.0	100629213 m^3	100.00	2031639 m^3	100.00

Source: Field Survey, 2015

In the Ist sector, few sediments are deposited, except for huge boulders and rocks due to the rapid flow through narrow gorge of the Tamakoshi river. Fluvial deposits like boulders, sand, pebbles and gravels could be seen near Lamabagar, where the fluvial process had created a unique natural dam which is more than 400 meters high. The size of boulders ranged from 3.29 cm^3 to 36.41 cm^3. As a consequence of these boulder deposits, crusher factories with different capacities have been set up. The crusher extracts more than ten tons of boulders per day and supply as raw materials. This also works as construction materials in the site of the Upper Tamakoshi Hydroelectric Project.

In the second sector, the sedimentation process appears to be very high and include soil, stones, and silt due to frequent flash floods. At the sites where the Tamakoshi receives additional tributaries, the coarse materials comprised stationary boulders of 2-3 m^3, gravel, pebbles and stones (about 3/4) and sand (1/4). With 2,100 cm^3, some boulders were larger than that in the upstream section. The mean size of the pebbles was 311 cm^3, and the mean volume of gravel and sand together 9644.5 m^3, nearly 4% of the total volume generated in the basin.

In the third sector for instance, the two sites of Dholi Khola and Bhange Khola respectively contribute to a yearly estimated deposit of 119,554.89 m^3 and 1,328.87 m^3. The daily extraction of material amounts to about 23.86 m^3, ranging between 5.6 m^3 and 39.5 m^3 (Table 5.13). Another sediment component is sand, whose volume increases in downstream. The daily extraction of sand ranged from 5.6 m^3 to 277.2 m^3. Several crushers have been set up there for the commercial production of gravels and sands to meet the demand within the basin itself. Manual extraction of sands and gravels occurred on sites without road access.

In the fourth sector, altogether about 133,155 m^3 of sand and boulders with a mean size between 3,721.97 m^3 and 1,586.85 m^3 were extracted per year (Table 5.13). The river power, sediment deposit and their composition are presented in Fig. 5.18, 5.19 and 5.20 respectively.

Figure 5.18: **River Power**

Figure 5.19: **Sediment Deposit**

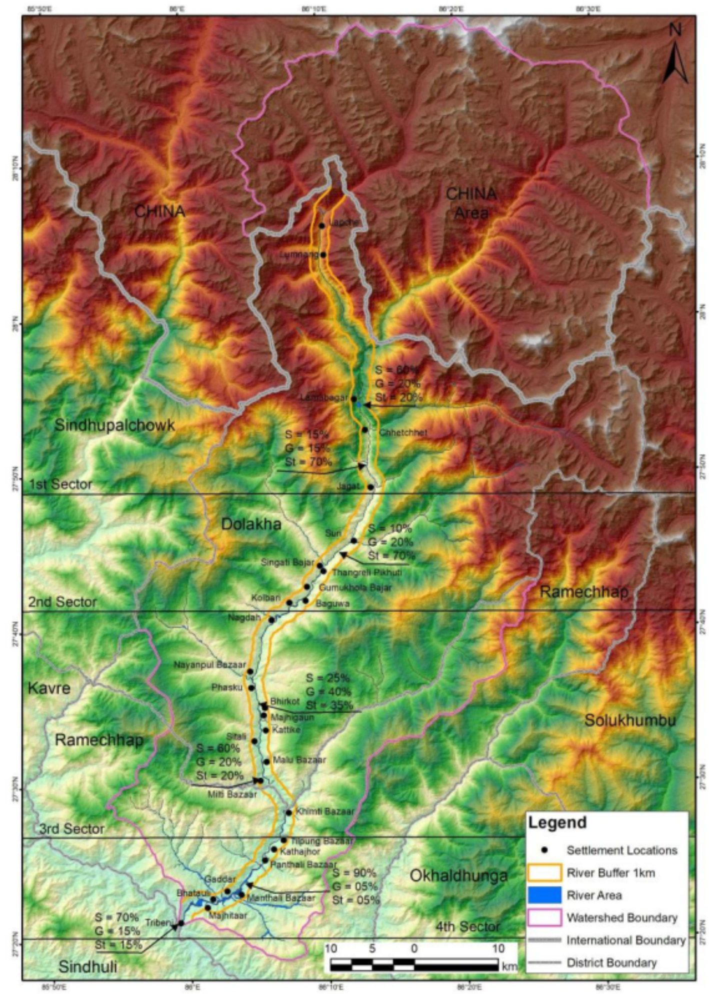


Figure 5.20: **Composition of River Materials**

Temporal difference of the size measured in the area shows that the mean size of boulder during June/July is 5256 cm^3 but decreases to 1233 cm^3 during month of August.

Similarly the river flow and its deposit of the boulders show the similar trend in the first, second and the third sector. The mean size and coefficient of variation (CV) boulder is 329.97 cm^3 and 67.93 cm^3 respectively in the first point. The value is raised in the second point (mean 119.75 cm^3 and cv. 191.31 cm^3). But it is found only 340.93 cm^3 and 97.94 cm^3 respectively in the sector IIIrd . The trend is reverse in the Ivth sector where all the points are found to be in decreasing point. (Appendix VI). The relationship between flow of the river and boulder size is verified with the help of correlation coefficient. The relationship is found not significant with r= 0.19 only. The value of regression model is equivalent to a=1147.43. b= 6.22.

The rate of sedimentation in the basin is low compared to the other study. SWECO Norge AS 2010), and NES showed 270,000 tons per year (NEA, 2006). Carson (1985), Messerli (1989) also showed similar trend of siltation. This is probably higher than the erosion rates within the Tamakoshi River basin due to differences in relief and land use. Sedimentation rates have been studied in the Phewa Tal watershed and erosion rates were determined at 0.000955 m^3 year (Sthapit and Leminin, 1992).

Other sediment data in main Himalaya region are found to be 2,000—3,000 tons/km^2/year, Tamor river, 8,200 tons/km^2/yr, Sun Koshi, east Nepal 4,500 tons/km^2/yr (Sharma, 1977), Karnali River 5100 tons/km2/yr (Sharma, 1974).

Downstream ecological impacts often follow from three environmental alterations (Rood et. al 2007): changes to the quantity and timing of downstream water flow low (Williams and Wolman, 1984; Rood and Mahoney 1990; Magilligan,et. al2003), reduce passage of alluvial materials and particularly suspended sediments (Ligon 1995; Kondolf, 2000), and the fragmentation of river corridors, with interruptions in downstream and even upstream passage of biota (Ward and Standord 1995a, 1995b; Jansson et., 2000).

The Tamakoshi watershed is relatively intact compared to other basins of Nepal like Dudhakoshi and Trishuli. The sediment yield by flow of river and other activities are also comparatively low because of following reasons:

1. There are glacial lakes and valleys (such as Rolwaling valley and Tsho Rolpo glacier lake) that trap all sediments from the upstream glacial areas. The

orientation of the valley is also in the East-West direction, which erodes less materials than the north and south valley.

2. There is no occurrence of large floods (except 1991 July, explosion of Chubung glacial lake, Rolwaling), neither in the recall of local people up to 80 years old nor the present people (Discussion with Phurba Sherpa 80, Simigaon). There is no sign of boulders deposition as one can observed in different parts of Sunkoshi and Dudha Koshi basins.
3. Most of the basin lies in the high Himalaya (Sector I) where the rainfall gets almost half compared to station located nearby such as Jiri and Charikot and Boach. Similarly, the southern part (sector IV) also gets almost half rainfall compared to the middle part (Sector III). Even the penetration of monsoon is less effective over the Nagadha upwards.
4. The velocity of the Tamakoshi River gets less particularly stopped by the old slides at Lamabagar and velocity gets less in the IVth sector. This slide blocks the valley at a height of approximately 200 meter and traps sediment over length of 2-3 km.

The trend of average annual discharge of the Kali Gandaki river and the Seti river shows a decreasing trend of yearly flow by 19.82 m^3/s and 7.9 m^3/s respectively. The trend of a low flow is also recorded in Bagmati and the Roshi River (Dahal, Shrestha, Tripahi & Ojha, 2018). The low flow in downwards is attributed to diversion of water, urbanization, extraction of water and river resources in the middle part. However, the flow of the Madi river (0.149 .15m^3/s), Marsyangdi (0.39 m^3/s), Budhigandaki (0.50 m^3/s) and Trisuli (2.73 m^3/s) has demonstrated an increased trend in mean annual flow of the river. The seasonal flow of the Tamakoshi river is similar to all the rivers of the above mentioned rivers as high during the months monsoon in the of July/August and low in the pre-monsoon in the months April/May.

3

The uneven spatial distribution of water resources as private lands, particularly has led to the practices of actively extracting ground water, which has lowered the water table (Yan, & Wu, 2005).

3

River discharge is likely to increase for some time because of accelerated melting of snow which indirectly affects the water availability and food security for the large human populations (Immerzeal et al., 2010; Nepal and Shrestha 2015). On the Tibetan plateau, including river run off increasing over 5.5% (Yao et al., 2007).

Pradhan (2000) has opined that even though snow melting starts in March, the river run off does not increase until May when the snow melting exceeds the evaporation loss of soil moisture and river runoff owing to high temperature after March (Pradhan, 2000). The study shows that even for those rivers, which have catchments above 3000 m (assumed to be snowline) one cannot definitely say the contribution made by snowmelt. It is often difficult to distinguish between contribution of rainfall and snowmelt in a river runoff in Nepal (Alfrod, 1992).

A noteworthy point is that 70 % of this flow are recorded from the months of June to September in Kathmandu valley (Maharjan and Dangol, 2007). Similarly relationship has been supported by Maharjan and Dangol (2007) Echolm, (1976), Gyawali (2001) & Dixit, (2001) and Sharma (1997). But a different view is found in study of Pradhan, (2000).

The water flow in the Karnali River Basin is different from the water flow recorded in the Tamakosh River basin (Khatiwada, Panthi, Shrestha and Nepal, 2016).

Six of seventeen settlements on the Chinese sides of the boarder are exposed to flash flood risks from upstream of GLOF. Bhotokoshi on Nepal sides, 30 settlements are at risk of flash floods and 10 per cent households either own property on flood prone area. The value of flood on Nepal side was estimated to be more than US $ 324 million, much of it in infrastructure including road and hydropower projects. Overall livelihood was relatively high in the posing accessible northern areas Balephi, Bhoteokoshi watershed in Nepal (CDG, 2015).

5.11 Chapter Summary

Spatial flow starts from 19.88 m^3/s in Lapche to 258.76 m^3/s in Tribeni. The highest water is available in monsoon covering 58.50 per cent and maximum flow is found in sector III (49.74%) i.e. 4.977610^{10} m^3/s temporarily the pre-monsoon flow is lower than the post monsoon flow in major river and tributaries of the Tamakosh river.

The water flow of Singati tributary (sect II) is found the highest (3.74 m^3/s), the lowest is Bhatauli (Sector IV). The overall precipitation of the IVth sector is only 13 per cent and highest is 1940 mm/yearly in the IIIrd sector and the precipitation of other sectors lie between these units.

The flow direction starts from the west direction and degree ranges from 12^0 to 45^0 in the Ist sector to 178^0 to -18^0 in the fourth sector. Likewise, the slope gradient of the river ranges from 12.52^0 in the Ist sector to <0.00020 in the fourth sector. The sinuosity ranges from 1.27-1.0 to 0,6 -1.27 in the fourth sector. The path value ranges from 7.4 to 9.7 in the sector first to 7.5 to 2.52 in the sector fourth.

The correlation coefficient between river power and cumulative distance is found to be negative (–0.224). The power of the river is found higher in the sector Ist which is 26.80-333.70 nTu and lowest in sector IV with 60.33-3.30 nTu.

The volume of sediment deposit ranges from 39850 m^3 in Lamabagar to 13,000 m^3 in Tribeni. The high exploitation in middle part which accounts to 44452 m^3 in Bhange, 19756.80 m^3 in Charange khola. The percentage of sand and gravel extraction is found only 60 % in the Ist sector to 90% in the fourth sector. The volume of boulder ranges from 329.97 cm^3 to 3719.46 cm^3. The size of boulder is more than double during monsoon than pre and post monsoon period. July and December are the wettest and driest months of the year. The lowest mean annual rainfall was recorded in 2002 (602.7 mm) which is the driest year and wettest year was 2002 with 1345 mm/year).

The angle of river water and depth of the water flow played a significant role in deposit of sediments in the Tamakoshi River. The distance and contribution of flow of water are found to be favourable in the IIIrd sector (value 0.99) and negative in the IVth sector (value). The coefficient of flow variable is found to be 99.55 % in Lapchi to 116% in Sukajhor Khola. The flow curve is more fluctuate in the IVth sector than Ist and IInd sector.

The maximum temperature is increased by 0.027% with R^2 value 65.75 and minimum temperature is raised by 0.02% with R^2 value 44.61. The correlation between rainfall and runoff is only 0.23, which is, indicates weak correlation.

After discussion about the hydrology in this chapter the river geochemical features and river ecology is briefed in the sixth chapter.

CHAPTER VI

RIVER GEOCHEMICAL FEATURES AND RIVER ECOLOGY

This chapter discusses the geochemical features of the flow regimes in the context with reference to the season, water colour, river sub-startum, fish species, their migration pattern, species dominance, seasonal fishing activities and fish market.

6.1 River Geochemical Features

The chemical composition of the main river varies tremendously over its different stages, as it flows through an extensive river basin and receives several feeder streams and other drainages. The river continuum concept states that the geomorphological features of the river course and its basin determine the chemistry of river water. Moreover, it is influenced by the amount of precipitation and human activities. In a large river system like the Tamakoshi, the concentration of most of the nutrients, dissolved salts, pH and other chemical elements increase as the water travels from its source to the end. The chemical analysis helps to the people of the riparian communities on the one hand it also helps create awareness among the people of riparian about the chemical composition of the river water, as well as for managing and conserving the habitats of fish, other animal species, and the ecological services on the other.

Table 6.1 shows ranges, parameters, such as temperature, DO (dissolved oxygen), TDS (total dissolved solids), EC (electrical conductivity) and BOD (biological oxygen demand) of the Tamakoshi River suitable for the growth of different types of fish and their production. Particularly, the value of these variables differs of the river in the IIIrd and IVth and sectors are found to be more suitable for fishing activities than those in the Ist and IInd sectors area due to strong currents, narrow channel width, the low volume of water, and complex geographical condition in the latter region.

The water chemistry of the Ist sector of the Tamakoshi is not suitable for aquatic habitat as the values of temperature, DO, TDS and BOD are below the threshold level, whilst the values of parameters like DO (97.1-9.18 mg/l) and TDS (18-98mg/l) are suitable for growth of aquatic species in the IIrd and IVth sector (Shrestha and Shrestha, 2019). The value of EC ranging 36-97 μS/cm lies well within the Nepal

Drinking Quality Standards, because a higher EC value creates stress to the fish. The river water is alkaline in nature (pH7.5-8.8) and some of its parts in the sector IIIrd area is acidic (Table 6.1 Fig. 6.1- 6.4, Appendix VII).

Table 6.1: ***Distribution of Chemical Parameters by Stream Sectors***

Parameters	Sector I	Sector II	Sector III	Sector IV	Reference: Shrestha and Shrestha (2019)
Water temperature (°c)			Threshold for fish population		
Pre-monsoon	10.3-14.6	11.8°c-12.5	13-16.1	17-18	13-18: Cold
Monsoon	13	13-15	15-18	21-22	18-24: Cool
Post-monsoon	10.8-11.9	10.1-12.3	12.3-16.3	17.1-17.9	24-32: Warm
Dissolved Oxygen (mg/l)					
Pre-monsoon	7.2-8.8	7.1-8.6	7.2 -9.1	7.4-8.8	0.0-1.0: Danger
Monsoon	5.6-10.4	10.2-11.1	10.0-12.7	11.1-12.7	1.0-5.0: Sustainability
Post-monsoon	5.6-10.4	8.1-9.3	7.7-10.1	7.2-8.3	5.0: Threshold level
Total Dissolved Solids (mg/l)					
Pre-monsoon	29-74	28-86	82-87	86-92	50-200(mg/l)
Monsoon	34-70	61-72	68-77	72-78	
Post-monsoon	37-61	33-68	54-68	62-77	
Electrical Conductivity (μs/cm)					
Pre-monsoon	36-66	36-73	49-197	80-82	50-400(μs/cm)
Monsoon	38 -74	57-68	71-75	71-72	
Post-monsoon	40 -63	39-53	48-78	74-77	
Potential of hydrogen (pH)					
Pre-monsoon	7.5-8.5	6.9-7.6	6.7-8.7	8.8-8.8	4-5: Low grow
Monsoon	7.3-7.8	6.1-6.8	6.1-7.8	7.8-7.9	6.5-9: Good
Post-monsoon	6.8-7.5	6.84-6.84	6.6-7.5	8.1-8.1	7-9: Best
Biological Oxygen Demand (mg/l)					
Pre-monsoon	0.64-3.7	1.23-1.72	0.98-2.91	2.99-2.99	<2 = Clear river
Monsoon	0.2-1.9	1.11-1.61	1.6-1.89	2.0-2.0	>5 = Highly polluted
Post-monsoon	0.21-1.8	1.01-1.5	1.5-2.13	2.1-2.12	

Note: mg/l = milligram per liter; l = liter; μS/cm = micro siemens per centimeter

Thus, it can be grossly stated that the overall quality of the water of the Tamakoshi is good at some places and it is found that in some places it is excellent. It is not polluted and parts of the sector IIIrd and the IVth are more suitable for aquatic habitats than the entire upstream area. The distribution of water temperature is found to be higher in the IVth sector because of wide surface area and air temperature. Similarly the value of TDs and EC are measured low in Gongar and Rolwaling. Water flow in high altitude, short distance of travel of water, low nutrient content in narrow river valley are the causes for this. However, the value of EC is tested higher in Malu. Schist dominated rock, high surface erosion covered by calcareous dominant rock with carbonic materials are determinant role for this (Fig 6.1 to 6.4).

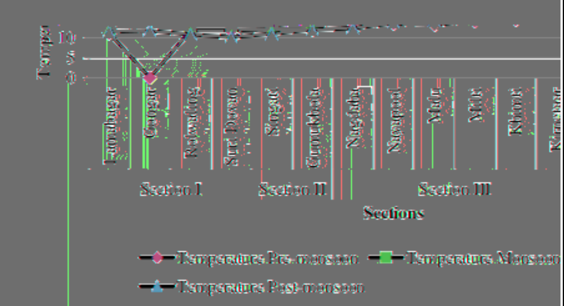


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Figure 6.1: **Spatial and Temporal Distribution of Temperature**

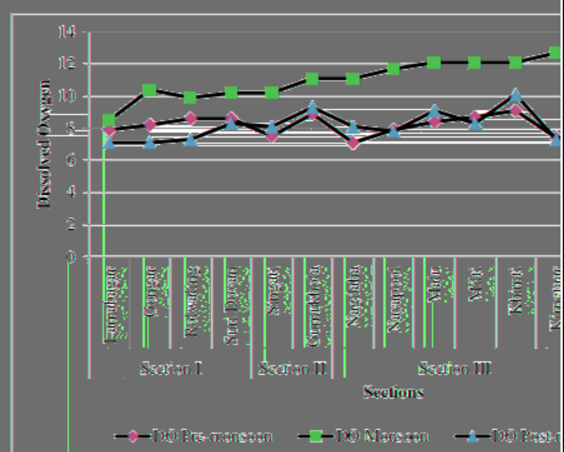

Figure 6.2: **Spatial and Temporal Variations of DO**

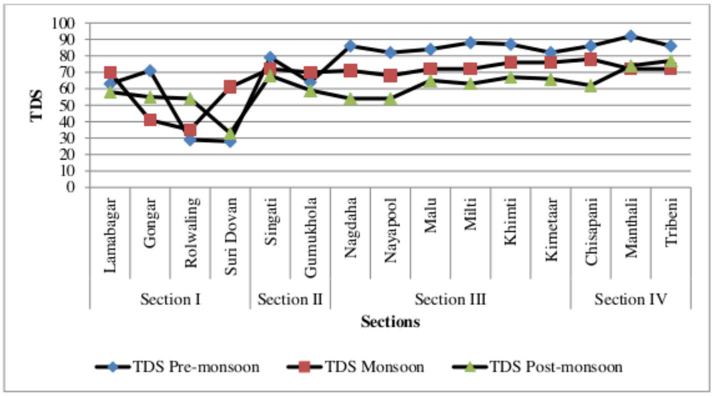

Figure 6.3: **Spatial and Temporal Distribution of TDS**

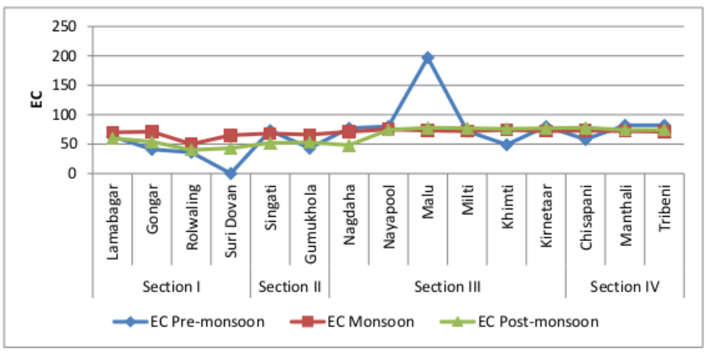

Figure 6.4: **Spatial Distribution of Electrical Conductivity**

6.2 Water Color

Water color is one of the main indicators of the ecological condition of the river basin. Suspended solids mainly in the form of soil particles (sand, silt and clay); microscopic plants and animals are the main causes for changing the color of this water. The water colour of Tamakoshi River is found transparent during pre-monsoon and post monsoon but during monsoon the water colour is found to be dark due to rainfall land slide, mud flow, soil erosion and consequently high concentration of suspended and high load.

