KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

Final Project Proposal on

Potential Study of Medium Hydropower Project of Nepal: A Case Study of Kabeli-A Hydroelectric Project (KAHEP)

Prepared By:

Bikesh Mainali (028062-20)

Trishna Prajapati (028074-20)

Sarita Sapkota (028084-20)

Swapnil Regmi (028078-20)

Sandesh Shrestha (028090-20)

Submitted to:

Er. Suman Shrestha
Assistant Professor
Department of Civil Engineering

Dr. Shyam Sundar Khadka
Associate Professor
Department of Civil Engineering

18,April, 2020

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Associate Professor Dr. Shyam Sundar Khadka, for providing us with this invaluable opportunity to gain professional experience through this project. We are also sincerely thankful to Department of Civil Engineering, Kathmandu University, especially the departmental In-charge, Assistant Professor Manish Prakash for allowing us to undertake this final year project. We are deeply grateful to Integrated Hydro Fund Nepal Pvt. Ltd., the Department of Hydrology and Meteorology (DHM), and the Department of Electricity Development (DoED) for providing valuable data and resources essential to our research.

We also extend our appreciation to all the faculty members of the Department of Civil Engineering for their academic support, and to our seniors who generously shared their insights and experiences. Lastly, we acknowledge the inspiration drawn from prior works in this field, which helped us approach our project with better clarity and direction.

ABSTRACT

The final year project proposal titled "**Potential Study of Medium Hydropower Project of Nepal: A Case Study of Kabeli-A Hydroelectric Project (KAHEP)**", is presented to the Department of Civil Engineering by the members of Group-11 students. Kabeli A Hydroelectric Project (KAHEP) located in Panchthar and Taplejung district being developed by by Integrated Hydro Fund Nepal Pvt Ltd. Through our work, we aim to explore the viability of this hydroelectric project by examining each hydraulic structure involved—focusing on their design, functionality, and stability. So far, we've carried out a surface-level review of related literature, which will guide us as we move forward into more detailed design studies and technical analysis to develop a comprehensive report.

18 April,2025

To
The Project Supervisor,
Department of Civil Engineering,
Kathmandu University

Subject: Approval for final year project proposal

Respected Sir,
We are pleased to submit our final year project proposal titled **"Potential Study of Medium Hydropower Project of Nepal: A Case Study of Kabeli-A Hydroelectric Project (KAHEP)"** for your review and consideration. This proposal has been prepared as a part of the academic requirement for the Bachelor of Engineering in Civil Engineering with a specialization in Hydropower.
The report outlines the fundamental aspects of our proposed study, including its background, objectives, research methodology, and the expected outcomes. We kindly request your evaluation and approval of our proposal. We also look forward to your valuable insights and continued support throughout the course of this project.

Sincerely,

The Project Team
Bikesh Mainali (22)
Trishna Prajapati (34)
Sarita Sapkota (44)
Swapnil Regmi (38)
Sandesh Shrestha (50)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTAR 1 INTRODUCTION

1.1. Background

The Kabeli-A Hydroelectric Project (KAHEP) is situated in Province No. 1 of Nepal, spanning the districts of Panchthar and Taplejung. The project was first proposed during the Koshi River Basin Master Plan Study conducted between 1983 and 1985. In 2010, Kabeli Energy Limited secured the development rights by signing a Project Development Agreement (PDA) with the Department of Electricity Development (DoED), Government of Nepal.

The project utilizes a 15 km natural loop of the Kabeli River formed with the Tamor River. Water from the Kabeli River is diverted through an approximately 4.67 km-long tunnel and discharged into the Tamor River to generate electricity. The project has a gross head of 120.5 meters and is designed for a flow of 37.23 m^3/s, based on the 40th percentile flow of the river.

KAHEP was initially intended to be a Peaking Run-of-River (PROR) project with a peaking reservoir made possible by damming the Kabeli River at the headworks. The plant was scheduled to run during two peak hours each day: two hours in the morning and four hours in the afternoon. The annual average energy generation was initially estimated at 213 GWh before accounting for outages, and 201 GWh after considering a 6% outage. On October 12, 2015, Zhejiang Hydropower Construction and Installation Company Limited was given the Engineering, Procurement, and Construction (EPC) contract, and construction got underway. However, due to various challenges, construction was halted. After a three-year pause, the project is now set to resume with updated feasibility studies. The design has been revised to a Run-of-River (RoR) type project.

The project's installed capacity is 37.6 MW, according the updated Power Purchase Agreement (PPA) and the revised feasibility study. The annual contracted energy is 218.354 GWh, comprising 67.206 GWh (30.78%) of dry season energy and 151.148 GWh (69.22%) of wet season energy. The primary objective of the project is to generate electricity and sell it to the national grid under a PPA signed with the Nepal Electricity Authority (NEA), the sole government agency authorized to purchase electricity.

Through the Kabeli-A switchyard, which is connected to the 132 kV Kabeli Corridor transmission line constructed by NEA, power from KAHEP will be evacuated to the national grid. It is anticipated that the project will greatly improve Eastern Nepal's (Province No. 1) electrical supply.

1.2. Project Area Description

Kabeli-A Hydroelectric Project (KAHEP) is a 37.60 MW Run-of-River (RoR) Project located in Panchthar and Taplejung district of Province no. 1 in Eastern Nepal. The Head Pond site is located near Thulo Dhuseni and the powerhouse site is located on the left bank of Tamor River just upstream of the confluence of Piple Khola with Tamor at Pinase Ghat. Geographically, the project area is located between longitudes 87°42′E to 87°55′E and latitudes 27°16′N to 27°22′N, at an elevation ranging from 400 to 1,200 meters above sea level.

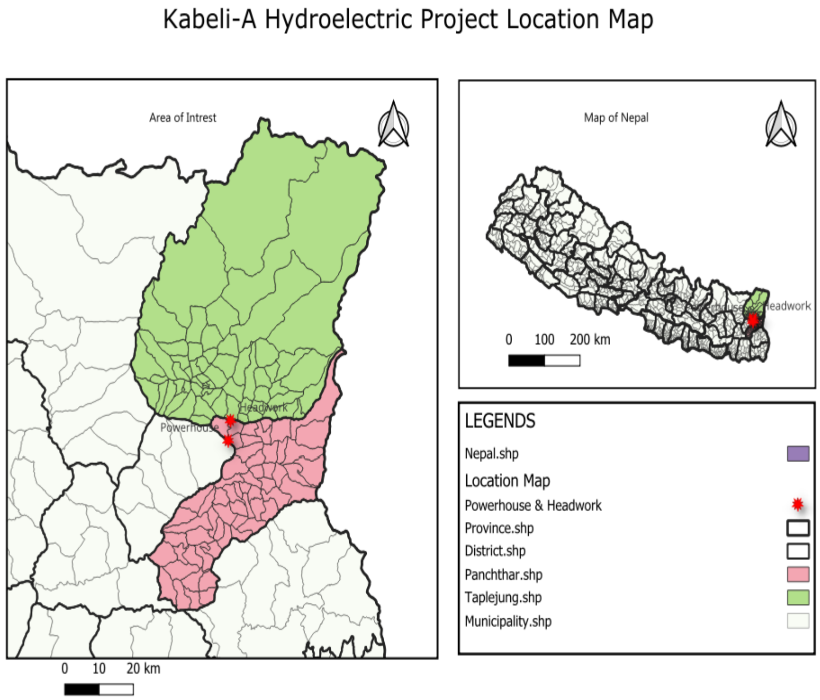


Figure 1 Location of KAHEP

Source: Final DPR report of KAHEP

1.3. Accessibility

The Kabeli-A Hydroelectric Project (KAHEP) is located approximately 680 kilometers from Kathmandu and is accessible via a combination of major highways and local roads. The primary route from Kathmandu follows the BP Highway (Koteshwor–Banepa–Bardibas, 190 km), continues along the East-West Highway (Bardibas to Charali, 303 km), and then proceeds through the Mechi Highway (Charali to Ganeshchowk, 187 km). The nearest airport is Suketar Airport in Taplejung, located about 40 kilometers north of the Mechi Highway's endpoint.

