POSSIBLE IMPACTS ON FISH DYNAMICS DUE TO IMPLEMENTATION OF PROPOSED III TRISHULI HYDROELECTRIC PROJECT

A dissertation submitted for the partial fulfillment of the requirements for the Master's Degree in Environmental Science

Submitted by

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LETTER OF RECOMMENDATION

This to certify that **Mr. Janak Raj Pathak**, a student of Tribhuvan University, Central Department of Environmental Science, has completed this dissertation entitled **"Possible Impacts on Fish Dynamics due to Implementation of Proposed III Trishuli Hydroelectric Project"** for the partial fulfillment of the requirements for the Master's Degree in Environmental Science, prescribed according to the syllabus "Env. 650". His works are based on exploration and calculation of data, carried out by him under our supervision and the results presented in this dissertation are original and not submitted for any degree elsewhere. So, we strongly recommend this work for approval.

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LETTER OF APPROVAL

This dissertation in title “**Possible Impacts on Fish Dynamics due to Implementation of Proposed III Trishuli Hydroelectric Project**” conducted and submitted by **Mr. Janak Raj Pathak** has been accepted as a partial fulfillment of the requirements for the completion of Master’s Degree in Environmental Science.

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ABSTRACT

Hydropower is a proven renewable resource of electrical energy. It is the cheapest, the cleanest and environment friendly source of energy a country can tap, if implemented properly. Despite of all these benefits and importance, the environmental constraints arising as a result of hydroelectric projects cannot be eliminated in this 21st century where the whole world is taking pace towards eco-friendly sustainable development. Among these various environmental effects which evolve as a result of the implementation of hydroelectric project, the impacts on the life cycle of ichthyofauna are one of them. The construction of dams to divert water to the powerhouse causes serious effect on fisheries. The present study **"Possible Impacts on Fish Dynamics due to Implementation of Proposed III Trishuli Hydroelectric Project"** aims in determining the effects likely to be caused on the fish population due to the implementation of III Trishuli Hydroelectric Project.

Third Trishuli Hydroelectric Project is a run-off the river type project located in Salang VDC and Benighat VDC of Dharding district in the Central Development Regions of Nepal. The river is a snow fed river from which a design discharge of 115.25 m^3/s will be diverted for power generation through a side intake on the right bank by constructing 8 m high concrete gravity dam across the river. The present research is the outcome of the study carried for 10 months starting from December 2005 to October 2006 and both the field visits and desk study were done in this period of time.

The present study revealed 16 species of fishes in an around the proposed project area i.e. from the confluence of Malekhu Khola and Trishuli River to the confluence of Thopal Khola and Trishuli River of about 7 km length. Among these identified fish species *Neolissochilus hexagonolepis, Tor putitora* and *Schizothoraichthys progastus* have been quoted vulnerable in the National Red Data Book. Similarly, among these captured species; *Tor putitora* is long distance migrant, *Labeo dero, Schizothoraichthys progastus, Garra annandalei, Glyptothorax sps., Lepidocephalus guntea, Barilius barila, Aspidoparia jaya, Neolissochilus hexagonolepis* and *Barilius barna* are mid-migratory and the rest of others *Channa orientalis, Crossocheilus latius, Schistura beavani, Puntius sarana, Nemacheilus corica and Botia almorhae* are resident or local migrant fishes. Present analysis of physical, chemical and biological parameters of water from two sections i.e. intake and powerhouse indicate that water is suitable for fish development.

The concept of obstruction to migration is often associated with the height of the dam. The proposed concrete hydroelectric dam which is about 8m high blocks the entire path of migratory fishes unless and until some mitigative ways or fish passes has not been installed across the dam. CPU analysis indicate that population density of fishes are higher at the confluence of the rivers than elsewhere. Construction of dam near these sites can have substantial effect on fish community.

The reduced flow of water downstream the dam decreases the spawning ground and availability of food supply. The release of 10% of the minimum mean monthly flow i.e. 6.2 m^3/s water can augment to reduce such problems in the dewater zone to some extent however the habitat cannot be restored to its original state. Channelization of water and depositing gravels to create pools to increase spawning habitat can be effective in getting optimum result. In addition to problems relating to fish passage at obstacles, there are indirect effects of dams which may prove of major significance such as changes in flow, water quality, the increase in predation and drastic changes to the habitat upstream or downstream. Most of the local fishermen, now take agriculture as their main occupation and they don’t have clear vision about the effects of dam on fisheries. Sahani people are the migratory fishermen group from Terai Region. Impacts to these people can be eliminated for they can move to other regions if the fishing problems are serious. Certain unwelcome situations arising during the construction and operation of the reservoir have interactive, negative influences on ecology and environment. Thus appropriate precautionary measures should be adopted during construction and operation of the project so that there is minimum impact on fish community in the existing habitat.

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ACRONYMS

ADB	Asian Development Bank
APHA	American Public Health Association
ARO	Assessment and Review Office
BOD	Biological Oxygen Demand
CEQ	Council on Environmental Quality
COD	Chemical Oxygen Demand
CPU	Catch Per Unit
DDC	District Development Committee
DHM	Department of Hydrology and Meteorology
DO	Dissolved Oxygen
DPC	Diphenylcarbazide
EDTA	Ethylene Diamine Tetra Acetic Acid
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environment Protection Act
EPR	Environment Protection Rules
GoN	Government of Nepal
GWh	GigaWatt hour
ICIMOD	International Center for Integrated Mountain Development
IEE	Initial Environmental Examination
IUCN	International Union for Conservation of Nature and Natural Resources
km	Kilometer
KV	Kilovolt
KW	Kilowatt
m	Meter
MoEST	Ministry of Environment, Science & Technology
mm	Millimeter
MW	Megawatt
NCS	National Conservation Strategy
NEA	Nepal Electricity Authority
NEPA	National Environmental Policy Act

NEPAP	Nepal Environmental Policy and Acton Plan
nm	Nanometer
NRDB	National Red Data Book
NRs.	Nepalese Rupees
P^H	Power of Hydrogen
PPM	Parts Per Million
SDV	Secchi Disc Visibility
SEA	Strategic Environmental Assessment
TDS	Total Dissolved Solids
THEP	3rd Trishuli Hydroelectric Project
TSS	Total Suspended Solids
UN	United Nations
UNEP	United Nations Environment Program
USPH	United States Public Health
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization

CHAPTER – ONE

INTRODUCTION

1.1 GENERAL

The Himalayan Kingdom of Nepal is situated between 80º 4' to 88º 12' East longitudes and 26º 22' to 30º 27' North latitudes. With an area of 147,181 square kilometers, the fascinating country is a landlocked country wedged between the two Asian giants, China in the north and India in other three directions. It is almost rectangular in shape with 120 to 240 km width and nearly 900 km length. Within this small area lies one of the most diverse topographies and varied biodiversity to be found in the world. This is but to be expected in a country where the land rises from barely 67 meters above sea level all the way to the top of the world, at the summit of Mount Everest at 8,848 meters in a distance of 100 kilometers or so. Geographically, Nepal can be divided into seven regions going south to north. Although these divisions have mainly to do with altitude, they are equally different in the physical terrain as well. All across the south is the Terai lowlands, an extension of the Indo-Gangetic plain into the political borders of Nepal, and then comes the Hills and finally Mountains to the extreme north. These are the three broad physiographic divisions of Nepal.

The snow-clad Himalayas, eternal glaciers, perennial streams and fresh water lakes make Nepal rich in water resources. Over 6,000 rivers and streams with an approximate total length of 45,000 km drain the country. Water is a key natural resources of Nepal supporting the economy and livelihood of the people. The main source of water in the country is the rainfall of the monsoon season that deposits about 80 percent of Nepal's average rainfall of 1,530 mm between June to September. The mean annual precipitation in the country varies from 6,000 mm in the southern plains to less than 250 mm in the high Himalayas. Precipitation in the high mountain areas is usually deposited in the form of snow and serves as a year round source of flow to major river systems. Water is a plentiful resource that Nepal has which remains to be substantially developed. With a rapid increase in population, demands for drinking water, sanitation, irrigation, industry, energy and recreation have also increased. Himalayan topography has provided steep gradient to the Nepalese rivers from 8,848 m (Mt. Everest) to 67 m in the Terai in a distance of 180 km, with an average difference of elevation nearly 1,470 m. In one way this steep topography has been a set back to take the modern development in the hinter land in the form of road and others but on the other hand it has become a boon for the development of hydropower (Sharma, 1978).

1.2 WATER AND ENERGY RESOURCES OF NEPAL

Water is the major renewable resources of Nepal occupying 0.1 percent of the total world water system. The total annual precipitation of Nepal is estimated to be 220 km^3 (Thapa and Pradhan, 1995) among which 22 km^3 is solid in the form of snowfall and 198 km^3 is liquid in the form of rainfall. Snowfall totally contributes to the Himalayan Rivers. But rainfall contributes part of its volume to the Himalayan Rivers (105 km^3), part to Mahabharat Rivers (17.5 km^3), part to Churia Rivers (14.5 km^3) and also to ground water (61 km^3). So, the total water balance of Nepal is estimated to be 207 km^3 with annual contribution from Himalayan Rivers (127 km^3), Mahabharat Rivers (17.5 km^3), Churia Rivers (14.5 km^3) and Rivers from outside Nepal (48 km^3). Out of the Total precipitation of 220 km^3 only 207 km^3 is estimated in the annual water balance of Nepal, rest is lost as evaporation, evapotranspiration, soil moisture, etc. With this annual water balance of Nepal, the rivers of Nepal have been categorized into three grades considering their characteristic lean season flows (Sharma, 1977).

i) First Grade Rivers

The First Grade Rivers are Mahakali, Karnali, Narayani and Saptakoshi with snow and glaciers as the main source for sustained lean season flow.

ii) Second Grade Rivers

The Second Grade Rivers are Bagmati, West Rapti, Babai, Kamala, Mechi and Kankrat with sustained lean season flow from spring and ground water.

iii) Third Grade Rivers

The Third Grade Rivers are Tilawa, Sirsia, Ratu, Hardinath, Sunsari, Banganga, etc. originating in the Siwalik with very low dry season flow or no flow at all.

These river systems, lakes and reservoirs have high potentiality of hydropower generation. The estimated hydropower generation from these water sources is about 83,000 MW and 42,000 MW have been proved to be economically feasible (WEC-1998). First hydropower plant of 500 KW was constructed in 1911 A.D. in Pharping. After 25 years, in 1936 second hydropower of capacity 900 KW was constructed as Sundarijal Hydropower. After this, Panauti in 1965 with 2,400 KW then Kulekhani and latest and largest Kaligandaki – A with installed capacity of 144 MW in 2002 are the hydropower

plants of Nepal. Nepal so far has only been able to harness about 606 MW or less than 1 percent of its hydropower potential through a combination of public and private effort. A number of small, medium and large sized projects for a total of 22,000 MW capacity are planned and proposed for construction within the next 20-25 years period (NEA-2003).
Since majority of the rural population still does not have access to electricity and lack the benefits that can be derived from it, construction of III Trishuli hydroelectric project was felt necessary. The proposed project is a run-off-the-river but snow fed type project and thus the plant factor will be very attractive and about 11 MW of electricity round the clock can be generated (Feasibility Study Report 2006, IMA).

1.3 FISHES OF NEPAL

The huge source of inland water of Nepal support many and varied forms of fresh water biota. These lentic and lotic water bodies have been the natural habitat and spawning ground for many cold water fishes since time immemorial (Shrestha 1990). The great diversity in fish species is due to the variation in topography, altitude, climatic conditions and river torrents and currents. While Nepal occupies just over 0.1 percent of the earth's land surface, it supports 2.2 percent of fresh water fish species (ADB, 2004). The climatic conditions vary from hot monsoon to alpine types which support large species of fish population. Shrestha (1995) reported 184 indigenous fish species in Nepal, out of which 57 are common, 63 are insufficiently known, 23 are rare, 32 are threatened, 8 are vulnerable and 1 is given protected status. Later 186 fish species were reported from Nepal (Shrestha, 1998) and these fishes were classified after Jayram (1999). The National Red Data Book enlists *Neolissocheilus hexagonslepis, Anguilla bengalensis, Chagunius chagunio, Tor putitora, Brachydanio rerio, Schizothorax richardsoni, Schizothoraichthyes progastus and Psilorhynchus pseudecheinus* as vulnerable species whereas *Tot tor* is the only species listed as endangered by the book. Among these fish species of Nepal few species are listed under long distance migrant. The long distance migrant are *Tor tor, Tor putitora,* 2 *Bagarius species, Anguilla bengalensis* and *Pseudeutropius antherinoides*. The mid range migrant are *Neolissocheilus hexagonslepis, Schizothorax sps.* and *Labeo dero* whereas many other species are resident one. Nearly 2% population of Nepal is engaged in aquaculture and fish have food value, recreational, larvicidal, medicinal, aquarium, academic and aesthetic values in Nepal.

1.4 STUDY METHODOLOGY

To evaluate the fish population and species, the physical characteristics of Trishuli River was recorded firstly by walking along its banks both upstream and downstream from the project area. The existing habitat and spawning sites was identified at the confluence points near the project area and by consulting with local fishermen. During the survey, fishes were collected with the help of cast net of different sizes and other locally available fishing implements such as gill net, fishing rod, Paso, etc. along the existing habitats and spawning sites as per the local fishermen. Fish sampling were carried out with the help of local fishermen and the fish specimen caught by other local fisherman were evaluated along the sampling area. Similarly, water quality, phytoplanktons and zooplanktons were analyzed in the study period. Detailed study methodology has been discussed in Chapter Five.

1.5 SALIENT FEATURES OF III TRISHULI HYDROELECTRIC PROJECT

The salient features of the project according to the Feasibility Study Report 2006 are summarized in the following table.

Descriptions	Parameters
Location	Salang and Benighat VDC, Dhading, Central Development Region, Nepal
Latitude	27º 48’ 08” N to 27º 49’ 24” N
Longitude	84º 46’ 54” E to 84º 50’ 00” E
Type of power plant	Run-off-the-River snow fed type
Hydrology	
Catchment area at intake site	6,035 km^2
Long term annual average flow	315.65 m^3/s
Average minimum 1 in 2 year flow	62.02 m^3/s
Design flood at intake (1 in 100 yrs.)	7,112 m^3/s
Design flood at powerhouse (1 in 100 yrs)	7,195 m^3/s

Descriptions	Parameters
Proposed Structures	
Diversion weir	
Type	Controlled and uncontrolled Ogee type gravity diversion structure.
Crest level	346.6 m
Length	120 m
Height	8 m above natural bed
Radial gate	14 nos of hydraulically operable gate of 6m wide and 3.5 m high.
Intake chamber	
Type	Side intake fitted with 5 numbers of mechanized gates.
Size of opening	7 X 4m clear opening 5 numbers
Intake invert level	343.50 m
Approach canal	
Type	Concrete lined rectangular open channel
Length	20 m including the curved section
Width	38 m
Height	4 m
Bed slope	1:3500
Spillway	Side spillway
Headrace tunnel	
Shape	D-shaped
Length	~500 m
Height	3.5 m
Diameter	7 m
Cross-sectional area	43.74 m^2 (Final finished area)
Bed slope	1:1810

Descriptions	Parameters
Headrace canal	
Type	Concrete lined open canal
Shape	Trapezoidal
Length	2240 m
Bottom width	9 m
Top width	17 m
Depth	4 m
Side slope	1:1
Bottom slope	1:2610
Penstock	3 Surface steel penstocks having thickness of 16-20 mm, 3.5 m diameter & ~120 m long, each unit having discharge 38.42 m^3/s
Powerhouse	Surface powerhouse with net head of 20 m and design flow 115.25 m^3/s, capacity 20MW, 3 Kaplan turbines each of 6.7 MW capacity.
Tailrace canal	Rectangular covered channel, area 28 m^2, length ~117 m 1:500 bed slope.
Transmission line	Connection to the 132 KV transmission line whose length will be ~500 m
Access road	Length ~2 km ,gravel road single lane and one Belly bridge over the river
Construction Period	
Construction period from award of civil contract	3 years
Energy generation	
Mean annual energy per year	137.43 GWh
Dry energy	34.95 GWh
Wet energy	102.48 GWh
Project Cost	US $ 38.413 million

CHAPTER – TWO

LITERATURE REVIEW

2.1 EVOLUTION OF EIA

EIA was first introduced in the United States in 1969 as a requirement of the National Environmental Policy Act (NEPA). Since then, an increasing number of countries have adopted EIA, introducing legislation and establishing agencies with responsibility for its implementation (Clayton, 2006). NEPA was made effective on 1st January 1970 and it consists of provisions for environmental assessment. It has introduced three terminologies – environmental inventory, environmental assessment and Environmental Impact Statement (EIS), and contains three main elements – a general policy on the environment, a requirement for the production of an EIS for major federal actions and the establishment of the Council on Environmental Quality (CEQ) to administer the provisions of the legislation.

In 1970s, some high-income group countries such as Canada in 1973 and Australia in 1974 adopted environmental assessment as a regulatory procedure. Later Columbia and Philippines introduced EIA procedures in 1974 and 1979 respectively. The decade of 1970s could be considered as the formative stage on EA. The project level EA expanded in 1980s. Japan and European Union member countries introduced it in the national system in 1984 and 1985 respectively. More countries used EA as a mandatory regulatory procedure after the UN Conference on Environment and Development, popularly known as the Earth Summit in 1992 (Uprety, 2003).

Nepal is relatively new to the concept of EIA. In the past, EIAs were conducted for individual development proposals, usually at the initiative of bilateral and multilateral donors according to their respective policies. The National Conservation Strategy (NCS), 1987 recognizes the urgent need of the adoption of EIA, and has made the establishment of a national system of EIA a priority (IUCN, 1996). Although NCS gave full priority to the adoption EIA in 1987, The Sixth Plan (1980-85) for the first time in the planning history of Nepal, recognized the need for EIA study for infrastructure projects (NPC, 1980).

Although the core concept is similar, the definition of EIA varies: “Environmental Impact Assessment as a national instrument shall be undertaken for proposed development activities that are likely to have significant adverse impacts on the environment and are subject to the decision of a competent national authority" (Agenda 21 UN, 1993). The World Bank (1991) defined it a tool to assist Task Masters in making good decisions to screen projects efficiently for their environmental impacts, to clarify to governments what is needed for sustainable projects, and to design them effectively. EPA, 1997 defined EIA as a report on detailed study and evaluation to be prepared to ascertain as to whether, in implementing a proposal, the proposal does have significant adverse impact on the environment or not, whether such impacts could be avoided or mitigated by any means or not.