Spatially the water in the Ist sector is white and blue colour, almost similar pattern in the IInd sector. However, the colour gets brownish in sections IIIrd and IVth. This is due to anthropogenic and natural cause. The extraction of sand, gravel and boulders from the river and landslides at different sites are causes of this. The colour of the Tamakoshi River is unpolluted and clean which can be seen for functioning aquatic ecological system.

6.3 River Sub-stratum and Fish Species

The data for the river sub-stratum has been generated through observation along the river stretch and photographs of google image and under water course of river corridor. Along the corridor different types of flow regime are observed but most of them are generalized either in rapids or in pools (Photo 10). The rapids and pools are the home of fish. Detail of sample fish species is presented in Table 6.2.

Table 6.2: ***Fish Species Abundances***

S.N.	Local Name	Scientific Name	No. of Fish Caught	Percentage Abundance
1.	Buche Asla	*Schizothorax richardsonii*(Gray-Hard)	43	21.25
2.	Chuche Asla	*Schizothorax progastus*(McClelland)	35	17.5
3.	Titae Capree	*Psilorhynchus pseudecheneis*(Menon & Dutta)	21	10.5
4.	Katle	*Acrossocheilus hexagonolepis*(McClelland)	18	9.0
5.	Katle	*Neolissocheilus hecaagonolepis*	15	7.5
6.	Katingae	*Pseudecheneius sulcatus* (McClelland)	7	3.5
7.	Ghopte	*Glyptothorax cavia* (Ham.)	4	2.0
8.	Katuse Cabre	*Glyptothorax pectinopterus*(McClelland)	4	2.0
9.	Buduna	*Garra gotyla*(Gray)	5	2.5
10.	Rajbam	*Anguilla bengalensis*	11	5.5
11.	Bam	*Mastacembalus armatus*	8	4.0
12.	Sahar	*Tur purtitora*	14	7.0
13.	Sahar(Thalarain Majhi)	*Tor Tor*	15	7.5
14	Traces ++			
	Total		200	100.00

Source: Field Survey, 2014/2015.

Traces species of fishes: Gardi, Thed, Kande, Wawala (Bagt, Gwala (Kandi), Bhagyl (Bhagi,) Pokhet, fagata (*Baarrilius barli*), Gooangh, Halude, Labre, Nakato, *Telkabre,* Titemansine (Psilorhynoches), Sime, Masane, Lohere and *Jalkapure*.

From the table 6.2 it has been clear that a total of 200 fishes of 30 different species were collected during the field survey. Of the total species recorded, *Schizothorax richardsonii* (Buche Asala) and *Schizothorax progastus* (Chuche Asala) are found to be the dominant species among the collected fishes accounting 21.25 and 17. 55 per cent respectively (Table 6.2). A sector wise detail description of the fish species is presented below.

In the sector Ist, few types of fish species (2-4) have been recorded. In places with braided river channel fish abode was found only during the monsoon season when temperature of both air and water is high, the geo-chemical situation in other than summer season appeared to be unfadorable for breeding and growth of fishes.

A run type is found in the main channel whereas pool (22%) and riffle or rapids (78%) type are found mostly in a bifurcated section of river. River substrata or the bottom is composed of big boulders, stones and gravels and pebbles. A minimum portion of sand deposit is observed in other parts of river except Lamabagar.

Besides this natural dam and a couple of small natural falls pose difficulty for fish migration. The tributaries joining the Tamakoshi are very steep and provide rarely suitable abode for different types of fish.

In the sector IInd, eight species of fishes are recorded and feeder streams joining the river is found to have provided a good habitat for *Copper masheer* (Sahar). The lower section is dominated by Golden Masheer, locally known as *Sahar*. Migration of new fish species such as Katle, Buche Asala, Sun Asala types from the upper part or feeder streams are observed particularly during the monsoon season. Both rapids and pools are located in several places in the section. It is estimated that 17% of the sector is covered by pools, 32% by swift deep and 51% by rapids.

In the sector IIIrd, a total of 15 different species of fishes are found. There is a good habitat for fish species such as snow trout and copper masheer. The confluence site of two or more rivers provide the favourable habitat for migratory large fishes like snow trout, masheer and catfish. In fact, the local indigenous fishes are small such as barbs (*Puntius*) and stone-carps (*Psilorhynchus pseudecheneis*). But, the area has more rapids and low pools. Until it comes to Malu only 10 % of the riverbed is covered by pools and 30% is covered by swift deep and 60% of the riverbed is covered by rapid.

The places like Bhange, Thulobagar, Charange have a good fish habitat for snow trout. Similarly, middle reaches near –Milti and Khimti provide a good habitat for Copper Masheer. The lower section is dominated by Golden Masheer, also known as Sahar and part of this sector is good for long range migratory fishes.

In the sector IVth, total of 30 fish species have been recorded. As per interview with local fisher man there were of 30 species of fishes (Communication with Gorie Majhi age 65 Manthali 2014) were reported are as follows: Buche Asala, Chuce Asala. Sun Asala, Katle, Kabre, Buduna, Halunde, Goonch, Labre, Rajbam. Gurdi, Sahar. Nakato, Telkabate, Tite, Fageta, Baghi, Lahari, Bhayatal, Sime, Masane, Jalkapoor, Dharke Sahar, Balijung, Raghu bam, Patipaura, Hile, Patiphora, Khurpe and Bulle.

The geo-chemical and environmental conditions appear to be favorable for fishes like golden masher and copper masher for breeding during the monsoon (June-September) and snow-trout for spawning twice (March-April and September-October) a year. These are migratory fish species coming from long distances.

The area is characterized by lower number of rapids and more by pools. Twenty percent of the riverbed is covered by pools, fifty percent by swift deep and thirty percent by rapids. The number of pools over the stretch are broad and big in size and extension (Appendix VIId).

Diatoms are the most dominant algal group found in different sites of the basin but the Nayapool downwards is suitable for growth. However, some filamentous algae such as Spirogyra and Oscillatoria are also abundant especially at station Nayapool downstream. Diatoms in the Middle Hills of Nepal indicate unpolluted or only mildly enriched conditions (Jüttner *et al*. 2012). Relatively high percentage of diatoms at the four sections is therefore indicate a good water quality except for biological parameters. Many organisms of turbulent streams persist by avoiding the turbulence. There is no specifically adopted suspended organism (plankton), there would be little for their population to grow before the water had moved fair downstream. Drift may also help unavoiding predator. Larger animals which are most at risk from fish predation appear to drift at night frequently than smaller (Moss, 1998).

Phytoplanton is a passively floating or weakly mobile phytosynthtic aquatic organism, primarily cyanobacteria and algae are needed for the aquatic animal like fish, frog and toad in the river. The phytoplankton need in a food chain in aquatic habitats is based on the consumption of primary producers. These Pennate diatoms occur in both fresh

water and l marine habitats (Shrestha, 2002). FGDs also reveal that the species like Asala, Katle, Kande and Buchhe are found all time but *Tite* is available during August and September (Shrawan/ Bhadra).

6.3.1 Migration of Fishes

The brief summary of native, migration of both short and long distance fishes with specie are presented in the Table 6.3 and 6.4.

Table 6.3: ***Migration and Yielding of Fishes***

Species name Latin / English / Nepali	Migratory status	Migratory Pattern (Months) J	F	M	A	M	J	J	A	S	O	N	D	Spawning Season	Spawning Substrate	Locational Characteristic
Tor putitora (Golden Mahseer) Sahar	Long range						⬆	⬆	↑	↑	⬇	⬇	↓	Sept-Oct	Gravel bed (Adult-rest in deep pools)	Chaityaghat- Tribeni
Tor tor (Mahseer) Falame Sahar	Long range						⬆	⬆	↑	↑	⬇	⬇	↓	Sept-Oct	Stones and gravel	
Anguilla bengalensis (Fresh water Eel) Raja Bam or Bam	Long range		↑	⬆	⬆	↑	⬇	⬇	↓					June-July	Mud & Sand detritus in sea water	
Clupisoma montana (Jalkapoor) Jalkapoor	Long range							↑	⬆	↑	⬇	↓		Sept-Oct		
Bangarius bangarius (Bagarid catfish) Goonch	Long range			↑	↑	↑	↑	↑	⬆	⬆	⬇	↓	↓	July-Aug	Mud & Sand detritus (Adult-	
Neolissochelius hexagonolepis (Copper Mahseer) Katle	Mid range			↑	↑	↑	⬆	↓	↓	⬇				May-July	Gravel (Adult-resting in deep	Bhorle, Singati, Nayapool
Schizothorax richardsonii (Spotted snow trout) Buche	Mid range	↑	↑	⬆								⬇	↓	Sept-Oct March-April	Pebbels and gravel	
Schizothorax plagiostomus (Spotted snow trout) Sun Asala	Mid range	↑	↑	⬆								⬇	↓	Sept-Oct March-April	Pebbels and gravel	
Schizothorax progastus (Long nosed snow trout) Chuche Asala	Mid range	↑	↑	⬆								⬇	↓	Sept-Oct March-April	Pebbels and gravel	

Source: Field Survey 2014/015.

Legend

↑ Low volume of upward Migration

↓ Low volume of downward Migration

⬆ High volume of upward migration

⬇ Low volume of downward migration

It is evident from the Table 6.3 that the migration takes place between the III[rd] and IV[th] sector of the basin more than Sector Ist and IInd. The sector IIIrd and IVth are good for fish habitat for both mid-range and long range migratory fishes. Among the fish species found in this area, most of the small fishes such as barbs (*Puntius*) and stone-carps (*Psilorhynchus pseudecheneis*) are resident ones. The large fishes such as snow-trout and masher are migratory.

The confluence sites in the downstream area, where feeder streams join the main river have shown a good habitat for snow trout, Sahar (*Copper masheer*), golden masheer, and catfish. They also have shown to be favorable for migratory fish species from the Ist sector, such as Katle, Buche Asala, Sun Asala, snow trout, masheer and catfish, particularly during the monsoon season. Migratory fish species like golden masheer and copper masheer were observed breeding during the monsoon period (June-September), and snow-trout were observed spawning twice (March-April and September-October) in the downstream area that had travelled all the way from the upstream section. The geo-chemical and environmental conditions such as slow river water current, wide banks and deep water have proven to be favourable condition for those species.

Majority of the fishes of the Himalayan waters seem to lead a dormant life and inactive during winter months espically from November to February. During this time, flow of water is low and fishes like snow trout resort to deeper pool areas, where they lie dormant at the bottom making only little to no movement or limiting activity. More over the food drifting the time is scarce the algal blooms die off and other bank vegetation and insect food is poor and there are few aquatic insects or small fry available for large fish to feed upon have their source in Himalayas are filled with cold snow-melt water during the first half of the year.

The Mahseer do not deposit their egg or spawn all at once like salmon, but they do so several times during a period of several months (May to September). As a result, they never run out of eggs except during the cold months of December and January. Spawning schools of Mahseer are often located by tribal hill people in shallow water brooks. It’s necessary to provide a clear fish water corridor for fish for river journey or migration; in the first burst of rain during May and June when the Masheers have to go up stream, the rivers are much swollen or flooded that they have no difficulty to reach upstream destination by jumping over the barrier of the dams. All impediment or low obstacle of about 3-5 meters made by dam and are to be cleared out of the way by great rush of falling water.

Fish swing is a common phenomenon in ox-bow lakes or abandoned river courses called Bagar. To catch fish, fishermen use a variety of fish poison to take advantage of receding water.

Fish frightening or scaring is a primitive fishing tactic. Fishermen use scareline made of coin rope interlaced with plantain hark. Fishes dwelling in rapids are frightened and and forced to enter death chambers created by fishermen.

Fishes of the carp family are very prolific; they deposit a great number of eggs at intervals during seasons. Mahseer is a cyprinid carp which lays a number of batches of eggs in gravel bottom hill-streams and creeks. The intergravel life of fertilized eggs of Mahseers and their emergence are intriguing aspects of further study.

Anabantide have an accessory chamber connected with grills, which enables them to breathe pure air. They wriggle out of sand and mud and glide over some distance in damp grass or mud. Fishermen are familiar of the air breathing habit and keep the fish in open jar and vessels to make long distance transport

Table 6.4: ***Migration Chracteristics of Fishes***

Migration types	Types	Condition	Spawning time	Locations
a. Domicile	Stone carp (Tite)	Lightening	May – Aug. Cract flood rice	Sigati, Nagdaha, Pikhuti
b. Short distance	• Snow trout • Blunt nose snow trout • Spotted • Gardi • Buduna	Gravel Boulder	Nov.-Dec. May-Sept. Sept – Oct.	Nagdaha, Charange, Milti, Khimti
c. Medium distance	• Copper masheer Acrossochelus • Katla	Gravel bounder	June-Aug.	Charange, Milti, Khimti
d. Long distance	• Sahar • Jalkapoor • Rajbam	Gravel bounder, sand Silt	June – Aug.	Charange, Milti, Khimti, Manthali, Tribeni

Source: Field Survey 2014/015.

Masheers spawning habitat of Tamakoshi is stable in the sector IIIrd and very productive in the downstream due to the warm water and wide spaces to grow due to high water volume and current. Tamakoshi has a steeper gradient upstream in Nagdaha area and gentle gradient downstream. This difference in stream morphology has implications in spawning habitat. The higher gradient upstream causes high flow velocity, few pool areas, and makes gravel-bed stream favourable for snow-trout. Downstream near Kirnetar, the river morphology is quite different from upstream sections. The lower part of the Tamakoshi has frequent sand bars (Sector III and IV) wider floodplain, lower gradient and water velocity, and frequent pools and riffles suitable for deep-bodied masheer and eel species. Moreover, the time of three to four month is enough for fish to grow from fingerlings to almost 300-400 gram during monsoon time. According to a local fisherman of Bhatauli, within a 6-8 months are favourable flow and condition make a fish up to one and half kg easily. It is reported from the field that the mature adult fish of Tamakoshi migrate headwater upstream in late May and July as peak river discharge from monsoon floods start to increase. These adult fish enters tributary streams for spawning broadcast. The adults remain for a short time and then migrate downstream in November to December after depositing eggs. Among the different species the Goangh is the one which weight more than other species and jackal is attracted to fish hunt in the river. Even some of them used to grow up to 40/50 kg. For this reason most of the places around Karambote to south became famous for it. The opinion is also confirmed by Prof. T.K. Shrestha (Interview was taken on 2072 in Central Department of Zoology, T.U., Kirtipur).

The fish species indicator, which support commercial fishing in the Tamakoshi, are; Carps: Snowtrout (*Schizothorax plagiostomus* and *S. richardsoni*), river carps (Labeo angra and L. dero). Torrent Catfishes: Stream catfish (*Glyptothorax trilineatus*), river catfish (*Glyptothorax telchitta*), Eels: Fresh water eel (*Anguilla bangalensis*), Murrels: Bhoti (*Channa punctatus*) and hile/helae (*C. gachua*). Loaches: Stone loach (Noemacheilus rupicola and N. corica) Barbs: Puntius ticto, Masheers: Golden masheer (*Tor putitora*), Deep-bodied masheer (*Tor tor*) and Copper Masheer (*Acrossocheilus hexagonolepis*).

6.4 Distribution of Fish Composition

The Field survey shows the different type of fish species and catch per unit (CPU) which has been presented in the following Table 6.5 as:

Table 6.5: ***Location of Fish Composition***

Location	Attempts	No. of Fishes	No. of Species	CPU
Lamabagar	5	4	1	0.5
Suri	5	4	2	0.5
Singati	5	10	4	0.5
Gumkhola	5	11	5	0.6
Dolti	5	13	5	0.6
Charange	5	13	4	0.6
Milti	5	14	5	0.6
Malu	5	14	5	0.6
Chisapani	5	18	13	1.0
Manthali	5	18	13	1.0
Sunkoshi	5	20	18	1.0

Source: Field Survey, 2014/015

6.5 Fishing Season and Methods

Fishing starts from May and lasts till December (Photo 11). The fishing activities in the first and half of the IInd sector are almost negligible during the winter due to cold water, pH and related chemical parameter. Favorable situations are prevailed in the section IIIrd and section IVth (Appendix VIId).

The field survey shows that within the stretch of the study area there are 49 different fishing spots and most of the fishing habitat areas are usually in the confluence of the tributaries like Dholi Khola, Dolti, Charange, Kathajhor, Bandre Pool, Manthali Ghat, Tribeni, Seleghat Tilpung and south.

From the field survey and FGD it has revealed that the maximum amount of fishing activities take place from October to January (Kartik- Magh) in which a total of 43 per cent of the fishing activities are carried out and very few fishing activities are carried out from June (Jestha) to August (Bhadra). Among the fisher men more than

84 per cent of them have involved more than 4 days a week and almost all households spent maximum from 10 -12 hours and minimum of 8-10 hours a day.

6.5.1 Temporarily Fishing

The fishing method also depends on the season. Most of the fishermen use Jalo (19.69%) followed by Laharop Paso (13.38%). Mostly *jalo* is used during the post-monsoon and pre-monsoon period only while *Balchi* is used during monsoon period only. Fishing is rerecorded to be practiced mainly from October to May by using *Laharo Passo* and very few fishing were done by casting net. The local fisher man used to fish by cast net during the monsoon from early in the morning to the evening in the sector IVth from Nayapool to Tribeni. The snow trouts are captured in large numbers within the area with the help of long line loops and hand line loops.

Local people along with Majhi use various fishing nets for fishing like nets, snares, *dhadiya* (meaning basker) and hooks. They put cut fish in receptacles called *phurlangs*, *jabi*, and *gurdi*. The school children and other fisher men fish by the Laharo passo. Some of them also fishing by hook line, tango and some of them by a gill net. Fishing by gillnet is found in the downstream of the river close to Manthali.

6.5.2 Illegal Fishing

Stream poisoning by using agricultural insecticide is also a common method of fishing. Fish poisons, are generally extracted from herbs which is traditionally called *ichthyotoxic*. Other herbs like *Sapium insigne* (Khirro) and *Engelharditia spicata* (Mauwa) are used in tranquilizing and killing fishes. Sometimes fishermen use top-listed harmful insecticides available in the market to kill the fish. Such harmful methods of fishing affect the snow trout population. Fish poisons (such as DDT) are mixed up with mud and sand and release in the fish shelters and pools to divert fishing.

They apply fish poison very carefully in a place where large fishes are concentrated. Within half an hour of application, the fish begin to get paralyze and it became easy to be grabbed by hand or collected by net. The fishermen usually divert the river channel or block the river and make it semi dry to catch fish easily by hands or by nets. Such practice kills not only adult fish but also developing eggs, fries and fingerlings.

Although electro fishing and use of explosives to catch fish are illegal in Nepal but such practices are still common. Most of people in the upper part use electric current for catches fish especially in Singati and its surroundings.