Geographically, the project area is situated approximately 50 kilometers north of Phidim Bazaar—the administrative center of Panchthar District—and about 40 kilometers south of Phungling Bazaar, the district headquarters of Taplejung. To facilitate site access, a dedicated project road has been constructed from Ganeshchowk to the powerhouse site of the Kabeli B1 Cascade HEP, which also serves as the entry point for KAHEP. Furthermore, the existing Bhaluchowk–Dhuseni–Kholakharka road, which currently reaches the tunnel outlet, will be extended along the headrace tunnel alignment up to the headpond area to improve internal project connectivity. The powerhouse site of KAHEP can be reached through two access routes a 16 km road from Bhaluchowk via Amarpur and Pinase and an alternative 16 km route from Kabeli Bazaar, running along the natural loop formed by the Kabeli and Tamor rivers.

CHAPTER 2 OBJECTIVES AND LIMITATION

2.1. Primary Objective

i. To carry out potential Study of hydropower by the hydrological analysis,hydraulic design and economic analysis.

2.2. Secondary Objectives

i. To carry out a structural analysis of water conveyance system.

ii. To learn to select and appraise possible alternatives after futher considerations

2.3. Limitations

i. Designs will be based on secondary data and the data that are not available shall be assumed suitably.

ii. The design works performed will solely be for the educational purpose.

iii. Only hydraulic designs of hydropower component will be done. Detail structural detailing of all hydraulic structures will not be performed.

2.4. Scope of the project

i. Review of available information on the project.

ii. Topographic survey and mapping of the project components in appropriate scales.

iii. Hydrological and meteorological data collection to design the project.

iv. Project component layout and pre-feasibility level design.

v. Power, Energy, and Revenue calculation.

vi. Project cost estimate through rate analysis.

CHAPTER 3 LITERATURE REVIEW

Hydroelectric power was a relatively cheap, reliable, sustainable, and renewable source of energy that can be generated without toxic waste and considerably lower emissions of greenhouse gases than fossil fuel energy plants. Conventional hydroelectric plants produce energy by the controlled release of 38 dammed reservoir water to one or more turbines via a penstock. The kinetic energy of the falling water produces a rotational motion of the turbine shaft 40 and this mechanical energy was converted into electricity via a power generator. In 2010, the world commission of dams have estimated the potential 42 production of hydroelectric energy to be more than four times the current annual worldwide generation. Currently, hydropower plants 44 produce about 20% of all electricity used world-wide (10% in United States) and this percentage was expected to increase substantially in the coming years 46 as the world was slowly moving away from fossil fuels in lieu of more sustainable and environmentally friendly sources of energy. More than 60 countries in 48 the world derive at least half of their entire electricity production (demand) from hydropower plants.

3.1.Classifications of hydropower

Hydropower projects can be classified based on the head, discharge and capacity which are discussed below.

3.1.1. Based on head

In Nepal most of the projects are huge elevation difference between headworks site and powerhouse site so it is classified as:

Table 1 Classification of hydropower based on head

Head(m)	**Type**
<15	Very Low Head
30-60	Low Head
60-150	Medium Head
150-300	High Head
>300	Very High Head

3.1.2. Based on capacity

Table 2 Classification of hydropower based on capacity

Type of hydropower Plant	**Power Generation Capacity**
Micro hydropower project	Up to 100kW
Mini hydropower project	100kW to 1000kW
Small hydropower project	1MW to 25MW
Medium hydropower project	25MW to 100MW
Large hydropower project	Greater than 1000MW

3.1.3. Based on functional basis or operation

Hydropower plant can be classified on the basis of actual operation in meeting the demand as:

- Isolated plant, and
- Grid connected (interconnected) plant.

In isolated grid system, the electricity is generated and distributed only for a small locality, without use of any advanced electromechanical distribution system. In Nepal, in rural areas several Small and mini hydropower are in isolated system.

In grid system, several projects are connected in one grid and operated through one point. In Nepal, there is INPS (Independent National Power System), where all projects are connected. The grid is owned by NEA and operated through load center at Swichatar, Kathmandu.

The grid connected power plant is further divided into:

- Base load power plant
- Peak load power plant

3.1.4. Based on storage Capacity

Hydropower plants can be classified on the basis of whether they provide a storage reservoir or not as below:

- **RoR / PRoR river plants:**

  Those plants, which do not regulate the hydrograph of the source river in seasonal term, are known as ROR plants. A run off river plant is located on a perennial river in which adequate discharge is available throughout the year. In such system weir is constructed across the river to maintain the required water level and discharge for the power plant located downstream. Keeping the consideration during peak hours, ROR plats may be constructed with poundage, which can regulate daily hydrograph or weekly hydrograph, store water (full or partial) to run the plant under full capacity. These types of plants are known as peaking run of river plant PROR. Plants in Kaligandaki-A, Marsyangdi, Middle – Marsyangdi, Sunkoshi and Panauti are PROR type whereas plants in Khimti — I, Bhotekoshi, Indrawati III and Khudi are ROR type.

- **Storage plants:**

  Those plants, which can regulate the hydrograph of river by one or more seasons, are usually known as storage plants. In such plants, a dam is constructed to create a large reservoir to permit carry over over-storage from rainy season to the dry season. Such plants are generally located on non-perennial rivers. These are generally medium head or high head plants. Storage plants involve high initial investment but provide a much more efficient and controlled use of the available water. The storage plants may be classified into seasonal storage, annual storage, pluri annual storage, pumped storage based on the regulation of flow or modification of annual hydrograph. Kulekhani I and II of total capacity 92MW is only one storage plant in Nepal. The storage project may be seasonal storage, annual storage, pluri-annual storage and pumped storage type based on the regulation of water.

3.1.5. Based on construction feature

Based on construction features, the hydropower projects may be of valley type and diversion type which are discussed below:

- **Valley type**

In a valley type plant, a dam is dominant feature, creating a storage reservoir behind it. Powerhouse is generally located at the toe of the dam. Diversion of water away from the source is not entertained.

- **Diversion type**

In diversion type plant, the water from the source is diverted through canal or tunnel to the powerhouse, situated away from the diversion point, in the same or neighboring river basin.

3.2.Types of ROR Projects

3.2.1. Run-of-river hydropower projects

A run-off hydropower project is a project that generates electricity from turbines when water is available in the river. It should be designed to use the flow of water in the river to generate electricity. Due to the large seasonal changes in flow in Nepal, the project should be designed to use the flow in the river manure during the dry season. The installed capacity of the program should be based on the reliable flow available throughout the year of the river, deducting the mandatory flow of downstream water demand. Weir or Barrage is constructed for the diversion of the water from the river which is conveyed through conveyance system and delivered to power house through Penstock Pipe. The Run-of-River type project have possible layout:

a) Run-of-River project with Canal option
b) Run-of-River project with Pipe option
c) Run-of-River project with Tunnel option

3.2.2. Peaking Run–of- River Hydropower Project (PRoR)

Peaking Run-of-River (ProR) hydropower projects are designed to generate power according to fluctuations in the power demand through hourly regulation of the daily flow available in the river. This capability can be achieved through daily pondage of the water at the head works during dry seasons when the flow in the river is less than the design discharge. During the rainy season when river discharge exceeds the design discharge, the plant shall operate like a RoR plat to facilitate bed load flushing. Base on site conditions and optimization, peak requirements shall usually be fixed for about 4 to 6 hours of plant operation during the dry season. The layout of peaking run-of-river projects is same as that of run-of-river schemes:

a) Peaking Run-of-River project with Canal option
b) Peaking Run-of-River project with Pipe option
c) Peaking Run-of-River project with Tunnel option

3.3. Hydrology

There are two terms that can be used to describe hydrology. Hydro means water and logy means knowledge, hence the study of or understanding of water is called hydrology. The occurrence, movement, storage, distribution, and qualities of surface and ground water on earth are the focus of the multidisciplinary field of hydrology. The field of hydrology encompasses the physical, chemical, and biological properties of water.