2.2 LEGAL PROVISIONS FOR HYDROELECTRIC PROJECTS

The theory of sustainable development – increasing standards of living without destroying the environment was brought during the Stockholm Conference 1972 with the establishment of United Nations Environment Program (UNEP).Twenty years later, in 1992, The Rio Declaration on Environment and Development sought to help Government rethink economic development and find ways to halt the destructions of irreplaceable natural resources and pollution of the planet. These conferences and conventions initiated the concepts that development activities and environmental protection should go in an integrated way and development works should be within the carrying capacity of the earth.

Appreciating the outcome of these conferences, GoN, has now started taking it as a challenge to protect the natural environment to provide equal opportunities, for its use, to both the present and future generations. The integration of environment and development issues in various sectoral development programs and their effective implementation is the long term vision envisaged in various national policies. Some of the legal provisions formulated for hydroelectric projects can be summarized as below;

Article 26 (4) of the Constitution of the Kingdom of Nepal provides "The state shall give priority to the protection of the environment and also to the prevention of its further damage due to physical development activities by increasing the awareness of the general public about environmental cleanliness, and the state shall also make arrangements for the special protection of the rare wildlife, the forests and the vegetation.

a) Acts

i) Environmental Protection Act 1997:

This is an umbrella Act for institutionalization of Environmental Assessment in Nepal and was commenced on 24th June 1997. The legal provisions under this Act are:

- Section 3: The proponent should carry out IEE and EIA in relation to the prescribed proposals.
- Section 7(1): Nobody shall create pollution, such as discharge, emit or dispose waste, sound, radiation or any such acts which will cause pollution or to allow pollution to be caused in a manner which is likely to have significant adverse impacts on the environment or to harm life or public health.
- Section 24: GoN may frame necessary rules for sources of pollution, standards, pollution prevention and control, water, air, sound and soil pollution conduction of IEE or EIA.

ii) Aquatic Animals Protection Act 1961 (Amendment 1999):

The act obliges the proponent to construct fish ladder at the dam site to ensure the movement of the aquatic animals, particularly the fish. If it is not possible, the proponent should establish a fish hatchery or a nursery, close to the dam site of the water resource projects for artificial reproduction and ex-situ conservation (Section 5 b). This act provides legislative protection for the habitats of aquatic species.

- Section 3: Confers the punishment to any party introducing poisonous, noxious or explosive materials into water sources or destroying any weirs, bridges or water systems, with the intent of catching or killing aquatic life.
- Section 4: Empowers the government to prohibit catching, killing and harming of aquatic animals through notification in the Nepal Gazette.

iii) Water Resources Act 1992:

This is the primary status regulating water quality in Nepal. Along with the Environmental Protection Act (1997) it provides for the establishment of rules and standards for regulating the discharge of pollutants to aquatic systems and for the prevention of degradation to the resources.

- Section 18,19 and 20 of the act provide for the fixing of the quality standards of water resources, establishment of tolerance limits for the discharge of pollutants and reduction in adverse effects to water quality due to erosion, floods, landslides or similar other causes.

iv) Electricity Act 1992:

- Section 24 forbids negative impacts on the environment such as soil erosion, floods, landslides and air pollution while producing, transmitting and distributing electricity.

vi) Local Self-Governance Act 1999:

It empowers the local bodies for the conservation of soil, forest and other natural resources and implements environmental conservation activities.

- Section 28 and 189 of the Act provide that Village Development Committee and District Development Committee are liable to formulate and implement the programs related to the protection of the environment and biodiversity.

b) Rules and regulations

i) Environmental Protection Regulation 1997 (Amendment 1999):

In accordance with the power conferred by Section 24 of EPA 1997, GoN has framed the EPR 1997 and it has entered into force on 26th June 1997.

- Rule 3: A proponent shall be required to carry out the IEE of the proposals mentioned in Schedule 1 and EIA of the proposals mentioned in Schedule 2.
- Schedule 1, Section E: The concerned party shall conduct an Initial Environmental Examination (IEE) for proposals of 1 to 5MW.
- Schedule 2, Section E: The concerned party shall conduct an Environmental Impact Assessment (EIA) for proposals exceeding 5MW.
- Rule 13: The concerned body should monitor and evaluate the impact of the proposal on the environment resulting from the implementation of the proposal. If greater impacts than those stated in the EIA report are noticed, the relevant agency is required to give necessary directives to the proponent to mitigate the adverse impacts or to adopt measures to control them. The proponent is obliged to carry out those directives.

ii) Water Resources Rules 1993:

- Rule 17 (e) of the regulation describe that any person or corporate body, who desires to obtain a license for utilization of water resource must state in his application that appropriate measures will be taken to lessen the adverse effects due to the project on the overall environment. Measures are to be taken for the conservation of aquatic life and water environment and for mitigation social and economic effects of the project in the concerned area.

iii) Electricity Rules 1993:

- Rule 12 and 13 obliges the proponent willing to produce and transmit electricity to analyze environmental impacts of the proposed projects and include environment protection measures including arrangements for the settlements of the displaced people.

iv) Local Self Government Regulation 2000:

Local self governance regulation empowers the local bodies to coordinate and implement development program and for rationale utilization of local natural resources.

- Rule 7 (68) empowers the VDCs for monitoring and supervision of development work implemented in the VDC.

c) Guidelines

i) National EIA Guidelines 1993:

Prior to the enactment of the environmental legislation, GoN implemented the National EIA guidelines since July 1993 in order to integrate environmental aspects in the development project and programs by conducting IEE or EIA. These guidelines call for identifying socio-economic, biological, physico-chemical and cultural impacts and proposing mitigation measures to avoid, eliminate, minimize or mitigate each adverse impact to augment beneficial impacts resulting from the project.

ii) Water Resource EIA Guidelines 1993:

This document laid down a number of guidelines by which to conduct an EIA report prior to the national requirements. These recommendations were later confirmed in the Environmental Protection Rules (1997).

iii) Environmental Planning Guideline 1998:

This guideline includes environmental issues to be considered during the preparation of environmental plans at village, municipality and district levels. This also includes institutions roles and responsibilities for their implementation including the approval process.

d) Policies

GoN started the formulation of the environment-friendly policies since the early 1980 and encouraged the proponent to integrate environmental aspects in the development projects and programs by carrying out EIA studies from the Sixth Plan (1980-85) onwards. This commitment was re-enforced in the Seventh Plan (1985-90), which stated that the developmental programmes will be implemented only after EIA study. The Eighth Plan (1992-97) and Ninth Plan (1997-2002) have emphasized the need for development of hydroelectricity with special attention for mitigation of adverse environmental impacts and integration of watershed management aspects in water resource development. Tenth Plan (2002-07) gave priority to the monitoring and evaluation of the projects that have under taken EIA will be made effective. Similarly, environmental programs will be operated as an inseparable part of environment management in the development programs.

i) Hydropower Development Policy 1992:

This policy incorporated the concept of EIA for identification and minimization of adverse impacts of hydropower projects and made commitment to implement Environmental Protection Measures recommended by the EIA study. One of the objectives of this policy was to "render assistance in the conservation of environment by supplying clean energy through the development of hydroelectric power." The policy clearly requires maintaining minimum monthly downstream water release in the river and stream at 10 percent of the total discharge or as recommended by the EIA study.

ii) Nepal Environmental Policy and Acton Plan (NEPAP) 1993:

NEPAP emphasis the need for mitigating adverse environmental impacts to address urban and industrial development, air and water pollution and infrastructure development through effective implementation of EIA guidelines for water resources. It identifies alteration of ecology from riverine to lake interventions and deals with destruction of forests and wildlife, threats to the survival of migratory aquatic species, climate changes and the risk of dam failures due to seismic activities, loss of agricultural land and displacement of local population as most significant environmental impacts of a hydropower project

iii) National Conservation Strategy 1988:

The National Conservation Strategy was endorsed in 1988 which includes a number of programmes to internalize EIA system in Nepal. According to the Strategy: The proponent of a development project or industrial activity that may have significant detrimental social and or environmental impacts must prepare and file with an Assessment and Review Office, a statement concerning the potential socio-economic and environmental effects of the proposed development project. The impact statement must be prepared in accordance with the guidelines provided by ARO.

iv) The Water Resources Strategy 2002:

This Strategy emphasis to understand the environmental processes fully, to avoid adverse impacts, improve conditions and/or to reduce negative elements (WECS, 2002). The Strategy underscores the need for effective implementation of EIA and SEA norms and recommendations.

v) The Biodiversity Strategy 2002:

This has also a strategy to conduct EIA in accordance with the provisions of EPA 1997 and EPR 1997 to assess significant impacts of development activities on biodiversity.

2.3 PREVIOUS STUDY ON FISHERIES ON DIFFERENT RIVERS

Karna (1993) reported ***29*** species of fish from ***Trishuli River*** during his 10 months study. He found migratory as well as resident species but they were not uniformly distributed in the river and said that water current, altitude, temperature and river bed play significant role in the fish distribution. According to him, construction of dams for the generation of electricity is an important support to raise the economy of the country but there isn't planning for fisheries management in Trishuli River such as fish ladder, fish ways, fish lifts, etc. for migratory fish. Lack of such fisheries management resulted the migration block to the economic important fishes, so planning for fishery management should be taken in consideration during the construction phase of dam.

Sharma (1978) found ***13*** species of fish in ***Trishuli River***. He suggested that hydroelectric dam in Sunkoshi and Trishuli Rivers have practically obstructed the migratory fishes from upper to lower part or vice-versa. In summer the main river bed gets completely dry due to the low discharge of water. Constant runoff water through main river bed from the barrage will be helpful to perpetuate fish migration. The barrage also can be provided with fish lifts of deep pool type. He also gave emphasis on closing of fishing during breeding season and establishment of fish sanctuary to provide constant and quantitative increase of fish population.

Joshi (1988) suggested that the impact of dam in ***Sunkoshi River*** system is more pronounced and has affected the abundance of fish population in the river. The construction of dam has brought great many changes in structure and function of natural water courses as well as its physical, chemical, and biological characteristics of the river. The migration of fishes towards downstream from higher reaches is physically checked by the hydro dam. He gave emphasis on the arrangement of fish ladders or fish lifts so as to move fishes, especially the migratory fishes freely to and fro the river without having any physical disturbances.

Khadka (1996) reported 8 orders of zoo benthos and ***9*** species of fishes from river ***Monohara***. She found that greater varieties of macro invertebrates were present at the unpolluted sites and lesser varieties towards the polluted sites.

Manandhar (1994) in his study on the effect of physico-chemical parameters on the fish fauna in the ***Indrawati River*** found that water temperature, P^H, DO, total hardness and total alkalinity were directly proportional to or have positive effect on the abundance of fish species in water body. Among these, total alkalinity has negligible effect on the fish species. He concluded that physico-chemical parameters determine the abundance of fish species although each of these parameters has variable effect on the fish species.

Pandey (2002) reported ***19*** species of fish from ***Bheri River***. According to him fish fauna of the Bheri River were governed by different parameters such as temperature, velocity, transparency, P^H, DO, total alkalinity and total hardness showed positive correlation and one parameter i.e. CO_2 showed negative correlation indicating the role of different parameters on fish fauna.

Sharma (1978) mentioned the effect of dam on a river as to put a barrier in the migration of fish in the up as well as lower site of a dam. He wrote that varieties of fishes found in the countries of the Himalayan block are not able to jump much if the dam is very high.

Bajracharya (2001) suggested that construction of dam increase the sediment load, water pollution and remove of boulders from the river cause disturbance to fish habitat. According to him ***Bhotekoshi river*** water diverted to the powerhouse reduced the flow in between the dam and the powerhouse. The reduction in water which is more severe during dry season decrease the available spawning and rearing area of fish. Reduced flow also increases the water temperature due to greater exposure to solar radiation and reduces food availability thus causing an overall decline in fish productivity.

Acharya (1998) recorded ***11*** different species of fish in ***Thaule Khola***. According to him, the parameters which supported the diversity of fish fauna in Thaule Khola or showed positive correlation were temperature, depth, transperancy, P^H, hardness and total alkalinity. But CO_2 and chloride had negative correlation to fish fauna.

Chaudhary (1999) reported 68 fish species from ***Budhikhola***. He suggested that fish population in the river is decreasing due to different manual activities like bridging, damming and natural calamities like heavy flooding and erosion.

Sah (1995) reported ***23*** species of fish from different sections of ***Trishuli River***. He concluded upper reaches of river dominated with snow trout, middle reaches by Mahaseer and lower reaches by slow moving catfishes. He also mentioned that dam established near Devighat has stopped the migration of economically important fish species.

Pokharel (1998) has studied the current status of hydropower in Nepal and impact of ***Jhimruk Hydroelectric Project***. The study concluded that the project brought negative as well as positive impacts. He mentioned that due to the implementation of the project there has been reduction in the flow of water downstream and thus has reduced agricultural production, raised the temperature of water and lay off some fishermen from their traditional jobs. But the project infact generated employment, skill development and increased access to piped drinking water. Above all the project also raised literacy through different programs.

Gurung (2000) mentions that the implementation of ***Modikhola Hydroelectric Project*** has affected 560 populations of 80 households. According to him, air pollution has increased due to construction activities. It has affected various multipurpose tree species, wildlife, fish and other aquatic life.

Paudel (1996) mentions that due to the favor of nature, Nepal is full of water power resources. Hence the utilization of these resources will definitely improve the economic condition of the country and prevailing living standard of people. But lack of coordination in development activities is worsening environmental quality. According to her, it is in this light that due care should be given to environment friendly hydropower generation.

Masuda and Karki (1979) reported 28 species, Shrestha (1981) reported 12 fish species, Karna (1993) reported 29 species and Shrestha T.K (1990) reported 34 species of fishes from Trishuli River. Fishes of Nepal has been studied by Beaven (1877), Gunther (1859-1890), Hamilton (1822), Jayaram (1999), Hora (1920-1952) and many others.

CHAPTER – THREE

RATIONALE OF THE STUDY AND SCOPE OF WORK

3.1 RATIONALE OF THE STUDY

Mostly a dam is built across a river to control its flow and create a reservoir to store or divert water. A dam is usually an important increment of nearly all hydropower developments. The implementation of hydroelectric project decreases the energy crises of a country. However, the disruption of migration and spawning of fish population due to the implementation of the project cannot be over looked. There are some fish species which may adapt with a large flooded dam area, but there are some other fish species like Salmon, a migratory species that live part of their lives in fresh water and part in salt water. In Nepal fishes like *Tor* species, *Bagarius* species are long distance migratory fishes. Thus, hydropower projects on a river severely impede these migratory fishes which run in their migration to and from their hatch sites. Without the installation of fish ladders and by passes, these migratory fish population cannot surmount high dams and reach their breeding, spawning or feeding grounds. Before the dams are built water carries juvenile fish in the downstream region of a river thereby scattering the fish population and hence fulfilling the occupational behavior of some social groups. But after the construction of dam, much of juvenile fish are killed when they pass through the turbine blades and also they are exposed to predators in the deep confined reservoir. Dams also alter the magnitude, chronology, quality of stream flow and affect fish stock by reducing the available space, size, quality, frequency of spawning nursery and food producing zone. Thus to evaluate these insurmountable effects for the fish population due to the implementation of hydroelectric project in the virgin river, this study is needed.

Trishuli River is a large snow-fed river which is inhabited by large number of fresh water fishes. The impact of development works such as construction of hydroelectric dam across the river on fish communities can be studied effectively in this river. The project site is accessible from all seasoned road and none of the scholars have studied the impacts on fish dynamics due to development activities on this particular river until now. Thus, III Trishuli Hydroelectric Project was chosen as my study ground.

3.2 OBJECTIVES AND SCOPE OF WORK

The objective of the study is broadly classified in General and specific category and the coverage is briefly mentioned hereunder:

a) General Objective

The main objective of the study is:

- To determine the effects likely to be caused to the fish community due to the implementation of proposed III Trishuli Hydroelectric Project.

b) Specific Objectives

Specific objectives of the present study are:

- To identify the existing ichthyofauna and their distribution pattern in the project area.
- To determine downstream release requirement.
- To identify the spawning and feeding grounds of the existing fish community in the project area.
- To determine the water quality of the intake and powerhouse sites of the project area and forecast the possible change in quality of water due to project implementation.
- To evaluate hindrance likely to be created due to the high dam across the river for the migration, reproduction, habitation and food behavior of fish population.
- To suggest proper mitigation measures to minimize impact on fish community due to project implementation.

3.3 LIMITATIONS:

Final result of this study is not free from errors due to the following constraints:

i) Limited time for the completion of study.

ii) Constraints on financial support to conduct research study.

iii) Lack of laboratory facility and easy access to fish lab.

iv) Frequent field visits could not be made because of instability in the country.

CHAPTER – FOUR

STUDY AREA IN BRIEF

4.1 LOCATION

The proposed project, III Trishuli Hydroelectric project is located in Salang VDC and Benighat VDC of Dharding district in Central Development Region. It is about 75 km from Kathmandu and along the side of Prithivi highway near Richoktar, Malekhu. The project is going to be developed in the Trishuli River which is one of the main river systems of Nepal originating from the Higher Himalayas and Tibet of China. It is a perennial snow fed river full of fresh water fishes. The proposed project is located approximately at 84º46’54” - 84º50’00” East Longitude and 27º48’08” - 27º49’24” North Latitude. The headwork is located at an altitude of 342 m and the powerhouse is at 317 m above the mean sea level (Fig. 4.1)

The study area lies within the project area covering approximately 7 square kilometers. The study sites were fixed along the Trishuli River enclosed by the project area focusing mainly on the confluence of the rivers. Malekhu Khola, Thopal Khola and Gomati Khola are the streams mingling with Trishuli River that are near or within the project area.

4.2 RIVER MORPHOLOGY AND SEDIMENTOLOGY

Trishuli River is one of the main snow-fed rivers of Nepal flowing through Rasuwa, Nuwakot and Dharding and Chitwan districts of Central Development Region. It is one of the major tributaries of Gandaki River System. Trishuli River enters Nepal through Rasuwa draining Tibetan high lands and meets another Trishuli River originating from Gosainkunda Lake near Dunche of Nepal. Trishuli joins Kaligandaki at Deoghat after which it is called as Narayani River. In this way, the river makes different meandering loops and crosses about 130 km length before mixing into another river. It is fed by major rivers like Budhi Gandaki at Benighat and Marsyangdi at Mungling. Around the project area, Trishuli is fed by medium streams like Malekhu Khola, Thopal Khola, Bhante Khola and Gomati Khola.