The Majhis in the Tamakoshi basin adopted various methods for preservation of catching fish like smoking, salting and drying up in the sun. Fishes are dried up in smoking chambers to remove additional moisture. This is a simple and cheap method of fish preservation. The fish are dried up in the sun on mat for two to three days. They sell these dried fishes during the occasions of Dashain, and Tihar and in other festivals, however, they also sell in Kathmandu and Charikot during the off seasons at the price of Rs. 600-800 per Kg.

The incomes accrued on the same year through these catches were NRs 27,000 and NRs. 15,000 respectively for full time and part timer catches (Ranjit, 2002). The amount of fish production in the Sunkoshi is lower than the fish production of Tarai districts. For example, the Fishery Department of Jhapa showed that a total of 1080 tons of fish is produced in a year. The existing price of the fish ranges from NRs. 400 to 700/Kg. The total amount of the revenue is equivalent to NRs. 5 crore 40 lac (equivalent to 50.4 million). (The Himalayan Times June 17, 2018).

6.5.3 Fish Market Network

The most important fish market in the study area are from Suridovan to Manthali (Figure 6.5) are shown in the map.

Figure 6.5: **Loctioon of Fish Market**

The distribution of the fish species are commonly more in downstream than the upstream. "The river continuum concept has attracted much support, and most stream systems probably do depend, to some extent, on allochthonous organic matter derived from the catchments" (Moss, 1998). The temperature itself is between 15-20^{0}C. The local condition like manure, mulching, number of livestock's and forest coverage. provided good condition for phytoplankton to grow.

The fish species (Spp.) recorded in the whole TRB is 30. These species are less than Koshi river system, 108 Spp .(Menon 1949), Karnali river system, (119 Spp.) 51 spp (Jha) Narayani (131 Spp.)(IUCN, 1996) and more than Dudhikoshi (19 spp), Likhu (11 spp). Begnas taal (24 Spp), and Sunkoshi which is 28 species , K, Karnali and Pokhara valley where 26 Spp. of fish belonging to 5 order, 8 females and 20 genera were recorded (Pokharel, 2011).

The rivers along with lakes, ponds and reservoirs make up about 5% of Nepal's land mass area (FDD, 1998). In Nepal, ethnic people such as Majhi catches large size fish using a traditional fishing net which avoids unique national killing of other intentional aquatic fauna (Primack, Poudel & Bhattarai, 2013). Substance fishing and commercial fishing are of great importance in many developing countries. Fish provides a vital source of protein in some communities.

6.6 Chapter Summary

The river water chemistry is a key factor for river ecology. The chemistry system of the large river varies tremendously as it flows through the extensive river basin and several feeder streams and other sources mix with it. The chemistry of river water depends on the geomorphological system of the water basin. Moreover, it is also influenced by precipitation and pollutants from the human activities. In large river system like the Tamakoshi river system, the concentration of most nutrients, dissolve salts, pH and other elements decreases as the distance from its sources increases.

The analysis shows that all parameters including temperature, DO. TDS, EC and BOD of the river water shows that the basin that found to be suitable for different types of fishing activities and growth. Particularly, the lower midstream and downstream of the sector IIIrd and IVth of the Tamakoshi River are found to be more suitable for fishing activities than the Ist and IInd sector due to its steeper slope and complexes geographical condition.

The water colour of the Tamakoshi River is transparent with low turbidity during pre and post monsoon and dark and grey during the monsoon. It is due to heavy rainfall, landslides and more nutrient flow during monsoon. The total species found in the basin is 30 which ranges from two species in the sector first to 30 species in the sector IVth. The river sub-strata is composed of different boulders, stones, gravels and mud/sand. Only 22 percent pool and 78 per cent ripids are found in the Ist sector and the respective portion of the rapids and pools are more than 40 percent in the IIIr and IVth sector.

Three types of fishes (resident, medium and long distance) migration is found in the basin. More breeding centers are found in confluence of major and tributaries. More than 49 locations are found along the Tamakoshi River and fish in activities are more during pre- and post-monsoon than monsoon. The fishing market centers are located along the river side of the basin and Majhis are involved. The communities along with river are the main cause of these phenomena. The partial income they earn ranges from 1,000 to 4,000 per day during post monsoon period and less than 1000 during pre-monsoon time. Following the discussion on ecology the succeeding chapter discuss on the interaction between the river ecology and local communities.

CHAPTER VII

INTERACTION BETWEEN RIVER ECOLOGY AND LOCAL COMMUNITIES

This chapter deals with level of interaction, product resources, economic participation, ecology in the riparian zone, dealing with socio-economic issues, community interaction analysis and hydro-ecology.

7.1 Level of Interaction

The data gathered from the household survey and focus group discussion (FGD) from Lapchi to Manthali are classified into different six main themes. According to the Millennium Ecosystem Assessment (MEA 2005), ecosystem services has identified four categories of ecosystem services, viz. (i) supporting (nutrient cycles and oxygen production), (ii) provisioning (production of food and water), (iii) regulating (control of climate and diseases) and (iv) cultural (spiritual and recreational benefits). Accordingly, the four categories of the ecological services of the Tamakoshi River available to the local people for use and conservation included irrigation, drinking water, hydropower, fish species, river sediments, drifting woods, and natural and cultural aesthetic values. Broadly, the ecosystem services in the basin range from agro ecosystem to aquatic ecosystem, including clean water, irrigation and power generation, decomposition of waste, and resilience and production of food systems (Table 7.1).

Table 7.1: ***Perceived products and ecological interactions***

Major ecological services	Perceived products and ecological interactions
Natural and aesthetic • Religion/spiritual elements	• Development and maintenance of temples with arts at confluence site of two and more rivers, aesthetic elements and value, sacred river
Product resources • Water supply and irrigation	• Water as means of livelihood, life blood, health and sanitation; irrigation to increase production of food crops; growth of plants
• Sand and gravel	• Means of livelihood of marginal groups; commercial use for infrastructure construction; over extraction and ecological degradation, losing traditional catching methods of fish species
• Miscellaneous (drift wood, water mills, boat, share benefits, etc.)	• Wood collection for fuel wood; use of non-timber forest products for fishing and domestic purposes; boating and rafting; hill-basin interactions in flow of people, products and resources; micro-watershed conservation; terrace farming and soil conservation; growth of settlement built-ups; water mills and micro hydroelectric plants; landslides and floods; distribution of shares of hydro-electric projects among local people; increasing landless groups
• Fishing	• Means of livelihood of Majhi and other marginal groups with no own land for food production; increasing demand of fish due to rising hotels; decreasing in fish abundance due to use of noisy devices; prohibition of fishing around Buddhist monastery area
Ecology of riparian belt	• Aquatic biodiversity of indigenous and migratory fish species and trans migratory birds, abode of fish and other insects and animals and indigenous people and their ecological interdependence; flow of river water and maintenance of chemical properties; interventions of human activities affective riparian ecology, displacing indigenous people by migrants; efforts to maintain river ecology are essential; participatory of indigenous groups in policy decision

Source: Field Survey 2014-2015

7.1.1 Product Resources

(i) River water

Among the river products for water irrigation of the Tamakoshi and its tributaries is vital, providing the base for crop production, sustaining the livelihood of the people, and balancing the ecological system in the basin. The local people mostly depend on the traditional method of irrigation such as small channel, locally known as '*Kulo*', particularly to water their rice fields and other seasonal crops. For instance, in the sector IIrd and IIIrd, two *kulos,* respectively 1.5 km and 3.3 km long, on both sides of the Tamakoshi have been used to irrigate fields in Sitali, Panthali, Manthali, and Kunauri areas. The beneficiaries of this irrigation ranged from 20 households in Sitali to 100 in Manthali. The command area is arranged from 25 ha in Sitali to 100 ha in Maghephant of Manthali. In addition, six modern irrigation canals have been constructed to irrigate fields in villages from Milti to Tribeni (confluence point). Access to irrigation varies remarkably between the river sectors, as can be seen from Table 7.2 the irrigated area increases strongly from the sector II to sector IV.

Thus the irrigation water of the Tamakoshi and its tributaries are found to help to produce food through adopting intensive farming methods and to can meet about 70% of the total demand for cereals. Before the coming into existence of the modern irrigation channels, the basin was a food deficit area and had to import food from outside at expensive prices because it had to be carried by porters.

Table 7.2: ***Distribution of Irrigable Land by Sector***

Category	Sector I	Sector II	Sector III	Sector IV
Area (ha)	2.5	121	182	253
Command area (ha)	0.25	18	90	200
Irrigated area (%)	5	50	55	70

Source: Field Survey, 2014, 2015.

The river is the source of domestic water supply. There is a close relationship between supply of water and quality of life of the people. Generally, the people living close to water sources get a better quality of life than those living at distance. The quality of life of the people in rural areas can be expressed in terms of saving time for fetching water. So, if the women in particular spend little time in fetching water they can reduce their domestic work burden and invest more time in farming and thereby improve their living condition.

In the basin, people use two complementary water sources: natural sources (river and springs) and artificial sources (piped water). Their contribution to the supply of water has changed between places and sectors and over the time. In the beginning, the inhabitants of the basin depended entirely on the rivers and spring sources for domestic uses (drinking, bathing and washing). Over the past few decades, however, they were gradually linked to the public water supply, which reduced their dependency on the natural source. At present piped water meets almost 70% of the total water demand in the basin for drinking, while the rest comes from local streams or springs. In all four sectors, not all households have access to the public water supply. For instance, the Majhi community is found to rely on river water for consumption, and people living in scattered villages on the hill slopes in the upstream area also get water directly from springs or streams.

Drinking water supply through public and private taps has been provided to the market towns (Malu, Kirne) in the IIIrd and IVth sectors. Yet all households have not yet been covered although efforts to construct drinking water projects were underway. Particularly in the relatively large market towns (Manthali), the water supply was inadequate. It was found that some people had to pay two rupees per liter for drinking water which were ferried by tractor from the Tamakoshi River while others, who were unable to pay, had to travel up to five hours to fetch water, and those living in the upland terraces or hills or on ridges had to queue for hours to obtain water from the public taps. In the market towns of the sector IIIrd of the basin, fetching drinking water from public taps was found to be slightly better, as they had been installed at 5 to 30 minutes walking distance from their homes. There was inadequate supply of pipe water to the households in the IVth sector, as only slightly over 60% of the households there found to have access to the water supply facilities. This meant that a significant proportion of the households had to depend on natural sources such as stream, springs and wells. It can be said that there was differential accesses among the households to the water supply facilities due mainly to inadequate provision of pipe water through public and private taps. Particularly poor households, marginalized

(Majhi, Tamang) communities and the people living in the scattered villages over the hill slope and ridges had to depend on natural sources.

The economic benefits from the river's ecological services go beyond the extraction of sediments for the local communities and include employment generation and income, as well as revenues to the local government. These activities and income also contribute to the development of infrastructure in the basin. Several stakeholders such as laborers, politicians, construction enterprises, business men, and government agencies appear to be involved in the extraction activities of the resources. However, these activities are a challenge to river ecology. Haphazard or uncontrolled exploitation of the river resources can be observed in the IIIrd and IVth sectors, where development activities and settlement growth are encroaching on the river banks and hill slopes. The situation is expected to worsen in the future, affecting badly the riverine communities and physical infrastructure. This therefore calls for strict regulation and monitoring of the extraction of sand and gravels, and commercial fishing by mechanical methods from the agencies concerned. Excessive use of natural resoruces to control from the regulatory bodies.

Sand mining has ecological implications. Its adverse effects were seen on river bank erosion, the turbidity of the water, the lowering of the groundwater table and water storage in the river bed. These have implications to alter the physical and biological systems of the rivers. Other consequences include a changing river profile and water course. The issue between sand mining and ecological conditions is tricky and complicated where different types of stakeholders from labourers to politicians are involved (Srivastava 2017).

(ii) Driftwood

The forest products brought by river during the time of high flow is another benefits to the people living in the downstream which are often carried away from the headstream during the rainy season. These logs drifting down the rivers during the rainy season in summer is a resource freely available to the local people, a benefit occurred to the people living in the sector IIIrd and IVth of the Tamakoshi River. These logs are collected for personal and economic gain. As these are freely available resources, it highly benefits the people living in downstream of Tamakosh river.

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Every year they collect wood floated the river. According to the FGD or communication with the local people in the field survey an individual earns at least NRs. 5,000 to 30,000 per year from selling such woods and logs. From field survey, an estimated stake of driftwood from the confluence area in the downstream section was 2,000 cubic meters per flood (Communication with Dhanu Majhi, age 65, Tribeni).

The wood collected so far is the major source of cooking for the riverine people, and for poor people it has been a means to earn their livelihood by selling. The field survey indicated that the supply from this source met about one-third of the annual fuel wood requirement of the people living in the IVth sector.

(iii) Fish species

The Tamakoshi River basin is home to cold and warm water fish species are suitable for this fishes geomorphologic composition and constant flow of water in the river. The local indigenous fishes, including barbs (*Puntius*) and stone-carps (*Psilorhynchus pseudecheneis*) though small in size provide a means of living to many indigenous ethnic communities.

The field survey showed a total of 200 fishes belonging to 30 different species were found in the river. (See section 6.3 for detail).

(iv). Natural, aesthetic and spiritual aspects

The natural, aesthetic and spiritual elements of river water and its resources appear to be closely linked to the daily activities of the riparian communities, which can be described with a popular belief among the Majhis:

“If there is river flow, we have life because we get food, enjoy feasts and get all other things; but if flow disappears we will also disappear from here. All our rituals from birth to death are deeply link with the flow of river water and its features. The association is so strong that even our children cannot spend a single day without seeing the flow of the river" (Kanchi Majhi, Akase, Manthal, 2015/08/26).

(v). Water mills

Besides, river water is diverted through channels to run water mills. A total of 30 water mills lie along the river. Among these three in the sector II, nine in the sector IV and 18 in the IIIrd sector. Six water mills have been upgraded to run by electricity with peloton turbines. However, due to electrification of the watermills of the bazar area –Singati, Nagdaha, Malu, Kirne, Manthali have been abandoned and replaced. Some of them have disappeared after the earthquake of 2015. In addition to this there are two *Lokta* factories located in Sunkoshi and Manthali municipality which use water of Tamakoshi for industrial purposes.

7.1.2 Economic Participation

From the Household Survey and Focus Group Discussion (FGD) it has been clear that the most of people expect the ownership of project by participating in the share capital of the Tamakoshi river project from the alternate use of the flow regime. It is a kind of paradigm shift of flow from traditional to modern use. The people from middle parts (Singati to Devitaar- sector II and III) want benefits of the hydropower production from their river flow. The people of Devitaar seek for 10 per cent share while people from Malu ask for reduced rate of energy generation and Charange proposes the free share of the project. Some people even opined that more shares should be provided to the people living in the vicinity of the project. They are concerned more with distribution of share than the flow exploitation. Local people got share from UTHP.

7.1.3 Ecology in the Riparian Zone

The FGD discussion shows importance of forest and wildlife in the basin due to the flow regime. They have emphasized it from the upper part Singati to Charange. The local people are of opinion that the forest and wildlife in the riparian zone existed because of flow of water in the river. The changing scenario of the flow disruption may result in disruption of the whole forest ecology and wild life. The existing forest of Sal (*Shorea robusta*), Pine (*Pinus roxburgii*) Chilaune (*Schima wallichii*) and Alder (*Alnus nepalensis*) flourishes in river valley with high flow regime. The dryness is a symbol of low flow and a full of mature tree is the symbol of full flow.

Wild mammals in the forest areas include deer, leopard (*Panthera pardus*) and Jungle Cat (*Felis chaus*) and these mammals are directly or indirectly dependent on the flow regime for their pray and drinking water. Monkeys and Jackles are more common in these locations. The forest habitats are homogenous, discontinuous and frequently intervened by the presence of farm land and settlements. A total of 24 species of mammals and 37 species of birds were reported in the forest near Gumukhola, Nagdaha and Charange Among the amphibians, frogs are very common showing the importance of flow regime and its association with the local people.

7.1.4 Dealing with Socio-economic Issues

The damming of flow has created other problems other than fish migration. Moreover, this leads to change the number of fish species also, its river flow sub-stratum and direction. Water resource projects are nationally prioritized, socially driven regionally demanded and locally welcomed. The construction of the Khimiti Hydro Project in the IIIrd sector of the basin is the result of development of settlements along the Kirne taar and Devi taar. The main attraction of the water resource is availability of constant water flow and high gradient in the Tamskoshi River basin. The allocation of the HPP raise the people in the locality getting better services, highway expansion, connection between Khimti and Charikot. The area is densely populated has road connections with market center, electricity, and other infrastructure facilities are available here.

7.2 The Community Interaction

The results of the community interaction methods have been used categorically. In this method, the O is assigned for underscore or no answer. Similarly, the number of Ist and IInd is given for unimportant and moderately insignificant. The number third, fourth and five are assigned for moderately important, important and very important.

From the table 7.3 it is clear that the third sector has the highest interaction value which turns to be 66 and the first sector has the least among the four sectors in an interaction. The analysis of interaction method as developed by National EIA Guidelines (Interaction Matrix value) also shows the that major interaction with water flow is found in the third sector where the value is found to be 6540 and the least in the 1st Sector which is equivalent to 2870 (Appendix VIIIc).

Table 7.3: ***Analysis of Interaction Scoring Using Likart Scale***

S. N.	Parameter	I	II	III	IV	Total
1	Watershed and sub-water shed	2	4	4	5	15
2	Surface Water Flow	5	5	5	5	20
3	Socio-ecology	2	5	5	5	17
4	Biodiversity of Gaurishanker Conservation Area	5	5	3	3	16
5	Residual flow	1	1	1	5	8
6	Terrestrial ecology	2	5	5	2	14
7	Aquatic ecology	1	4	5	5	15
8	Sensistic cremation	1	3	5	3	12
9	Plants/Vegetation	3	5	5	3	16
10	Landscape ecology	5	5	5	3	18
11	Livestock	5	4	4	3	16
12	Aesthetic	4	4	4	3	15
13	Geo-morphology	5	5	5	2	17
14	Soil and river resources	3	5	5	3	16
15	Topography disturbances	5	5	5	3	18
	Total	49	65	66	53	233

Source: Field Survey, 2014

7.3 Chapter Summary

The ecological resources such as water, fish, driftwood, and river sediments available in the Tamakoshi River are essential for sustaining the livelihood of marginal indigenous people, particularly the Majhis, other ethnic groups, and the Dalits of the riparian settlements. Hydrology of the river is high during pre- monsoon than post monsoon. The flow diversion can alter the whole system of river ecology along with floral and faunal environment. Major interaction with flow regime is found in the sector third. This is also mainly due to the fact that the river water is the life blood of the communities and is deeply associated cultural traditions.

CHAPTER VIII

OPINION SURVEY ON FLOW DIVERSION AND RIVER HYDROLOGY OF TAMAKOSHI RIVER BASIN

This chapter focuses on the perception of local people and public authority on environmental flow, impact of environmental flow, cumulative impact of flow, flow diversion, people's perception on basin hydrology, river ecology and river resource, community and livelihood options.

8.1 Perception of Local People

Research on perception, attitude, and behaviour emerged as a distinctive area of enquiry during the early 1960's (Burton and Kates 1964) and Mitchel (1979) has observed, "the social role of attitude and perception studies is to provide an input into the planning process and to serve as a vehicle for public participation in decision making" (Mitchell. 1979). "Perception" is the process by which we receive information or stimuli from our environment and transform it into psychological awareness. It is interesting to see that people infer about a certain situation or phenomenon differently using the same or different sets of information (Ban and Hawkins 2000). The perception of flow diversion was collected from the household survey and FGD.

According to the house hold survey more than fifty per cent of the people (56.44%) are in favour of diversion of flow and less than one fourth (23.46%) are against it (Appendix VIII). The section wise general perception of local people shows that the diversion of water from the main trunk river is welcomed by all the people except some people from the IV sector. The cost benefit analysis done by the local people is associated with incoming development activities. The local people are ready to use water for hydropower benefit of road, electricity, development and availability of share capital, increase in investment in the development activities and promotion of local tourism.