A scientific technique for gathering information on the flow of a river at a specific point is known as hydrological observations. When evaluating the water resources in terms of quantity, quality, distribution in time and place, and their potential for project design and development to satisfy various water demands, the data's trustworthiness is a crucial factor. The findings from various hydrological stations mainly include the gauge, discharge, suspended sediment, bed material and water quality.

The amount of water that passes through a certain location in a stream during a predetermined amount of time is known as the stream flow or discharge. Typically, discharge is expressed in cubic feet per second. A cross-sectional area of the stream or river is measured to determine discharge. Then, a Flow Rate Sensor is used to determine the stream's velocity. In order to get the discharge, multiply the cross-sectional area by the flow velocity, i.e.

$$Q = A \times v$$

The hydrological analysis is carried out by the following process:

3.3.1. Flow Estimation Method

For ungauged basins, the mean monthly flows and flow duration curve shall be determined from following three methods:

1) Medium Irrigation Project Method
2) Water and Energy Commission Secretariat (WECS)
3) Catchment Area Ratio (CAR) Method

❖ MIP Method

The MIP method presents a technique for estimating the distribution of monthly flow throughout a year for ungauged locations. For applications to ungauged sites, it is necessary to obtain one flow measurement in the low flow period from November to April.

In the MIP method, Nepal has been divided hydrologically into seven zones. Once the catchment area of the scheme, one flow measurement in the low flow period and the hydrological zone is identified, long term average monthly flows can be determined by multiplying the unit hydrograph (of the concerned region) with the measured catchment area.

Hydrological zone can be identified based on the location of the scheme in the hydrologically zoned map of Nepal.

For catchment areas less than 100 km^2, MIP method is used for better results.

- WECS/DHM Method

It is developed for predicting river flows for catchment areas larger than 100 km^2 of ungauged rivers based on hydrological theories, empirical equations and statistics.

In this method, total catchment area, areas between 5000 m to 3000 m are required as input.

Flow contribution per unit area for 5000 to 3000 m and from lower elevations is assumed to be in different proportions during flood. However, for long term average monthly flows, all areas below 5000 m are assumed to contribute flows equally per km^2 area.

The average monthly flows can be calculated by the equation

$$Q = C * (\text{Total basin area})^{A1} * (\text{Basin area below 5000m} + 1)^{A2}$$
$$* (\text{Monsoon wetness index})$$

Where A1, A2, A3 are coefficients of different months.

- Catchment Area Ratio Method

If the two catchments area hydrologically similar, then the extension of hydrological data for proposed site under study could be done simply multiplying the available long-term data at hydrologically similar catchments with ratio of catchments areas of base and index stations. This method is useful if the hydro meteorological data of the index station having similar catchment characteristics with the base station are available for the data extension

3.3.2. Catchment Area

A catchment area is just the region from which surface runoff originates. It is sometimes referred to as a catchment, a drainage basin, or a watershed area.

The catchment area is measured in km2. When the catchment area is under 25 km2, it is expressed in hectares. It refers to the entire area that empties into the river or stream being considered. Any rain that falls on a river's catchment area will wash off the land and into the waterway, adding to the volume of the river either by surface runoff or baseflow (underground water flow). The ridge line marks the edge of a watershed.

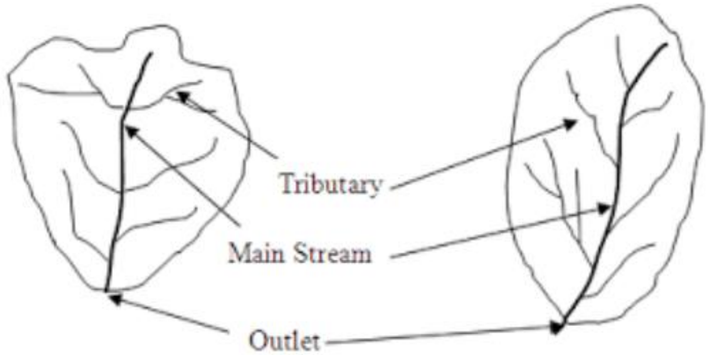


Figure 2 Catchment

3.3.2. Hydrological Equation

In general, hydrological equations describe the basin-scale water balance that expresses the equality of an input and an outflow at the time step of a hydrological year.

a formula for calculating the flow rates of water across any stage of the hydrologic cycle. It is written as follows:

$$I - O = \Delta S,$$

where I denotes inflow into the system during a specified period, O denotes outflow from the system during a specified period, and S denotes change in storage during the period.

3.3.3 Flow Analysis

All analytical methods based on the introduction, processing, and detection of liquid samples in flowing media are collectively referred to as "flow analysis." The foundation of flow analysis is a flow stream that includes characteristics like flow rate, volume, and composition.

The sorts of flows are identified by flow analysis. The following are some hydrological flow types:

1) Steady & Unsteady Flows.
2) Uniform & Non-uniform Flows.
3) Laminar & Turbulent Flows.
4) Compressible & Incompressible Flows.
5) Rotational & Irrotational Flows.

3.3.4. Flow Duration Curve

The flow-duration curve is a cumulative frequency curve that show the percent of time specified discharges were equaled or exceeded during a given period. It combines, without regard to the order of occurrence, the flow characteristics of a stream across the whole range of discharge in a single curve.

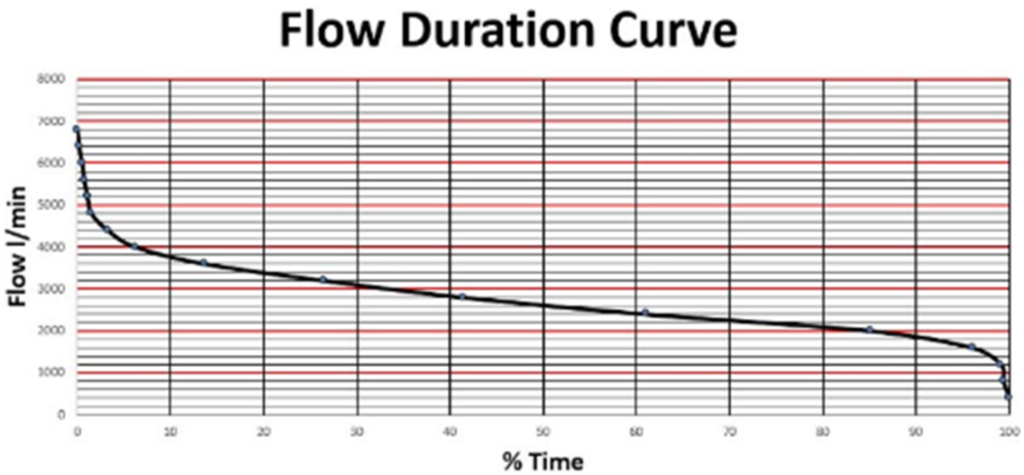


Figure 3 Flow Duration Curve

3.3.5 Flood Analysis

Hydrologists utilize flood frequency analysis as a technique to forecast flow values along a river that correlate to particular return periods or probabilities. Gumbel was the first to suggest using statistical frequency curves for floods. The best frequency distribution is chosen from the existing statistical distributions such as Gumbel, Normal, Log-normal, Exponential, Weibull, Pearson and Log-Pearson. Flood frequency curves are then produced using the probability distribution that best fits the yearly maxima data. The design flow values corresponding to particular return periods can then be estimated using these graphs and used for hydrologic planning.