Trishuli River has several meandering structure around the project area. After Malekhu bridge, the river heads north and again towards south at Arbastar making a semicircular

Figure 4.1: Study Area (●) with Major Rivers of Nepal

loop. After Arbastar, it again meanders towards northern direction up to Majhigau making another loop. Trishuli River is observed to have many meandering loops with plenty of pools and riffles in and around the project area. Large boulders and sandy plains were seen around the banks of rivers. Sand, silt and rounded pebbles is the major composition of river banks. The river is accessible from all seasoned black-topped road. However, the project area is not directly linked with all seasoned road, there should be a linkage with earthen road from Richoktar, Malekhu down to the proposed headworks area.

Total suspended solids from the water of intake and powerhouse sites were observed to be 89.2 mg/l and 237.8 mg/l. This sediment was measured during the low flow season when the rivers usually have minimum suspended solids. But, since Trishuli River originates from highlands and its catchment area is also large, sediment load will be much higher than this measured value during high flows. Sedimentology data at gauging Station 447 has been available but no any measurement station between Station 447 and the proposed headworks area. On the basis of available data, literature review, the design team came to conclude to adopt an average sediment concentration for the design of the settling basin as 5500 PPM (Feasibility Study of THEP, 2006). Major mineral composition of the sediment along the bank of Trishuli River was found to be mica, feldspar, quartz, and other silicates. Water carries enormous amount of sediment when the river will be flooded which is problematic both for fishes and hydropower generation. This thousands of tons of sediments carried by Trishuli River will be deposited behind the dam and cause reservoir siltation. Excessive sediment interferes with the survival of fish and other aquatic organisms. High floods carry sediments ranging from few microns to several inches in diameter. Fine silts move along the water but larger particles move by siltation and surface creep. These sediments decrease the transparency of water thereby disrupt light penetration in deep water. They also cause choking of gills among the fishes.

4.3 HYDROLOGY AND METEOROLOGY

The Trishuli River is one of the main tributary of the Gandaki River. The catchment area of the proposed project at intake site from the 1:25,000 scale topographic map and relevant literature is about 6,035 km^2. The catchment area of Trishuli River also lies in Tibet, China and thus it is a bit difficult to estimate the catchment area because of unavailability of topographical map. Its catchment area in China has been estimated referring different available literatures.

The Trishuli River is a gauged river and therefore direct measurements are possible for this River. However, there is no gauging station close to the project area and thus prorated factor need to be established to transfer data from Gauging Station no. 447 located at Betrawati. Data series of 1977 – 1995 from Gauging Station no. 447 of Trishuli River and of 1969 – 1995 from Gauging Station no. 448 of Tadi Khola has been used to calculate the flow information (DHM 1964-1995). For the hydrological study, all stations as noticed in the area as well as close to the catchment area were used and Theissen polygon method was applied to derive average precipitation in the catchment area (Feasibility Study of THEP, 2006).

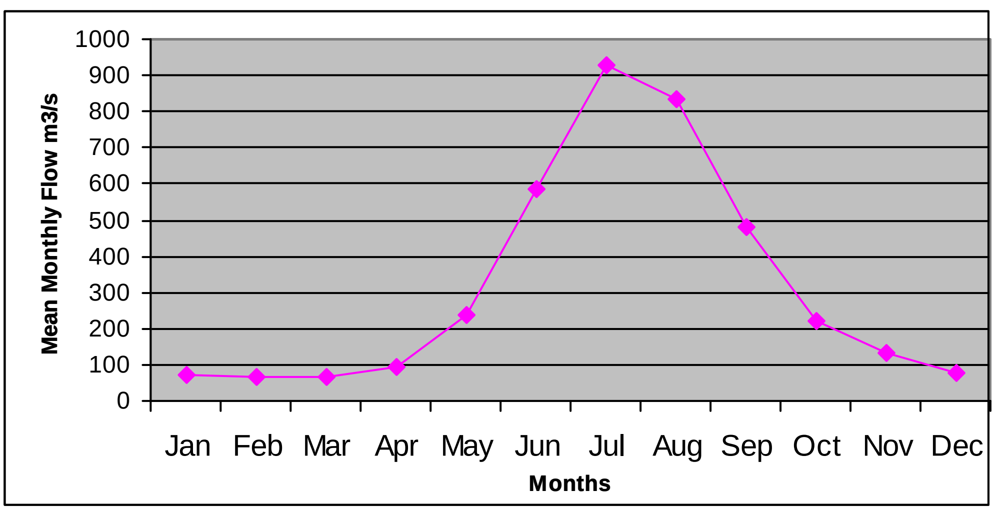
The mean monthly flow as obtained is presented in Table 4.1

Table 4.1 Adopted mean monthly flow at the proposed headworks, m^3/s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Flow	70.78	65.65	68.11	94.75	237.54	583.60	926.43	833.17	478.58	219.37	130.78	79.15

Source: Third Trishuli Hydroelectric Project, Feasibility Study, 2006

The mean monthly hydrograph is shown in Graph 4.2.



Long term annual average flow of Trishuli River is found to be 315.65 m^3/s and average minimum 1 in 2 year flow is 62.02 m^3/s. Similarly, 100 years return period flood at the proposed headworks is found to be 7,122 m^3/s.

The catchment area of the project lies in the sub-tropical region. Precipitation records of different stations have been used to generate annual average precipitation using Theissen polygon method. The annual average precipitation is estimated as 1900 mm from Theissen polygon method. It has been noticed that the South-East monsoon during June-September contributes majority of rainfall. The minimum and maximum temperatures of the project area are observed to be 3.2º C and 35.3º C respectively according to the data series of Index 809.

4.4 GEOLOGY

The project area lies in the Lower Nuwakot and Upper Nuwakot Group of the Lesser Himalaya (Yamanaka and Iwata, 1982). These two groups of rocks are separated by the Uniformity. The project area consists of slates, limestone and dolomite. The Dharding Dolomite of the Lower Nuwakot Group is exposed at right bank of Trishuli River far north of the project area. The Dharding Dolomite sharply overlies Benighat Slates. The Benighat Slates and Malekhu Limestone of the Upper Nuwakot are exposed in the project area.

The project site is located in the southern limb of the Jalbire Syncline. Except this, no major geological structures were found near the project area. The foliation structure is simple in the area having a moderately south dipping nature. In general, the foliation strikes S80ºE and dips 40º due southwest. Colluvium deposits are found along the most parts of the study area. It comprises angular big boulders and rounded pebbles in sandy silty clay matrix. Residual soil is red in colour and developed over weathered rock mostly in gentle slope. Alluvial soil deposits are found along the banks of the Trishuli River. It comprises sand, silt and gravel and is light grey in colour. Landslides are observed in the area mainly along the bank of the river, which contains both recent and old landslides.

4.5 SOCIO-ECONOMY

Majority of people around the project area are dependent on agriculture and animal husbandry as their occupation. The people along the highway own shops and small hotels where highways passengers can have required facilities. Different people inhibit this area which includes Brahmin, Chettri, Maghi, Gurung, Magar and Sarki. Most of the adult people were found to be illiterate and children were seen to go to the school at Salanghat. Almost all people speak Nepali and were observed to have nuclear family system except few. Houses were huts with thatched roof and some large houses with tin or tile roofs. All the people possessed their own land where they cultivated seasonal crops. Highway people were noted to have higher income than the people along the main project area. Brahmin, Chhetri and Maghi are the main inhabitants along the project corridor. Income for most of the people were said to have less than NRs. 20,000 per year. Very few local people are dependent on fishing as their main occupation. Here, Sahani people from Terai area take fishing as their main occupation. Thus, the people around the project were found to have simple, solidarity socio-economic life.

4.6 FLORA AND FAUNA

Riverine Forest with *Acacia catechu* (Khair) and *Shorea robusta* (Sal) as the dominant trees were observed around the project area. Other trees that were identified are; *Melia azedarach* (Bakaino), *Bombax ceiba* (Simal), *Schima wallichii* (Chilaune), *Dendrocalamus strictus* (Bans), *Terminallia bellirica* (Barro), *Terminallia chebula* (Harro), *Mangifera indica* (Amp), *Pinus roxburghii* (Sallo), *Terminalia alata* (Saj), *Dalbergia latifolia* (Satisal), *Syzygium cerasoides* (Kyamuno), *Dalbergia sissoo* (Sisso), *Aclina cordifolia* (Karma), *Garuga pinnata* (Dab-dabe), *Litsea polyanthus* (Kutmiro), *Ficus lacor* (Kavro), *Ficus religiosa (Pipal)*, *Ficus semicordata* (Khanayu), *Phyllanthus emblica* (Amala). The ground vegetation consists of wide variety of grasses and other shrubs and herbs such as *Eupatorium adenophorum* (Banmara), *Artemisia vulgaris* (Titepati), *Urtica dioica* (Sisnu). There are six community forest user groups involved to protect forest in his area but none of them fall on the project corridor. The forest observed along the project area is not rich in condition but some trees like *Shorea robusta* (Sal), *Acacia catechu* (Khayir) are recorded as protected species according to Forest Regulation, 1995 and some plants like *Terminallia bellirica* (Barro), *Terminallia chebula* (Harro), *Artemisia vulgaris* (Titepati) are recognized as having medicinal value.

Animals that were seen and reported from the project are *Panthera pardus* (Common Leopard), *Macaca mullatta* (Monkey), *Ratuta spp.* (Squarrels), *Hystrix indica* (Porcupine), *Herpestes spp.* (Mongoose), *Martes flavigulla* (Marten), *Canis aureus* (Jackal), *Felis marmorata* (Wild cat).

Among the birds; *Aquila heliaca* (Eagle), *Catreus wallichii* (Cheer Pheasant), *Psittacula krameri* (Parrot), *Anas spp*. (Duck), *Bubulcus ibis* (Cattle Egret), *Streptopelia senegalensis* (Dove) were common.

4.7 PROJECT DESCRIPTION

Third Trishuli Hydroelectric Project is the run-off the river type of project. The river is a snow fed river from which a design discharge of 115.25 m^3/s will be diverted for power generation through a side intake on the right bank by constricting 8 m high concrete gravity dam across the river. Right after the intake, surface settling basin is located in flat cultivated land. The waterway is a combination of free flow tunnel and trapezoidal but lined open canal. The length of tunnel is about 500 m where as the open canal length is about 2240 m. A surface forebay at the end of open canal is proposed from where a surface penstock pipe will convey design discharge down to the powerhouse. The length of the penstock will be about 120 m. Three penstocks will be taken from forebay down to the powerhouse. A surface powerhouse will be constructed at Majhuwatar. There will be three units of Kaplan turbine. Rectangular type of concrete lined tailrace canal will be constructed and flow will be released back to the mother river again. There will be ~24.5 m gross head available. With the available head and discharge, the capacity of the proposed power plant will have an installed capacity of 20 MW with 137.43 GWh annual energy generations.

CHAPTER FIVE

STUDY METHODS

5.1 GENERAL

The study was carried out for 10 months starting from December 2005 to October 2006 and field visit was made twice in this period of time. Preliminary field survey was made in December 2005 and sampling stations were identified. These sampling stations were visited in February 2006 for the purpose of data collection. The field visit was made in such a season that maximum fish species could be caught in the river section and there is no interference of the flood. To fulfill the above mentioned objectives, both desk study and field visit was done.

5.1.1 Desk Study

A preliminary desk study was carried out based on the available topographic maps with a view of identifying potential sampling sites. A 1: 25,000 scale topographic maps of Malekhu area with Sheet No. 2784 04C and 2784 04D published by Survey Department of Nepal in co-operation with the Government of Finland has been used in the desk study. Sheet No. 2784 04C is the main topographical map used in this study to align study sites. Similarly, secondary data were obtained from journals, books, previous studies and other literatures in order to gather more information about the project and to make the study convenient.

5.1.2 Field Visit and Data Acquisition

The physical characteristics of Trishuli River were first recorded by walking along its banks upstream and downstream from the project area to evaluate fish population and species during the field visit. The existing habitat and spawning sites were identified at the confluence points near the project area and by consulting with local fishermen. During the survey, fish was collected with the help of cast net of different sizes and other locally available fishing implements such as Gill Net, Fishing Rod, Paso, etc. along the existing habitats and spawning sites as per the local fishermen. Fish sampling was carried out with the help of local fishermen and the fish specimen caught by other local fishermen was also evaluated along the sampling area. Field observations were made to study the fish diversity, water quality and planktons of the proposed project area. Other required information was taken through interviews and questionnaires with the local people (Refer Annex-2).

5.2 STUDY AREA

The present study was confined within the range of about 7 km distance along Trishuli River and its territory. Different sites were located starting from the confluence of Malekhu Khola and Trishuli River to the confluence of Gomati Khola and Trishuli River. Fish sampling was done within this section focusing mainly on the confluence of the rivers, but water quality test was done only along the intake site and powerhouse site. Phytoplankton and zooplankton were studied near the confluence of Thopal Khola and Trishuli River. Five major sampling stations established are briefly discussed herein and shown in Fig. 5.1 below:

Station I

This station is the confluence of Malekhu Khola and Trishuli River along the left bank of Trishuli River about 200 m North of Malekhu bridge. Water was clear and large number of fish, loving cold waters can be seen on this site. People have used this station as a place of washing cloths, bathing, cleaning commercial fish and gravel mining.

Station II

This station is located at the confluence of Thopal Khola and Trishuli River along the right bank of Trishuli River. The river had bifurcated in this section due to small hillock at the center of the channel. Plenty of algal blooms can be seen along the banks of the river and the velocity of water is quite high compared to Station I due to rapids and ridges. Local cremation place is also located in this station. Sampling of zooplankton and phytoplankton were also done on this site.

Station III

Station III is located near Arbastar just above the suspension bridge along the left bank of Trishuli River. This is the intake site of the proposed project and the joining point for Arbastar and Richoktar. About 8 m high gravity dam that is around 120 m long will be constructed at this site and the water will be diverted towards Arbastar along the right bank of Trishuli River to the powerhouse. There are paddy fields and other cultivable lands along the left bank and activities of the people are high at this station. Sampling of water was done here.

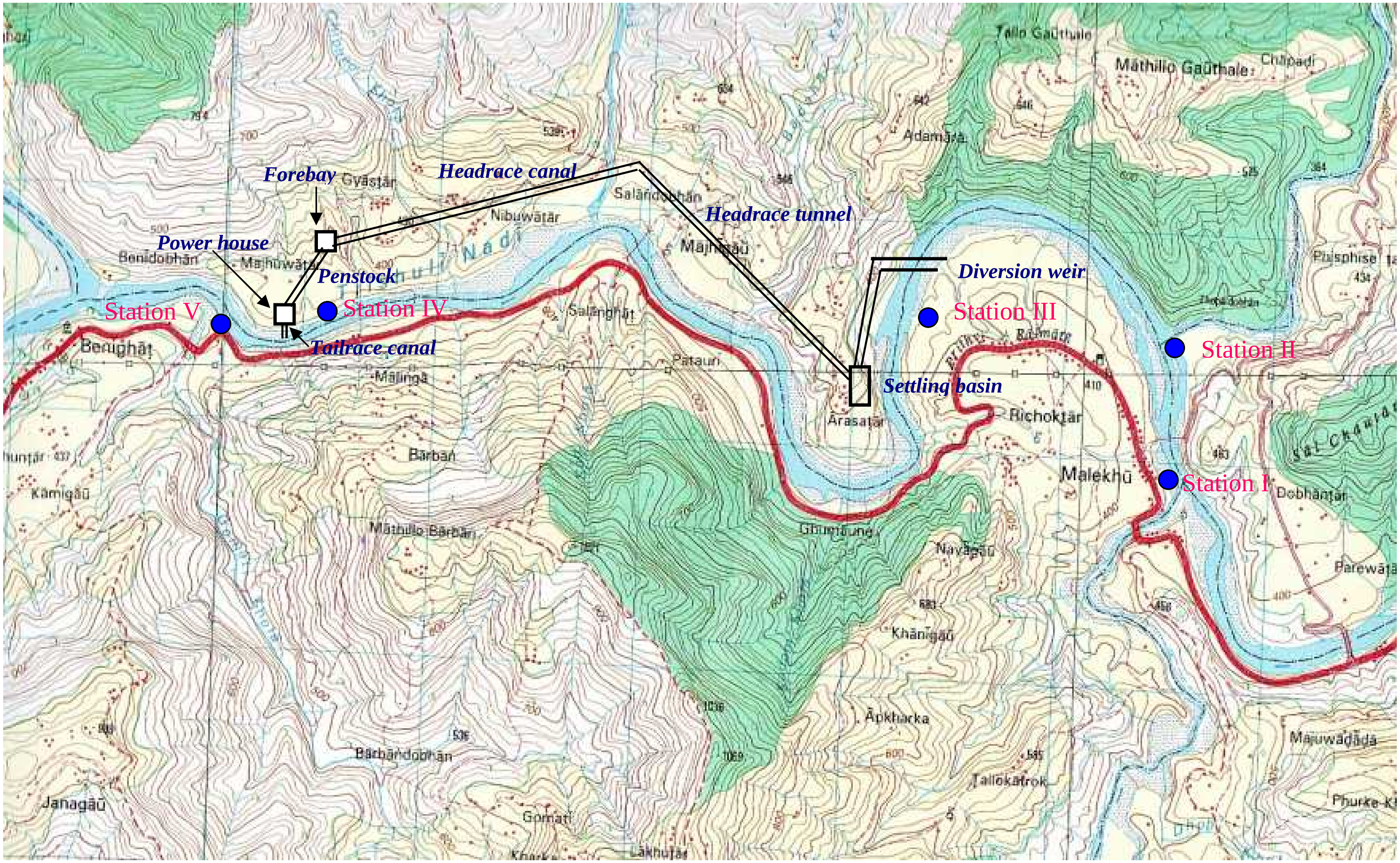


Figure 5.1: Study Area with Major Sampling Stations (●) and General Infrastructures of the Project

Station IV

This station is located at Majhuwatar along the right bank of Trishuli River. This is the powerhouse site of the proposed project. A stretch of tabulated land can be seen just above Trishuli River where farmers had cultivated crops. Settlements are very thin here except few huts. Water was sampled in this station as well.

Station V

The last station is located at the confluence of Gomati Khola and Trishuli River. This is the point where the tailrace canal from powerhouse meets the natural stream. Small temple and crematorium is located here. According to the local fishermen, cold water from Gomati Khola had made this place a good spawning ground for fishes.

5.3 DATA ACQUISITION

Primary and secondary data both were collected during the study period. Primary data were collected directly by field observations, interviews and questionnaires. Field observations were made to study the fish diversity, water quality, planktons and vegetation of the proposed project area. Other required information was taken through interviews and questionnaires with the local people (Refer Annex-2). Similarly, secondary data were obtained from journals, books, previous studies and public interactions. Both of these data were taken as the base to get factual result.