The people from Lapchi, Lamabagar and Singati welcome it. Likewise, people from Torkehet (sector III) to Garimudi have a positive attitude. The people from Malu to Manthali have been affected by Khimti Hydropower Project. However, some of them raised negative impact of flow diversion like soil erosion, landslides, sand mining and possible collapse of the local market, decreasing fish population and problems in flora and fauna. The ethnicity mainly so called groups like Tamang, Magar, and local people whose daily livelihood is associated with the flow regime have opposed it.

The flood level is essential to the local people for fishing and hunting of other flora of the animal world. They feel quite happy when it happens. Instead of a natural flow, a swift flow will be from manmade artificial tunnel with a control mechanism. This situation is shown by vector analysis and its summation in four sections.

FGD held in the sector third (Section III from Maryang to Kirne) came up with the conclusion that flow diversion can dry up some of the areas in this sector. Most of the local people are aware of the issue of drying up and natural hazards of the river. In addition, the area is also a place of good water flow.

8.1.1 River Flow and Diverstion

The second aspect of the flow diversion is related with e-flow which is also collected from the household survey and interview with key informants. The overall percentage of the reaction is presented in the Table 8.1 below.

Table 8.1: ***Perception on Flow Diversion***

Sector/ Theme	I	II	III	IV	Total	Percentage
1. Fine	14	1	19	0	49	11.89
2. No effect	33	5	0	0	38	9.22
3. Deforestation	0	32	24	0	56	13.5
4. Dewatering/ low flow	0	10	27	12	49	11.89
5. Environmental damage	6	6	23	8	43	10.43
6. Fish disappearing	0	12	27	11	50	12.13
7. Disappearing water resources	0	6	27	7	40	9.70
8. Others	7	15	60	5	87	21.21
Total	60	103	191	53	412	100%

Source: Field Survey, 2014, 2015

It is evident from the Table 8.1 that the 12.13 percent respondents view that the flow diversion will reduce the fishes in the river and it is followed by dewatering and developing is fine (11.89%).

Perception of people towards the flow and its diversion for analyzing the spatial and temporal variation of interaction with flow regime it also basis of comparing the experience of the local people, policy makers and government official discussion on power production from the river basin and a diversion of water from the main trunk river has been welcomed by all people.

8.1.2 Impact of Flow Diversion

River flow changes due to diversion of flow for hydropower, irrigation take place as urbanization; population growth and economic development proceed requiring to reallocate water for different purposes, such as agriculture land and implement municipality water supply system. River flow may have impact on water quality ; commercial and non –commercial agriculture, timber, wildlife and fisheries; on ecosystem and biodiversity emissions of pollutants; water-borne diseases ; social impacts, including impacts on cultural/historic sites, cultural identity, social cohesion, access to social services, etc. (Dyson et al, 2003).

The EIA is legally mandatory in every aspect in hydropower development projects. Amendments in the Hydro Power Policy 1992, Environmental Act 2019 and Environmental Conservation Rules 2020 have made it mandatory. The envisaged impact by the flow diversion was received only 258 (62 %) percent out of total 412 the survey result of the basin has been described in the Table 8.2 below:

Table 8.2: ***Impact of Flow Diversion***

S.N.	Utility of Water Resoruces Sectors	Outcome of flow diversion				Total	Percent
		I	II	III	IV		
1.	Daily use	2	5	10	25	32	12.4
2.	Religious and cultural sites	2	5	20	8	35	13.56
3	Cremation sites	1	8	14	6	29	11.40
4.	Agriculture Irrigation	1	2	3	4	10	3.87
6	Wild life	2	5	8	14	18	6.97
7.	River resources	1	2	13	12	30	11.62
8	Swimming	0	3	10	30	24	9.30
9	Fish species	2	5	15	10	52	20.15
10.	Riparian vegetation	3	5	10		28	10.85
	Total	14	40	103	109	258	100

Source: Field Survey, 2014 and 2015

From the above Table 8.2 it has been revealed that flow diversion has major impacts in fish species (20.15%), religious sites (13.56%), cremation sites (11.40%), and river resources (11.62%) (Table 8.2).

The changes in flow regime bring major changes in its hydro- geomorphologic system, river channel and many aquatic systems. This would ultimately affect people living in the riparian zone (Communication with Dr. Suman Shakya, Ecologist, 2072, ENPHO Nepal, Baneshwor). The augmentation of flow by tributaries is not enough to sustain the aquatic life in the downstream as most of the soil easily socks such flow easily during the dry season (Communication with Prof. Dr. Tej K. Shrestha).

8.1.3 Cumulative Impacts of Flow Diversion

A cumulative impact includes total effect on natural flow in the TRB in the long run. Cumulative impacts include a total of all impacts to a particular resource that have occurred, are occurring, and likely to occur as a result of any action, including the direct and reasonable foreseeable indirect impacts of a future activity. The overall impact received form KII is illustrated in Fig 8.1.

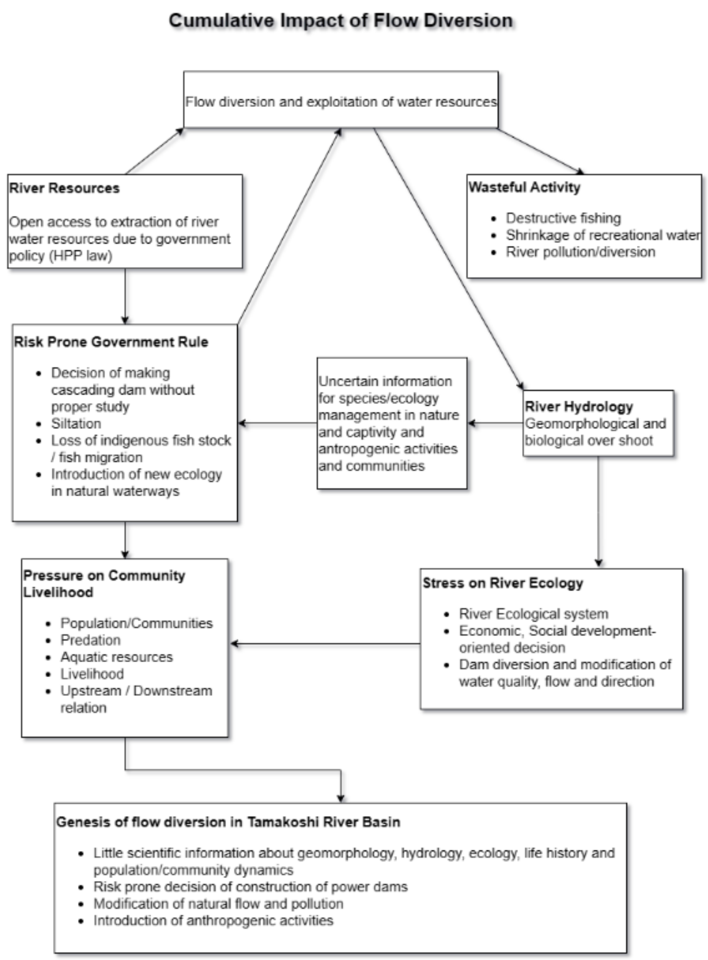


Figure 8.1: **Cumulative Impact of Flow Diversion**

The data collected from the household survey (412 HH) show that overwhelming percentage of people in the study area are unaware about the cumulative impact of e-flow (47%).34 per cent people have a negative perception about cumulative aspect of flow regime and only 20 % of them are positive towards the cumulative aspect of flow regime (Appendix – VIII).

The respondents of the sectors II, IIIrd and IVth raise concerns than other sectors. The first sector is inhabited by Sherpa, Tamang and other groups which are associated with Buddhism and their associations with the flow of water are very low. In contrary, the IInd and IIIrd are relatively associated with flow regime. In contrasted to the above sectors, the sector IV is inhabited by Majhi people whose culture, religious, day today life and are totally rely in the flow regime.

In the study, information has been derived qualitatively to those people who were attained in strategic position. The jeast of their information has been presented in the following points:

- The existing provision of e-flow is not sufficient for river ecology
- River basin should be considered in ecological planning
- E-flow in cascading dam will lead to collapse of the basin- ecosystem
- Existing law of e-flow should be changed

The detail points of discussion of e-flow implementation are presented in the Appendix VIIIB.

Eight FGD (Appendix II) has identified following guidelines for the study :

a. Ecology and environment of river basin– Participants are of view that springs, water sources, and fishery and other related resource are associated with flow regime and the main river and its tributaries are the sources of boulder, sand and other materials.

b. Electrification and capital share distribution– Local people demanded to provide electricity to all in which had not been electrified and capital share as well.

c. Food basket – Participants raised the question regarding the loss of productivity of agriultural land along the Tamakoshi River once the flow is diverted and flow is obstructed.

d. The major concern was the loss of food basket along the Tamakoshi River and its compensation and rehabilitation packages. They also revealed that the people should be properly compensated and need to implement plan to conserve the ecological condition of the river basin.

e. Downstream water use - People in downstream side (Sector II downwards) use water of main Tamakoshi and its tributaries for irrigation and other purposes. Once the water is diverted for hydropower, the stretch of the area would be considerably drier than before. Then the river ecology (floral and faunal) may severely disrupted by the diversion of river.

f. Deforestation – The stretch from Tamakoshi sector Ist to IVth is densely forested at different places. The FGD concern on long stretch is that forest area might come under pressure from heavy logging and facilitate smuggling due to diversion.

g. Livelihood support - The FGD raised the concern about livelihood of the area. The Khimti and Upper Tamakosh Hydropower Projects have provided ample opportunities (electrical training, bakery making etc.) of skill development, infrastructure development and small industry for their livelihood improvement. It has been hoped that the coming projects would bring in more opportunities at the local level through variety of income generating activities. Emphasis was laid on improvement of livelihood of Majhi, Thami, Newar and Tamang. The ILO provision of 169 (Gurung, 2005) is related to the tribal and indigeneous people and when Swiss Development Corporateion (SDC) implemented their road development project, the local people were hired as workers.

h. Fish friendly dam and e-flow - They raised the issue of natural resources like flowing water and relation with fisheries and livelihood of the local people

The existing price of the fish ranges from NRs. 400 to 700/Kg. According to the FGD and informal discussion SEA 40 fishermen are full –time on fishing and 365 are part time on fishing in the Tamakoshi River. Among these market the fish markets of Singati, Nayapool, Khimti and Manthali area are prominent ones in the basin.

8.2 Perception on Watershed Hydrograph

In the FGD, seven participants ranging from former parliamentarian, studnets, teachers and local residents have expressed their opinion about basin hydrology.

Mr. Kamal Sunuwar, a fomer parliamentarian expressed his view that any development project needs to consider the basin hydrology and due to water extraction. KHEP is one of the most expensive hydropower projects ever implemented in the Khimti basin and felt the need to assess the terms and conditions of the project on hydrology. A student of grade 12 Mr. Padma Nepali felt the need of afforestation in the hills and sloppy land after the implementation of e-flow. Mr. Lila Mani Pokharel a teacher felt the need of provision to irrigate the impact of the hydropower development projects in the basin and emphasized on the coordination among DCC, irrigation office and DSCWM. Tara Bahadur Koirala, another teacher expressed his view that to maintain flow regime and river hydrology, the forthcoming ecological consideration in the project should lay their emphasize on irrigaton facility. Mr. Bhola Karki, a resident of Ghyangsukathoor also opined in the same line with the Tara Bahadur Koirala. Bikram Karki a member of DCC regards hydrology is the gift of basin and felt the need to preserve it. Shanti Majhi and Ramesh Magar both belong to fishing occupation look the river basin as their life line which affects social and cultural life. Manish Shrestha, a resident of Manthali did not want the diversion of water from their farmland when the whole hydropower projects are undertaken.

8.3 River Ecology and River Resources

Four prticipants of KII ranging from former chairman of Gelu to residenct of Ramechhap and Dolakha have expressed their view on river ecology and river resoruces. Bhairab Karki, former chariman, Gelu stressed on the need to allocate a part of revenue from hydropower projects to undertake development activities in the river basin. Dillinath Rimal, a resident of Namdu felt the need to preserve the fertile land of the municpality along the river banks. He also exmpahasized on the need to provide the support to local indigeneous people and provide 10 percent share capital of the project to such people. Ganesh Tamang, a political activist stressed on the need to participate to local people in the development activites of basin.

8.4 River Ecology, Community and Livelihoods

Eights participants of FGD belonging to above group have expressed their views regarding river ecology, community and livelihood. In this group, a civil servant of Npeal government also provided his view. Tej Bahadur Karki, a resident of Manthali, opined that the construction materials are available due to flow regime. It should be utilized for the welfare for the basin people. Hari Shrestha of Bhimeshwor municipality, stressed the need to provide natural flow to the local people and for their irrigation facility is the most important for the livelihood of the people. Rishikesh Uprety, a farmer stressed on the need to promote the fishery occupation of the local people. Gopal Neupane, former chair of Melung is of the opinion that for the basin development and environmental protection, e-flow should be used. Amber Khadka and Tara Karki, both the political activistst opined that e-flow should not affect the irrigation facility, which farmers are using now. Ram Krishna of Ghyang Sukathor village stressed on the need of support by DCC/DSCWM to support the reduction of the fish and fishery due to reduce flow regime. Ram Hari Dahal of Jhule said that local people should be given priority and employment opportunity in the project in the basin area. Rameshwor Dahal, a local development officer stressed on the need of coordination of DCC, among DSCWM and other local institutions to promote socio-economic development of the basin.

8.5 Opinion of Authority

Tek Bahadur Gurung, Director of NARC opined that the IUCN should study fish species and other aquatic ecology of the Tamakoshi River. Ram Krishna Upadhyay of Department of Fishery felt the need to preserve fish hatchery and fishery activities due to implementation of e-flow in the river basin. Mr. Rameshwor Vaidya inquired about the responsibility of the government and other local institutions to construct the climate proof dam and it is the responsibility of the government to safeguard such calamity like loss of fish species and other hatcheries. TN Sapkota, an engineer of DDC Dolakha viewed that the government should give priority to energy production by preserving the existing ecology of the river.

8.6 Perception on River Based Resources

Mr. Ratna Bahadur Sunuwar is of view that the flow of river is the main environmental concern of Ramechhap and Dolakha districts. He complained that the government and other implementing agencies ignore asspirations of peole while implementing development projects in the basin. Mr. Tirth Bahadur Thapa of SWISS Nepal Forest Project stressed on the need to have sustainable employment rather short term employment. He further noted that community forestry along the river might impact on the e-flow of the river. The overall summary of the FCD is presented below:

Summary of Perception of Local People

Process	Characteristics
Basin Hydrology	• Khimti hydropower project, and Tamakoshi hydropower project low flow down stream. It has positive impact, issue is drying up and downstream water use and concern is high cost of electricity unit. • natural hydrology dried up in old channel. It has negative impact, issue is drying up and concern is irregular flow. • e-flow is not sufficient to natural flow. It has negative impact, issue is fish abode its migration and concern is fish diversity and disappearing. • irriation, 2000 capacity dewatering in sector IIIrd and IV. It has negative impact, issue is moisture availability and concern is food production. • lifeline/livelihood because of e-flow hydrology. It has negative impact, issue is avaibility of fish and river resoruces and concern is livelihood. • no sufficient fertile and and religious faith more vulnerable to Majhi and other community. It has negative impact, issue is avaibility of fish and river resoruces and concern is livelihood.
River ecology and river resoruces	• Ten percent share free of development project(hydropower) which has positive impact, issue is water use and concern free share. • revenue generation vs. river resource conservation conflict, which has positive impact, issue is hydro power production and concern is ecological services and hydrology of basin.

	• loss of forest cover in riparian zone, which has negative impact, issue is dried up and concern is the loss of forest and bio-diversity. • sand mining decreased, which has negative impact, issue is the reduction of river resources and concern is livelihood riparian people • road construction which has positive impact, issue is availability of construction material and concern is the development activities. • scarcity of gravel and other river resrouces- fish, water snail which has negative impact. Issue is availability of construction material and concern river ecology.
River ecology, community and livelihoods	• Watershed dependent livelihood threatened has created negative impact. Issue is the distrubance in watershed and concern is livelihood. • poor people depend on daily extraction of sand for livelihood is threatened and rich people depend on extraction from machine, which has negative impact. Issue is the production and concern is employment. • fish exploitation decreased, which has negative impact. The issue is fish diversity and concern is fish abode. • stone quarrying decreased, which has negative impact, Issue is generation f resoruces and concern is stone production. • purity of local people and development model of SWISS, which has positive impact. Issue is public participation and concern is HPP model. • fish movement and migraition stopped has negative impact. Issue is water flow and concern is river ecology and fish migration. • no use of e-flow which has negative impact, Issue is low flow and concern is implementation of law. • Socio-economic and infrastructure related with flow regime hault which has positive impact, issue is infrastructure and

	share and concern is development.
River based soruce, hydrology and overall ecology	• Need to protect local peole's aspiration and preservation of local employment in river resrource. It has positive impact, the issue is employment and concern is river resource and water flow.
Opinion of authority	• Energy production must be increased with ecological conservation of river basin which keeps positive impact. The issue is energy production and concern is strategic policy

Source: FGD/Field Survey, 2014/015

A similiar result was found in the irrigatin on canal of East Rapti Irrigation project. The augmented flow of East Rapti River was not enough to support ecology of Chitwan National Park (Khadka and Joshi, 1992; Primick, 2013), Gang and Yamuna River (Dutta, 2014) Yangauli River, New Zealand (THT, Aug. 12, 2018), Kaligandaki, (THT August 8, 2019) Marshyangdi (Shestha, 2000).

Owusul et al. (2023) found that construction of hydropower not only raises the energy, rather it equally raises the problems in downstream area like changes in livelihood, disappearing of aquatic diversity and so on. Litnov and Golonov (2004) concluded that there is decline of ecological diversity (flora and fauana) due to dam onstruction, Bruckerhoff, Leasure and Magulick (2011) viewed that the e-flow is still dout in fulfillling the ecological system of the river; Mishra. Trapathi and Babel (2014) discovered that the changes in flow regime with respect to the temperature changes the ecological system of Gandaki river and Mr. Sada (2017) detected that 10 per cent flow as ecological system may raise problem of water user in the downstram and does not fulfill the reqirement of ecological system and raise water uses problem between upstream and downstream ; CDG (2015) raised the question of changing geomorpheological system of downstream area following the dam construction.

The integrative reviews of some environmental impacts by Williams and Wolman (1984) have identified that flow of minimum requirement of water must be maintained as per demand of the local biological use. According to Babinski, "erosion expands most dynamically at an early stage of the operation of dams. There is a period of abrupt changes in a river bed attributable to building of dams. The change in velocity will change in sediment distribution along the river. It causes a long-lasting scour in the river bed resulting in increment of total runoff of sediments. As a result, the quantity and composition of sediment as the river delta are changed. The Diversion of the flow river may create conflicts among user groups. The Kathmandu Valley Water Supply Project (Khadka and Khanal, 2008) aims to pay levy to downstream water users of the Melamchi River Water Project as compensation to downstream water users and fishing communities.

The threatening impact of building large dams nearby village as well as ecology is no secret. Even though hydropower generates clean energy, large dams and small dams have a serious impact on the environment. The construction of dams for hydropower project impacts river and wild life habitats, displace humans, affect fish population and interrupt natural flow of sediments into river systems. Other effects if CO_2 emissions. An analysis from 100 studies of reservoir islands of 15 dams in North, Central and south America, Europe and Asia showed that in more than 75% of cases, dams had an overall negative impact on reserves Iceland species affecting species, population density, ecological community composition and species behavior (Times of India Jan 17, 2021).

8.7 Chapter Summary

The perception made by local people on flow regime, interaction varies spatially and temporarily. Although the perceptions made by local people vary from time and scale but their perceptions also tally with scientific perspectives: Geographically, these things are valid. Many people claim that the flow regime of major and minor rivers are interlinked and has changed for the last three decades. The major flow is related with livelihood (fishing community, river ecology, and sand gravel mining, aesthetic and religious purposes) of the people in localities from the sector II downstream. Many people are of opinion that temperature has increased in the last two decades along with the change in flow regime. This fact is also proved by the discharge of water in the Busti station (647). This is a new concept as they have no capacity to utilize its own resources but they expect investment on water from donor agencies. The perception towards the flow of the river is positive in the IIIrd and IVth sector than other sectors. However, majority of them are unaware about the cumulative impact of flow diversion. They are eager to have Capital Share from hydropower projects than the ecological significance.