When designing dams, bridges, culverts, levees, highways, sewage treatment facilities, waterworks, and industrial buildings, flood frequency plays a crucial role in providing predictions of how frequently floods may occur. These estimations are helpful in that they offer a measurement parameter for analyzing the damage related to particular flood flows.

Understanding the idea of return period is crucial to understanding how flood frequency analysis functions. The probability that an event will be exceeded in a certain year is the inverse of the theoretical concept of return period. Recurrence interval, also known as return time, gives an estimation of the likelihood of any occurrence occurring within a year. For instance, the flood of this magnitude will only occur once every 100 years according to the 100-year return time. It is crucial to realize that just because a flood with a 100-year return time happens right now, that doesn't guarantee that another one of this size won't happen in the next 100 years.

The flood frequency curve is used to calculate an estimate of the intensity of a flood event by connecting flood discharge data to return times. In order to plot the discharges versus the return periods, either a linear or a logarithmic scale is used. Utilizing a cumulative density function, the observed data is fitted with a theoretical distribution to obtain an estimate of the return period for a certain discharge or vice versa (CDF). The users can now analyze the flood frequency curve with this assistance.

- Gumbel’s Method

Gumbel’s deviation probability distribution is widely used for extreme value analysis of hydrologic and meteorological data like floods, maximum rainfalls and other events. Gumbel defined the flood as the largest value of 365 daily flows and annual series constitute a series of largest values of flow.

$X_T = x + K \times \sigma$ (n-1) ………(i)

Where, σ(n-1) = standard deviation of sample of size $N = \sqrt{\frac{\sum(x-y)^2}{N-1}}$

$$K = \frac{Y_T - Y_N}{S_N}$$

Where y_t is reduced variant for given time T, y_n is reduced mean and S_n is reduced standard deviation.

The value of Y_T can be calculated as

$$Y_T = -\left[ln.\,ln\frac{T}{T-1}\right]$$

$$or, Y_T = \left[0.834 + 2.303loglog\frac{T}{T-1}\right]$$

3.3.6. Hydrograph

A hydrograph is a graph that plots the discharge rate (rate of flow) over time past a particular point in a river or other channel transporting flow. Typically, the flow rate is stated in cubic meters per second (m^3/s) or cubic feet per second (ft^3/s). For the purpose of assessing the surface water potential of a stream, reservoir study, or drought study, hydrographs might be either annual or seasonal.

3.3.7. Rating Curve

The rating curve is a relation between stage (river level) and streamflow (discharge). In HEC RAS, the rating curve is constructed with the aid of boundary conditions to determine the level of the surface waters. From the resulting curve, a high flood discharge may be found for a 100-year return time.

3.4. Hydraulic Components

3.4.1. Weir

A weir is a small barrier built across a stream or river to raise the water level slightly on the upstream side; essentially a small-scale dam. Weirs allow water to pool behind them, while allowing water to flow steadily over top of the weir. Additionally, the term weir can be used to refer to the crest of a spillway on a large embankment dam.

Some key considerations for the design of the weir are as follows:

1. Type: A weir should be permanent in nature for hydropower project. Sloped weir, ogee shaped weir or other types of weir are practiced in hydropower project
2. Location: The weir should be adjacent to the intake. This will assure that water is always available and there is no sediment deposit in front of the intake. A sufficient capacity under sluice should be designed to pass flood water and high sediment concentration. Divide wall separate the weir portion and under sluice portion.
3. Height: The weir should be sufficiently high to create enough submergence and driving head. The height of the weir should be such that the water level rises above the upper edge of the intake mouth. In case of an orifice intake, the weir height should be such that the orifice is submerged during the dry season.
4. Operation: The weir profile should be such that movement of bed load is possible and boulders can roll over it
5. Stability: Weir should be designed to prevent from overturning, lifting or sliding during the high flows and floods.
6. Seepage control: proper arrangement of cutoff wall and clay blanket should be designed as a integer part of weir to control seepage through weir.

7. Surface protection: in mountainous river with steep gradient, it carries huge sediments and heavy boulders during flood time. So the surface of the weir should be properly designed to withstand the impact of such boulder. Heavy boulder lining, hard stone lining, steel lining etc. are possible protection measure of the weir surface

Weirs can be constructed out of several different materials, depending on their age and purpose. Wood, concrete, or a mixture of rocks, gravel, and boulders can all be used to construct a weir.

In a weir, the surface over which the water flows are known as the crest. The flow of water that moves over top of this crest is known as the nappe, which is simply the water that makes it overtop the weir. This nappe does not exist with dams, as dams permit no flow of water over the structure. If this nappe falls a significant distance through the air – meaning that the weir increases the elevation of the water prior to the weir – the weir is said to have free discharge. However, if water flows partially underwater as a result of little elevation increase from the weir it is said to be submerged or drowned.

Figure 4 Weir

3.4.2. Undersluice

The under-Sluices are the openings which are fully controlled by gates, provided in weir wall with their crest at a low level. They are located on the same side as the off-taking canal. Under sluices are also called scouring sluices because they help in removing the silt near the head regulators.

Functions of Under-Sluices

i) Preserve a clear and defined river channel approaching the regulator.

ii) Control the silt entry into the canal.

iii) Pass the low floods without dropping the shutter of the main weir.

iv) Provide greater waterways for floods, thus lowering the flood level.

v) They scour the silt deposited on the river bed above the approach channel

Figure 5 Undersluice

Source: (Sautya, 2018)

3.4.3. Intake

Intake is the structure to obtain the required quantity of water from the river or the reservoir for the different engineering purpose such as irrigation, po power generation, water supply etc.

Intake is "a structure to divert water into a conduit leading to the power plant" or simply defined as a structure to divert water to a waterway. Not specifying what type of waterway: a power channel or a pressure conduit- and reserving the word forebay or power intake, to those intakes directly supplying water to the turbine, via a penstock.

A water intake must be able to divert the required amount of water into the power canal or into the penstock without producing a negative impact on the local environment and with the minimum possible headloss. The intake serves as a transition between a stream that can vary from a trickle to a raging torrent, and a controlled flow of water both in quality and quantity. Its design, based on geological, hydraulic structural and economic considerations requires special care to avoid unnecessary maintenance and operational problems that cannot be easily remedied and would have to be tolerated for the life of the project. Intakes of run-of-river hydropower projects shall be designed to draw the desired quantity of water, limited to design discharge, from the river under controlled conditions.

The general arrangement of the intake shall be decided considering the following primary factors:

a. Topographical features of area.

b. Type of development, ie. simple run-of-the river or pondage run-of-river project.

c.Proposed project configuration behind intake.

d. Content and nature of sediment in the river.

e. Construction planning.

f. Compatibility and integrity of intake with other headworks components.

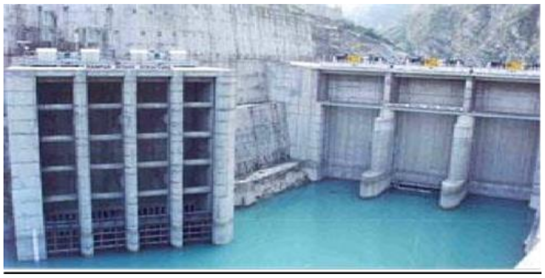


Figure 6 Intake

Source: constructionheadline.com

3.4.3. Trash rack for side intake

Intake structure contain some important components of which trash racks plays vital role. Trash racks are provided at the entrance of penstock to trap the debris in the water. If debris along with water flows into the penstock it will cause severe damage to the wicket gates,turbine runners, nozzles of turbines etc. these trash racks are made of steel in rod shape. These rods are arranged with a gap of 10 to 30 cm apart and these racks will separate the debris form the flowing water whose permissible velocity is limited 0.6 m/sec to 1.6m/sec.