5.4 WATER QUALITY ANALYSIS

The physico-chemical parameters of water were analyzed after APHA (1998) and Trivedi and Goel (1986).

PHYSICO-CHEMICAL PARAMETERS

P^H:

The P^H of the water was measured with P^H paper. P^H paper was dipped into the water and change in colour was observed. This change in colour was compared with the reference colour denoting different P^H value, thus the P^H of water was identified.

Temperature:

Ordinary thermometer was used to measure the temperature of water. The thermometer was dipped into the water for 5 minutes and the reading was taken.

Turbidity:

Turbidity was measured with the help of Secchi disc. Secchi disc of standard format was dipped into the water and its visibility was measured.

Conductivity:

Conductivity was measured with the help of conductivity meter. The sensor of the conductivity meter was dipped in a beaker containing sample water for 2 minutes. The digital screen displayed the conductance of the sample water which was noted.

Conductivity = observed conductance X cell constant X temperature factor at 25 (1.02)

Total Solid:

An evaporating dish was taken, dried in a hot air oven at 110°C for 20 min. and was cooled to room temperature in a desiccators. The dish was weighted and 50ml of sample water was taken in the dish. It was then evaporated to dryness, dried in hot air oven at 110°C for 20 min. and cooled to room temperature in desiccators. The final weight of the dish was noted and Total Solids of the sample water was calculated as follows:

$$Total\ solids\ (mg/l) = \frac{A - Bx1000x1000}{V}$$

Where,

A = Final weight of the dish with total solid

B = Initial weight of the dry dish

V = Volume of the sample taken for the test

Total dissolved Solids:

Another evaporating dish was taken, dried in a hot air oven at 110°C for 20 min., cooled to room temperature in desiccators and the dish was weighted. 50ml of sample water was taken, filtered through a filter paper and the filtrate was collected in the pre weighted dish. It was then evaporated to dryness, dried in hot air oven at110°C for 20 min. and cooled to room temperature in desiccators. The final weight of the dish was noted and Total Dissolved Solids of the sample water was calculated as follows:

$$Total\ dissolved\ solids\ (mg/l) = \frac{A - Bx1000x1000}{V}$$

Where,

A = Final weight of the dish with total dissolved solid

B = Initial weight of the dry dish

V = Volume of the sample taken for the test

Total Suspended Solids:

Total suspended solids were calculated by subtracting Total Dissolved Solids from Total Solids.

Total Suspended Solids (mg/l) = Total Solids - Total Dissolved Solids

Total Alkalinity:

Total Alkalinity of water was determined by Titrimetric Method. In this method 50ml. of sample was taken in a conical flask and 2 drops of phenolphthalein was added to it. When there was no change in colour 2 drops of methyl orange was added to this solution as an indicator to give orange colour. It was then titrated with standard H_2SO_4 (0.1N) and the end point was noted when the colour changed from orange to pink. This process was repeated other two times for concurrent reading.

$$Total\ \ Alkalinity\ (mg/l) = \frac{V_1 x N x 50 x 1000}{V_2}$$

Where,

V_1 = Volume of the H_2SO_4 consumed in the titration

N = Normality of H_2SO_4 solution

V_2 = Volume of the sample taken for the test.

Total Hardness:

Total hardness of water was determined by Titrimetric Method. In this method 50ml. of sample was taken in a conical flask and 1 ml. of hardness buffer was added to it. 1mg of Erichrome Black T was added to this solution as an indicator to give wine red colour. It was then titrated with standard Ethylene Diamine Tetra Acetic Acid (EDTA-0.01N) and the end point was noted when the colour changed from wine red to blue. This process was repeated other two times for concurrent reading. Water hardness may be caused by the sum of the concentrations of all the metallic cations other than cations of the alkali metals, expressed as equivalent calcium carbonate concentration:

$$Total\ \ hardness\ (as\ CaC0_3)\ (mg/l) = \frac{V_1 x N x 100 x 1000}{V_2}$$

Where,

V_1 = Volume of the EDTA solution consumed in the titration

N = Normality of EDTA solution

V_2 = Volume of the sample taken for the test.

Calcium Hardness:

Calcium hardness of water was also determined by Titrimetric Method. In this method 50ml. of sample was taken in a conical flask and 2 ml. of NaOH (0.05N) was added to it. 1mg of Murexide was added to this solution as an indicator to give pink colour. It was then titrated with standard Ethylene Diamine Tetra Acetic Acid (EDTA-0.01N) and the end point was noted when the colour changed from pink to purple. This process was repeated other two times for concurrent reading.

$$Calcium\ hardness\ (mg/l) = \frac{V_1 xNx40x1000}{V_2}$$

Where,

V_1 = Volume of the EDTA solution consumed in the titration

N = Normality of EDTA solution

V_2 = Volume of the sample taken for the test.

Magnesium Hardness:

Magnesium hardness was determined by subtracting Calcium Hardness from Total Hardness.

Magnesium Hardness = Total Hardness – Calcium Hardness

Chloride:

Chloride was determined by Argentometric Method. In this method 50ml. of sample was taken in a conical flask and 2 ml of $K_2Cr_2O_4$ was added to it as an indicator to give light yellow colour. It was then titrated with standard $AgNO_3$ (0.02N) and the end point was noted when the colour changed from light yellow to brick red. This process was repeated other two times for concurrent reading.

$$Chloride\ (mg/l) = \frac{V_1 xNx35.5x1000}{V_2}$$

Where,

V_1 = Volume of the $AgNO_3$ solution consumed in the titration

N = Normality of $AgNO_3$ solution

V_2 = Volume of the sample taken for the test.

Carbon dioxide

Carbon dioxide of water was determined by Titrimetric Method. In this method 100ml. of sample was taken in a conical flask and 4 drops of phenolphthalein was added to it as an indicator. When there was no change in colour (if the solution turns pink by the addition of indicator CO_2 is absent) it was then titrated with standard NaOH (0.05N) and the end point was noted when the colour changed from colourless to pink. This process was repeated other two times for concurrent reading.

$$Carbondioxide\ (mg/l) = \frac{V_1 x N x 44 x 1000}{V_2}$$

Where,

V_1 = Volume of the NaOH consumed in the titration

N = Normality of NaOH

V_2 = Volume of the sample taken for the test.

Dissolved Oxygen:

Dissolved oxygen of water was determined by Winkler's Method. In this method, BOD bottle of capacity 300ml. was filled with sample water avoiding any kind of bubbling after placing the cap. 2ml of $MnSO_4$ solution and 2ml of KI solution were added to it which gave precipitate. The stopper was placed and the solution was shaken repeatedly and kept for a while to settle the precipitate. 2ml of concentrated H_2SO_4 was added to the solution to dissolve the precipitate. 50ml of this solution was taken in a conical flask and 4 drops of starch was added to it as an indicator to give blue colour. It was then titrated with standard $Na_2S_2O_3$ (0.025N) solution and the end point was noted when the colour changed from blue to colourless. This titration was repeated other two times for concurrent reading.

$$Dissolved\ Oxygen\ (mg/l) = \frac{V_o x N x 8 x 1000}{\frac{V_2 (V_1 - V)}{V_1}}$$

Where,

V_o = Volume of the $Na_2S_2O_3$ consumed in the titration

N = Normality of $Na_2S_2O_3$

V_2 = Volume of the sample taken for the test

V_1 = Volume of BOD bottle

V = Volume of $MnSO_4$ and KI added

Biological Oxygen Demand (BOD):

For the calculation of BOD, 50ml of sample water was taken in a volumetric flask with capacity 1 liter. To this water 950ml of dilution water (distilled water bubbled with compressed air for about 30 min. and 1 liter of this water was added with 1 ml each of Phosphate Buffer, Magnesium Sulphate, Calcium Chloride and Ferric Chloride and mixed thoroughly) was added and mixed maintaining P^H around 7.0 by using NaOH (1N). Then two BOD bottles with capacity 300ml each were taken wrapping one with complete black cloth. Both the bottles were filled with sample solution from volumetric flask and among them the one wrapped with black cloth was kept in a incubator at 20°C for 5 days. The dissolved oxygen of the sample solution from second bottle was calculated by using Winkler's method mentioned earlier and was noted. Similarly, dissolved oxygen of the incubated bottle was also calculated after five days using same technique and BOD was calculated as follows:

BOD (mg/l) = (DO_0 – DO_5) X Dilution Factor

Where,

DO_0 = Initial dissolved oxygen of sample solution

DO_5 = Dissolved oxygen of sample solution after five days

Chemical oxygen demand (COD):

Chemical Oxygen demand of the given sample was determined by open reflux method. 50 ml of sample water taken in a round bottomed flask, ground joint with reflux condenser adding few glass beads to avoid bumping. 10ml of $K_2Cr_2O_7$ (0.25N), a pinch of Ag_2SO_4 and $HgSO_4$ and 30ml of concentrated H_2SO_4 was added to the sample water. The apparatus was setup and the whole solution was refluxed for 2 hours on a hot water bath. After two hours the reflux unit was allowed to cool down. After cooling, the content was diluted into twice the volume by adding distilled water and cooled to room temperature. 25ml of this sample solution was taken and about 2-3 drops Ferroin was added as an indicator to give green colour. This solution is titrated with Ferrous Ammonium Sulphate (Mohr's salt-0.1N) and the end point is noted when the colour of the solution changed from green to reddish brown. This process was repeated for the blank solution (distilled water) as well and the end point was noted. Concentration of COD in the sample water was calculated as follows:

$$COD\ (mg/l) = \frac{(B-A)xNx8x1000}{V}$$

Where,

A = Volume of Mohr's salt consumed with the sample solution.

B = Volume of Mohr's salt consumed with the blank solution.

N = Normality of Mohr's salt

V = Volume of the sample taken for the test

Phosphate (Using Ammonium Molybdate):

A) Preparation of calibration standard:

1ml of stock solution (10 PPM) was pipetted in a volumetric flask of capacity 100ml. The volume of this solution was increased to 100ml by the addition of distilled water and 2 ml of Ammonium Molybdate followed by 5 drops of $SnCl_2$ was added to this solution. A blue colour appeared and the calibration standard of 0.1 PPM was ready for the measurement of absorbance. Similar standard solution of 0.2, 0.3, 0.4 PPM concentration were prepared with similar process.

B) Preparation of sample solution:

50ml of sample solution was taken in a volumetric flask with capacity 100ml. 2ml of Ammonium Molybdate followed by 5 drops of $SnCl_2$ was added to this solution. Blue colour appeared and the absorbance of all the standard solution and sample solution were taken at 690nm in a Spectrophotometer. Graph was plotted between Absorbance Vs. Concentration and the concentration of sample solution was noted.

Ammonia (Nessler's Method):

A) Preparation of calibration standard:

4ml of stock solution (10 PPM) was pipetted in a volumetric flask of capacity 100ml. The volume of this solution was increased to 100ml by the addition of distilled water and 1 ml of 10% $ZnSO_4.7H_2O$ followed by 1ml of 10% NaOH was added to this solution. The solution was shaken when white precipitate appeared, it was filtered with the help of filter paper and the filtrate was collected. 1 drop of 50% EDTA and 2 ml of Nessler's reagent (K_2HgI_4) was added to this colourless filtrate and shaken well. Light yellow colour appeared and the calibration standard of 0.4 PPM was ready for the measurement of absorbance. Similar standard solution of 0.2, 0.3, 0.4 PPM concentration were prepared with similar process.

B) Preparation of sample solution:

100ml of sample solution was taken in a volumetric flask with capacity 100ml and the chemicals as used in the preparation of calibration standard were added to it in the same amount and the same process. Light yellow colour appeared and the absorbance of all the standard solution and sample solution were taken at 420nm in a Spectrophotometer. Graph was plotted between Absorbance Vs. Concentration and the concentration of sample solution was noted.

Iron:

A) Preparation of calibration standard:

4ml of stock solution (10 PPM) was pipetted in a volumetric flask of capacity 100ml. 2ml conc. HCl and l ml Hydroxylamine Hydrochloride ($NH_2OH.HCl$) were added to that solution. Again, 10ml Ammonium Acetate Buffer ($NH_4C_2H_3O_2$) and 4ml of Phenanthroline were added which gave orange red colour. The volume of this solution was increased to 100ml by the addition of distilled water and the solution was shaken well. It was then allowed to stand for 15 min. for maximum colour development and the calibration standard of 0.4 PPM was ready for the measurement of absorbance. Similar standard solution of 0.2, 0.3, 0.4 PPM concentration were prepared with similar process.

B) Preparation of sample solution:

50ml of sample solution was taken in a beaker and 2ml conc. HCl and l ml Hydroxylamine Hydrochloride ($NH_2OH.HCl$) were added to this sample solution. Then some glass beads were kept in the flask to avoid bumping and it was heated to boiling. To ensure dissolution of all iron, boiling was continued till the volume of solution reduced to half the original volume. The solution was cooled to room temperature and transferred to 100 ml volumetric flask. Then, 10ml Ammonium

Acetate Buffer ($NH_4C_2H_3O_2$) and 4ml of Phenanthroline were added which gave orange red colour. The volume of this solution was increased to 100ml by the addition of distilled water and the solution was shaken well. It was then allowed to stand for 15 min. for maximum colour development. The absorbance of all the standard solution and sample solution were taken at 510nm in a Spectrophotometer. Graph was plotted between Absorbance Vs. Concentration and the concentration of sample solution was noted.

Chromium (DPC Method):

A) Preparation of calibration standard:

4ml of stock solution (10 PPM) was pipetted in a beaker and several drops of Methyl Orange was added to that solution. Again, Conc. NH_4OH was added until the solution just began to turn yellow and 1:1 H_2SO_4 was added drop wise until the solution was acidic. After this the solution was made approx. 40 ml by the addition of distilled water and several glass beads were added to the beaker containing the solution. It was heated to boiling and 2 drops of $KMnO_4$ was added to give dark red colour. The solution was boiled 2 min. more and 1ml of Sodium Azide (NaN_3) was added to it continuing boiling to fed the red colour (More NaN_3 was added if there was no fading of red colour). When the red colour had faded completely the solution was cooled to room temperature and 5 drops of H_3PO_4 and 5 drops of H_2SO_4 (0.2N) was added to the solution. Finally the solution was transferred to 100ml volumetric flask and its volume was increased to 100ml by the addition of distilled water. 2ml of Diphenylcarbazide was added which gave pink colour and the solution was shaken well. It was then allowed to stand for 10 min. for maximum colour development and the calibration standard of 0.4 PPM was ready for the measurement of absorbance. Similar standard solution of 0.2, 0.3, 0.4 PPM concentration were prepared with similar process.

B) Preparation of sample solution:

50ml of sample solution was taken in a beaker and the chemicals as used in the preparation of calibration standard were added to it in the same amount and the same process. Pink colour appeared and the absorbance of all the standard solution and sample solution were taken at 540nm in a Spectrophotometer. Graph was plotted between Absorbance Vs. Concentration and the concentration of sample solution was noted.

5.5 FISH SAMPLING

For the fish sampling, physical characteristics of Trishuli River around the project area were first recorded by walking along its banks in order to provide an accurate description of the existing habitat, distribution and spawning sites. Fishes were collected with the help of local fishermen. The sampling was done by using Cast nets, Gill nets, Hooks and other locally available fishing implements. The fish specimens caught by local fishermen were also purchased for sampling and all these specimens were preserved in 5% formalin. Local fishermen were interviewed by using structure questionnaire to document their knowledge on distribution, importance, spawning and migratory behavior of the local fish species available in the river.

5.6 PHYTOPLANKTONS AND ZOOPLANKTONS

Phytoplanktons and zooplanktons were collected with the help of plankton net of mesh size 60 μ and standard sieve of 600 μ. Different algal blooms were also collected. These samples were preserved in 5% formalin and brought to the laboratory for identification. Identification of these planktons was done after Encarta (2006).

CHAPTER SIX

RESULTS

6.1 WATER QUALITY AT INTAKE AND POWERHOUSE SITES

The various field observations related to water quality at the proposed intake and powerhouse sites have been tabulated and presented in Table 6.1 below. The calculated values are compared with the standard guideline values for finding variation from the standard.

6.1) Water Quality at Intake and Powerhouse Sites

S. N.	Water Parameters	Units	Observed/Calculated Values		Guideline Values
			Intake Site	Powerhouse Site	
Physical					
1	P^H		8.0	8.5	6.5 - 8.5
2	Turbidity	SDV in cm	76.0	77.0	N/A
3	Temperature	°C	15.0	14.5	N/A
4	Conductivity	us/cm	111.0	305.0	N/A
5	Total Solids	mg/l	163.5	440.3	1000.0
6	TDS	mg/l	74.3	202.5	500.0
7	TSS	mg/l	89.2	237.8	5.0
Chemical					
8	Total alkalinity	mg/l	20.0	40.0	N/A
9	Total Hardness	mg/l	54.0	170.0	500.0
10	Ca Hardness	mg/l	14.42	36.07	100.0
11	Mg Hardness	mg/l	39.58	133.93	30.0
12	Chloride	mg/l	8.52	7.1	250.0
13	Free CO2	mg/l	4.4	4.4	N/A
14	DO	mg/l	8.92	9.73	4.0 – 6.0

S. N.	Water Parameters	Units	Observed/Calculated Values		Guideline Values
			Intake Site	Powerhouse Site	
15	BOD	mg/l	40.6	40.6	5.0
16	COD	mg/l	20.0	16.0	4.0
17	Phosphate	mg/l	0.053	0.072	0.1
18	Ammonia	mg/l	Not detected	Not detected	1.5
19	Iron	mg/l	0.18	0.04	0.3
20	Chromium	mg/l	Not detected	Not detected	0.05

Note: Guideline value as per WHO or USPH Standard
Date of Sampling: February 10-17, 2006

6.2 FISHERY RESOURCES AROUND THE PROJECT AREA

The fishes around the project area were identified and classified after Shrestha (1994).

1) *Tor putitora* (Hamilton-Buchanan), 1822

This migratory species is a game fish of Nepal, locally known as Sahar or Mahaseer (Fig. Plate I-A). Mahaseer belongs to Cyprinidae family and the word "Mahaseer" indicates a big headed fish. This fish is one of the long range migratory species found in the Himalayan Rivers of Nepal and important for food, game and trade. In the large rivers like Koshi, Karnali, Gandaki, Bheri, Seti and Narayani zones, these fishes are as long as 2000 mm and weigh more than 50 kg (Shrestha, 1997). A female Sahar is larger than a male. Generally, these fishes are observed to migrate from lower reaches of river to the head reaches for spawning and the time for spawning is monsoon season i.e. June to September when the river has high volume of water. The spawning ground for Sahar is at the confluence of the rivers or in creeks where the water is well oxygenated and has moderate velocity.