The implementation of flow diversion will impact in riverine livelihood, geomorphological setting, ecological and aquatic aspects. There could be irreversible loss to river resource. The 60 percent low flow area will be emerged as a major problem. 40 percent e-flow has due to diversion of river flow due to construction of the hydropower project. The local inhabitants using riverine resources for their socio-cultural and economic activities will be impacted. The major concern is the aquatic ecosystem, fisheries and other river resources. Moreover, habitat fragmentation in such area may result in wildlife mobility and limit food chain.

CHAPTER IX
SUMMARY, CONCLUSION AND RECOMMENDATION

9.1 Summary

Interaction between physical process between river and local people in a river basin area is closely related. There is a close nexus between the flow regime and human activities. The general objective of the study is to examine the interaction between river ecology and local communities and the specific objectives are:

- to examine the charactures of basin hydrology
- to identify the linkages between basin hydrology and river resources in the context of overall river ecology;
- to analyze the interaction between river ecology and local communities with specific emphasis on the livelihood based on aquatic ecology; and
- to explore the perception of local people towards the basin hydrology, flow diversion and cumulative impact of flow diversion.

The total area of the basin within Nepal side is 2700 km^2 and the stretch of the river flow covers 106 km from China boarder to Tribeni, a confluence of the Tamakosh with the Sunkoshi River. The study area covers ten rural municipalities and two Municipalities' (Bhimeshwore and Manthali). The study area accounts for 42 per cent of total district of Dolkha and Ramechhap districts and it has been divided into four spatial hydrological domains like Ist, IInd, IIIrd and IVth sectors. Likewise, the year has been divided into three seasons: pre-monsoon, monsoon and post-monsoon.

The study is guided by ecological principles and methods and it has adopted both quantitive and qualitative methods. A total of 15 different water flow samples from three locations from each sector and six chemical parameters from three seasons (pre-monsoon, monsoon and post monsoon) of the year were collected for the study of geo-ecological parameters. Likewise, 412 household's samples were selected for the data collection randomly within 1000-meter buffer of the Tamakoshi River. Similarly, 8 FGDs at least two from each sector and were conducted in the four sectors. Observations, household's survey and key informant interviews, were methods to generate data. Information about the positive and negative aspects has been collected by using open-ended questions. Options have been expressed in the percentage figure according to their occurrence. However, the temporal and spatial aspects of the subject have been converted into numerical form in terms of magnitude (M), extent (E) and duration (D) using Lopold Matrix. Likewise, GIS/RS and different analog maps have been also used for the study.

The summary of the major findings are as follows:

9.1.1 Basin Hydrology

The theoretical basis of hydrology to maintain river basin ecological system and its interaction with settlement is not sufficient. The theories of hydrology (Serman) are examined graphically along with assumption under which they have been formulated. Their relevancy is justified with reference to empirical study derived from quantitatively and qualitatively in the TRB. The graphical and other models are further strengthened with illustration in the form of mathematical model; line models and in algebraic forms. The models are tested based on field observations of relevant hydrology, aquatic ecology, settlement and its interaction.

The total availability of the water in the basin is $7.47134 \times 10^{10} m^3/s$ out of which 16.47%, 9.49% 49.74% and 24.28% are distributed in the sectors Ist, IInd, IIIrd and IVth sectors respectively.

The flow of the river is found to be 19.88 m^3/s in Lapche and 322 m^3/s in Manthali which ranges from the lowest to the highest. There are 32 major tributaries of the Tamakoshi River and the flow contribution of Khimit, Charange and Rolwaling ranges from 5 to 10 percent in total annual flow. The flow of river during the pre-monsoon (index 91.09%) is lower than the post monsoon (45.36%). During the monsoon it is raised by 123%. The river flow is significant in the sector first due to constant flow. In the sector second and third, the flow is contributed by tributaries flowing from the high mountain and rainfall due to that the tributaries of sector fourth remain dry during the winter. The flow almost remains constant due to consumptive use (pumping for drinking and irrigation) of water in the upstream. However, high level of interaction between river flow and local people takes places in this sector.

Similar the correlation between river power and distance is only -0.024. Water depth and sinuosity have played a significant role in the deposition of sediments in the river basin.

9.1.2 River Resources

The communities use traditional fishing techniques for subsistence fishery which generates marginal economic benefits. The power of the river is highest in the first sector which ranges from 26.8 to 333.73 nTu and lowest in the fourth sector which ranges from 64.33 nTu to -3.33 nTu. The size of the boulders during the monsoon turns out to be double than the size in the pre-monsoon and post monsoon. The relationship between the current river power and its cumulative distance is negatively correlated (-0.22).

The major production of sand and gravels takes place is in the IIIrd sector. However, drifting wood is another extraction resource in the IVth sector. The agro-ecological condition of the IIIrd section is the most important condition for the basin.

The river has deposited river materials like stone, sand boulders and gravels, which amounts from 39,850 m^3 in Lamabagar and 133, 153 m^3 in Masantari. The percentage of sand is the lowest in the Ist sector (20%) and the highest in the IVth sector (90%).

9.1.3 Aquatic Ecology

The number of fish species ranges from two in the sector Ist to 30 in the sector Ivth. The sector III and Ivth are ideal area for fish abode throughout the year. The geo-chemical characteristics are conducive for the growth of the cold and warm fishes. Similarly, the dependency of community on the fishes also increases along with the flow regime of the river.

The temperature, pH, BOD, EC and water colour show that there is a close relationship between the local litho logical structure and characteristics of river water chemical. It indicates that except the upper stretch of the basins other areas have congenial environment for fish farming. The major flow is connected with the livelihood of the local people in the forms of irrigation, industrial uses, amenities, religious, drifting woods, river resource, and fishing activities.

The relationship among the river hydrology, river ecology, river resource, and aquatic ecology is favourable in the middle part (Sector III) than other parts. The flow depth and senosity have played a significant role in sediment deposit and aquatic ecology. The overall river flow resource is concentrated in the third and fourth sector along with the fish species and its number is also rich in the same sector than other sectors. The livelihood of the local people is found highly associated with the flow regime in IIIrd sector/IVth sectors than other parts of the basin.

9.1.4 Perception on Interaction and Flow Diversion

In cold and warm water flows, local fishes in short and long distance migratory fishes area available. Majority of people fishing during the pre- and post-monsoon than the monsoon season.

The value of interaction matrix between sectors communities and flow is highest in the third sectior (66; 6540) and the lowest in the Ist sector (49; 2870). The major flow regime is related with livelihood, irrigation, industrial use, recharging underground water, drifting woods, (fishing community, ecology, sand gravel mining and religious purposes) of the people in the localities from Charange to the downstream.

There is a wide spread of awareness among the local people about the benefits of the flow interruption. More than 50 per cent of the people are in favour of diversion of flow and 23.73 per cent are against it and rest of the people (27.33%) are not aware about its consequences. They have expected more energy, development activities and economic benefits. There remains a significant barrier on about long term ecological disruption. A total of 42 km stretch of the river will be turned into a dewatering zone. This represents 40 per cent of the total stretch of the Tamakosh River. It will create a dry zone near to the 60 communities. This situation leads to the disruption of socio-ecological system of the Tamakoshi River.

9.2 Conclusions

The study was imitated with an objective of exploring interaction between river ecology and local community in the Tamakoshi river basis in the central mountain region of Nepal. It has provided a glimpse of the river flow and its ecology the Tamakoshi river basin area which is characterized by different ecological system and inhabited by several communities with different types of livelihood activities. The study also attempts to evaluate the ecological flow due to the hydropower project in different biophysical settings of the Tamakoshi river basin. Following are some of the important conclusions that can be derived from the present research work.

The use of different philosophical methods accompanied by a methodology with qualitative and quantitative technique to handle different types of data and information collected from a range of sources has been considered to be a strength of the study. Likewise, the extensive use of recently developed tools like geographical information system, hydrological equations and remote sensing in analyzing various components of sustainability in relation to river ecology, river hydrology and river resource management practices of different communities sharing river ecosystem are considered fruitful. Simplification through the qualitative and quantitative method and specific analysis through qualitative method are found useful in exploring understanding and explaining the reality of the Tamakoshi river basin.

The role of the flow regime, locational characteristics of riparian communities and influence of natural flow factors have been found significant in flow dimension of river base livelihoods among different communities in the Tamakoshi river basin. Likewise, the development of various infrastructure especially hydropower along the Tamakoshi river basin has not only helped to increase the spatial coverage of diversion of water flow but also raise the expectation of capital share from the hydropower project. Furthermore, the success of community based and foreign based investment has created a necessary background to initiate various development activities and local development approaches in the area.

Similarly, the study of overall status of river flow regime, basin hydrology, geo-ecology and river resource in relation to flow variables such as river power, slope, and drainage density provided that the traditional knowledge of local people using flow regime for agriculture livelihood and resource mobilization are in accordance with the maintenance of ecological sustainability in the river basin. Except for some locations, the interactions of local community with river ecology in the area have been found to be more encouraging. Similarly, there are ample opportunities to improve the level of ecological sustainability of the river basin. Thus, the use of the concept of sustainability in ecological, economic, and cultural contexts are considered to be unique features of the present study.

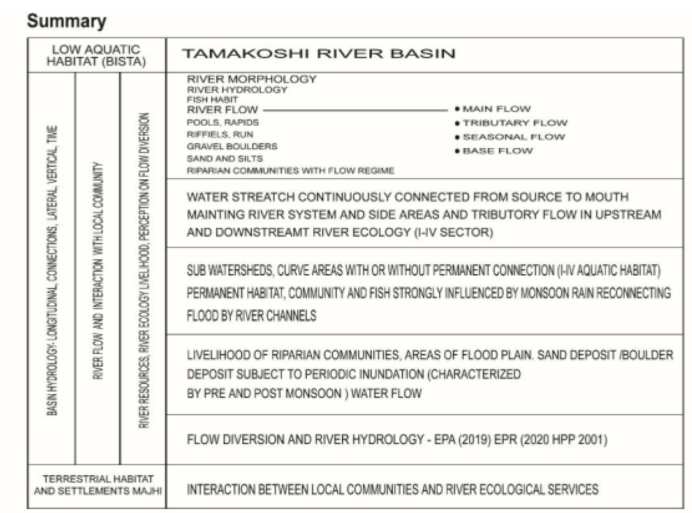
River flow increases with distance during post monsoon period and it remains alomsot similar during the etime of pre-monsoon and monsoon. Various factors, geological, geomorphological, rainfall and watershed conditions are responsible for this. The trend of temperature, rainfall is increasing and flow rate is aso increasing to some extent.

The uniqueness of the study lies in its flow and river power, sediment deposition and basin order and distribution of community along with the riparian zone. The high value of attraction was found in water flow which is the main attraction of the community location. Presently, they are attracted due to its commercial production (HPP share). High order basin has low number of communities and low flow with low order has high ranking communities. Majhi has highly interacted with the flow regime and Bista of Lapchi has low interaction with flow regim and the hilly community range between these communities. High flow of water attributed with low number fish species than low flow with high number of species. As a result the high ineeraction is found in low flow than high flow area.

Different characteristics of hydrological distribution, orientation of sub-watershed basins and the distribution of various communities were intact nature connotation with flow regime. Unique distribution of flow hydrology and location of communities are the main attraction of exploiting flow regime.

Covich (1993) has shown that stream flow regimes have a major influence on the biotic and abiotic processes that determine the structure and dynamics of stream ecosystems. High flows are important not only in terms of sediment transport, (lateral interaction the concept of river continuum) but also in terms of reconnecting flood plain wetlands to the channel. High flows promote fauna dispersal. Thus, spreading populations of species to a variety of locations depend on this. The life cycles of many riverside species require an array of different types of habitat whose temporal availability is determined by the flow regime. Adaptation to this environment allows riverside species to persist during periods of droughts and floods (Loucks & Van Beek, 2005; Poff et al., 1997).

Finally, it can be concluded that river basin hydrology, ecology, and community are changing perceptibly both in a temporal and spatial scale. Changes are also taking place in the attitude and behavior of the riparian communities resulting in a kind of diversification of flow pattern, land use, river resource and other management practices. Therefore, changing state with flow regime and its ecological significance has been the apparent manifestation of the present day basin hydrology, river ecology, its relation with livelihood and changes of technology. Overall summary is presented as follows:



9.3 Recommendations

The study was carried out in the central mountain region where lots of hydropower projects are concentrated to exploit the natural flow regime of the Tamakoshi river. The upper part of the area is not accessible from the road network and area covers 1000 meter of the Tamakoshi river, which has ten RMS and two municipalities and they are chosen for the analysis. The boarder part of the upper side needs two days walk from the road network near Lamabagar. Therefore the present study feels the need of another in depth study to verify the interaction between river ecology and local communities, their relation with flow regime, river resource management, river geo-ecology and its perception towards river ecology. It helps to generalize the changes in river flows that are taking place in the other river basins of Nepal.

Likewise, this research has used the river corridor of 1000 meter along the flow of the Tamakoshi River for evaluation of interaction between river ecology and riparian communities. A question may arise here to the merit of mapping and analysis of the situations by demarcating only the area associated with flow regime and river basin community. Therefore, other researchers have an opportunity to make analysis more specifically and realistically by taking beyond 1000 meter buffer and more stations in the basin.

There is ample scope to develop or include some other indicators of river basin hydrology, river geo-ecology, river resource, and interaction between ecology and community. Similarly, the scope is to develop a specific methodology for river ecological interactions at different spatial and temporal scale. So, the further research with these initiatives would be useful in devising a concrete evaluation system to benefit the ecological planners, policy makers and developmental agencies for more accurate and relevant results.

The connectivity of headwater to downstream reaches must be evaluated in future. It should include basin hydrology, interaction and e-flow to understand cumulative effect of changes in headwaters.

A basin strategy with a concrete model (policy, plan, and program) should be studied in detail addressing the need of riparian communities, ecological systems and hydrological conservation. Moreover, the study recommends further study to cover those study which are not covered in this study of river flow dependent people like Majhi, Thokar and Newar and revisit 10% model of ecological flow.

The process characterization of different watershed and its network should be considered in different aspects of guidelines, study and implementation. So the government should evaluate policy guidelines and develop practical ones. The other aspects are :

Tamakoshi river is trans boundary river, flood, GLOF, snow melt might have effect on flow and channel morphology, the present study covers Nepal part, so further study involving China is needed.

The present study is focused on the main channel but major tributaries are also important to study. Intense monitoring of discharge in different locations to evaluate the upstream -downstream linkages is necessary. At the end, the present study recommends to use further hydrological parameter (precipitation, abstraction of water, evaporation, flood routing, ground water flow) geo-ecological parameter, river resources, and social indicators in mapping the ecological resources of the riparian zone. This study has overlooked several details of river flow patterns and products which should have been valuable for further explanation of the availability and use of river resources and ecological benefits at different levels.

APPENDICES

Appendix I

Sampling Household

S.N.	Villages	VDCs/ Municipality	Surveyed HH Number	
			Tot HH	Sample Households
1	Lapche, Lamabagar	Lamabagar	35	10
2	Manthali	Orang	30	10
3	Bhorle	Khare	15	10
4	Simigaon	Gaurishankar	60	10
5	Bhirmuni	Bulung	12	10
6	Singati	Laduk	50	10
7	Suridobhan	Suri	15	10
8	Jhangreli	Jhyanku	15	22
9	Churikharka	Lamidada	150	30
10	Gumukhola	Sunkhani	75	25
11	Malepu	Kshetrapa	25	12
12	Pikhuti	Jungu	25	20
13	Nagdaha, Nayapool	Bhimeshwor Minicipality	90	60
14	Charange	Phasku	150	12
15	Kande	Namdu	35	15
16	Majhigaon	Bhirkot	45	10
17	Andheri	Pawati	12	10
18	Gopikhola	Gairimudi	35	12
19	Kaimati	Ghyangsukahokar	30	12
20	Baguwabesi	Bhedpu	18	10
21	Bahrabise	Japhe	12	10
22	Ratmata	Malu	35	14
23	Sitali	Melung	35	10
24	Milti, Devitaar	Phulasi	120	16
25	Nayabasti	Sahare	20	12
26	Khimtibensi,	Khimti	60	12
27	Gelu	Gelu	25	15
28	Tilpung bensi	Tilpung	18	12
29	Chisapani, Rajgaon	Manthali Municipality	200	72
30	Masantar	Pakarbas	35	15
		Total	1482	412

Source: Field Survey 2014, 2015

Appendix II

HOUSEHOLD QUESTIONNAIRE SECTION –

A: GENERAL INFORMATION OF SETTLEMENT

1. Name of VDC:

2. Ward No:

3. Name of Settlement:

4. Feature of settlement: Clustered ☐ Scattered ☐

5. Major ethnic groups (please give no. of HH)

Brahman ☐ Chhetri ☐ Newar ☐ Tamang ☐ Thami ☐

Magar ☐ Jirel ☐ Surel ☐ Other, Specify ……………………..

6. Prevailing infrastructures #

#01. Road; 02. Bridge; 03. Track; 04. Electricity; 05. Telephone; 06. Post office

7. Number of cottage/small industries within settlement.

Cottage industry	Location/ward no.	No of industry
Water mill		
Paper mill		
Saw mill		
Rice mill		
Dairy industry		
Hotel		
Lodge		
Restaurant		
Other, specify		

SECTION – B: GENERAL INFORMATION ABOUT FAMILY

1. Name of respondent:

2. Name of household head:

3. Sex:

4. Ethnic identity:

5. Religion:

6. How many members in your family: Male ☐ Female ☐

7. Provide information of each of the family member

S.N.	Name	M/F	Age	Relation with HH head*	Education**		Occupation #	Skill/ Training##

Codes:* *01. Husband/Wife; 02. Son/Daughter; 03. Son-in-law/Daughter-in-law; 04. Grand son/daughter; 05. Nephew/Niece; 06. Brother/sister; 07. Other relative (specify)*

*** 01. Illiterate; 02. Just literate; 03. Primary (1-5) education; 04. Secondary (6-10) education; 05. SLC;06. Intermediate; 07. Bachelor; 08. Masters; 09. Post graduate; 10. Other(specify)*

 # 01. Nothing; 02. Farming; 03. Animal husbandry; 04. Fishing; 05. Teacher; 06. Student; 07. Civil service; 08. Wage labor 09. Business (shop); 10. Other (specify)

01. Nothing; 02. Mason worker; 03. carpenter; 04. Tailor; 05. Blacksmith; 06. Shoe maker; 07. Weaver (cotton/woolen garment); 08. Heavy driver; 09. Light driver; 10. Construction (plant operator/steel work); 11. Electrician; 12. Plumber; 13. Other (specify)

8. Educational institutions close to your settlement.

Institution++	Location	Ward No.	VDC

++ Institutions: 01. Primary; 02. Lower Secondary; 03. Secondary; 04. Higher secondary;

Ownership of land

9. How much land do you have? Total Land [ ] Ropani [ ]

10. Yearly production of following (last year)

Crops	River Flow Zone				Sold Amount & Quantity
	Under Cultivation		Annual Production		
	Khet	Bari	Khet	Bari	
Food Crops					
Paddy	Irrigated				
	Rain-fed				
Maize					
Wheat	Irrigated				
	Rain-fed				
Millet					
Pulse					
Buckwheat					
Other (specify)					
Cash crops					
Potato					
Oilseeds					
Sugarcane					
Other (specify					

Quantity= Kiligram /Dharni

11. Food crops produced in your land is sufficient to feed all the family members for;
a) Up to 3 months [ ] b) 4-6 month [ ] c) 7-9 [ ] months
d) 10-12 month [ ] e) whole year [ ]
f) Additional food gains are sold

12. Do you keep livestock? Yes [ ] No [ ]
If Yes, Provide the following information.

Livestock	Normal Flow Zone	Number
Cattle		
Buffalo		
Yak		
Sheep		
Pigs		
Poultry		
Ducks		

SECTION – C: WATER AND RIVER FLOW

13. Drinking water: Sources of drinking water for household purpose

Household tap	☐	d. Community tap	☐
b) Well (Kuwa)	☐	e. Rer/Stream	☐
c) Other (specify)	☐		

14. What are your sources of income other than agriculture?

a) Services

a. Retail shop	☐	d. Industry	☐
b. Fishing	☐	e. Wage labor	☐
c. Stone quarrying	☐	f. Other, specify	☐

15. Is your family dependent on Tamakoshi River?

Yes ☐ No ☐

If yes, how?

a) Stone quarrying	☐	e. Fishing	☐
b) Sand quarrying	☐	f. D rinking Water supply	☐
c) Other, specify	☐		

16. What is the daily/Monthly earning from above activities?

Activities	Time of involvement		Place of involvement	Amount
	Full	Part		
Stone quarrying				
Fishing				
Sand mining				
Drinking water supply				
Other (specify)				

17. What is the trend of river water flow in in Tamakoshi River Basin within the last 5-10 years? Mentioned in per cent

a) Increasing ……b)Stand Still ……. …c) Decreasing …..