Figure 7: Trashrack

Source: Constructor.org

3.4.4. Gravel Trap

Gravel traps, as the name denotes are designed to trap gravel that enters the intake along with the diverted flow. If a river only carries fine sediment and not gravel (even during floods), then this structure is not required. However, most mountain rivers in Nepal carry gravel, especially during floods. In the absence of a gravel trap, gravel will settle along the gentler sections of the headrace or in the settling basin, where it is difficult to flush out.

Figure 8 Gravel Trap

3.4.5. Settling basin

The water drawn from the river and fed to the turbine will usually carry a suspension of small particles. This sediment will be composed of hard abrasive materials such as sand which can cause expensive damage and rapid wear to turbine runners. To remove this material the water flow must be slowed down in settling basins so that the silt particles will settle on the basin floor. The deposit formed is then periodically flushed away.

The main function of the desanding basin is to:

- maintain the hydraulic transport capacity of the waterways
- reduce the sediment load to the turbines,
- obtain the required power generation regularly.

Figure 9 Settling Basin

Source: spcl.com

3.4.6. Headrace Canal

The headrace canal serves to convey water to penstock intake, generally a forebay. In a run-of-river hydropower project, the structural components like desanding basin, cross-drainage works such as aqueducts, siphons, super passages, flumes, come across between the starting point of the canal and forebay forming the integral parts of a headrace canal. Since the silts settled in the desanding basin is to be periodically removed and discharged to the river using the higher velocity of flow, for obtaining a necessary purging head, generally this structure is located at some distance3 from the headworks site. The headrace canal is aligned, first, to reach the site appropriate for construction of a desanding basin, then, to reach the forebay site. The first portion of this canal, connecting river intake and desanding basin, called also approach canal (Section 3.1.1.1 above) will be short to the possible extent to minimize the length of silt flushing channel, while the portion lying between desanding basin and forebay (the main headrace canal) could have a length extending up to several kilometers depending upon the head to be concentrated in a hydropower project and, therefore, will have to pass through a number of crossings. The canal needs to be aligned as contour canal in a way to minimize cut and fill. The ideal design and alignment is that in which the earth obtained from digging in the bed is equal to the earth required for the formation of banks.

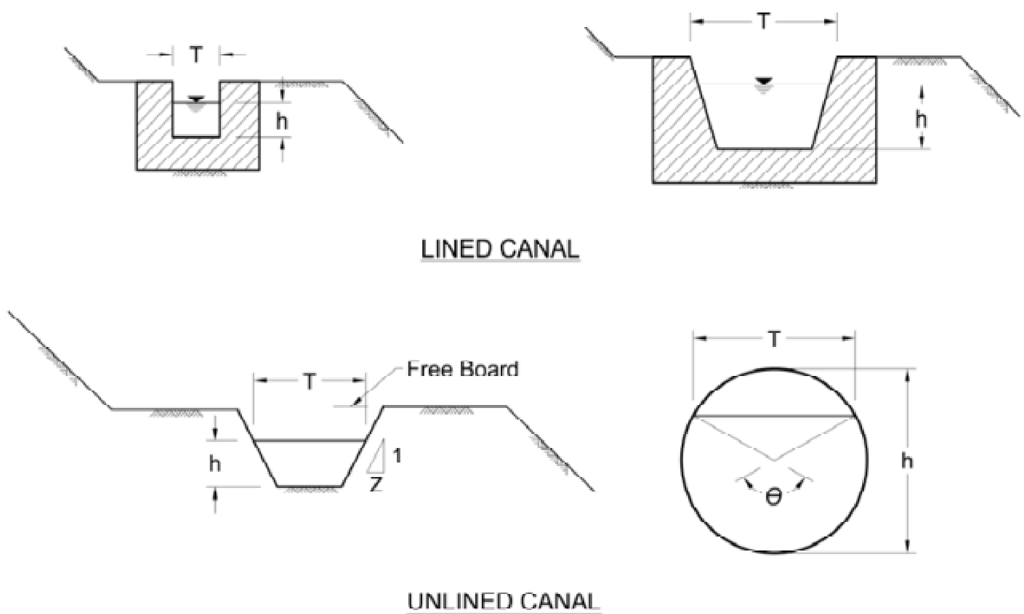


Figure 10 Typical Sections of the Canal

Source: DoED

3.4.6. Headrace Tunnel

Conveyance tunnels for hydropower plants can be distinguished into two main groups. Those which discharge with full sections directly to the turbines are referred to as pressure tunnels. Owing to the considerable difference in elevation they are subjected to very large internal pressure. In contrast, tunnels constructed for the sole function of conveying water by normal gravity from one side of a mountain to the other, or from the point of diversion to the head of the steep incline, are termed discharge tunnels. Between the two groups significant differences exit as far as loads, cross-section and shape are concerned.

Pressure tunnels are subjected to an internal water pressure which is frequently many times in excess of the external rock and groundwater pressure. The resultant tensile stresses can be resisted most economically by a circular cross-section. Pressure tunnels are therefore built with a circular or horseshoe-shaped cross-section, the latter being more readily adaptable to drilling methods. These tunnels cannot be built, unless the rock is completely immobile and solid, i.e. pressure tunnels, or pressure shafts must not be constructed in rocks interlaced with faults and cracks and tending to slip, or in those liable to tectonic movements.

Simple discharge tunnels, on the other hand, usually designed with a modified horse-shoe crosssection, the internal pressure executed by the water conveyed is negligibly small in comparison with the rock pressure acting on the tunnel. But the application of a reliable interior water seal is essential.

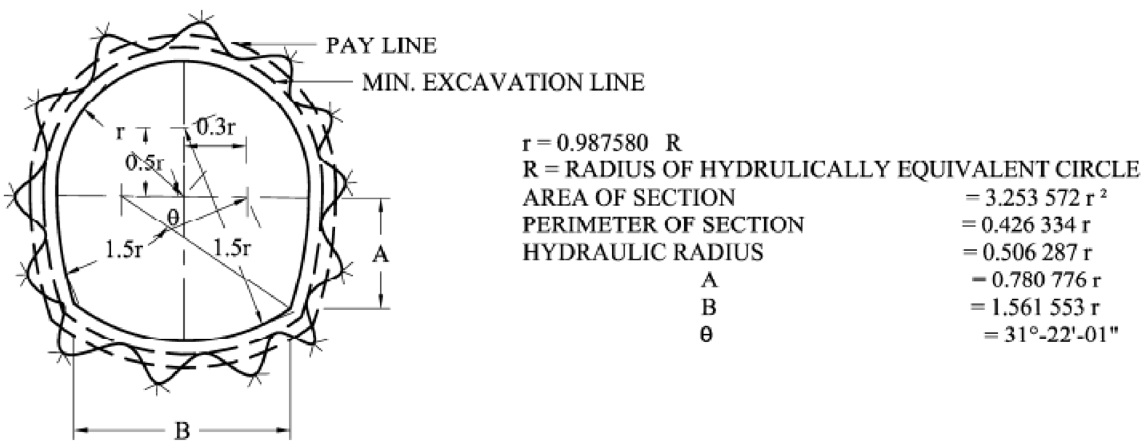


Figure 11 A Modified Horse-shoe Section

Source: DoEd

3.4.7. Surge tank

Surge tank is located between the headrace pressure conduit and the steeply sloping penstock pipe and is designed either as a chamber excavated in the mountain or as a tower raising high above the surrounding terrain. Surge tank requirements are established from considerations of the conduit length and profile, velocity, WR^2 (Product of the revolving parts of the unit and the square of the radius of gyration -turbine runner, shaft and generator rotors), economics and operating requirements relating to governing and stable operation. In some instances surge tanks are applied both upstream of the penstock and downstream of the powerhouse. In any hydropower projects where the water is brought to the machines by a long pressure conduit, considerable inertia effects arise from the large mass of water in motion. This mass is of such magnitude that considerable force is necessary to accelerate or retard it. Moreover, water hammer effects will result even from partial load changes if the resulting turbine guide vane movements are at all rapid, as in fact they must be if undesirable speed rise is to be prevented. The pressure rises resulting from water hammer can be limited by the use of relief valves or similar appliances, but though these appliances will limit pressure rises effectively on reduction of load; i.e. on closure of the turbine guide vanes, they can not assist in accelerating the water column on increase of load, i.e. opening of the guide vanes. Where the pressure conduit is of considerable length, therefore, it frequently becomes desirable to introduce a surge chamber at a suitable point along the pressure conduit system.