The head length of Sahar is greater than height of body and the snout is long and pointed. The colour of top of the head and dorsal part is olive green and the rest of body is silvery golden. The body is covered with large scales and anal and pelvic fins are yellow with orange red rims. Short barbels are also present and has constricted gas bladder that is advantageous for its migratory nature. Sahar prefer to live in highly oxygenated water, thus it cannot survive in deoxygenated, polluted and silted water. The damming and silting of river water kills the fingerlings and adult fish. The reason for the rapid decline in Sahar population in the rivers of Nepal is silting of river bed, damming, diverting and changing water tables.

2) *Labeo dero* (Hamilton-Buchanan), 1822

This is a mid-migratory fish species locally known as Gardi or Rohu (Fig. Plate I-B) in some places. This fish is found in big rivers of Nepal like Koshi, Karnali, Gandaki, Bheri and Narayani zones. Maximum size attained by this fish is about 45 cm and weigh about 3 kg (Shrestha, 1990). This fish is a local migrant one which moves upstream for spawning during early monsoon. These fishes are found in oxygen rich pools where water is clear and cool.

This fish is characterized by deep groove across snout and covered with pores without any lateral lobe. The maxillary barbells are short and the fins are tinged with red. It is a silvery fish with silver colour on sides and belly. It is also an important food and game fish affected by dams.

3) *Channa orientalis* (Bloch and Schneider), 1801

Channa orientalis belongs to the family Channidae and commonly known as Hile (Fig. Plate I-C) fish in Nepal. Hile fish are resident species or sometimes local migrant which move short distances and go from one water body to another. They are found in stagnant muddy water, swamps, tanks, marshy lands, canals and at the confluence where small rivers join large rivers. These fishes have accessory respiratory organ, thus they can survive for a long period of time without water (Shrestha, 2003). They are observed to breed throughout the year but usually during the early monsoon.

They have dull or muddy colour with yellow to silvery flanks throughout the body. The fins are also dark in colour and base of pectoral fin have red and orange bands. The body is elongated and fairly round in cross section.

4) *Neolissochilus hexagonolepis* (Mc Clelland), 1839

This fish belongs to the family Cyprinidae and locally known as Katle (Fig. Plate I-D) in Nepal. It is characterized by bony dorsal spine, two pairs of barbels and lower lip separated from jaw with horny covering. It is a mid-distant migratory fish whose migration is reported to be limited to few miles only. They ascend to river tributaries during breeding season and are generally observed to breed during the post monsoon season. They attain a maximum size of 600-650 mm and are found within the altitudinal range of 76-784 m. in Gandaki, Karnali, Koshi and Narayani zones (Shrestha, 1994). They are well distributed in deep water pools of rivers, tail water of dams and at the edges of reservoirs where there is plenty of algal components.

The abdomen of the fish is observed to be round with olive green colour on the dorsal side. The body is silvery white below with golden bands above lateral line. The scales are large, thus the name "Katle" evolved. Fins are grey in colour with tubercles on snout and operculum.

5) *Schizothoraichthys progastus* (Mc Clelland), 1839

This fish prefers to live in cold waters of rivers and hill streams of Nepal. Being a cold water fish they are slow to mature. These are mid-migratory fishes known as point-snouted snowtrout or Chuche Asala (Fig. Plate I-E) in Nepali. Asala jump 5 to 10 feet above water level and may live out of water for about 10 minutes. Movement of the snowtrout is limited by oxygen supply and the temperature of the water. River which carry trouts are usually large, turbulent streams with current speed 0.95 m/sec. to 3.67 m/sec (Shrestha, 2003). According to local fisherman, snowtrouts move upstream during post monsoon season for spawning and migrate downstream after spawning where they reside permanently.

This fish has pointed head with tubercles on snout. It has deep gray coloration on the back and distinct white below. Dorsal part of the body is slightly convex. Some yellow spots are observed scattered on the body. It has four barbels and fin tips are dark with forked tail. It is widely distributed in ice-cold water of Karnali, Koshi, Trishuli and Mechi zones.

6) *Barilius barila* (Hamilton-Buchanan), 1822

Barilius belongs to the family Cyprinidae. Locally it is known as Chahale or Faketa (Fig. Plate I-F) and is a resident species but sometimes mid migrant in search of food and spawning. These fishes are well distributed in the rivers and streams of the foothills, Terai and Bhabar tracts. They occupy clear water zones of slow flowing streams. These fishes are known to inhibit underneath of rocks or in gaps made of stones or pebbles. Fishing of Faketa is all the year round, where the trapped fish is cooked fresh or dried in smoke for future use. These minor carps are principal food fishes consumed as food in Nepal.

The abdomen is fairly rounded while the jaws are compressed. Scales are of small to medium size. Barbels may be present or absent. Body colour silvery on sides and belly. There are 11-12 vertical dark bands in the body except in the lateral line. Maximum size recorded for this fish is 125 mm (Shrestha, 1994). It is distributed in most of the hill streams of Nepal.

7) *Barilius barna* (Hamilton-Buchanan), 1822

This is another hill stream fish of Nepal belonging to the family Cyprinidae. They are found in pools and rubbles where the water flow is slow but the movement of water is constant. Locally they are known as Faketa (Fig. Plate II-A) and are migratory species for feeding and breeding purpose. These fishes have colour blotches important for recognition and generally they move in groups known as shoaling.

Body has vertical dark bands which originate from dorsal part and reach behind the lateral line. Barbels are absent and the lateral body is compressed and deep with rounded abdomen. Scales are medium to small and fins spotted with yellow and red (Shrestha, 1981). They are found in Karnali, Koshi, Gandaki, Mahakali, Narayani and other streams of foothills.

8) *Crossocheilus latius* (Hamilton-Buchanan), 1822

This fish is fairly well distributed in water bodies all over the Himalayan rivers and streams. These fishes locally known as "Lodi" (Fig. Plate II-B) are associated permanently or temporarily with the algal blooms or carpets of floating vegetation. So, they are observed to inhabit pools with low flow of water and are the resident species. This is a medium size fish whose eyes are located in the middle of the head in young ones and behind the middle in adults.

The colour of the abdomen is silvery with greenish white tinge along upper side of the body and some black spots. The mouth is placed underneath the snout, which projects more or less. Barbels occur in two pairs, of which lower pairs sometimes absent. The lower lip has a sharp inner edge and is not continuous with the upper lip. These fishes are found in Koshi, Karnali, Trishuli, Mahakali, Gandaki and other Himalayan rivers.

9) *Lepidocephalus guntea* (Hamilton-Buchanan), 1822

This fish belongs to the family Cobitidae and locally known as Ghutum or Lata (Fig. Plate II-C). It is more common in the fresh waters of Terai and Hills but rarely occurs in higher altitudes. Altitudinal range for the distribution of this fish is 76-1372 m. (Shrestha, 1994). This mid-migratory fish is a larvivorous species which is larvicidal during their young stage and change their feeding habits as they grow. This fish resides in fast flowing water with plenty of dissolved oxygen.

The body is elongated, fairly compressed but the back is not elevated. The body colour is directly yellow and a black band extends from the snout to the tail region. Black spots occur on back, caudal and dorsal fins. Barbels are in two pairs; maxillary and rostral.

10) *Schistura beavani* (Gunther), 1868

This is another hill stream fish belonging to the family Balitoridae. Locally this fish is known as Gadela (Fig. Plate II-D) and is a resident species. Gadela is observed to the minimum altitude of 1380 m of fairly fast flowing cold water or turbulent streams with abundant pools and rapids. This fish loves to stay underneath the rocks or gravels.

These fishes have colour blotches important for recognition. General body colour yellowish with 9-10 brown vertical bands just behind head to the base of caudal. The tapering body have dark band on caudal base. Barbels are six and maximum length is up to 75mm.

11) *Puntius sarana* (Hamilton-Buchanan), 1822

Puntius sarana is a resident species belonging to the family Cyprinidae. Locally this fish is known as Maina or Sidhree (Fig. Plate II-E) and is regarded as commercial food fish of Terai, which is sun dried and used as flavouring agent. It is common in streams and rivers of Terai and hills generally in pools and rapids.

The body is elongated and well formed. The colour of the body is silvery on sides and dark on belly without any black patch. Dorsal fins originate almost opposite to the base of the ventral fin and two pairs of barbels are present.

12) *Nemacheilus corica* (Hamilton-Buchanan), 1822

This fish is distributed in the fairly fast flowing cold waters of the Himalayas. They belong to the family Balitorinae and love to reside underneath gravels or rocks. Locally it is known as Gadewula (Fig. Plate II-F) for they are baited with earthworms. These fishes are predatory which are generally carnivorous.

The body is sub-cylindrical and black blotches along the complete length of the body are its characteristic feature. This fish is used for medicinal purpose by the local people.

13) *Botia almorhae* (Gray), 1831

Botia almorhae, locally known as Baghi (Fig. Plate III-A) belongs to the family Cobitidae. This hill stream fish prefer to live under the rocks and in gaps of gravels or cobbles. This too is a resident species which have structural modification to adapt in fast flowing water and spotted appearance to hide itself in the algal water or rocks. This fish remain colourful throughout lifetime and are regarded as pristine rare ornamental species of Himalayan drainage (Shrestha, 2003). The colour of the body is gray on yellowish ground. Body and head is reticulated.

14) *Garra annandalei* (Hora), 1921

Garra annandalei (Fig. Plate III-B) belongs to the family Cyprinidae and is a mid-migrant species. Locally it is known as Buduna and widely distributed in all clear waters of hill streams of Asian-sub continent. They inhabit turbulent stream with abundant pools and rapids generally fed by brooks and hill streams (Shrestha, 1995). These species are associated permanently or temporarily with algal bloom or carpets of floating vegetation. They generally dwell at the bottom of hill streams, thus have elongated or dorsoventrally flattened body.

It has medium size mouth located ventrally and is a plankton feeder. Snout is smooth with small oval ventral disc. The colour of its body is greenish -brown or bluish-green on the upper part and yellowish on the lower. Fins have a yellowish ting, darker along the margins (Beavan, 1990).

15) *Glyptothorax sps*.

This species is locally known as Kabre (Fig. Plate III-D) and belongs to the family Sisoridae. This fish inhabit still or slow moving water and body of this fish is flattened dorsoventrally from dorsal and ventral parts. This mid-migratory fish have structural modifications to move in hill streams. They have special adhesive organ which is used for adhesion to rocks and stones.

The body colour is muddy on dorsal side with many black dots and patches throughout the body and head. Fins tinged with black dots. The mouth is shifted towards the ventral side behind the tip of the snout. These fishes are devoid of thick scales on the ventral surface of body. They are usually found in Koshi, Karnali and Narayani zones.

16) *Aspidoparia jaya* (Hamilton-Buchanan), 1822

Aspidoparia jaya is a common hill stream fish locally known as Choktae (Fig. Plate III-E). This mid-migratory fish grows to the maximum size of 80cm (Shrestha, 1994). They prefer to live in pools and slow flowing water where there is adequate DO.

Body colour is silvery white with small scales. Barbels and lower lip absent. Mouth small and inferior.

The observations along with information collected in the field regarding fish species and their characteristics of Trishuli River are tabulated and presented in Table 6.2.1 below. Fishes were identified after Shrestha (1994) and spawning seasons were known from Andhikhola fish report (2005).

Table 6.2.1 Fish species and their characteristic features of Trishuli River

S. N	Scientific Name	Local Name	Average Length (cm)	Average breadth (cm)	Average Weight (gm)	Spawning Season	Behaviour	Protected Status in NRDB
1.	Tor putitora	Mahaseer	6.8	1.5	3.12	Jun-Sep.	Long migratory	Vulnerable
2.	Labeo dero	Gardi	25.4	6.3	207.39	Mar-Apr	Mid-migratory	-
3.	Channa orientalis	Hile	11.5	2.0	12.12	May-Jun.	Resident	-
4.	Neolissochilus hexagonolepis	Katle	12.5	2.3	16.06	Sep-Oct.	Mid-migratory	Vulnerable
5.	Schizothoraichthys progastus	Asala	24.7	4.3	108.30	Aug-Sep.	Mid-migratory	Vulnerable
6.	Barilius barila	Faketa	10.7	1.9	11.57	Sep-Oct.	Mid-migratory	-
7.	Barilius barna	Faketa	8.1	0.7	3.39	Sep-Oct.	Mid-migratory	-
8.	Crossocheilus latius	Lodi	14.3	2.7	25.72	Apr-May	Resident	-
9.	Lepidocephalus guntea	Ghutum	6.7	0.8	3.39	Sep-Oct.	Mid-migratory	-
10	Schistura beavani	Gadela	5.1	0.7	1.76	Mar-Apr.	Resident	-
11	Puntius sarana	Maina	6.6	1.7	3.14	Sep-Oct.	Resident	-
12	Nemacheilus corica	Gadewula	8.0	1.2	3.64	Feb-Mar.	Resident	-
13	Botia almorhae	Baghi	12.6	2.6	19.61	Apr-May	Resident	-
14	Garra annandalei	Buduna	9.8	1.6	11.32	Sep-Oct.	Mid-migratory	-
15	Glyptothorax sps.	Kabre	9.9	2.8	13.13	May-June	Mid-migratory	-
16	Aspidoparia jaya	Choktae	8.2	1.8	8.03	Mar-Apr.	Mid-migratory	-

The Catch per Unit (CPU) for various sites is depicted in the figures 6.3.1 to 6.3.5. In every station 10 attempts were made and only the successful attempts were recorded.

6.3 AVERAGE CPU AT DIFFERENT SITES

6.3.1 Confluence of Malekhu Khola and Thopal Khola (Station I)

Fishing gear used - Cast Net

No. of fishes caught – 13

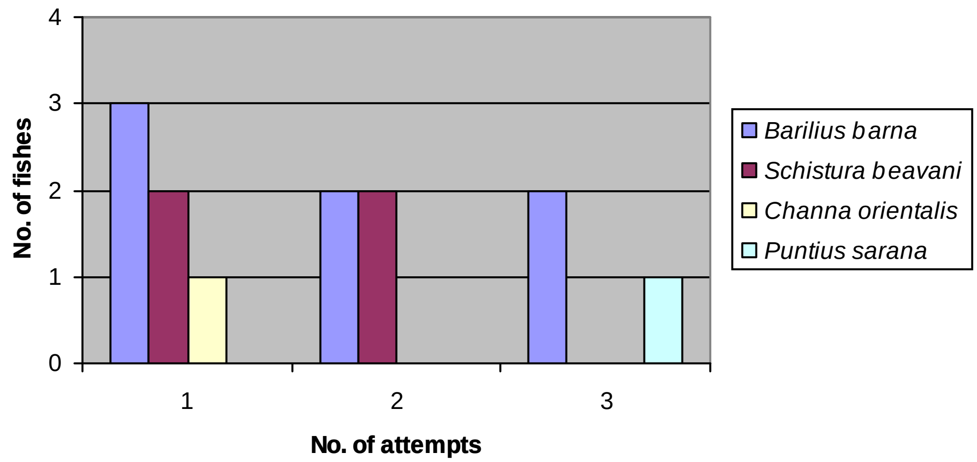


Fig. 6.3.1. CPU at the confluence of Malekhu Khola and Thopal Khola

6.3.2) Confluence of Thopal Khola and Trishuli River (Station II)

Fishing gear used - Cast Net

No. of fishes caught – 10

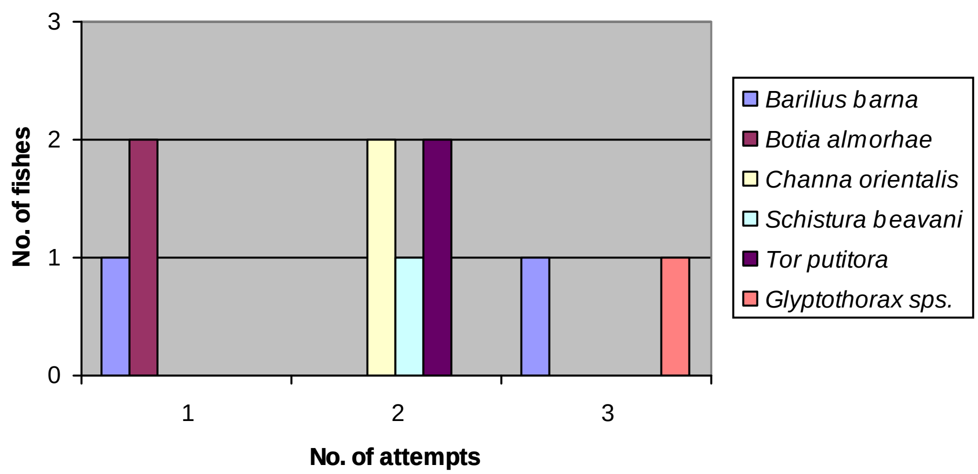


Fig. 6.3.2. CPU at the confluence of Thopal Khola and Trishuli River

6.3.3) Section below Arbastar (Station III)