18. If water flow is decreasing trend what is the main cause of this ?

19. What is direction of flow of river water in your locality within the last 5-10 years ? direction : a) shifting right ……b)shifting left …… c) scouring …..d)Other

20. What type of services do you derive yearly from the running water of Tamaksohi/ tributary?

a) Pre monsoon …… b) Monsoon ……. c) Post Monsoon …….

21. What is the condition of ground water (spring) in your locality within the last one decade?

a) Increasing condition… per cent b) decreasing condition… per cent

c) As it is percent

22. If present trend of decreasing/ increasing continued in the use of water what sort of problem do you see in future?

23. What is the maximum use of water of the river?

a) Irrigation b) industries c) domestic purposes d) canals e) hydropower

24. What types of services you have received from Tamakoshi River and its tributaries?

a) Water…..b) Wet land production…. c) Fishes….d) sand/ gravel… e) grazing and ………..) other services **…….**

25. How do you irrigate your farm land?

a) Rain water b) spring c) River water d) other sources

26. Are you using pump water (Manthali and surrounding sites you to irrigate your farm land?

a. If yes a pls. time ………..

b. Dry Area Zone

c. Pumped water

27. What is the impact of flow diversion from the Tamakoshi in terms of Magnitude? (M), Extent(E) and Duration (D)?

Magnitude-	a) High ☐	b) Medium ☐	c) Low ☐
Extent -	a) Site Specific. ☐	b) Local ☐	c) Regional ☐
Duration -	a) Long term ☐	b) Medium term ☐	c) Short term ☐

28. Plese provide ascending value for your settlement

a) Water ☐ b) Fuel ☐

c) Arable land ☐ d) Building materials. ☐

b) Grazing land ☐

D: CHECK LIST FOR KII, FGD AND OBSERVATION SHEET

KII CHECKLIST

1. How many household are living in riparian zone ?
2. Are people dependent in river flow ?
3. What is the trend of flow in the river Tamakoshi River ?
4. What is the impact of flow in the community ?
5. What are the idea of local people towards the flow regime ?
6. Are increasing and decreasing flow impact livelihood of riparian zone ?
7. Have you observed changes inflow and it impact on the local community ?
8. What are impacts of the flow diversion by the hydropower project?
9. How will hydro-power impact the basin ?
10. What is the situation of migration in the hydropower project area ?
11. What is your idea about the e-flow proposed by EIA and EPA ?

CHECKLIST FOR FGD

Issues-What are the major settlements in the riparian zone

- What types of livelihood do they practices ?
- Do flow regime provide them enough for necessary livelihood

Issue-Flow Pattern

- Has the flow regime same for the last twenty years
- What types of flow regime did you notice within the last 10 years ?
- Are you satisfied with the flow diversion by hydro-power project ?
- What types of impact will occur in the flow change by hydropower ?

Issue - Aquatic

- Which place is suitable for the most aquatic habitat ?
- Which place is best for fishing ?
- Are you involve in illegal fishing ?
- What is the major impact of low flow and high flow in the aquatic animal ?

Issue- Perception on flow diversion

- Did you have any idea but the flow changes?
- What will happen to flow diversity continue for 20 years?

- What do you think will happen to surrounding in the next twenty years after flow diversion?
- What types of religious and cultural do you perform in the Koshi River

OBSERVATION SHEET

Name of place …………………...Ward ………VDC ………District……

1. Major communities ethnic group in riparian zone.
2. People depend in the flow regime or other.
3. Number of people extracting sand and stone and other aggregate (%).
   Sand…….. gravel………. stone. ……
4. Wage earning from the sand, gravel and stone.
5. Places of export and people coming in the site from other part- list name and place
6. Major crops grown in the settlement
7. Use of land for agriculture and commercial production
8. Livestock number found in gazing land
9. Major activities happened during observation

Name List of KII And FGDs

Name List of KII

S.N	Full Name	Organization
1	Prof. Dr. Tej Kumar Shrestha	Department of Zoology, TU
2	Prof. Dr. Uma K. Raya Yadav	Central Department of Zoology, TU
3	Dr. Ananda Raj Joshi	National Planning Commission
4	Dr. Ram Bhadur Khadka	SchEMS
5	Mr. Arun Bhakta Shrestha	WECS
6	Prof. Dr. Kunjini Joshi	Central Departen of Botany, TU
7	Dr. Suman Shakya	ENPHO
8	Prof. Dr. Sanjaya N. Khanal	Kathmandu Univeristy
9	Prof. Dr. Subodh Sharma	Kathmandu Univeristy
10	Mr. Bigyan Shrestha	UTHP
11	Mr. Ganesh Naupane	UTHP
12	Mr. Rabi Maharjan	DFO, Dolakah District
13	Shyam Kumar Magarati	DSCWM, Dolakha
14	Madhukar Upadhaya	DSCWM, Babarmahal

Persons involved in FGD

S.N	**Name of Participants**	**Address**	**Age**
Place : Lamabagar and Jagat , Date : July 29, 2014, No of Participants : 20			
1	Chitra Bahadur Bhandari	Secretay, Lamabagar	Age -55
2	Umesh Gautam	Secreetay, Orang	Age -65
3	Buddhi Bahadru Rimal	Secretay, Bulung	Age -35
4	Santosh Kumar Timseena	Secretay, Laduk	Age- 36
5	Yam Bahadur Khadka	Lamabagar	Age -30
6	Lal Bahadur Koirala	Lamabagar	Age -31
7	Narendra Khadka	Lamabaagar	Age- 29
8	Shyam Kagi KC	Lamabagar	Age -25
9	Shiva hari Bhandari	Lamabagar	Age -36
10	Natra Bahadru Karki	Lamabagar	Age- 34
11	Shuk deve Pokhare	Gongar	Age -29
12	Bishal Karki	Bhainsea	Age -23
13	Yam Bahadur Shrestha	Jagat	Age -30
14	Moham Bahadru Mihjar	Jagat	Age -31
15	Kumar Bhujhel	Khanikhola	Age -29
16	Netra Kumar Shrestha	Suri	Age -25
17	Jagat Bahadur Siwakoti	Lamidanda	Age -28
18	Uddab Khadka	Laduk	Age -55
19	Lal Bahadru Tamang	Lamabagar	Age -55
20	Maya Tamang	Lamabagar	Age -33
Place : Singati and Gumukhola , Date : July 29, 2014, No of Particpants : 37			
21	Bhanu Bhakata Acharya	Secretay, Sunkhoni	Age -32
22	Jagnath Siwakoti	Farrme, Sunkhani	Age -18
23	Krishna prashad Rimal	Farmer , Namdu	Age -25
24	Rup Bahadur Tamang	Contractor, Boach	Age -43
25	Rameshi Siwakoiti	Secretay, Namdu	Age -25
26	Man Bahadur Gamang	Gairimudi	Age -40
27	Badri Chalugain	Bhirkot	Age -35
28	Thakur Prashad Pokharel	Japhe	Age -20

29	Keshab Prashad Prasai	Malu	Age -23
30	Muktinath Ghimire	Sahare	Age -22
31	Kamal Bahadru Bista	Charikot – Nagadaha	
32	Pashupati Khadka	Chilankha	Age -36
33	Shiva Raj Giri	Gongor	Age- 34
34	Hom Bahadur Khadka	Lamabagar	Age -29
35	Nav Raj Khadka	Suri	Age -23
36	Mr. Kamal Sunuwar,	Formorparliamentarian, Dolakha	Age -55
37	Padam Nepal	Student, Singnati	Age -18
38	Lilamani Pokhjarel	Teacher Gumukhola	Age -49
39	Tara Bahadur Koirala	Gumukhola	Age -43
40	Bhola Koirala	Farmer, Ghyang Sukathokar village	Age -54
41	Shanti Majhi	Fisher man, Malepu	Age- 64
42	Ramesh Magar	Fisher mand Malepu	Age- 54
43	Mahesh Shrestha	Manthali	Age -33
44	Yam Bahadur Shrestha	Jagat	Age -30
45	Moham Bahadru Mihjar	Jagat	Age -31
46	Kumar Bhujhel	Khanikhola	Age -29
47	Netra Kumar Shrestha	Suri	Age -25
48	Shanker Lama	Maoist	Age -25
49	Lila hari Pokhare	Sitapaila Sec School	Age -36
50	Bhola Bahadru Karki	Ghyangsukathokar	Age -34
51	Megh Rahj KC	Chyama	Age -29
52	Santosh Kc	Chyama	Age -23
53	Rishikesh Upreti	Bhedpu	Age -30
54	Narayan Shrestha	Barbishe	Age -31
55	Badri Bahadur Kutuwal	Bhirkog	Age -29
56	Tara Bahadur karki	Barbiseh Bazar	Age -25
57	Bhabendra karki	Ratmate	Age -44
58	Lok Bahadur Ramtel	Japhe - 6	Age -27

Place : Charange and Malukhola , Date : August 10, 2014, No of Particpants : 40			
59	Sajib Pokharel	Japhe - 6	Age -55
60	Dhruba Raj Pokharel	Japhe - 7	Age --42
61	Ramchandra Bhandari	Melung -7	Age -66
62	Sita Ram Upreti	Bhirkot -9	Age -50
63	Sndesh Tamang	Bhirkot -7	Age -50
64	Yam Bahadur Khadka	Japhe - 7	Age -33
65	Tara Devi Bhujel	Japhe - 8	Age- 44
66	Sarita Adhikari	Japhe - 7	Age -24
67	Hari Bahadur Khadka	Bhirkot -2	Age -35
68	Bashanta Thapa	Bhirkot -2	Age -55
69	Dal Bahadur Bhujel	Bhirkot	Age -54
70	Ram Krishna Karki	Japhe -9	Age -25
71	Pawan Karki	Japhe -8	Age -28
72	Bishwo Adhikari	Phulasi -2	Age -60
73	Jagat Bahadur Shrestha	Phulasi -7	Age -55
74	Shambhu K C	Sahare - 5	Age -41
75	Baburam Khadka	Sahare -5	Age 41
76	Dil Bahadur Shrestha	Melung -5	Age -55
77	Nainananda Pokharel	Japhe -2	Age -54
78	Durga Bahadur Khadka	Malu - 2	Age -25
79	Home Bahadur Khadka	Malu - 2	Age -28
80	Govinda Bahadur Khadka	Malu - 5	Age -60
81	Top Bahadur Khakda	Malung - 5	Age -55
82	Hari Prashad Pokharel -	Japahe- 2	Age -41
83	Gopal Prashad Pokharel	Japahe- 4	Age -41
84	Arjun Pokharel	Japahe- 2	Age -31
85	Amrit KC	Sahare -2	Age -21
86	Ram Krishna Pokharel	Japhe -2	Age -28
87	Hari Pokharel	Japhe -2	Age -26
88	Shiva Rana	Japhe -6	Age -25

89	Bhawan Nath Ghimire	Japhe -7	Age -43
90	Janak Pokhrel	Japhe -6	Age -49
91	Raju Karki	Japhe -9	Age -34
92	Pradeep Pokharel	Japhe -2	Age- 35
93	Surya Bahadur B.K	Bhdedpu -2	Age -21
94	Hom Bahadur Shrestha	Melung - 4	Age- 24
95	Ramchandra Pokharel	Japhe -2	Age- 33
96	Jaman Sing karki	Meljng a- 2	Age -22
97	Usha Pokharel	Japhe - 7	Age -32
98	Menuka Pokharel	Japhe - 5	Age -29
99	Dhal Bahadur Bhandari	Japhe - 6	Age -40
Place : Akase and Manthali , Date : August 23 , 2015, No of Participants : 18			
100	Nava Raj Subedi	Sahare - 4	Age -33
101	Padam Kumari Shrestha	Manthali -8	Age -56
102	Cfhhatra vir Shreatha	Manthali - 7	Age -44
103	Ramkagi Karki	Tilpung -4	Age -55
104	Harka maya Majhi	Chisaani -2	Age -34
105	Bhakta Bahadur Karki	Tilpung-2	Age-33
106	Bishnu Maya Majhi	Bhaluwajhor - 8	Age -21
107	Tilbahadur Majhi	Bhaluwajhor - 7	Age - 66
108	Silbahadur Majhi	Pakarbas - 8	Age - 21
109	Kumar Kharel	Pakarbas - 6	Age -44
110	Loknath Prasai	Bhatauli - 4	Age -67
111	Kumar Majhi	Bhalujhor -2	Age -55
112	Phalbahadur Majhie	Bhalujhor -3	Age - 44
1113	Som bahadur Mahhi	Bhalujhor - 2	Age - 55
1114	Kulbahadur Majhi	Bhalujhoe - 3	Age- 21
115	Kalbir Majhi	Bhalujhor - 3	Age - 30
116	Som Bahadur Mahie	Bhalujhor - 3	Age -22
117	Kalbir Majhie	Bhalujhir - 4	Age -23
118	Sher Bahadur MaJhie	Bhalujhor - 5	Age - 33
119	Chhoti Maya Majhie	Bhalujhor - 2	Age -55

APPENDIX III.

A. SETTLEMENT HIARCHY, LOCATION, INFRASTRUCTURE

HH	No of Settlements	Name of locality with households in parenthesis
0-50	44	I- Lapchi (40) [99] Lumnang (13) [20] Orang (5), [69], Gongar (10), [140], Chhetchhet [70] Suridivan (15), [68] Jamune (9) [80], II- Suri (22), [75] Suridovan (15) [85] Jhangreali (8), [80] Pikhuti, [80] Baguawa (9), [100] Phalante (15), [69] Koshikhet, (15), [69] Torikhet (11), [75] Malepu (25), [106] Gumukhola (40), [181], Kande (5) [68], Namdubusti (39), [120], Bhede (6), [65], Andheri (4), 65] Khimti (49), [70] Devitaar (60), [266], Kirnetaar (125), [32], Ratmate (3), [120], Torikhet (3), [130], Baguwa (10), [130], Bhirkot (56), [137]. Karambote (7), [140], Odare (44), [48] Nagdaha (26), [149], Nyagal, [20], Busti (27). [20], Dehi (5), [110], Gahati (20), [120] Phedi/Tilahar (30), [70], Thamidanda (50), [80], Thalahgari (25), [80] III- Tilbung (20), [154], Jugar (6), [90], Haldebensi (26), [137], Kathajhor (9), [140], Panthali (6), [125], Natalibensi (8), [125], Bandrinbesi (9), [80], Karambote (33), [93], Gaikhura (46), [80], Odare (44), [88], Kunauri (35), [90].
50-100	8	I- Lamabagar (35), [165], Simigaon (80), [160] III – Majhigaon [178] IV-Kirnitaar (90), [250], Chisapani (80), [174], Mugitaar, Hattitar (69), [195], Bhirkot (26), [112], Ratmate (70), [80]
100-150	4	III- Nayapool, Barbise [70] IV-Pipleboate, [120]
150-200	3	III- Milti /Jyamire/Sitali (155), [155] III Devitaar, Khimti, Akasai [174]
200 and above	3	II-Singati, [311], IV-Manthali, [318], Rajgaon (125), [180]

Source: Field Survey, 201 & 2015.

Note: ( ) = Household number, [ ] Hierarchy

B. INFRASTURUCTURE (ROAD AND BRIDGE)

S.N	Road	Bridge	Remarks
Sector I	Earthen road Dolkha-Sipring - Lamabagar	8 bridge (BBD, SBD) 40-60 m length Trust bridge, wooden bridge and new steel bridge	Only on highway Singati Lamabagar Poor infrastructure, Seasonally accessible
Sector II	Earthen road Dolkha-Singati Dolti- Singati	7 bridew (BBD,SBD) 12.2 -35 m length Suspension bridge,	Highway-Singati Lamabagar and other trail routs, connectivity goor moderateinfrastructure, Moderately accessible
Sector III	Road Charikot – Dolti-Singati Charikot- Tilpung-Manthli	5 bridge (CARE ,SBD) 28.72 -199. m length Suspension bridge, Strategic bridge, Busti, Nagdaha, Devitaar, Nayapool	Highway- Two Highly connected south and north Good infrastructure, accessible
Sector IV	Tilpung- Khurkot (Tribeni) fair water head (26km) Trails 42.5 km blacktopped	14bridge (BBL ,SBD) 69.72 -212. m length Suspension bridge, Strategic bridge, Busti, nagdaha, Devitaar, nnayapool	Highway- Two Highly connected south and north Good infrastructure, accessible throughout the year

Source: Field Survey 2015

C. LOCATIONAL CHARACTERISTICS

Name of settlement	**Locational Characteristics**
Lapche	• Located in the confluence of Lapchi and Jung khola • Mainly bisa caste • No infrastructure • One day walking distance before Phalak • Last settlement of northern part (32 Hhs)
Lumnang	• Second last of the north settlment • No link with infrastructure • Migrates to the settlement from Lapche during winter
Lamabagar	• Located in upper part of Tamakoshi HPP and Tamakoshi river • Scatter settlement with linear pattern • Flat land • Entry point to Lapche • Market centre of 5 northern VDC
Simigaon	• Located in upper part of the Tamakoshi river • Three clusters facing to north, west and south toward the Tamakoshi river • Entrance to Rolwaling valley
Gongar	• Located 11 km south of Lamabagar • Liner type settlement

	• Main second centre of Lamabagar
Suri Diovan	• Located near Khare Khola and Tamakoshi confluence • 200 meter above Khare khola , 15 households
Bhorle	• Located in route to GCAP, bank of Tamakoshi • 2 clusters(Suri Bhorle and Laduk Bhurle • 31 HH with 20 shops
Jhangrili	• Ward no 3 of Jhyanku • River bank of Tamakoshi • 12 Households , linear pattern
Kholikhem	• Linera pattern • Located on edge of Singati Khola • 500 meter above Singati Bazar
Singati	• Located in confluence of Singati and Tamakoshi river • Main market centre of northern 11 VDCs • Fast developing market centre of northern part
Gumukhola	• Second important bazaar of north part of TRB • Economic hub centre of 4 VDC 'S • Located in confluence of Gumukhola and Tamakoshi • Clusterd pattern (Overshadowed bazar) • Part of Sunkhani
Koshikhet	• Linear settlement • Located in west part of Tamakoshi • 4 households
Nagdaha	• Flat area • Small centre of market • Old market centre • Greater interaction
Nyagal	• West slope of Tamakoshi • Located agt 980-1040 amsl • 3 clusters with 40 -50 HH • Access from new open road from Dolakha
Nayapool /Charange	• Boarder market • Limited range of goods and services • Small market centre of Phasku • Linear in pattern • Located in river side
Busti	• Located NW of Nayapool • Ward no 6 BM, 27 HH
Namdu busti	• Located in western part of Nayapool • 35 households resided • About 500 meter from Tamakoshi river
Milti	• River side settlement • Flat land and nearby location of Miltikhola and Tamskoshi • Agricultural growing centre

Devitaar	• located at 640 meter from sea level • older settlement than Khimti • 15 different types of shops
Khimti	• River side settlement • Growth due to HPP location • More growing • HPP official centre
Gadari	• Located east of the Tamakoshi river • Linera settlement of Majhi • More dependen in the river than other
Odare	• Located west of the Tamakoshi river • Clustered settlement of Majhi • More dependent in the river than other
Chisapani	• Old linear settlement • Nearby river side • More people depend on flow resource for agriculture, fuels work, fishing and other activities
Tribeni	• Confluence of Tamakoshi and Sunkoshi • Religious centre • No major settlement over confluence • Market seasonal centre

Source: Field Survey 2014, 2015

APPENDIX – III

D. Livestock Population

Sector	Cattles	Cow/Ox	Goat/ Sheep	Buffalo	Pig	Ducks and Fowls	Chauri and Yak	Total
Section I								
I (Total)	10	102	1091	5	8	188	105	1509
Percentage	0.66	6.95	72.29	9.33	0.53	12.45	6.95	100
Section II								
II (Total)	572	178	528	115	0	411		1804
Percentage	31.70	9.85	29.26	6.37	0.00	22.78		100
Section III								
III (Total)	875	336	860	246	40	1498		3955
Percentage	22.12	8.49	21.74	8.74	1.01	37.07		100
Section IV								
IV (Total)	336	376	1081	149	633	908		3483
Percentage	9.64	10.79	31.03	4.27	18.17	26.06		100

Source: Field Survey, 2015/014

E. Fishing

Sector	Gender		Total Population	Daily fishing/ kg	Income	Total/day	Total
	Male	Female					
I	-	-	-	-	-	-	-
II	36	37	73	75	13.48	1200	730
III	128	109	226	275	74.82	3106.59	1984.8
IV	59	47	106	122	27.04	1100	660
Total	223	193	405	472	115.34	5406.59	3374.8

Source: Field Survey, 2014/015.