The main purposes of surge tank are:

1. Surge tank intercepts water hammer pressure waves caused by sudden turbine closure, protecting the pressure tunnel and penstock from excessive overpressure by providing a free water surface to reflect and dampen the pressure surge.
2. It supplies water to the turbines during startup or increased demand until the flow in the conduit stabilizes, preventing flow discontinuity in the tunnel and ensuring smooth operation.
3. It helps stabilize water level fluctuations by absorbing and dampening oscillations caused by rapid changes in turbine load, maintaining system equilibrium through controlled upsurge and down surge movements.

The maximum and minimum downsurge is computed using the formula:

$$Zmax\ upsurge = Zmax\ (1 - \frac{2Po}{3} + \frac{Po^2}{9})$$

$$Zmax\ downsurge = Zmax\ (-1 + 2Po)$$

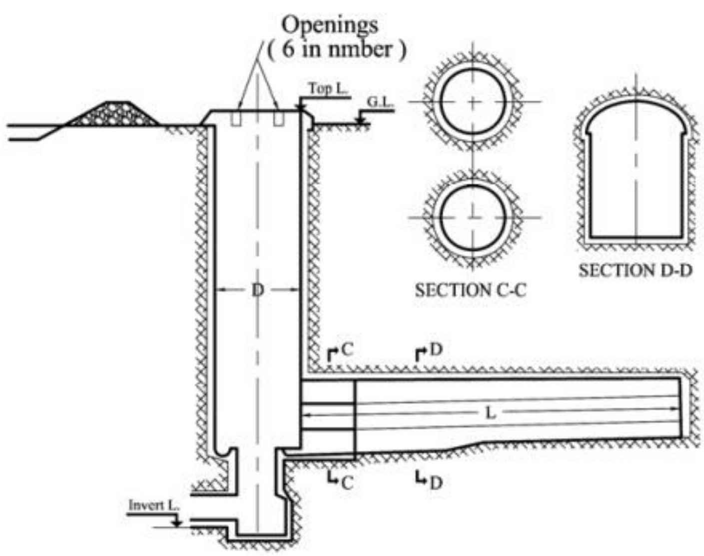


Figure 12 : Surge Tank with Variable Section

Source:DoEd

3.4.8. Anchor blocks and support piers

Anchor blocks rigidly hold the penstock pipe. It is normally provided at every bend and at every 30m span of straight sections of penstock line. It should be provided immediately upstream of powerhouse to minimize the penstock load on turbine.

Functions of an Anchor Block

1. It counteracts the high-pressure forces acting on bends, valves, or branch points in the pipeline.
2. It anchors the penstock at strategic points to prevent displacement due to hydraulic pressure.
3. It Reduces stress on the pipeline and prevents damage due to vibrations and external loads.
4. It controls movement due to temperature changes, preventing excessive stress on joints

Support piers support the penstock vertically and prevent the penstock from sagging. It allows theaxial movement of penstock.

Figure 13 Anchor Block

3.4.9. Penstock

Penstocks are designed to carry water to the turbines with the least possible loss of head consistent with the overall economy of the project. These are pressurized water conduits which convey water to the turbines from free water surfaces. These free water surfaces might be either surge chamber devices or reservoirs or forebays. The most economical penstock will be the one in which the annual value of the power lost in friction plus annual charges such as interest, depreciation, a maintenance will be a minimum. The variables outering the problem are: (i) daily variation of flow through penstock (ii) estimated load factor over a term of years, (iii) profile of penstock, (iv) number of penstocks, (v) material used in construction, (vi) diameter and thickness, (vii) value of power lost in friction, (viii) cost of penstock installed, (ix) cost of piers and anchors, (x) total annual charges of penstock in place, and (xi) maximum permissible velocity. It is extremely difficult to express these variables in a comprehensive formula. In addition the penstock should be structurally safe to prevent failure which would result in loss of life and property.

The penstock is usually made of steel, although reinforced, concrete, GRP, HDP penstocks have also been built recently in increasing numbers. For heads up to 100 meters even wood stave penstocks have been applied.

Figure 14 Penstock

3.4.10. Powerhouse

Power house is a building provided to protect the hydraulic and electrical equipment. Generally, the whole equipment is supported by the foundation or substructure laid for the power house.

In case of reaction turbines some machines like draft tubes, scroll casing etc. are fixed with in the foundation while laying it. So, the foundation is laid in big dimensions.

When it comes to super structure, generators are provided on the ground floor under which vertical turbines are provided. Besides generator horizontal turbines are provided. Control room is provided at first floor or mezzanine floor.

The powerhouse was designed to house the turbine, generator, and other electro-mechanical equipment. It also included a service and maintenance bay, a control panel room, a transformer area, and a high-voltage panel. To facilitate the lifting of heavy installations, an overhead traveling crane or a chain pulley mechanism was equipped. Additionally, the powerhouse was constructed with safety measures to protect it from potential hazardous floods in the river basin.

Figure 15 Powerhouse

Source: Nepal Energy Forum

3.4.11. Tailrace

The tailraces generally convey water from the powerhouse after use in power generation to the downstream channel. In case if the tailrace water is, again, used in the second power station, the tailrace directly conveys water to the second power station like in Trishuli-Devighat cascade and Kulekhani-I and II cascade. The tailraces could be open canal, closed conduit or tunnel depending upon site situation and layout design. As with the headrace canal the tailrace enables maximum head utilization at a site. Often headrace canal (for generalization say headrace conduit) and tailrace are used together to develop the full head.

Figure 16 Tail race

3.4.12. Selection of turbine

Selection of turbine type and determination of plant capacity, turbines require the detailedinformation on head and possible plant discharge be collected accurately of different conditions.

The following points should be considered while selecting right type of hydraulic turbine.

1. Specific Speed

   High specific aped is essential where the head is low and output is large, because otherwise the rotational speed will be low which means cost of turbo-generator and powerhouse will be high. On the other hand, there is practically no need of choosing a high value of specific speed for highinstallations, because even with low specific speed high rotational speed can be attained with medium capacity plants.

2. Rotational speed

   Rotational speed depends upon specific speed. Also the rotational speed of an electrical generator with which the turbine is to be directly coupled depends on the frequency and number of pair of poles. The value of specific speed adopted should be such that it will give the synchronous speedof the generator.

3. Efficiency

   The efficiency selected should be such that it gives the highest overall efficiency of various conditions.

4. Part load operation

   In general the efficiency at part loads and overloads is less than that with rated (design) parameters. For the sake of economy the turbine should always run with the maximum possible efficiency toget more revenue.

   When the turbine has to run at part or overload conditions Deriaz turbine is employed. Similarly,for low heads, Kaplan turbine will be useful for such purposes in place of propeller turbine.