Fishing gear used - Cast Net

No. of fishes caught – 5

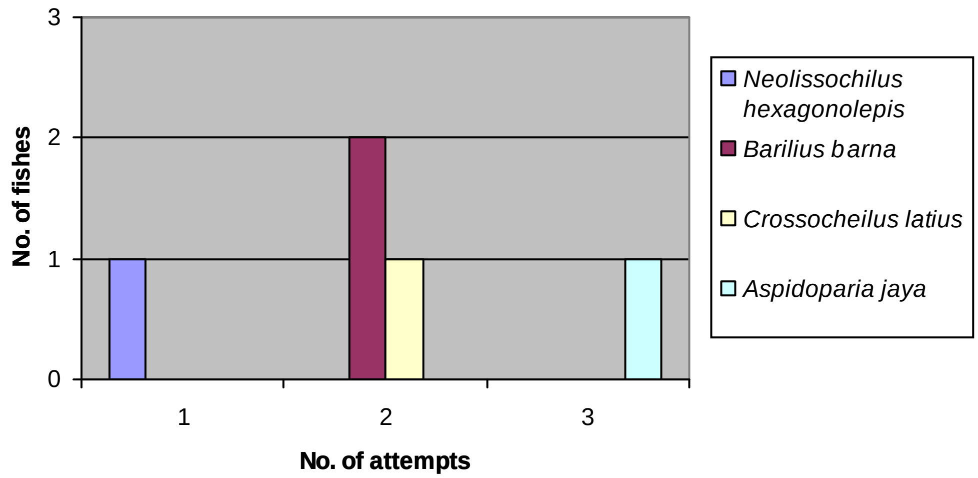


Fig. 6.3.3. CPU at the Section below Arbastar

6.3.4 Section below Nibuwatar (Station IV)

Fishing gear used - Cast Net & Gill net

No. of fishes caught – 8

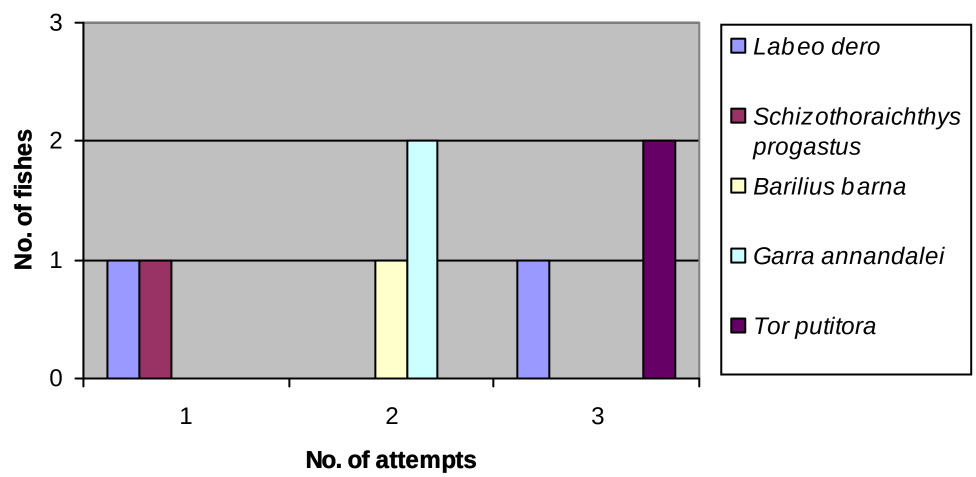


Fig. 6.3.4. CPU at the Section below Nibuwatar

6.3.5 Confluence of Gomati Khola and Trishuli River (Station V)

Fishing gear used - Cast Net & Hooks

No. of fishes caught – 6

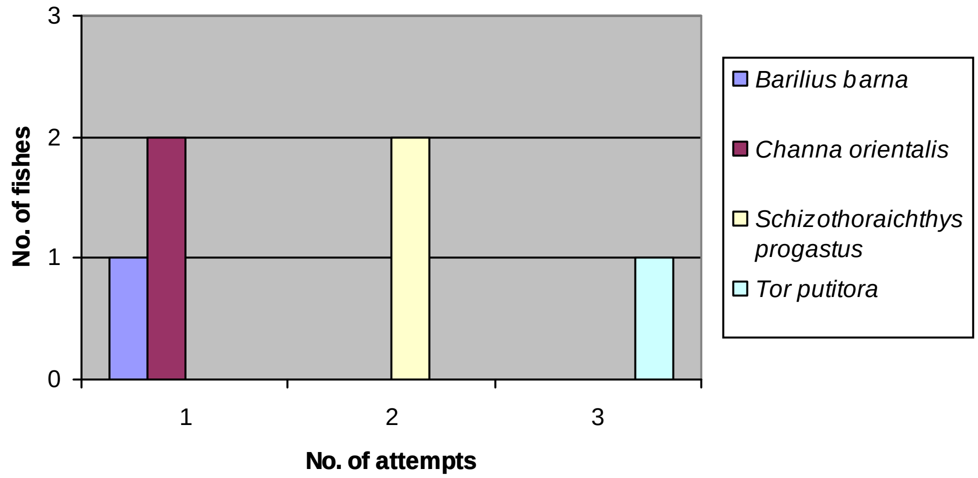


Fig. 6.3.5. CPU at the Confluence of Gomati Khola and Trishuli River

The above figures indicate that population density of fishes are higher at the confluence of the rivers than elsewhere. Local fishermen also report that fishes are easy to catch at the confluence of Malekhu-Trishuli and Thopal Khola and Trishuli River. Construction of dam near these sites can have substantial effect on fish community.

6.4 PHYTOPLANKTONS AND ZOOPLANKTONS

The velocity of Trishuli River is high and is a pollution free river, thus the diversity of phytoplanktons and zooplanktons are quite low as compared to stagnant water. Lab analysis of phytoplanktons sampled with plankton net revealed that *Fragilaria, Navicula, Amphora, Diatoms, Anabaena, Chara, Microspora, Oscillatoria, Spirulina, Vallesneria, Spirogyra* and *Ceratophyllum* were common in Trishuli River. The green algae and filamentous algae were also found. The zooplanktons include Protozoons, *Rotifers, Cladocera, Ostracoda, Crustaceans* and *Copepoda* which are important food for juvenile fish. Among the insects Mayfly, Dragonfly, Caddisfly, Water Bugs, Water Beetles, Mollusca and their larvae were common.

CHAPTER SEVEN

DISCUSSION

7.1 WATER QUALITY AND FISHERIES

Water quality plays significant role for the over all development, spawning and migratory behavior of all fish species. Present analysis of physical, chemical and biological parameters of water from two sections i.e. intake and powerhouse sites indicate that water is suitable for fish development. Change in these water qualities may bring adverse affects on fishery resources of Trishuli River, thus appropriate precautionary measures should be adopted during construction and operation of the project. Water-chemistry changes can be significant for fish. Release of anoxic water from the hypolimnion can cause fish mortality below dams (Bradka & Rehackova, 1964). Some of the water quality parameters analyzed at the project site in Trishuli River are discussed below.

P^H

Desirable range of P^H for fresh water fish is 6.5-9.0 (Shrestha, 2006).When P^H is less than 6.0 fish get diseased and gradually they die. Similarly, above 9.0 is also toxic to fishes. P^H values at the intake and powerhouse sites were observed to be 8.0 and 8.5 respectively which are within the tolerance limit. Change in P^H of water during construction or operation of the project and oil and lubricants from moving machineries are lethal for fishes. P^H less than 6.0 is less productive whereas alkaline water is more productive so fish favour alkaline water in terms of food.

Turbidity

Secchi disc visibility (SDV) of 30-50 cm is desirable for fish (Shrestha, 2006). Transparency has direct influence in determining the illumination of water. Transparency disrupts light penetration thus affect the maturation of fish and biological production. Suspended particles and turbid water cause choking of gills among fishes. Turbidity as measured from the intake and powerhouse sites were 76 cm and 77 cm respectively, which indicate that water is free from undesirable suspended particles. Appropriate mitigation techniques should be followed during the construction of the project so as to decrease the suspended particles in the river and increase transparency.

Temperature

Fish is a cold blooded animal (polikilotherm). Temperature effects spawning, growth, feeding and migration of fish. It also helps in mixing of water. Rise of temperature cause mortalities of cold water fishes such as trouts, but usually increase temperature causes the mortality indirectly acting through change in the oxygen content so destroying the respiratory conditions. Fish can perceive water temperature change which are smaller than 0.1ºC (Laevastu & Hayes, 1984). Every species has its characteristic optimum temperature range and temperature tolerance limits which might change seasonally in a given stock. It is frequently claimed that fish grow larger and older at low temperature and that is due to their lower metabolic rate and lower activity or sometimes to the greater availability of food. Shrestha (1991) stated that most of the cold water fishes of Nepal thrive and spawn in between 12ºC and 20ºC. Water temperature of intake and powerhouse sites was observed to be 15ºC and 14.5ºC respectively. Dam construction may result stratification of water in the reservoir which varies water temperature in different zones. But this effect cannot be taken seriously. Water temperature changes have often been identified as a cause of reduction in native species, particularly as a result of spawning success (Petts, 1984). Cold-water release from high dams of the Colorado River has resulted in a decline in native fish abundance. (Holden & Stalnaker, 1975).

Total Solids

Suspended solids decrease transparency of water thereby disrupting light penetration in deep water. These particles also cause choking of gills among fishes as mentioned earlier. The total amount of dissolved salts in water affects fishes mainly through change in the osmotic pressure and density of water. Many of the freshwater fishes cannot withstand great change in the amounts of dissolved salts and are called stenohaline (Nikolsky, 1963). Similarly dissolved salts also influence food of fishes. Dam construction across the river leads to a considerable accumulation of salts in reservoir which enhance the growth of phytoplankton and zooplankton in the reservoir; this in due course reduces DO. Planktons help in producing camouflaging colorations among fish and act as fish food but their excess growth depletes DO. Total suspended solids of the intake and powerhouse was observed to be 89.2 mg/l and 237.8 mg/l respectively. Similarly, TDS of the same sites was 74.3 mg/l and 202.5 mg/l respectively. This is within the range of SDV. Total dissolved solids and free ions increase conductivity of water. Thus, free ions and total solids should not exceed the tolerance limit during construction and operation stage of the project.

Alkalinity

Alkalinity is better considered as the measure of P^H buffering, so alkalinity neutralizes acid which act as poison in water bodies. Thus, certain level of alkalinity is considered as good for fish management. Alkalinity with 40 mg/l as $CaCO_3$ is considered good for fish (Shrestha, 2006). Alkalinity of the intake site was measured to be 20 mg/l and that of powerhouse was measured to be 40 mg/l. Alkalinity of the river can increase due to dumping of rocks containing alkaline salts and soapy water. Severe rise in alkalinity increase productivity of river system thereby reducing DO and fish becomes diseased.

Total hardness

Researchers have mentioned that hardness is not given much importance for fishery management. Hardness of about 20 mg/l is efficient for fish (Shrestha, 2006). Hardness of water at intake and powerhouse sites was observed to be 54 mg/l and 170 mg/l respectively. Since hardness of water is not given much importance for fishery management, certain change in its concentration during project implementation may not have substantial effect on fisheries.

Chloride

Chloride content of water from intake site was found to be 8.52 mg/l and that from powerhouse site was found to be 7.1 mg/l. There is no detail study about the impact of chloride in fisheries. However, high chloride content is considered to be an indicator of pollution in natural fresh water. Acharya (1998) found negative correlation between chloride content and fish fauna in Thaule Khola.

Free CO_2

CO_2 even in relatively small dose causes death of fishes because CO_2 leads to the reduction of blood's capacity to absorb oxygen. CO_2 up to 15-20 mg/l has no adverse effect on fishes but it is dangerous beyond this level (Sharma & Grover, 1982). CO_2 content of the water of both intake and powerhouse sites were observed to be 4.4 mg/l. Moderate amount of CO_2 in water seem to speed up photosynthesis but high concentration is a key to cultural eutrophication. Damming of water can raise the value of CO_2 in Trishuli River as a result of decomposition of vegetation and respiration of aquatic flora and fauna.

DO

DO is an important parameter for the development, reproduction and migration of fish. DO also provide information about quality of water. DO of less than 1 mg/l is lethal for most fish population (Shrestha, 2006). DO value of 5-7 mg/l is good for fish development (Sharma & Grover, 1982). However, some fish species like *Channa orientalis* can survive in limited value of DO. Lower DO concentration affects upstream migration by reducing swimming ability of migrants. Thus, Do level of >9.5 mg/l is recommended for successful migration (Shrestha, 1997). DO value of water from the intake and powerhouse were observed to be 8.92 and 9.73 mg/l. Siltation of river and thermal pollution reduce DO content of water. Similarly, damming of water also reduces DO value to some extent, thus care should be taken to maintain the DO value during the construction and operation of the project. The over-saturated water with atmospheric gases particularly oxygen and nitrogen spilling from the crest is also not desirable for fisheries. The Yacyreta dam on the Parana river, Argentina generates supersaturated levels of total dissolved gases that can affect the health condition of fish: in 1994, massive fish mortality was observed in a 100 km reach below the dam (Bechara et al., 1996).

BOD and COD

BOD of the intake and powerhouse sites was found to be 40.6 mg/l each. Similarly, COD values were observed to be 20.0 mg/l and 16.0 mg/l respectively from the two sites. BOD is an index of organic pollution in water bodies. High BOD value decrease oxygen concentration and increase CO_2 of particular water body. COD also indicate the amount of organic load in water. Damming of river increase eutrophication in the so formed reservoir thereby adding organic load which is turn increase BOD or COD value. Increase in BOD or COD value is undesirable for fish because they deplete oxygen concentration of water bodies.

Phosphate

Productivity of plant which in turn limits the productivity of fish is greatly influenced by the concentration of phosphate in water bodies. Phosphate concentration of 0.2-0.4 mg/l is considered desirable for fish in flowing water (Sharma & Grover, 1982). Excess nitrates and phosphates cause cultural eutrophication of water bodies which depletes oxygen concentration and increase CO_2 concentration (Miller, 1996). Phosphate content of water from intake and powerhouse was 0.035 mg/l and 0.072 mg/l respectively. Damming and channelization of water can bring runoff of fertilizers and animal wastes which can increase phosphate concentration in Trishuli River after the implementation of project.

Other Parameters

Chromium and ammonia were not detected from the waters of intake and powerhouse sites. Iron values were found to be 0.18 mg/l and 0.04 mg/l respectively from the intake and powerhouse sites. Nikolsky (1963) mentioned that concentration of iron of 0.2 mg/l causes a sharp reduction in the metabolic rate of fishes and slows down their growth; conversely a concentration of 0.1 mg/l was found to stimulate their growth. He also notified that aluminum higher than 0.5 mg/l can be fatal for fishes. The toxic effect of metallic compound leads first to the coagulation of the mucous secretion of the gills and the protoplasm of living cells which disrupt metabolism and respiration among fishes. Operation of constructional equipments and power generators can discard metallic compounds in Trishuli River whose slight concentration is fatal to existing fish population, thus precautionary measures should be implemented during utilization of these heavy machineries. Surface water impact studies may need to address the implications of projects in a transboundary or transnation context. This is particularly important in that the major effects of project are often experienced downstream (Canter, 1996).

7.2 IMPACT OF DAM ON FISHERIES

The proposed project is planned to have about 8 m high gravity dam that is around 120 m long and will have side intake. This gravity dam will run across the entire river forming a reservoir above the dam. Researchers have mentioned Trishuli River as the most diverse ground for cold water fishes. Sharma (1978) reported 13 species, Masuda and Karki

(1979) reported 28 species, Shrestha (1981) reported 12 species, Karna (1993) reported 29 species and Shrestha T.K (1990) reported 34 species of fishes from Trishuli River. The present study revealed 16 species of fishes in an around the proposed project area i.e. from the confluence of Malekhu Khola and Trishuli River to the confluence of Thopal Khola and Trishuli River of about 7 km length. This indicates that Trishuli River has diversity in cold water fishes and many fish species are yet to be explored.

Among these presently identified fish species *Neolissochilus hexagonolepis, Tor putitora* and *Schizothoraichthys progastus* has been quoted vulnerable in the National Red Data Book. All the above mentioned fishes whether they are long distance migratory, mid-migratory or resident species find difficulty for spawning fooding or moving due to barrier effect of dam. Diversion of water for power generation from the reservoir causes high mortality of fry and fingerlings which are hatched in the upstream region of the dam. On passing through the turbine most of the juvenile fishes are either killed or exposed to predators in the canal region. Similarly, passage through spillways may be a direct cause of injury or mortality due to the free fall condition. The mortality rate for juvenile fishes in Francis and Kaplan turbines varies greatly, depending on the properties of the wheel (diameter, speed of rotation, etc), their conditions of operation, the head, and the species and size of the fish concerned. The mortality rate varies from under 5% to over 90% in Francis turbines. On average, it is lower in Kaplan turbines, between 5% and approximately 20%. The difference between the two types of turbine is due to the fact that Francis turbines are generally installed under higher heads (EPRI, 1992). The manner in which energy is dissipated in the spillway can have a determinant effect on fish mortality rates. Experiments have shown that significant damage occurs (with injuries to gills, eyes and internal organs) when the impact velocity of the fish on the water surface in the downstream pool exceeds 16 m/s, whatever its size (Bell & Delacy, 1972).

The natural food of fishes can broadly be classified as Planktons, Nectons, Benthos and Detritus. Analysis showed that there are plenty of phytoplanktons like *Fragilaria, Navicula, Amphora, Diatoms, Anabaena, Chara, Microspora, Oscillatoria, Spirulina, Vallesneria*, etc. and zooplanktons like Protozoons, *Rotifers, Cladocera, Ostracoda, Crustaceans and Copepoda* in the project area enough to support the existing fish community. But after the construction of dam, dewater zone below the dam may be deprived of these planktons and fishes belonging to this area may starve. The cumulative effect of diminished peak discharges, stabilized water levels, reduced current velocities and water temperature eliminated spawning grounds below the dams on the Qiantang and Han rivers, China: six migratory fish and five species favoring torrential habitats declined severely (Zhong, 1996). Similarly, reservoirs that are sufficiently deep are fed with nutrients rich silt and fertilizers which increase the productivity of the reservoir. Though fishes get adequate food materials in this case, they may find difficulty in taking sufficient oxygen due to eutrophication of reservoir.

7.2.1 Impact on Migratory Fishes

Trishuli River harbours some migratory cold water fishes. Among the captured species; *Tor putitora* is long distance migrant, *Labeo dero, Schizothoraichthys progastus, Garra annandalei, Glyptothorax sps., Lepidocephalus guntea, Barilius barila, Aspidoparia jaya, Neolissochilus hexagonolepis* and *Barilius barna* are mid-migratory and the rest of others are resident or local migrant fishes.

The act or process of moving from one region or section to another either between or within the marine water and fresh water by the fish community for the process of spawning, breeding, feeding or other reasons is known as fish migration. Jones and Mayers (1968) and McDowall (1988) proposed some terms to describe fish migration:

1) Diadromous: Truly migratory fishes which migrate between the sea and freshwater. They are futher classified as;
    a) Anadromous: Moving from seas to fresh water for breeding. e.g. Salmon
    b) Catadromous: Moving from fresh water to the sea for breeding. e.g. Eel
    c) Amphidromous: Diadromous fishes where migration from freshwater to the sea or vice versa is not for the purpose of breeding but occurs regularly at some other definite stage of life cycle. e.g. gobies
2) Potadromous: Truly migratory fishes whose migration occurs wholly within freshwater. Their entire lifecycle occurs within freshwater (Northcote, 1998).
3) Oceanodromous: Truly migratory fishes which live and migrate wholly in the sea.

Both Diadromous and Potadromous fishes are observed in Trishuli River.

The concept of obstruction to migration is often associated with the height of the dam. The proposed concrete hydroelectric dam which is about 8m high blocks the entire path of migratory fishes unless and until some mitigative ways or fish passes has not been installed across the dam. According to local fishermen migratory fishes like *Tor putitora, Labeo dero* and *Schizothoraichthys progastus* can jump 2-3 m high to cross the barrier.