APPENDIX – III.

F. WATER SOURCES

Settlement/VDC	Households and population		Major caste/ethnic groups	Drinking water situation	
	HH	Pop.		Nearest source	Distance from the settlement (in meter)
I	30	335	Tamang, Sherpa	Pipe water	Appro 100
II	40	300	, Chhetri, Tamang	Spring water	Appro 100
III	40.81	245.18	Brahmin, Chhetri, Newar, Tamang	Pipe water, Spring water, river	Appro 1165
IV	26.26	306.66	Brahmin, Chhetri, Newar, Majhi	Pumping station, Khola,	Appro 800

Source: Field Survey, 2014/015 y = a+bx, a= 208.231; b = 16.879, r = 0.5529

APPENDIX-III.

G: RESPONDENTS VALUE FOR SETTLEMENT LOCATION

S.N.	Sector	Water (10)	Arable land (5)	Grazing land (3)	Fuel (3)	Building materials(3)	Total Score
				Sector I			
	Sub - total	12	14.5	11	11.5	10	58.16
	Mean	2	2.41	1.836	1.91	1.66	9.6
				Sector II			
	Sub.Total	24	14	7	6	8	59
	Mean	**6**	**3.5**	**1.75**	**1.5**	**2**	**14.75**
				Sector III			
	Sub-total	**83**	**37**	**23**	**18**	**18**	**179**
	Mean	**8.3**	**3.7**	**2.3**	**1.8**	**1.8**	**17.9**
				Sector IV			
	Sub-total	81	36	25	13	15	162
	Mean	**9**	**4**	**2.77**	**1.44**	**1.66**	**18**

Source: Field Survey, 2014/015.

APPENDIX - IV. FLOW CHARACTERISTICS

A. THE STRETCH WISE DISTANCE AND FLOW

S.N	Sector	Distance	Mean Flow (m3/s)
	Sector I		
1	China boarder- Jung khola	2.3	27.66
2	Jung Khola- Rolwaling	1.0	38.18
3	Rolwaling- sipring	6.8	64.60
4	Sipring - Orang Khola confluence	4.5	73.50
5	Orang – khare	3.5.	73.56
	Total Distance+flow	18.9	277.55
	Mean Distance	3.62	55.55
	Sector II		
1	Khare Khola-Tinakhu	2.5	142.89
2	Tinakhu–Singati	2.25	146.89
3	Singati Khola – Gumukhola /Jhyanku	3.6	158.59
4	Gumukhola Khola – Dolti Khola	7.5	176.77
	Total Distance	**21.22**	**498.95**
	Mean Distance	**4.24**	**164.65**
	Sector III		
1	Dolti- MaryangKhola confluence	3.35	231.18
2	MaryangKhola-Charange/Gopi	5.65	231.88
3	Charange/GopiKhola- AndheriKhola	1.3	232.98
4	Andheri Khola – Dholi Khola	4.025	233.18
5	Dholi Khola – Ghyang Khola	1.5	234.69
6	Ghyang Khola- Ladke Khola	2.87	235.16
7	Ladke khola- Phedi Khola	0.825	137.11
8	Phedi – Malu Khola	0.85	238.233
9	Malu Khola – Sahare /MiltiKhola	3.55	143.12
10	Sahare/Milti khola – Khimti Khola	4.0	245.86
11	Khimti Khola- Tilpung Khola	3.625	258.34
	Total Distance	**31.54**	**2419.73**
	Mean Distance	**2.86**	**219.99**
	Sector IV		
1	Tilpung -Kathajhor Khola	3.25	260.16
2	Kathjhor Khola-Mahadev Kh	1.55	261.33
3	Mahadev Khola – SukajhorKhola	5.55	298.16
4	Sukajhor – Ranajhor Khola	0..625	322.96
5	Ranajhor – BhatauliKhola	0.6	334.17
6	Bhatauli – Tribeni	8.25	258.76
	Total Distance	**19.825**	**1735.54**
	Mean Distance	**3.30**	**289.25**

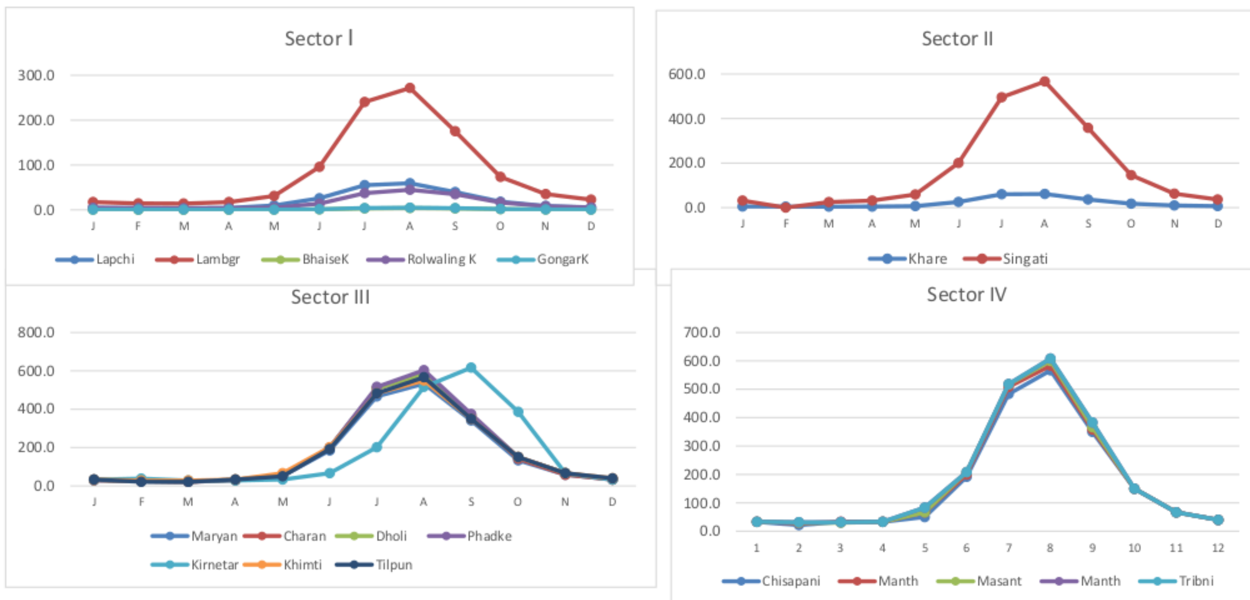
Source: Field Survey, 2014-015/ Self calculation.

APPENDIX IV

B: MEAN MONTHLY FLOW

Spat Stn	Months											
Record	J	F	M	A	M	J	J	A	S	O	N	D
Lapchi	4.51	3.90	3.89	4.46	9.89	25.74	55.10	59.27	39.73	18.07	8.5	5.52
Lambgr	17.26	14.41	13.90	17.21	30.81	95.78	240.31	271.60	175.18	73.35	35.13	22.63
Maryan	28.32	24.99	21.65	29.48	51.64	184.92	466.48	533.12	341.53	133.28	58.31	33.32
Charan	29.98	24.99	21.65	29.98	51.64	199.1	508.13	583.1	366.52	141.61	58.31	33.32
Dholi	31.65	24.99	21.65	33.32	51.64	199.12	508.13	583.1	366.52	149.94	66.64	33.32
Phadke	33.32	24.99	21.65	33.32	51.64	199.92	516.46	603.09	374.85	149.94	66.64	33.32
Kirnetar	33.32	38.32	28.32	28.32	33.32	66.64	201.58	516.46	616.42	386.51	66.64	33.32
Khimti	33.2	28.32	28.32	33.2	66.64	201.58	483.14	549.78	349.86	149.94	66.64	39.98
Tilpun	33.1	21.65	21.65	33.2	49.98	191.59	483.14	566.44	349.86	149.94	66.64	39.98
Chispni	33.2	21.65	33.2	33.2	49.98	191.59	483.14	566.44	349.86	149.94	66.64	39.98
Manth	33.2	28.32	33.2	33.2	66.64	199.92	508.13	583.1	358.19	149.94	66.64	39.98
Masant	33.1	29.98	29.98	33.2	66.64	208.25	516.46	599.7	366.52	149.94	66.64	39.98
Manth	33.32	31.65	31.65	33.32	83.3	208.25	518.12	608.09	383.18	149.95	66.64	39.98
Tribni	33.32	31.65	31.65	33.32	83.3	208.25	518.12	608.09	383.18	149.95	66.64	39.98

Source: Self-calculation based on Lapchi (Lapchi) Lambagar Data



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Lambgr
BhaiseK
Rolwaling K
GongarK
Sector II
600.0
400.0
200.0
0.0
J F M A M J J A S O N D
Khare
Singati
Sector III
800.0
600.0
400.0
200.0
0.0
J F M A M J J A S O N D
Maryan
Charan
Dholi
Phadke
Kirnetar
Khimti
Tilpun
Sector IV
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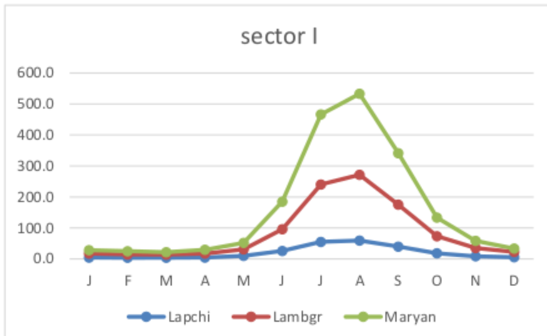
600.0
500.0
400.0
300.0
200.0
100.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12
Chisapani
Manth
Masant
Manth
Tribni

C: MEAN MONTHLY FLOW OF TRIBUTARIES

Spat Stn/Months	J	F	M	A	M	J	J	A	S	O	N	D	Tot
Tributaries													
Lapchi	4.51	3.90	3.89	4.46	9.89	25.74	55.10	59.27	39.73	18.07	8.5	5.52	19.88
BhaiseK	0.39	0.31	0.28	0.27	0.33	1.05	3.23	3.98	3.20	1.58	0.76	0.48	1.32
Rolwaling K	4.42	3.65	3.38	3.60	4.90	13.56	37.14	44.73	34.69	16.43	7.99	5.23	14.97
GongarK	0.47	0.38	0.34	0.33	0.40	1.28	3.92	4.81	3.86	1.89	0.91	0.58	1.59
Khare	5.21	4.56	4.19	4.57	6.99	25.74	60.04	61.17	36.44	17.77	9.61	6.65	20.25
Singati	31.59	26.65	24.98	31.59	59.14	200.34	495.67	566.44	358.19	145.77	62.47	36.65	169.99
Maryan	28.32	24.99	21.65	29.48	51.64	184.92	466.48	533.12	341.53	133.28	58.31	33.32	158.96
Andheri	0.22	0.19	0.18	0.20	0.34	1.05	2.82	3.58	2.20	0.93	0.44	0.28	1.03
Charan	29.98	24.99	21.65	29.98	51.64	199.1	508.13	583.1	366.52	141.61	58.31	33.32	170.69
Dholi	19.65	14.99	11.65	13.32	31.64	111.12	205.13	278.13	143.35	89.94	22.64	13.21	76.22
Dholi-1	0.11	0.10	0.09	0.10	0.17	0.54	1.43	1.82	1.12	0.47	0.23	0.14	0.52
Ghyan	0.35	0.30	0.28	0.31	0.53	1.66	4.43	5.62	3.45	1.47	0.70	0.54	1.63
Gope	1.78	1.5	1.41	1.59	2.7	8.47	22.69	28.77	17.69	7.49	3.56	2.3	32.56
Ladke	0.08	0.07	0.07	0.07	0.13	0.39	1.06	1.34	0.82	0.35	0.17	0.11	0.39
Milti	0.74	0.63	0.58	0.66	1.12	3.31	9.39	11.90	7.32	3.10	1.48	0.95	3.45
Phadke	3.32	4.99	11.65	13.32	15.64	19.92	21.46	60.09	37.85	14.94	12.64	10.32	18.84
Mahadev	0.38	0.32	0.30	0.34	0.57	1.79	4.80	6.08	3.74	1.59	0.75	0.48	1.76
Khimti	33.2	28.32	28.32	33.2	66.64	201.58	483.14	549.78	349.86	149.94	66.64	39.98	174.49
Tilpun	13.1	11.65	21.72	9.62	12.9	14.98	19.59	48.05	66.75	56.76	42.37	19.98	27.78
Kathajhor	0.16	0.13	0.12	0.14	0.24	0.74	1.98	2.50	1.54	0.65	0.31	0.20	0.72
Chispni	0.07	0.78	0.2	0.5	1.18	3.59	11.14	13.44	9.73	3.94	1.64	1.18	3.94
Ranajor	0.40	0.34	0.32	0.36	0.61	1.90	5.07	6.43	3.95	1.68	0.80	0.51	1.86
Sukajor	0.36	0.30	0.28	0.32	0.54	1.70	4.54	5.76	3.54	1.50	0.71	0.46	1.67
Bhatauli	1.08	0.92	0.85	0.97	1.64	5.12	13.70	17.36	10.67	4.53	2.15	1.38	5.03

Source: Self-calculatoin based on Chitrakar, 2014 based on hydrology data Lapche, Lamabagar.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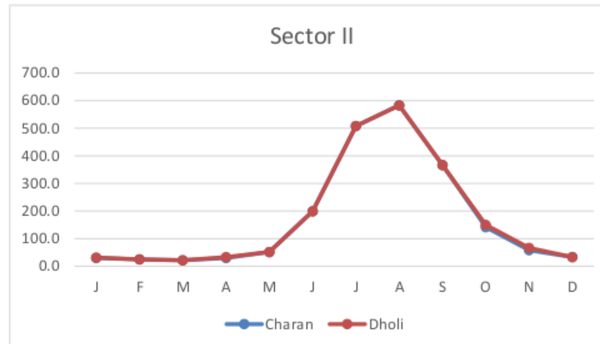
Lambgr
Maryan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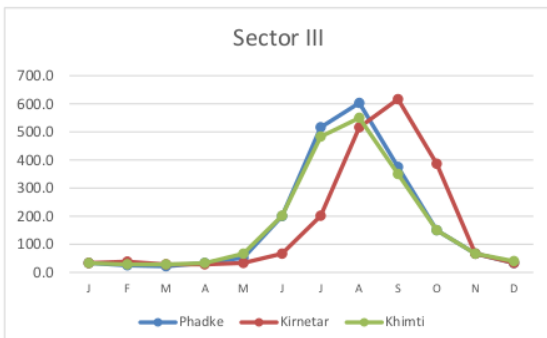
Charan
Dholi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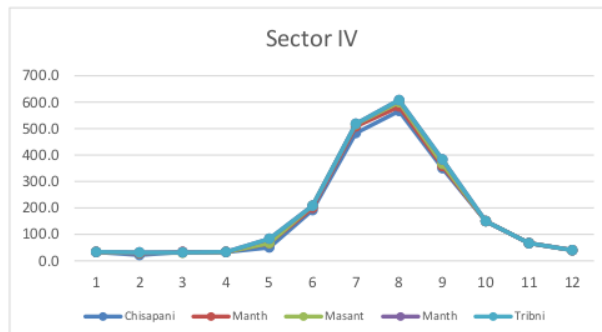
Phadke
Kirnetar
Khimti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300.0
200.0
100.0
0.0
1 2 3 4 5 6 7 8 9 10 11 12
Chisapani
Manth
Masant
Manth
Tribni

APPENDIX IV

D: SEASONAL FLOW AND INDEX

Sector	Pre-mm	monsoon	pos-monsoon	G. Total	G. $\bar{x}$	CV
I	20.31	183.39	39.24	170.03	14.19	98.01
II	1.93	37.08	4.14	43.15	12.72	101.16
IV	8.73	168.9	21.86	72.56	6.05	111.62
V	1.09	11.71	2.28	21.18	1.76	113.02

Source: Self calculated based on Series X HMG DWIP.

Water flow availability and index value (m^3/s.)

Section /Season	I	II	III	IV	Total	Percent	Overall index
Pre-monsoon	$4.349x10^9$	$5.115x10^9$	$1.4376x10^9$	$1.0311x10^9$	$4.4151x10^9$	4.53	8.99
Monsoon	$12.1344x10^9$	$6.5860x10^9$	$2.135x10^{10}$	$1.3649x10^{10}$	$4.37194x10^{10}$	58.50	123.11
Post – monsoon	$1.5119x10^8$	$2.402x10^9$	$1.405x10^{10}$	$9.615x10^9$	$2.7578x10^{10}$	39.90	55.64
Total	$1.6483x10^{10}$	$9.4995x10^9$	4.977610^{10}	$2.429251x 10^{10}$	$1.000536x10^{11}$	100.00	
Percent	16.47	9.49	49.74	24.28	100.00		
					$7.47134x10^{10}$		
Total Index	87.18	52.08	66.72	14.56			
Seasonal Index	56.67	36.87	33.93	6.32			

Sources: Field Survey, 2014 and 2015, self-calculated

APPENDIX –IV

E: RIVER BED SLOPE OF TAMAKOSHI RIVER

Section	S.N	Altitudinal Range (Meter)	Location	Slope
I	1.	2200- 2400	Lapche Bridge(Jung Khola)	4.150
	2.	2000- 2200	ChyaduKhola	2.330
	3.	1800-2000	Lamabaggar	2.360
	4.	1600-1800	RolwalingKhola	12.520
II	5.	1400-1600	Near Buthu	4.3610
	6.	1200 -1400	Above Suri	2.670
	7.	1000 -1200	Jhangri	1.210
	8	900 -1000	Torikhet	0.57430
III	9	800 -900	SungureTaar	0.3260
	10.	700 -800	Dude	1.0620
	11.	600-700	Kirnetaar/Khimti	1.6970
IV	12	500-600	Panthali	0.8550
	13.	400-500	Manthali	0.70950
	14.	< 400	Tribeni	0.30100

Source : Self-calculated based on Toposheet (Scale 1:50,000 and 1:25,000).

APPENDIX - V.

A: TEMPERATURE DISTRIBUTION (JIRI STATION)

Year	Max	Min
1992-95	20.42	7.89
1996-2000	20.63	7.91
2001-2005	20.57	8.04
2006-2010	20.97	8.33
2011-2012	20.82	7.86

Source: DHM, 2015

B: Rainfall in TRB

S.N	Locations	Altitude (m)	Precipitation (mm)	Reference date
1.	Nylam (Tibet)	2220	625	1961-1971
2	Nylam	2220	717	1976-86
3	Lamabagar	1950	850	UTHP
4	Charikot	2040	1940	2010
5	Nagdaha	850	1496.50	1977-2010
6	Melung	1100	1425.03	1960-2010
7	Ramechhap	1100	1029	1976-1990
8	Nepalthok	400	875	1975-1986

Source : Department of Hydrology and Metrology, and ICIMOD, 2015.