5. Cavitation's

   The installation of water turbines of reaction type over the tailrace is affected by cavitation. Thecritical values of cavitation indices must be obtained to see that the turbine works in safe zone. Such values of cavitation indices also affect the design of turbine, especially of Kaplan, propeller and bulb types.

6. Deposition of turbine shaft

   Experience has shown that the vertical shaft arrangement is better for large-sized reaction turbines, therefore, it is almost universally adopted, whereas, in case of large size impulse turbines, horizontal shaft arrangement is preferable.

7. Available head and its fluctuation

- ❖ Very high (350m and above): for heads greater than 350m, Pelton Turbine is generally employed and practically there is no any choice except in very special cases.
- ❖ High heads (150 m to 350 m): in this range either Pelton or Francis turbine may employ. Higher specific needs Francis turbine which is more compact and economical than the Pelton turbine, that for the same working conditions would have to be much bigger and rather cumbersome.
- ❖ Medium heads (60 m to 150 m): a Francis turbine is usually employed in this range. Whether ahigh or low specific speed would be used depends on the selection of the speed.
- ❖ Low heads (below 60m): between 30m to 60m both Kaplan and Francis turbines may be used.Francis is more expensive but yields higher efficiency at part loads and over loads. It is thereforepreferable for variable loads. Kaplan turbine is generally employed less than 30m. Propeller turbines are however, commonly used for heads up to 15m. They are adopted only when there is practically no load variation.

3.5. Power Calculations

Power is the rate of producing energy. Power is measured in Watts (W) or kilowatts (kW). Energy is what is used to do work and is measured in kilowatt-hours (kWh) or megawatt-hours (MWh).

The power can be obtained as:

$$P = Q * \rho * g * H * \eta$$

P = the electric power produced in kVA
Q = flow rate in the pipe (m3/s)
ρ = density (kg/m^3), Water = 1000
g = 9.81 = Acceleration of gravity (m/s²)
H = waterfall height (m)
η = overall efficiency ratio (usually between 0.7 and 0.9)

3.6.Cost Estimation

It presents the project cost estimates with details of cost breakdown to be acquired for the project. The cost estimate prepared here are the development costs for the final project.The estimated cost of a hydropower project provides the project proponent with vital information on the amount and schedule of funds for project development. It is also a key inputto the economic and financial analysis of the project for project evaluation. It includes:

3.6.1. Project Cost

The total amount of funds required to accomplish a project or piece of work, which includes both direct and indirect costs, is called the project cost. Any expenses incurred or anticipated to be incurred, as well as financial commitments made or anticipated to be made, in order to finish the project are referred to as project costs and are mentioned in the project baseline.

3.6.2. Expected Annual Revenue

Annual revenue is the total amount of money a company makes during a given 12-month period from the sale of electricity. Annual revenue does not account for any of the expenses.

3.6.3. Payback Period

The payback period is the time required to recover the initial cost of an investment. It is the number of years it would take to get back the initial investment made for a project.

3.6.4. Financial Indicators

The financial or economic indicator includes the financial analysis of the project. It focuses onthe source of funding for the project and annual income expenditures of the project such as NPV, IRR and B/C ratio. In the project, the financial analysis depicts that the project is financially sound and viable.

- Net Present Value (NPV)

  Net present value (NPV) refers to the difference between the value of cash now and the value of cash at a future date. It is a method used to determine the current value of all future cash flows generated by a project. NPV in project management is used to determine whether the anticipated financial gains of a project will outweigh the present-day investment meaning the project is a worthwhile undertaking.

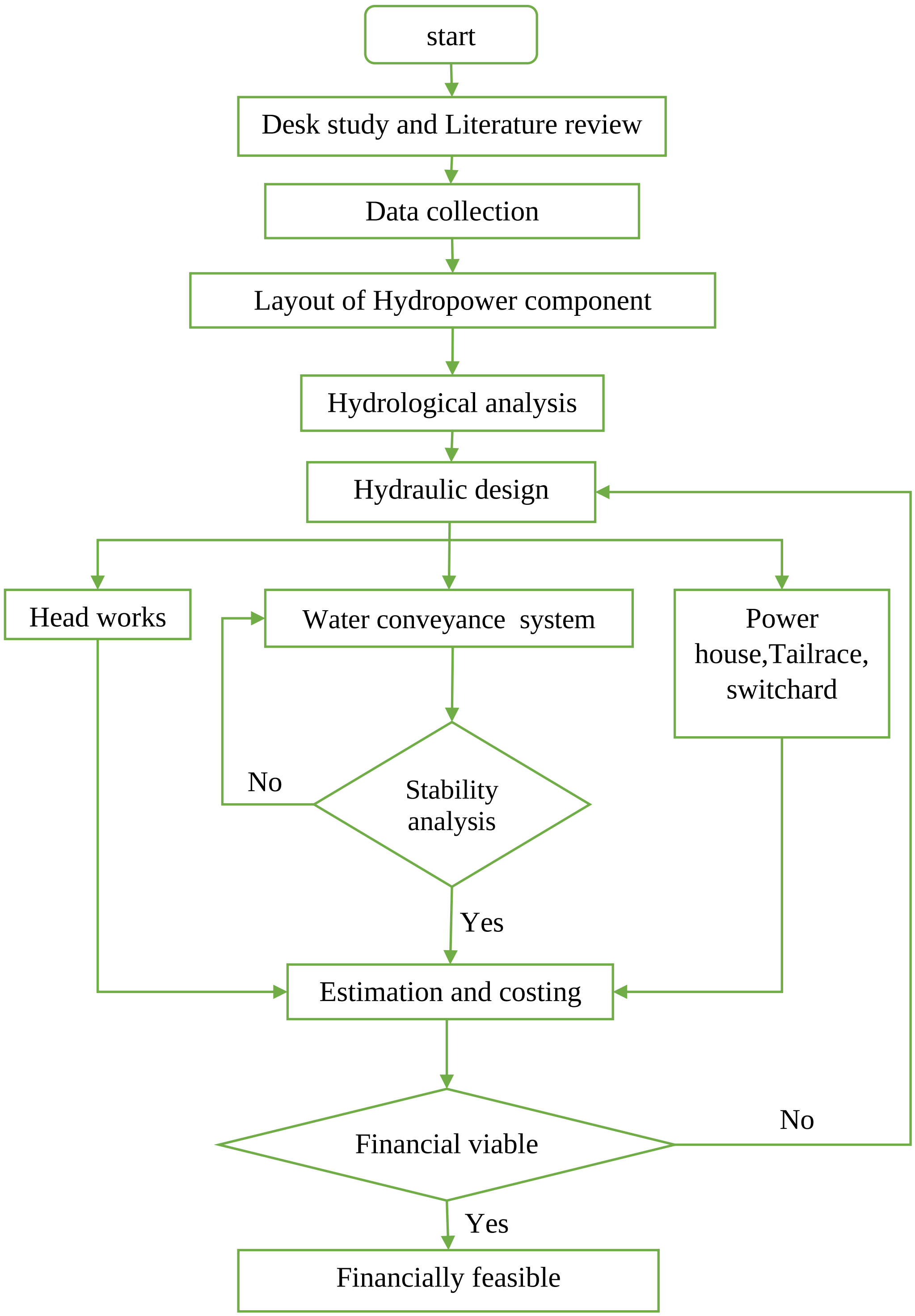
- Internal Rate of Return (IRR)

  The internal rate of return rule is a guideline for evaluating whether to proceed with a project or investment. The IRR rule states that if the IRR on a project or investment is greater than the minimum required rate of return, then the project or investment can be pursued. The IRR helps companies decide whether or not to proceed with a project.