Other migratory or resident species cannot jump this much height to reach their destination. Although fishes which migrate towards the downstream region of the dam may have narrow escape from the spillway crest, this is not possible for other migratory one which tries to move towards the upstream region. The construction of a dam on a river blocks or delays upstream or downstream fish migration and thus contribute to the decline and even the extinction of species that depend on longitudinal movements along the stream continuum during certain phases of their life cycle. In Kali Gandaki River 57 species of fish were recorded before dam construction but after dam construction only 20 species of fish were recorded (Pandey, 2004).

7.2.2 Impact on Spawning Ground

Minimum mean monthly flow of Trishuli River was estimated to be 62.02 m^3/s and if 10% of this total volume of water is released downstream the dam according to Hydropower Policy (1992) then the water downstream will be 6.2 m^3/s. Trishuli River stretches more than 100 m in width and if this reduced volume of water is not channelized then dewater zone below the dam up to the tailrace makes difficulty for the survival of existing aquatic life. The suitable water depth for spawning for *Tor putitora* is 2-5 m which is not possible in the dewater zone. This case is similar for other species which need sufficient water depth for spawning

The construction of dam and formation of reservoir not only disturb the migration path but also changes the habitat of existing fish stock. The upstream reservoir formation gives rise to a new environment due to the transformation of lentic environment to lotic environment. The current loving fishes like *Schistura beavani*, *Lepidocephalus guntea* and others are not well adapted to these lotic environment. Diversion of water for power generation from the reservoir reduce the volume of water in the natural stream and there is formation of dewater zone downstream the dam up to the tail race. According to the local fishermen, Salandobhan, riffles below Nibuwatar and area around the confluence of Gomati Khola and Trishuli River are famous spawning grounds for migratory fishes like *Tor putitora*. Small pools, rubbles and creeks along the banks of river are good nesting places for most of the fresh water fishes like *Barilius sps., Neolissochilus hexagonolepis* and *Crossocheilus latius*. Reduction in water level especially during dry season deteriorates their breeding and nesting habitats.

Similarly, water table rises sinking all fish habitats and spawning grounds above dam below Arbastar. The pools and creeks around the dam area are also considered as hatching grounds for mid-migratory fishes like *Barilius sps*., Fishes which are adapted to fast flowing current find difficult to maintain themselves in slow or still waters due to dam construction. The opportunity for the sperm and eggs to contact each other is considerably longer in stagnant water than in running water and chances of fertilization reduces. Spawning in insufficient velocity leads clumping of eggs which increase mortality from respiratory stress, fungus growth and predation.

Fish species preferring running water, riffles, creeks, holes with rocks and stones substrate like *Tor putitora, Garra annandalei, Neolissochilus hexagonolepis* and *Glyptothorax sps.* will reduce or disappear and other species loving lentic environment will appear in this zone. Freshwater fishes are subdivided into rhophilic species; adapted to living in a current e.g. many species of *Schizothoraichthys, Noemacheilus*, etc. and limnophilic species; adapted to living in still water e.g. Carps, Loach, etc. Shrestha (2003) mentioned that before the establishment of power station at Panauti, there were almost all representative of current loving hill stream fishes like *Tor tor, Neolissochilus hexagonolepis, Glyptothorax pectinopterus, Garra gotyla* and others. But after the erection of dam four species disappeared from the dam affected part of river. In these parts, hardy fishes such as *Channa punctatus, Heteropneustes fossilis* is taking place. Thus rhophilic species declines and limnophilic species increases in the reservoir area as seen in Panauti Rosi River.

7.2.3 Impact on Fishermen Group

The questionnaire survey indicated that majority of the fishermen group in this area are Sahani people who are permanent resident of Terai region. They visit this area especially during spring season for fishing and use cast net to catch fish. Some of these fishermen have been fishing in Trishuli River for more than 20 years ago as their main occupation. According to them more than 100 families from Terai region depend on fish catching from Trishuli River during spring season. Sahani fishermen catch 10-15 kg of fish in a month and sell them at the rate of Rs. 150 per kg. These experienced fishermen group reported other species of fishes such as *Clupisoma garua* (Jalkapoor), *Anguilla bengalensis* (Rajbam), *Bagarius bagarius* (Gonch), *Aspidoparia morar* (Karangi), *Labeo angra* (Thind), *Garra gotyla* (Lohari), *Puntius sps*. (Sidre), *Barilius shacra* (Chepuwa), *Channa punctatus* (Bhoti) and many others from Trishuli River accept those sampled. Among these fishes *Clupisoma garua* and *Anguiullia bengalensis* are the highly migratory fishes. According to these fishermen, fishes of the river have both food and economic values for them.

The project will have no substantial effect on migratory fishermen for they can move to other regions if the impact is serious. Most of the local fishermen, now take agriculture as their main occupation and they don't have clear vision about the effects of dam on fisheries. They have positive attitude towards the project and wanted the project to be implemented soon. But some of these local fishermen expected employment opportunity and irrigation facilities from the forth coming project.

7.3 MIGRATION OBSTACLES AND MITIGATION MEASURES

Fishways, most commonly referred to as fish ladders but also known as fish passes, are structures placed on or around man-made barriers such as dams and weirs to assist the natural migration of migratory fishes. Most fishways enable fish to pass around the barrier by swimming and leaping up a series of relatively low steps into the waters on the other side. The velocity of water falling over the steps has to be great enough to attract the fish to the ladder, but it cannot be so great as to wash fish back downstream or to exhaust them to the point where they cannot continue their journey upriver.

Written reports of rough fishways date to 17th Century in France where bundles of branches were used to create steps in steep channels to bypass obstructions. In 1852–54, the Ballisodare Fish Pass was constructed in County Sligo, Ireland, to draw salmon into a river that previously did not support fishery (Weikipedia, 2006). Some of the successful fish ladders or fish passes that has been designed to mitigate the obstacles for migratory fishes has been discussed below:

A pool and weir is one of the oldest styles of fish ladders. It uses a series of small dams and pools of regular length to create a long, sloping channel for fish to travel around the obstruction. Effectively, the channel acts as a fixed lock to gradually step down the water level; to head upstream, fish must jump over from box to box in the ladder.

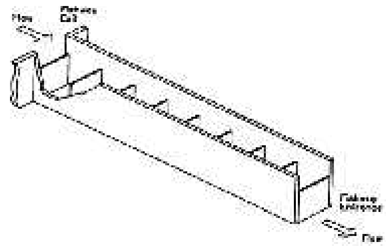


Figure 7.1: Pool and weir fish ladder

A vertical slot fish passage is similar to a pool and weir system except that each "dam" has a narrow slot in it near the channel wall. This allows fish to swim upstream without having to leap over an obstacle. Vertical slot fish passages also tend to handle reasonably well seasonal fluctuation in water levels on either side of the barrier.

A Denil fishway (Fig. Plate V-E) uses a series of symmetrical close-spaced baffles in a channel to redirect the flow of water, allowing fish to swim around the barrier. Denil fishways need not have resting areas, although pools can be included in one to provide a resting area or to help reduce the velocity of the flow. Such fishways can be built with switchbacks to minimize the space needed for their construction.

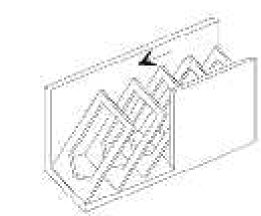


Figure 7.2: Denil fishway

Another method to help fish cross the dam is to put in a fish lift. The water currents direct the fish into a swimming pool size bucket that is on a big elevator. This bucket is raised up to the top of the dam and the fish are released into a flume. The flume leads out to the water above the dam. This method is applicable only for the upstream migration of fish.

John Day Dam (Fig. Plate V-B) is a hydroelectric dam spanning the Columbia River in the northwestern United States whose height is 56 m. The dam features a navigation lock plus fish ladders on both sides. This is one of the most successful fish ladder. Similarly, On the Massachusetts, a fish elevator lifts up to 500 fish at a time to 15.85 m to clear the Holyoke Dam. In its first year of operation, 1955, the Holyoke fish elevator carried 4,899 shad over the dam; by 2004, the typical annual number of fish lifted had risen to more than 500,000. The construction of the fish ladder and the eel ladder on Saint-Ours Dam, Canada was finished in the spring of 2001. The fish ladder and the eel ladder are operational since June 2001. Since the fish ladder has been opened, about fifteen different species have used it (dams.org, 2006).

7.4 IMPACT ANALYSIS OF THEP ON FISHERIES

Impact analysis of a proposed development work will evaluate the possible positive and negative effects of that development work on the natural and social environment. Here impact analysis is focused on fisheries and includes assessment of long- and short-term impacts on fish community due to the implementation of hydroelectric project on Trishuli River.

7.4.1 Beneficial Impacts

Construction Stage

i) Increase in food supply to some extent

Channelization of water can bring runoff of fertilizers and animal wastes which can increase phosphate concentration thereby increasing productivity of water. Similarly, waste food and other nutrients supplied by workers can increase food supply to some extent.

Operational Stage

i) Increase in the number of limnophilic fishes

Fishes which love lotic environment find good nesting and breeding places after the construction of dam across the fast flowing river. Carps and Loach prefer lotic environment, thus their number increases.

ii) Prevention of illegal fishing near the project area

Illegal fishing such as dynamiting, poisoning can be prevented around the project area because it is the duty of the project authority to stop these activities. This is of great advantage to fish community.

7.4.2 Adverse Impacts

Construction Stage

i) Siltation of river

Soft clay and silty soil is excavated by labor and hard gravel and mixed soil by the machine. The total materials extracted during the construction of the main canal will be disposed off at the spoil bank which will be washed by the rain water. This causes siltation of clear water and fishes will be affected due to chocking of gills and low light in deep waters.

ii) Change in water quality

Water quality will deviate from its normal value when the river will be laden with excess physical and chemical loads during construction stage. This change in water parameters is undesirable for the existing fish community.

iii) Noise pollution due to constructional activities

Of the total earthwork about 70% will be completed through machine. The project will also establish a work camp at the farmland to store construction equipment. This produces unwanted noise disturbing the fishes.

Operational Stage

i) Barrier effect to migratory fishes

The proposed concrete hydroelectric dam which is about 8m high blocks the entire path of migratory fishes unless and until some mitigative ways or fish passes has not been installed across the dam. This causes severe decline of migratory species in Trishuli River

ii) Siltation of the dam

During monsoon period water of Trishuli River carries huge amount of silt and sediment which in due course will be deposited in the dam system thereby increasing algal blooms and reducing DO of reservoir water. Reduced DO is lethal for fresh water fishes.

iii) Formation of dewater zone

Minimum mean monthly flow of Trishuli River was estimated to be 62.02 m^3/s and if 10% of this total volume of water is released downstream the dam according to Hydropower Policy (1992) then the water downstream will be 6.2 m^3/s. This reduced volume of water below the dam up to the tailrace makes difficulty for the survival of existing aquatic life in the dewater zone.

iv) Increase in mortality rate of fishes

On passing through the turbine most of the juvenile fishes are either killed or exposed to predators in the canal region. Similarly, passage through spillways may be a direct cause of injury or mortality due to the free fall condition.

v) Decrease in the number of current loving fishes

The current loving fishes like *Schistura beavani*, *Lepidocephalus guntea* and others are not well adapted to the lotic environment. Construction of dam and formation of reservoir creates lotic environment to some extent at the intake site.

vi) Clumping of eggs

The opportunity for the sperm and eggs to contact each other is considerably longer in stagnant water than in running water and chances of fertilization reduces. Spawning in insufficient velocity leads clumping of eggs which increase mortality from respiratory stress, fungus growth and predation.

The summary impact matrix of the Proposed III Trishuli Hydropower Project on fisheries is presented below in Table 7.1.

7.1 Summary Impact Matrix of III Trishuli Hydroelectric Project on Fisheries

Activity	Likely Impacts	Environmental Impacts				Environmental Measures	Responsibility
		Nature	Magnitude	Extent	Duration		
	Beneficial Impacts					**Augmentation Measures**	
Construction Stage	Increase in food supply to some extent	ID	L	SS	ST	Add nutrients as much as possible to prevent fish from starvation	Project
Operational Stage	Increase in the number of limnophilic fishes	D	M	SS	LT	Water flow should be maintained so that there is no reduction of rhophilic species	Project
	Prevention of illegal fishing near the project area	D	M	SS	LT	Strict supervision should be made for illegal fishing	Project
	Adverse Impacts					**Mitigation Measures**	
Construction Stage	Siltation of river downstream	D	H	SS	ST	Soil should not be disposed in the river banks	Project
	Change in water quality	D	M	SS	ST	Water quality should be monitored time to time	Project
	Noise pollution due to constructional activities	I	L	SS	ST	Equipments should be in condition and less noisy	Project
Operational Stage	Barrier effect to migratory fishes	D	H	SS	LT	Fish Ladder or passes should be constructed	Project

Activity	Likely Impacts	Environmental Impacts				Environmental Measures	Responsibility
		Nature	Magnitude	Extent	Duration		
	Beneficial Impacts					**Augmentation Measures**	
	Siltation of the reservoir	D	M	M	LT	Two tire gate should be constructed	Project
	Formation of dewater zone	D	M	SS	LT	More than10% of minimum discharge should be released downstream the dam	Project
	Increase in mortality rate of fishes	D	L	SS	LT	Netting can be done so as to prevent fish pass through turbines	Project
	Decrease in the number of current loving fishes	D	L	SS	LT	Fish passes should be effective	Project
	Clumping of eggs	I	M	SS	LT	Water flow from the dam should be ensured	Project

Note: D = Direct, ID = Indirect, H = High, M = Medium, L = Low, SS = Site-Specific, LT = Long-term, ST = Short-term

CHAPTER EIGHT

CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSION

Hydroelectric projects are the national assets of a country, as far as the economy is concerned. Power is a vital infrastructural input for economic and social growth of a country. Beside this, hydropower is a proven renewable resource of electrical energy. This is the cheapest; the cleanest and environment friendly source of energy a country can tap, if implemented properly. Hydropower which is termed as "white gold" can play a vital role for a developing country like Nepal. The National Water Plan (2002-2027) estimates that the maximum domestic demand for power by 2027 will be less than 7,000 MW. Even under a high growth, this scenario is only about 17% of the economically feasible potential i.e. 42,000 MW. This indicates that Nepal will have substantial surplus potential for foreseeable future, and in theory the surplus could be exported to neighboring countries, particularly to India and Bangladesh where energy shortages exist.

Despite of all these benefits and importance, the environmental constraints arising as a result of hydroelectric projects cannot be overwhelmed in this 21st century where the whole world is taking pace towards eco-friendly sustainable development. In Nepal, the experience in the construction, operation and maintenance of dams is still in its infancy. Environmental concerns of hydropower are related to development and production stages rather than consumption. The severity of these concerns depends on the size, type and location of hydropower projects- the bigger the project, the greater the environmental impacts (ADB/ICIMOD, 2006). Among these various environmental effects which evolve as a result of the implementation of hydroelectric project, the impacts on the life cycle of ichthyofauna are one of them. The construction of dams to divert water to the powerhouse causes serious effect on fisheries. The existing dams are deterrents to fish migration. They are altering the magnitude, chronology, quality of stream flows below them and affect fish stock by reducing the available space, size and quality of spawning ground.

Fish populations are highly dependent upon the characteristics of the aquatic habitat which supports all their biological functions. This dependence is most marked in migratory fish which require different environments for the main phases of their life cycle which are reproduction,

production of juveniles, growth and sexual maturation. The species has to move from one environment to another in order to survive. The building of a dam generally has a major impact on fish populations. Migrations and other fish movements can be stopped or delayed. The quality, quantity and accessibility of their habitat, which plays an important role in population sustainability, can be affected. Fish can suffer major damage during their transit through hydraulic turbines or over spillways. Changes in discharge regime or water quality can also have indirect effects upon fish species. Increased upstream and downstream predation on migratory fish is also linked to dams, fish being delayed and concentrated due to the presence of the dam and the habitat becoming more favorable to certain predatory species.

In Trishuli River, construction of about 8 m high gravity dam across the river severely impede the upstream and downstream migration of fish population unless a fish ladder, fish lift or other fish passes are installed. Migratory fishes like *Tor putitora, Labeo dero, Schizothoraichthys progastus* and others cannot cross this 8 m high gravity dam which declines their natural population. Finally some of the long distance migratory species like *Tor putitora* may soon be exterminated from the river. Fish passing through hydraulic turbines are subject to various forms of stress and likely to cause high mortality which is due to shocks from moving or stationary parts of the turbine, sudden acceleration or deceleration, very sudden variations in pressure and cavitations. Since the turbine used in the current project is Kaplan type the mortality rate may be low but it cannot be isolated. Similarly, passage through spillways may be a direct cause of injury or mortality which is due to shearing effects, abrasion against spillway surfaces, turbulence in the stilling basin at the base of the dam, sudden variations in velocity and pressure as the fish hits the water, physical impact against energy dissipators.

Dam construction can dramatically affect migratory fish habitat. The consequence of river impoundment is the transformation of lotic environment to lentic habitats. Independent to free passage problems, species which spawn in relatively fast flowing reaches can be eliminated. The reduced flow of water 62.02 m^3/s to 6.2 m^3/s downstream of the dam structure would decreases the spawning ground and availability of food supply. This can lead to changes in species composition with loss of obligate floodplain spawners. In addition to problems relating to fish passage at obstacles, there are indirect effects of dams which may prove of major significance such as changes in flow, water quality, the increase in predation and drastic changes to the habitat upstream or downstream. These changes in the water quality and habitat hamper the existing fish resources of the natural stream. The release of 10% of the minimum mean monthly flow i.e. 6.2 m^3/s water can augment to reduce such problems in the dewater zone to some extent however the habitat cannot be restored to its original state. Channelization of water and depositing gravels to create pools to increase spawning habitat can be effective in getting optimum result. Thus appropriate precautionary measures should be adopted during construction and operation of the project so that there is minimum change in their habitat.

Water storage reservoirs thus created at a very high cost are national assets of great importance. But certain unwelcome situations arising during the construction and operation of the reservoir have interactive, negative influences on ecology and environment. These unwelcome conditions are often difficult to judge to find their extent and rapidity and finally to evaluate the ultimate outcome of associated activities right at the beginning, however they have long term impacts which cannot be eliminated completely.

8.2 RECOMMENDATIONS

Impacts on fish dynamics due to the construction of dams across natural streams are severe in Nepal and need urgent attention. Some recommendations felt necessary for the effective mitigation of these impacts and management of fisheries are:

- Fish passages like pool-type fish passes, Denil fish passes, nature-like bypass channels, fish lifts or locks, collection and transportation facilities should be provided for migratory fish species to cross the obstacles created by dams. Only few special designs have been developed in Europe, Japan, New Zealand and Australia for catadromous species, namely for eels. These practices should be introduced in Nepalese rivers as well with suitable modifications.
- The critical point in upstream fish passage design is the location of the fish pass entrance and the attraction flow, which must take into account river discharge during the migration period and the behavior of the target species in relation to the flow pattern at the base of the dam. Some sites may require several entrances and fish passes.
- The most frequent causes of fish pass failure include lack of attraction flow, unsuitable location of the entrance, inadequate maintenance, hydraulic conditions (flow patterns, velocities, turbulence and aeration levels) in the fish pass not adapted to the target species. Thus appropriate attention should be given in the design and maintenance of fish pass.