C: YEARLY PRECIPITATION (JIRI) AND FLOW (BUSTI)

Year	Mean ppt (mm)	Mean flow ($m^{3/s}$)
1971-1974	2223.4	154
1976-1980	2138.3	140
1981-1985	2136.4	146.8
1986-1990	2156.6	143.8
1991-1995	2311.2	147.3
1996-2000	27.04	158.4
2001-2005	2596.8	138.2
2006-2010	2142.7	143.4

D: FLOW DIRECTION AND DIMENSION

S.N	Section	Distance	Sinocity Ratio	Width	Slope tan(0^0)	River Power nTu	Discharge (m^3/s)	Depth (m)	Sedimrmt (m^3)
Sector I									
1	Chi- Jun	2.3	1.27	25	2.33^0	**26.80**	27.66	1.36	1,100
2	Jun- Rolw	1.0	1.11	65	2.30^0	19.80	38.18	1.33	39,850
3	Rol- Sip	6.8	1.00	30	12.52^0	2441.73	64.60	1.36	300
4	Sip - Oran	4.5	1.1	30	12.52^0	2441.73	73.50	1.82	400
5	Oran- khar	3.5.	1.00	30	7.36^0	1941.73	73.56	1.84	450
Sector II									
1	Kha-Tina	2.5	1.10	25.5	4.36^0	94.50	142.89	2.19	150
2	Tina–Sing	2.25	1.26	31	3.16^0	74.50	146.89	2.19	2100
3	Sing–Gu/Jhy	3.6	1.10	34	3.16^0	54.80	158.59	2.30	5150
4	Gum/jhy – Dol	7.5	1.25	80	2.36^0	55.16	176.77	1.88	2394.5
Sector III									
1	Dol - Mary	3.35	1.37	83	0.57	106.01	231.18	1.82	2049.7
2	Mary-Char/Gopi	5.65	0.96	35	0.57	106.01	231.88	2.5	14950.46
3	Char/Gopi-Andh	1.3	0.93	23	0.57	366.91	232.98	2.56	23187.4
4	Andh – Dhol	4.025	1.03	48	0.59	366.91	233.18	2.44	44452.4
5	Dhol– Ghy	1.5	2.02	102	0.99	23.76	234.65	2.54	32844.0
6	Ghy- Ladk	2.87	2.82	109	0.99	23.76	235.16	2.66	30120.0
7	Ladk- Phed	0.825	1.08	43	1.06^0	36.29	137.11	2.66	2930.0
8	Phed–Malu	0.85	1.08	21	1.06^0	36.29	238.23	2.31	3029.18
9	Malu – Saha /Milt	3.55	1.05	47.4	1.0^0	36.29	243.12	2.31	3101.38
10	Saha/Milt – Khim	4.0	1.04	28.58	1.60^0	36.29	245.86	2.26	868.23
11	Khim- Tilp	3.625	0.97	42.42	1.70^0	76.31	258.38	2.26	1511.00
Sector IV									
1	Tilp -Kath	3.25	1.05	44	0.70^0	64.33	260.16	2.54	2075
2	Kath-Maha	1.55	0.6	150	0.70^0	64.33	261.33	2.55	2612.85
3	Maha – Suka	5.55	1.03	200	0.70^0	40.11	298.16	2.54	26100
4	Suka – Rana	0..625	1.03	453	0.60^0	27.11	322.96	2.6	7800
5	Rana – Bhat	0.6	1.08	210	0.30^0	11.40	334.17	2.6	14030
6	Bhat–Tribeni	8.25	1.27	230.63	0.30^0	3.30	258.76	2.7	13,000

Source: Self calculated, method adopted -
Senosity ration < 1- Straight, 1> snious and 1.5> Meander

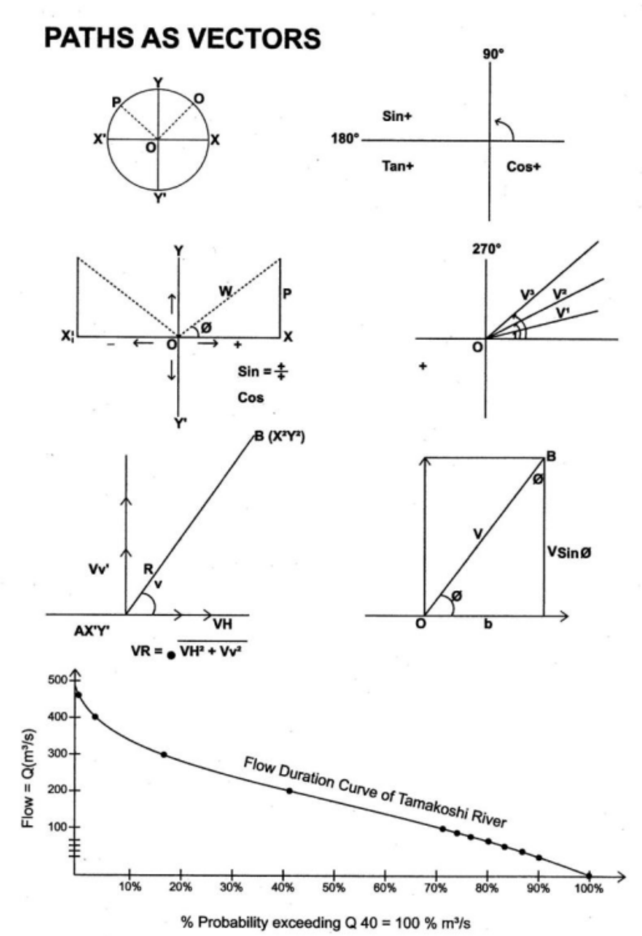
E: WATERSHED AREA AND ORDER

SN	Watersheds	Area	Watershed Order	VDCs
Sector I				
1.	16 Subwater sheds	7.59	28-40	5
Sector II				
2.	15 Sub-water sheds	76.24	10-29	29
Sector III				
3.	23 sub-water sheds	46.90	1-24	43
Sector IV				
4.	8 sub-water sheds	39.68	10-18	5

Source : Self calculation based on DFO, DSCO, 2014-2015.

Appendix -VI.

A: Paths as vectors



B: WATER FLOW DIRECTION AND VECTOR

Sector	SN	Section	Distance (km)	Angle	Vector	Location
I	0	Origin x= 27^0 40' 0^{0}'', y= 86^0 05' 0^{0}''		15^0	0	
	1	A-B	30.41	13^0	5.34	Chyadu and Jung Khola
	2	B-C	26.95	12^0	7.22	Jung Khola bridge
	3	C-D	26.18	19^0	12.52	South of Jung Khola
	4	D-E	31.95	30^0	11.11	Tallo Lamabagar
	5	E-F	32.75	34^0	9.55	Rolwaling
	6	F-G	33.49	45^0	6.87	Sipring
II	7	F-H	30.80	54^0	7.43	Khare
	8	H-I	27.72	55^0	7.29	Singati
	9	I-J	21.56	13^0	9.84	Dolti
III	10	J-K	18.86	180^0	8.32	Charanawoti
	11	K-L	21.17	175^0	16.07	Milti
	12	L-M	23.1	170^0	8.32	Khimti
IV	13	M-N	20.02	178^0	5.65	Chisapani
	14	N-O	15.4	-4^0	5.14	Manthali
	15	O-P	15.01	-7^0	6.11	Rajgaon
	16	P-Q	10.78	-10^0	6.78	Bhatauli
	17	Q-	9.62	-18^0	5.14	Tribeini

Source: Self calculated.

C: Sediment Deposition Pattern of TRB (vol m^3)

S.N	Watersheds	2014 (m^3)	2015(m^3)	Change	Mean	Percentage
Sector I						
1	Sub-total	34,700	45,000	10,300	39,850	15.41
Sector II						
2	Sub-total	2586.60	3876.33	1323	3214.83	3.73
Sector III						
3	Sub-total	9541.62	17926.41	12730.13	142,72.13	55.20
Sector IV						
4	Sub-total	633.77	10545.62	4511.87	8289.73	25.65
	Grand Total	70270.2	114366	97798	258533.72	100.00

Source: Field Survey, 2014, 2015.

D: The Composition of River Flow Materials

Locations	Sand (%)	Gravel (%)	Stone (%)
I			
Mean	12	26	54
II			
Mean	18	22	60
III			
Mean	35	31	28
IV			
Mean	65	22	15

Source: Field Survey, 2014/015.

E: BOULDER AND SIZE

Sector	Mean Size (cm^3)	Standard Deviation (cm^3)	C. V. (cm^3)
I	1678.07	1988.87	119.66
II	1205.76	12581.31	108.05
III	2902.25	3281.33	102.09
IV	2441.13	1761.73	72.22

Source: Field Survey, 2014 / 2015

F: MEAN WATER DEPTH OF THE TAMAKOSHI

Location	Pre-monsoon	Monsoon period	Post monsoon(m)
I	1.15	1.25	1.65
II	1.6	3.35	1.17
III	1.51	4.71	1.44
IV	1.33	4.93	1.3

APPENDIX VII.

A. : SPATIAL DISTRIBUTION TEMPT. (C^{O}), AND DISSOLVED OXYGEN (DO)

Locations		Temperature			Dissolved Oxygen		
		Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Sector I	Lamabagar	11.1	12.5	11.5	7.9	8.5	7.1
	Gongar	14.6-18	18	11.7	8.2	10.4	7.1
	Rolwaling	11.8	13	10.8	8.6	9.9	7.3
	Suri Dovan	11.8	13	10.1	8.6	10.2	8.3
Sector II	Singati	12.03	13	11	7.5	10.2	8.1
	Gumukhola	12.02	14	12	8.9	11.1	9.3
Sector III	Nagdaha	12.5	15	12.3	7.1	11.1	8.1
	Nayapool	13.5	15.7	14	7.9	11.7	7.8
	Malu	13.2	16.2	14.3	8.4	12.1	9.1
	Milti	14.1	16.7	14.7	8.7	12.1	8.3
	Khimti	14.5	18.4	16.1	9.1	12.1	10.1
	Kirnetaar	17	21	17.1	7.4	12.7	7.3
Sector IV	Chisapani	16.1	18	16.3	7.2	12.5	8.3
	Manthali	18	22	17.3	8.8	12.7	8.2
	Tribeni	18	22	17.9	7.5	11.1	7.2

Source:NEA 2006, Field Survey 2014.

B: DISTRIBUTION OF TOTAL DISSOLVED SOLIDS (TDS) AND ELECTRICAL CONDUCTIVITY (EC)

Sector	Locations	Total Dissolved Solids			Electrical Conductivity		
		Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
I	Lamabagar	63	70	58	63	70	60
	Gongar	71	41	55	41	71	54
	Rolwaling	29	35	54	36	50	40
	Suri Dovan	28	61	33	73-78	65	43
II	Singati	79	72	68	73	68	52
	Gumukhola	64	70	59	43	66	53
III	Nagdaha	86	71	54	36	69	49
	Nayapool	82	68	54	80	75	74
	Malu	84	72	65	197	73	78
	Milti	88	72	63	72	72	77
	Khimti	87	76	67	49	74	76
	Milche	82	76	66	58	73	78
IV	Kirnetaar	86	78	62	80	72	77
	Manthali	92	72	74	82	72	74
	Tribeni	86	72	77	82	71	74

Source:NEA 2006, Field Survey 2014.

C: DISTRIBUTION OF PH VALUES AND BOD OXYGEN DEMAND (BOD)

Sector	Locations	PH			BOD		
		Pre-monsoon	Monsoon	Post-monsoon	Pre-monsoon	Monsoon	Post-monsoon
Section I	Lamabagar	63	70	58	63	70	60
	Gongar	71	41	55	41	71	54
	Rolwaling	29	35	54	36	50	40
	Suri Dovan	28	61	33	73-78	65	43
Section II	Singati	79	72	68	73	68	52
	Gumukhola	64	70	59	43	66	53
Section III	Nagdaha	85	77	68	77	71	48
	Nayapool	82	68	54	80	75	74
	Malu	84	72	65	197	73	78
	Milti	88	72	63	72	72	77
	Khimti	87	76	67	49	74	76
	Kirnetaar	86	78	62	80	72	77
Section IV	Chisapani	82	76	66	58	73	78
	Manthali	92	72	74	82	72	74
	Tribeni	86	72	77	82	71	74

Source: NEA 2006, Field Survey 2014.

D: SUMMARY OF RIVER SUB-STRATUM & AQUATIC HABITAT

Sector	Sub-stratum (No.)	Major Activities in the Area	Species Occurrence	Remarks
I	Run – 16 Riffiles – 11 Rapids – 4 Pools - 7	Fishing prohibited religously	Snow trout	V-Shapve valley presence of 300 meter natural dam
II	Run – 2 Riffiles – 11 Rapids – 3 Pools - 6	Occasional fishing	Snow trout seasonal mashaeer	V-shape Big-bounders stones
III	Run – 26 Riffiles – 21 Rapids – 17 Pools - 26	Seasonal fishing by other Majhi dependent on fishing	9-15 species	V- and U-shave valley, big bounders stones, gravels and sand.
IV	Run – 6 Riffiles – 50 Rapids – 14 Pools - 27	Seasonal fishing by other Majhi dependent on fishing	15-30 species	Broad U-shave valley, stone, pebbles, sand and gravel

Source: Field Survey, 2014 and 2015.

APPENDIX VIII:

A: PERCEPTION ON RESOURCES USE

Location	Water	Forest	Soil
I	3.08	6.64	4.70
II	36.11	33.85	33.17
III	50.65	54.72	26.81
IV	10.18	4.79	11.84
Overall	41.01	32.15	26.83

Sources: NEA, 2006, Field Survey 2014, 2015.

B: PERCEPTION ON DIVERSION OF WATER FLOW

Sector	Positive	Negative	No effect	Wet dry	Spring dry	Drowning
I	**32 (8.82%)**	**6 (3.45%)**	**2 (6.45%)**	**-**	2 (4.34%)	-
II	87 (23.64%)	28 (18.30%)	16 (32.65%)	5 (16.12%)	5 (15.85%)	3 (6.0%)
III	189 (51.35%)	84 (54.90%)	18 (36.73%)	16 (11.07%)	3 (7.0%)	-
IV	60 (18.66%)	35 (22.87%)	13 (16.53%)	8 (50.80%)	6 (13.04%)	5 (10%)
Overall	368 (56.44%)	153 (23.46%)	49 (7.5%)	31 (4.75%)	46 (13.33%)	5 (0.76%)

Source: Field Survey, 2014/015

C: PERCEPTION ON CUMULATIVE IMPACT OF FLOW DIVERSION

S.N	Sector	Positive	Neutral	Negative
	I	3 (3.70%)	13 (6.73%)	10 (6.5%)
	II	32 (38.27%)	88 (45.59%)	27 (19.56%)
	III	39 (48.14%)	73 (37.30%)	81 (58.69%)
	IV	8 (9.89%)	20 (10.30%)	22 (15.21%)
Total 412		81	193	142
Percent (in %)		19.61	46.73	33.65

Field Survey, 2014/015.

D: INTERACTION MODEL

Sector	Parameter	Magnitude/ Sector				Extent/Sector				Duration/ Sector			
		I	II	II	IV	I	II	II	IV	I	II	II	IV
Hydrology and Aquatic Ecology	Hydro-ecology	H	H	H	H	R	R	R	R	LT	LT	LT	LT
	Landuse	L	M	H	H	S	S	L	S	ST	MT	LT	LT
	River Sub-stratum	H	M	H	H	R	R	R	R	LT	LT	LT	LT
	Macro Aquatic Life	L	M	H	H	R	R	R	R	ST	ST	LT	LT
	Fish Species /diversity	L	M	H	H	L	SS	R	R	ST	ST	LT	LT
	Migraory Behaviour (short)	L	M	H	H	L	L	R	R	ST	MT	LT	LT
	Migraory Behaviour (Long)	L	M	H	H	L	R	R	R	ST	ST	LT	LT
	Aquatic ecology	L	M	H	H	R	R	R	R	ST	ST	LT	LT
Ecological and water chemical	Soil Erosion	L	M	H	M	R	R	R	R	LT	MT	LT	LT
	Basin Condition	L	M	H	M	R	R	R	R	LT	LT	LT	LT
	Sub-watershed Condition	L	M	H	M	SS	SS	R	R	LT	LT	LT	LT
	Precipitation	L	M	H	L	L	R	R	R	ST	LT	LT	LT
	Main Flow	H	H	H	H	R	R	R	R	LT	LT	LT	LT
	Tributory flow	H	H	H	H	R	R	R	R	LT	LT	LT	LT
	Residual Flow	L	L	H	M	L	L	R	R	ST	MT	LT	LT
	Local Water Availability	L	L	H	H	SS	L	R	R	MT	MT	LT	LT
	Flow direction	H	M	H	H	R	R	R	R	LT	LT	LT	LT
	River Width	H	H	M	H	H	L	L	L	LT	LT	LT	LT
	Boulder Transportation Deposition	M	M	H	H	SS	R	R	R	MT	LT	LT	LT
	River Water Qualtiy	L	M	H	H	SS	SS	R	R	ST	MT	LT	LT
	Temperature	L	L	M	H	H	SS	R	R	ST	MT	LT	LT
	DO	L	L	H	M	L	L	R	R	MT	MT	LT	LT
	TDS	L	L	M	H	L	L	R	R	MT	MT	MT	MT
	EC	H	M	M	L	L	R	R	R	LT	LT	MT	MT
	BOD	L	M	H	H	L	L	R	R	ST	MT	LT	LT
	PH	L	M	H	H	R	R	R	R	LT	LT	LT	LT

Socio-economic, Culture and Livelihoods	Population	L	M	H	H	R	R	R	R	LT	LT	LT	LT
	Settlement	L	H	H	H	SS	L	R	R	LT	LT	LT	LT
	Local water mills	L	L	H	H	SS	L	L	L	ST	ST	ST	ST
	Water Source	L	M	H	H	L	L	R	R	MT	LT	LT	LT
	Occupation	H	H	H	H	R	R	R	R	MT	MT	LT	LT
	Education	L	M	H	H	R	R	R	R	ST	MT	LT	LT
	Religion	L	M	H	H	SS	L	R	R	ST	LT	LT	LT
	Cropping Pattern	L	M	H	M	SS	SS	R	R	MT	LT	LT	LT
	Production	M	M	H	H	SS	SS	R	R	MT	MT	LT	LT
	Livestocks	L	M	M	H	SS	L	R	R	MT	MT	LT	LT
	Land Holding	L	M	H	M	SS	SS	SS	SS	LT	LT	LT	LT
	Infrastructure	H	H	H	M	R	R	R	R	LT	LT	LT	LT
	Revenue Generation	H	M	H	M	L	L	L	R	LT	LT	LT	LT
	Fishing Activities	L	M	H	H	SS	R	R	R	ST	MT	LT	LT
	Fish Income	L	M	H	H	SS	L	R	R	ST	MT	LT	LT
	Market	L	M	H	H	SS	L	R	R	ST	LT	MT	MT
	Sand Mining	M	M	H	H	SS	L	L	L	MT	MT	LT	LT
	Cremation	L	L	H	H	SS	L	L	L	R	MT	LT	LT
	Share	H	H	H	H	L	M	L	R	LT	LT	MT	MT
	Drifting woods	L	L	M	H	SS	L	R	R	ST	MT	LT	LT
	Livelihood	L	M	M	M	L	L	L	L	MT	MT	LT	LT
	Total						∑57	∑1.00					

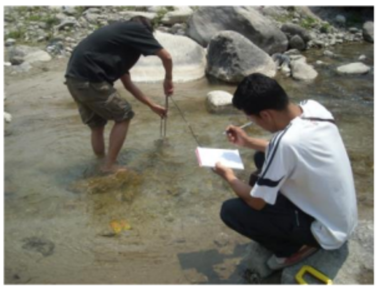
Source: Field Survey, 2014/015

Interaction Model

Sector	Magnitude	Extent	Duration	Total
I	1070	1280	520	2870
II	2070	1650	740	4460
III	2940	2630	970	6540
IV	2680	2640	960	6280

Source: National EIA Guidelines (1993).

LIST OF PHOTOGRAPHS



1. Measuring water flow, Charanga

2. Measuring sand and gravel

3. PH meter and GPS

4. Livelihood

5. Household survey with respondents

6. Interaction with respondents in Lamabagar

6.a. Winter flow, Natural dam

6.b. Monsoon flow, natural dam

7a. Monsoon flow, Tribeni.

7.b. Pre-monsoon flow in Tribeni

8.a. Monsoon flow, Bhatauli.

8.b. Post monsoon flow, Bhatauli

9. E-flow, Khimti river

10. Taking photo of substratum

11. Fishing

12. Majhi settlement, Manthali

13. Riparian Settlement, Nagdaha

14. Monson flow, Lamabagar.

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