- Benefit – Cost Ratio (B/C Ratio)

  A benefit-cost ratio (BCR) is an indicator showing the relationship between the relative costs and benefits of a proposed project, expressed in monetary or qualitative terms. If a project has a BCR greater than 1.0, the project is expected to deliver a positive net present value to a firm and its investors

CHAPTER 4 METHODOLOGY



4.1.Desk study and literature review

The initial investigation for the project was carried out with the support of resources provided by the consulting firm. Relevant literature including books on hydropower development, design guidelines, textbooks, manuals, technical drawings, and previous reports was thoroughly reviewed. A comprehensive desk study was conducted to familiarize the team with all essential parameters required for the successful completion of the project.

4.2.Data collection

Site-specific survey data and hydrological data was obtained from the consulting firm involved in the project.

4.3. Layout of hydropower component

We will layout the different component of the hydropower with the help of topographic map. We will choose the best possible location.

4.4. Hydrological analysis

The catchment area of the proposed site will be calculated. The obtained hydrology data will be used to find out the discharge at different period of time. We will plot the flow duration curve and obtain firm power and secondary power. Flood discharge for different return period of time will be calculated using Gumbel's method and Log Pearson's method.

4.5. Hydraulic design

We will design every component of the hydropower such as tunnel, intake, weir, gravel trap, settling basin, penstock, surge tank, anchor block, powerhouse and tailrace.

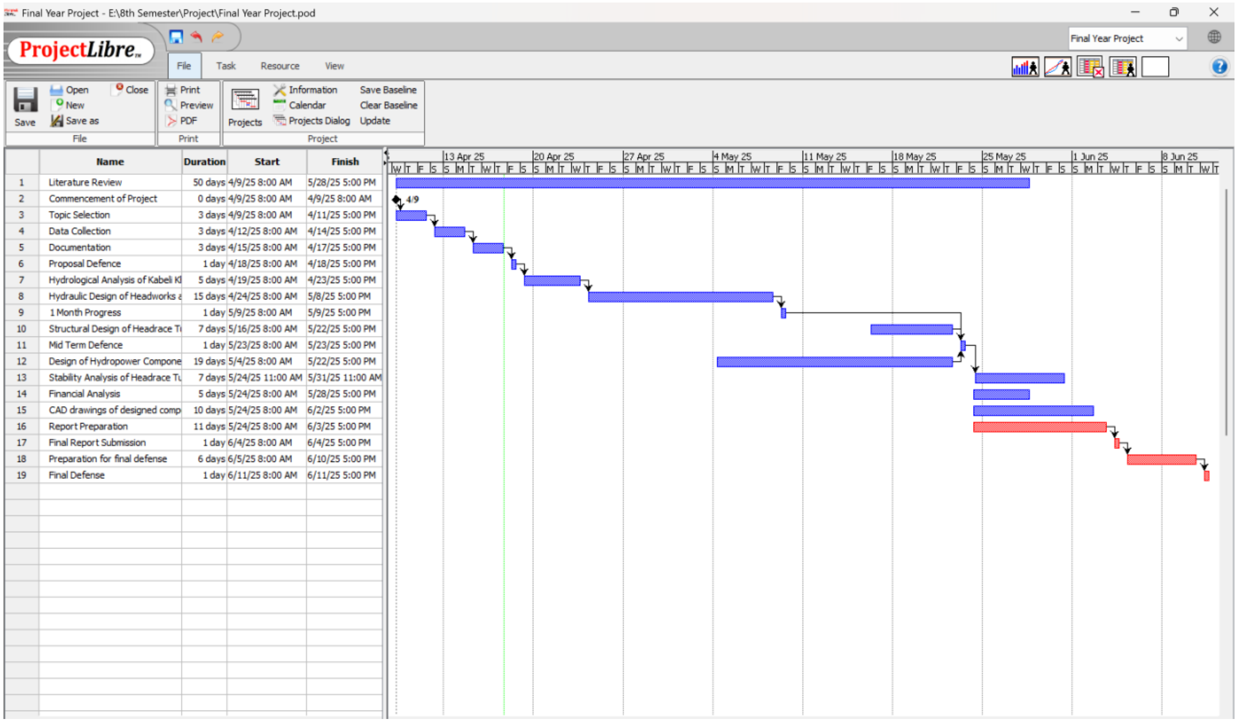
4.6. Stability analysis

We will check the overturning, sliding and bearing capacity of the component of hydropower.

4.7. Estimation and costing

The quantity estimation of every component will be carried out and their cost will deduct using the rates in accordance with the project location. The revenue that can be generated with the power production from this project will also calculate and financial analysis was done using benefit cost ratio method, internal rate of return, net present value and sensitivity analysis.

CHAPTER 5 WORK SCHEDULE



	Name	Duration	Start	Finish
1	Literature Review	50 days	4/9/25 8:00 AM	5/28/25 5:00 PM
2	Commencement of Project	0 days	4/9/25 8:00 AM	4/9/25 8:00 AM
3	Topic Selection	3 days	4/9/25 8:00 AM	4/11/25 5:00 PM
4	Data Collection	3 days	4/12/25 8:00 AM	4/14/25 5:00 PM
5	Documentation	3 days	4/15/25 8:00 AM	4/17/25 5:00 PM
6	Proposal Defence	1 day	4/18/25 8:00 AM	4/18/25 5:00 PM
7	Hydrological Analysis of Kabeli Kl	5 days	4/19/25 8:00 AM	4/23/25 5:00 PM
8	Hydraulic Design of Headworks a	15 days	4/24/25 8:00 AM	5/8/25 5:00 PM
9	1 Month Progress	1 day	5/9/25 8:00 AM	5/9/25 5:00 PM
10	Structural Design of Headrace Tu	7 days	5/16/25 8:00 AM	5/22/25 5:00 PM
11	Mid Term Defence	1 day	5/23/25 8:00 AM	5/23/25 5:00 PM
12	Design of Hydropower Compone	19 days	5/4/25 8:00 AM	5/22/25 5:00 PM
13	Stability Analysis of Headrace Tu	7 days	5/24/25 11:00 AM	5/31/25 11:00 AM
14	Financial Analysis	5 days	5/24/25 8:00 AM	5/28/25 5:00 PM
15	CAD drawings of designed comp	10 days	5/24/25 8:00 AM	6/2/25 5:00 PM
16	Report Preparation	11 days	5/24/25 8:00 AM	6/3/25 5:00 PM
17	Final Report Submission	1 day	6/4/25 8:00 AM	6/4/25 5:00 PM
18	Preparation for final defense	6 days	6/5/25 8:00 AM	6/10/25 5:00 PM
19	Final Defense	1 day	6/11/25 8:00 AM	6/11/25 5:00 PM

Figure 17 Work schedule

CHAPTER 6 EXPECTED OUTCOMES

Upon completion of the project, the following outcomes are expected:

- Hydrological analysis including catchment area estimation, rainfall and flood analysis, discharge calculation, and related assessments will be conducted.
- Hydraulic design of various components such as Weir, Intake, Gravel Trap, settling basin, Headrace Tunnel, Surge shaft,Penstock, Powerhouse Tail-race will be completed.
- Optimization of penstock will be done.
- Stability analysis of water conveyance will be done.
- Detail drawings of proposed components will be prepared.
- Economic analysis will be done.

REFERENCES

- Baral, Sanjeeb (2016). Fundamentals of Hydropower Engineering. Kathmandu: National Book Center Pvt. Ltd.
- Department of Electricity Development. (2006). Design Guidelines for Water Conveyance System of Hydropower Projects. Retrieved 2025.
- Civil Note PPT. (n.d.). *Under sluices and their function*. https://civilnoteppt.com/under-sluices-and-their-function/
- Sanima Power Company Ltd. (n.d.). *Sanima Power Company Ltd.* https://spcl.com.np/
- Nepal Energy Forum. (n.d.). *Pharping Hydropower Station*. http://www.nepalenergyforum.com/pharping-hydropower-station/