- Effectiveness of fish pass may be measured through inspections and checks: visual inspection, trapping, video checks. Monitoring of fish passage facilities to assess effectiveness is important not only for determining site-specific performance but also for evaluating potential applications to other sites.
- Water quality plays significant role for the overall development, spawning and migratory behavior of all fish species. Change in any physical or chemical parameters of water can be terminating factor and sometimes lethal for fishes. Thus appropriate precautionary measures should be adopted during construction and operation of the project.
- Hydropower policy (1992) instructs for the release of 10% of water downstream the dam. This 10% of water in Trishuli River is about $6.2m^3/s$ during dry season and can avoid in the formation of complete dewater zone downstream the dam and degradation of fish habitats to some extent. Thus, post monitoring of the project should be done so that desired quantity of water is released in the river during extreme dry season as well.
- Establishment of fish hatchery and fish research centre near the dam site can prevent degradation or extinction of fish species due to human development activities. Similarly, depositing gravels to create pools to increase spawning habitat, habitat enhancement by tree plantation and release of flushing discharge in the dewater zone can help certain fish species from extinction from the project area.

REFERENCES

Acharya, G.P. 1998. A study on the effect of physico-chemcial parameters on the fish fauna in the Thaule Khola. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

ADB. 2004. *Country Environment Analyses for Nepal*. Asian Development Bank, Kathmandu.

APHA. 1998. *Standard methods for the examination of water and wastewater, including bottom sediments and sewage. 20th Ed.* Clesceri L.S., Arnold E., Greenberg, Andrew D. Eaton (eds.) New York.

Asian Development Bank/ICIMOD. 2006. *Environment Assessment of Nepal: Emerging Issues and Challenges*. Kathmandu.

Bajracharya, B. 2001. Fish and Fishery resources of the Bhotekoshi and Sunkoshi River. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Beavan, R. 1990. Handbook of The Fresh Water Fishes of India. Narendra Publishing House, Delhi.

Beaven, R. 1877. Handbook of freshwater fishes. London: 125-135 pp.

Bechara, J.A., Domitrovic, H.A., Quintana, C.F., Roux, J.P., Jacobo, W.R. & Gavilan, G. 1996. *The effect of gas supersaturaion on fish health below Yacyreta dam (Parana River, Argentina)*. A5-A12.

Bell, M.C. & Delacy, A.C. 1972. *A Compendium on the Survival of Fish Passing through Spillwasys and Conduits*. Report Fish. Eng. Res. Prog., U.S. Army Corps of Eng., North Pacific Div., Portland, Oregon, USA.

BPC, 2005. *Status of fish in Andhikhola, Report on Fisheries.* Butwal Power Company Ltd. Kathmandu.

Bradka, J. & Rehackova,V. 1964. *Mass Destruction of Fish in the Slapy Reservoir in Winter 1962-63*, Vodni Hospodarstivi, Vol. 14: 451-452.

Canter, L.W. 1996. Environmental Impact Assessment, Second Edition. MacGraw-Hill, Inc.

Chaudhary, B.R.. 1999. Fish biodiversity and fishery resources of Budhikhola, a branch of the Karnali River. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Dalal-Clayton, Barry. "Environmental Impact Assessment." *Microsoft® Encarta®* 2006 [CD]. Microsoft Corporation, 2005.

DHM. 1964-1995. *Hydrological Records of Nepal. Stream flow summary (7 volumes).* GoN Ministry of Water Resources and Department of Hydrology and Meteorology, Kathmandu.

EPC. 1993. Nepal Environmental Policy and Action Plan. Environment Protection Council, Kathmandu.

EPRI. 1992. Fish *Entrainment and Turbine Mortality Review and Guidelines.* Report Stone and Webster Engineering Corporation, Boston, Massachussetts, USA.

GoN. 1979. *Fish and Fisheries of the Trishuli River. A report on the survey of the Trishuli River conducted in 1979*. Fisheries Development Section.

GoN. 1988-02. National Conservation Strategy, 1988, Water Resources Strategy, 2002 and Biodiversity Strategy, 2002. Government of Nepal.

GoN. 1993. National EIA Guidelines. Nepal Gazette (Rajpatra), Volume 43, Number 5, Kathmandu.

GoN/MOPE. 1997. Environment Protection Act 1997 and Environment Protection Rules 1997.Ministry of Population and Environment (MOPE) (Now-Ministry of Environment, Science and Technology), Kathmandu.

Gunther S. 1973. Fresh Water Fishes of the World, Vol. I & II. T.F.H Publications.

Gunther, A. 1861. *List of cold-blooded vertebrates collected by B.H Hodgson in Nepal. Proc. Zoo. Soc*. London: 213-227 pp.

Gurung, S.B. 2000. Impact of Modikhola Hydrolectric Project in Parbat district. Dissertation for the Masters Degree in Geography, Tribhuvan University, Kirtipur.

Hamilton, F.B. 1822. *An account of the fishes found in the River Ganges and its branches*, Vol. VII, Edinburg. 450 pp.

Holden, P.B. & Stalnaker, C.B. 1975. *Distibution and Abundance of Mainstream Fishes of the Middle and Upper Colorado River Basins, 1967-1973 in Transactions of the American Fisheries Society*, Vol. 104: 217-231.

Hora, S.L. 1937. Distribution of Himalayan fishes and its bearing on certain palaecogeographical problems, Rec. Ind. Mus. 39 (3): 251-259 pp.

IUCN. 1996. EIA Training Manual for Professionals and Managers. Asian Regional Environmental Assessment Programme, IUCN Nepal.

Jayaram, K.C. 1999. The Fresh Water Fishes of Indian Region. Narendra Publishing House, Delhi, India, 551 pp.

Jayaram, K.C. 1999. *The freshwater fishes of Indian region.* 2nd edition. Narendra publishing House, Delhi, India.

Jones, H.F.R & Mayers. 1968. Fish Migration. Edward Arnold Publication Ltd., London.

Joshi, P.L. 1988. Studies on fishery resources of Sunkoshi River with particular reference to dam and its impact on fishery. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Karna, B.K. 1993. A study on the fishery ecology of the Trishuli River. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Khadka, A. 1996. Study on the effect of physico-chemical parameters on the distribution of some benthic macro invertebrates and fishes in river Monohara. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Laevastu, T. & Hayes L.M. 1984. Fisheries Oceanography and Ecology. Fishing News Books Ltd.

Manandhar, S. 1994. A study on the effect of physico-chemical parameters on the fish fauna in the Indrawati River. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

McDowall, R.M. 1988. Diadromy in Fishes. Migration Between freshwater and Marine Environments. Timber Press Publishers. Portland, Oregon.

Miller, G.T. 1996. Living in the Environment. Principles, connections and solutions (9th Edt.). Wadsworth Publishing Company. 484pp.

MOLD. 1999. Local Self-Governance Act, 1999 and Local Self-Governance Regulation, 2000. Ministry of Local Development, Singadarbar, Kathmandu.

MOPE. 1997. Environment Protection Act, 1997 and Environment Protection Rules,1997.Ministry of Population and Environment (MOPE) (Now-Ministry of Environment, Science and Technology), Singhadarbar, Kathmandu.

MOPE. 1998. Environmental Planning Guidelines. Ministry of Population and Environment (MOPE) (Now-Ministry of Environment, Science and Technology), Singhadarbar, Kathmandu.

MOWR. 1992. Hydropower Development Policy, 1992. Ministry of Water Resources, Kathmandu.

MOWR. 1992. Water Resources Act, 1992 and Water Resources Rules, 1993. Ministry of Water Resources, Singhadarbar, Kathmandu.

MOWR. 1999. Aquatic Animals Protection Act, 1999. Ministry of Water Resources, Singhadarbar, Kathmandu.

National Water Plan (2002-2027). 2004. World Commission on Dams (WCD), London.

NEA. 1992. Electricity Act, 1992 and Electricity Rules, 1993. Nepal Electricity Authority, Kathmandu.

NEA. 2003. Nepal Electricity Authority: A year in review – FY 2002/2003. Nepal Electricity Authority, Kathmandu.

Nikolsky, G.V. 1963. The Ecology of Fishes. Academic Press London & New York.

Northcote, T.G. 1998. Migratory Behavior of Fish and its Significance to Movement through Riverine Fish Passage Facilities. Blackwell Science Ltd. Publisher, Oxford, U.K.

NPC, 1980. The Sixth Plan (1980-85). HMG/National Planning Commission, Kathmandu.

NPC. 1980-2007. The Sixth Plan (1980-85, The Seventh Plan (1985-90), The Eighth Plan (1992-97), The Ninth Plan (1997-02) and Tenth Plan (2002-07). GoN/ National Planning Commission, Kathmandu.

Pandey, L.H. 2004. Study on Fish and Fisheries Resource of Kali Gandaki River with Particular Reference to Impact of Dam. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Paudel, N. 1996. Hydroelectricity development in Nepal. Dissertation for the Masters Degree, Tribhuvan University, Kirtipur.

Petts, G.E. 1984. Impounded Rivers, Chichester, U.K. John Wiley & Sons Ltd. Publishers, 326pp.

Pokharel, B.M. 1998. The study of hydroelectricity in Nepal: a case study of socioeconomic impact of Jhimruk Hydro Project, Pyuthan. Dissertation for the Masters Degree, Tribhuvan University, Kirtipur.

Robinson, N.A. (ed.). 1993. Agenda 21, Earth’s Action Plan. IUCN Environmental Policy and Law Paper No. 27, Oceana Publications.

Sah, S.P. 1995. Study on the biodiversity of the fishes of Trishuli River with reference to the ecological change. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Santoshi Hydropower Company P.Ltd. 2006. *Third Trishuli Hydroelecrtic Project, Feasibility Study. Infrastructure and Management Associates (IMA) P.Ltd.* Kathmandu, Nepal.

Sharma, C.K. 1978. Natural Resources of Nepal. Published by Mrs. Sangeeta Sharma, 23/281 Bishalnagar, Kathmandu, Nepal.

Sharma, C.K. 1985. Water and Energy Resources of the Himalayan Block. Published by Mrs. Sangeeta Sharma, 23/281 Bishalnagar, Kathmandu, Nepal.

Sharma, N. 1978. Fish conservation in Sunkoshi and Trishuli River. Dissertation for the Masters Degree in Zoology, Tribhuvan University, Kirtipur.

Sharma, U. & Grover, S.P. 1982. An Introduction to Indian Fisheries.

Shrestha, J. 1981. Fishes of Nepal. Curriculum Development Center, T.U, Kathmandu.

Shrestha, J. 1994. Fishes, Fishing Implements & Methods of Nepal. Published by Smt. M.D. Gupta, Lalitpur Colony, Lashkhar (Gwalior), India.

Shrestha, J. 1995. *Enumeration of fishes of Nepal. Technical publication no. 10. Euro consults Arnhen.* The Netherlands, HMG/Nepal. Department of National Parks and Wildlife Conservation.

Shrestha, J. 1998. *Aquatic Habitat and Natural Water Fish and Fisheries in Nepal. Environmental Assessment Background Training Paper*, ADB TA-2613-Nep, NEA-ED, Kathmandu, Nepal, 28 pp.

Shrestha, J. 2006. Hydropower Developments and Fishery Issues (Unpublished)

Shrestha, T.K. 1990. Resource Ecology of the Himalayan Water, a study of ecology, biology and management strategy of fresh waters. Curriculum Development Center, T.U, Kathmandu.

Shrestha, T.K. 1995. Fish catching in the Himalayan water of Nepal. Published by Mrs. Bimala Shrestha, Kathmandu.

Shrestha, T.K. 1997. The Mahseer, in the rivers of Nepal disrupted by dams and ranching strategies. Published by Mrs. Bimala Shrestha, Kathmandu.

Shrestha, T.K. 2003. Wildlife of Nepal (II Ed.), a study of renewable resources of Nepal Himalayas. Published by Mrs. Bimala Shrestha, Kathmandu.

Thapa B.B and Pradhan B.B. 1995. Water Resources Development in Nepalese Perspective. Konark Publication Pvt. Ltd.

Trivedi, R.K. and Goel, P.K. 1986. Chemical and biological methods for water pollution studies. Environmental Publication, Karad.

Uprety, B.K. 2003. Environmental Impact Assessment, Process and Practice. Published by Mrs. Uttara Uprety, Koteshwor, Kathmandu.

WEC. 1998. *Energy in Nepal, 17th WEC Congress. World Energy Council, Nepal National Committee, Huston, September 13 – 18.*

WECS. 1993. Water Resource EIA Guidelines. Water and Energy Commission Secretariat, Kathmandu.

World Bank. 1991. Environmental Source Book. World Bank, Washington D.C.

Yamanaka, H. and Iwata, S. 1982. *'River Terrace along the Middle Kali Gandaki and Marsyandi Khola, Central Nepal'*, Journal Nepal Geological Society, Vol. 2, Special Issue, pp. 99-111.

Zong, Y. & Power, G. 1996. Environmental impacts of hydroelectric projects on fish resources in China, in Regulated Rivers: Research and management, Vol. 12:81-98.

http://en.wikipedia.org/

http://www.dams.org/

http://www.encarta.org

Annex-1

Questionnaire used for **Fish Study** in the Project Area

Date:

Name of interviewee: …………………………………………….

Occupation: ……………………………………………………

Residence: …………………………………………………..

Education: …………………………………………………..

Age: ……………………………………………………………

1) How long you have been fishing in Trishuli River? …………………………………….

2) Family Information:
i) No. of members in the family:……… ii) Male: ……. iii) Female: ……. iv) Total: ……

3.i) Are you dependent on fishing only or do you have other occupation as well?

………………………………………………………………………………………
ii) In which category of Fisherman do you lie?
a) Full time ( ) b) Part time ( ) c) Occasional ( )

iii) Roughly how many families of your community are dependent on fishing? …………

4) What techniques do you use to catch fish?

…………………………………………………………………………………………

5) At which season of the year will you get more fish in the river?
a) Monsoon season ( ) b) Spring season ( ) c) Winter season ( )

6) At which section of the river do you get more fish? …………………………………..

7) What are the different species of fish that you have catch in this river? Any migratory?

Name of the fish		

Tick for migratory

8) Which species of fish generally occurs in your catch? …………………………………

……………………………………………………………………………………………...

9) In which season of the year do you observe spawning activities and fingerlings of fish?

Species	Season	Species	Season

10) What do you do with the trapped fish?
a) Consume (   )   b) Sell (   )   c) Both (   )

11.i) What is the price of your catch per Kg? …………………………….

ii) How much fish do you capture in a month?.......................................

12) In your opinion, have the fish population increased or decreased in the recent years?
a) Increased (   )   b) Decreased (   )   c) Don't know (   )

13) What is the value of fish in your family and community? (Food, Economic, religious, etc.)

………………………………………………………………………………………

14) What happens when dam is constructed to use water of Trishuli River to generate hydro-electricity? Give your opinion.

………………………………………………………………………………………

………………………………………………………………………………………

15) What do you expect from the project, for yourself and your family?

………………………………………………………………………………………

Annex-2

List of **People Contacted** and **interviewed** during field visit

S.N	Name	Profession	Address
1.	Thaga Sahani	Fishing	Malekhu, Benighat V.D.C
2.	Pundev Sahani	Fishing	Dhanusha District
3.	Shambhu Sahani	Fishing/Selling	Rahautat District
4.	Amar Raj Seluwal	Fish Wholesaler	Malekhu, Benight V.D.C
5	Mangale Maghi	Agriculture	Maghigau, Salanghat V.D.C
6.	Juthe Maghi	Carpenter/Agriculture	Maghigau, Salanghat V.D.C
7	Ganga Bahadur Maghi	Agriculture	Maghigau, Salanghat V.D.C
9.	Bechan Dhami Danuwar	Hotel Worker	Malekhu, Benighat V.D.C
10.	Shankar Sahani	Fishing	Rahautat District
11.	Ramdev Sahani	Fishing	Rahautat District
12.	Navaraj Shrestha	Agriculture/Fishing	Malinga Gau, Benighat V.D.C
13.	Bhabikhan Sahani	Fishing	Gadu V.D.C, Rahautat District
14.	Manju Siluwal	Fish Selling	Malekhu, Benighat V.D.C
15.	Muna Sarki	Agriculture	Gomatipul, Benighat V.D.C
16.	Sita Praja	Agriculture	Gomatipul, Benighat V.D.C
17.	Jit Bahadur Maghi	Fishing/Agriculture	Maghigau, Salanghat V.D.C
18.	Shiva Kumar Seluwal	Agriculture	Benighat Bazar, Benighat V.D.C
19.	Ghetu Sahani	Fishing	Siraha District
20.	Krishna Parsad Seluwal	Agriculture	Arbastar, Salang V.D.C
21.	Chetnath Seluwal	Agriculture	Arbastar, Salang V.D.C

Plate-I

A) Tor putitora (Himilton-Buchanan)

B) Labeo dero (Hamilton-Buchanan)

C) Channa orientalis (Bloch and Schneider)

D) Neolissochilus hexagonolepis (Mc Clelland)

E) Schizothoraichthys progastus (Mc Clelland)

F) Barilius barila (Hamilton-Buchanan)

Plate-II

A) Barilius barna (Hamilton-Buchanan)

B) Crossocheilus latius (Hamilton-Buchanan)

C) Lepidocephalus guntea(Hamilton-Buchanan)

D) Schistura beavani (Gunther)

E) Puntius sarana (Hamilton-Buchanan)

F) Nemacheilus corica (Hamilton-Buchanan)

Plate-III

A) Botia almorhae (Gray)

D) Glyptothorax sps.

B) Garra annandalei (Hora)

E) Aspidoparia jaya (Hamilton-Buchanan)

C) Proposed Intake Site

F) Proposed Powerhouse Site

Plate-IV

A) Field Discussion with Supervisors

D) Fish Sampling with Gill Net

B) Fish Catching with Cast Net during Night

E) Interrogating with Local Fisherman

C) Sampling the Trapped Fishes

F) Analysis of Planktons and Sediment

Plate-V

A) Examining the Water Quality

B) John Day Dam with Fish Ladder, USA

C)Designing Fish Pass on Saint-Ours Dam, Canada

Sampling Water from Different Depths
Denil Fish Ladder Model of Fish lift