Chapter 4
Site Selection and Feasibility Study

4.1: Site Selection

4.1.1: Introduction

Selecting a suitable site is crucial for the success of any MMHP scheme. Many factors need to be taken into account, but data on flow and topography provide the base for establishing suitability as well as the power generation capabilities of proposed sites.

Long-term data on hydrology and meteorology are used in determining river discharges, seasonal variations, floods, and similar occurrences. Such data are needed to assess site potential and plant design and are also used to design regulatory and flood control systems.

Knowledge of the geomorphology of the project area and sites is needed to plan project layout and to design the structures and facilities that make up hydropower projects. Having sufficient and reliable data and knowledge of geotechnical, geological, and seismic conditions and sediment loads and so on enable the planning and design of practical sound layouts and structures. The amount of information needed and type of investigations depend on the type and size of the plant and the required life and reliability.

4.1.2: Tentative Layout Design and Power Calculation

Usually the first planning step is to determine which part of the stream is of interest, by means of existing maps and site surveys, and then to establish the river profile by field measurements; i.e., its course and gradients along the course. For quick reference, barometric levelling is used; but, as soon as possible, more reliable and accurate levelling must be carried out.

If planning parameters were to be ranked in order of importance, hydrology would probably come out on top. The head (together with the flow) determines the power of the water resource. All planning involving hydrology is based on the assumption that past history will be repeated in the future. Hydrology data are therefore based on long-term flow records. If such data are available, the work is relatively easy.

In the case of low-cost MHP plants, however, adequate hydrological data are usually not available and measurements of flow (discharge in some countries) three or four times a year, especially during the lean period, are considered to be adequate. Similarly, extensive geotechnical investigations are not considered necessary; mainly due to the lack of availability of such services as well as economic considerations. Use of local expertise in constructing water channels for irrigation has mostly been made in constructing the power channels as well. The thinking is changing now, as the average plant sizes are increasing and the reliability issue has become more crucial.

To determine hydropower capacity, the main characteristics of water resources are flow (Q) and head (H) which need to be determined or estimated as demonstrated in the following equations:

Power: $P(kW) = C \times H(m) \times Q(m^3/s)$

Energy: $E(kWh) = P(kW) \times T(hrs)$

P = power in kW

H = head (difference in height between the water levels at the forebay tank and the turbine outliet)

Q = waterflow in m^3/s through the turbine

$C = g \times n_w \times n_t \times n_g$

Where,

$n_w \times n_t \times n_g$ are efficiencies of penstock, turbine and generator (usually, the value of cons tan t, C lies between 5 and 7. In the case of indigenous equipment, and for initial calculations, the value of C is taken to be 6). g is the gravitational cons tan t ($9.81 m/s^2$).

T = time in hours

4.1.3: *Prefeasibility Study*

Planning and design of hydropower projects involve a number of different technical, environmental, social, and economic areas of expertise. Investigations have to be organised in a rational and structured manner. The result of project investigations may prove negative and investigations are therefore arranged in phases, so that unnecessary investigation of an unviable project is avoided. In each phase, the project is investigated to the depth necessary to reach conclusions concerning capability and suitability for the stated purpose.

The first step, in this respect, is to prepare a prefeasibility study. Based on the available data and information, the investigators define the main project elements and prepare a tentative layout of the project. Appropriate maps are needed for the study. Aerial photographs, if available, are of great value, especially for geological assessment. The initial field survey and the flow/head measurement and collection of hydrological data from other sources, if available, are a part of prefeasibility.

The prime concern of this study is to establish the main elements or parameters for the project, including power demand, power potential, and environmental constraints. The objective is to decide whether or not to go ahead with project implementation or additional detailed studies involving sizeable expenditure and risk.

Flow can be measured by using a large pipe and a measuring bucket or other container when the flow volumes are fairly small (e.g., up to 20 L/S). Many other devices and methods are adequately described in other technical manuals. Measuring head is easier than measuring flow, less expensive, and more accurate. The simplest method is the use of an altimeter. New digital altimeters are easier to use and more accurate than previous designs. The other simpler and less expensive method is the use of a transparent water-filled tube and a measuring rod.

The flow pattern can be improved and controlled by constructing water reservoirs and regulating gates. However, this is not a normal practice for MHP plants which are mostly 'run-of-the-river' types; meaning, having no storage capacity. The head can be increased or decreased by changing the length of the channel, and it is also affected by other factors such as appropriate location of intake, forebay, and powerhouse, as well as the path of the channel. Thus, head selection is usually a trade-off between many such factors. Once the locations for the forebay and powerhouse are selected, the head cannot be altered, whereas the flow may vary during different seasons and according to the regulatory systems installed.

Determining the highest possible flow is also important for making adequate arrangements to avoid damage from floods. Floods and their flow paths are also given due consideration in designing the layouts and locating the important components of the installation such as the powerhouse, penstock, forebay, and so on. For the purpose of plant design, normally the minimum flow available for nine to 12 months of the year is used.

Current and future demands for power need to be determined and matched to the potential of a given site. A methodology for demand assessment and matching is briefly described in Section 5.1.

For MHP installations in remote hilly regions, environmental effects are usually too small and not investigated. However, in the case of mini plants, such factors may be sizeable (e.g., length, size, and route of the power channel, area occupied by the forebay/reservoir, location of penstock and powerhouse, etc). In such cases, some investigations may be undertaken during the field survey and layout design.

In many cases in the HKH Region, only part of the available flow is diverted from the stream for power generation; and a small dam or other type of simple restriction (say, an arrangement of boulders) is constructed across the main stream to assure adequate flow of water to the power plant during the lean season. Subsequently, a basic design of the plant and its layout is prepared and costs estimated.

To summarise, the following factors need to be given due consideration in finalising decisions on site selection for installation of an MMHP plant.

- Demand for electricity or energy (e.g., for agro-processing)
- Potential and technical viabilities of site and plant
- Costs
- Estimated incomes and economic viability
- Other influencing factors (e.g., other uses of water, geology, flooding or landslide possibilities, and environmental consequences)
- Capability and keenness of beneficiaries (regarding cooperation, contribution, organisation, management, operation, payment of bills, etc).

If the overall results of the above considerations are positive, then a decision can be taken either to go ahead with a more thorough feasibility study or to initiate installation procedures and collect more detailed information to improve the design and reduce costs.

4.1.4: Sequential Study

When many potential sites are available in an area, time and money can be saved if the less attractive options are screened out in the early stages. Each step is based on the findings and results of the preceding steps. This gradual development of plans will ensure that all probabilities have been investigated and examined. It will also, when conducted in a rational manner, ensure that unsuitable projects are not pursued longer than necessary. Thus, the main objective is to select the most suitable site from more than one possibility in the minimum time possible.

The stepwise and sequential development of hydropower project planning is, while being technically sound and economically prudent, very time consuming. If projects are urgently needed, the time element must be given priority. Reduction of planning time is often achieved through reduction of planning steps. However, a certain amount of the reliability may be lost in the process.

4.2 Feasibility Study

The second stage, or feasibility, involves a more comprehensive investigation and analysis of the parameters of the contemplated project, directed towards its ultimate approval/rejection, financing, design, and construction. It is carried out in order to determine the technical, economic, and environmental feasibility of the project; especially if the prefeasibility study had left some questions unanswered, which is usually the case. The feasibility study report will provide the necessary information based on which owners/decision-makers can decide whether or not to implement the project, i.e., to proceed with the final design and construction. It is usually a necessary documentation/annexure to applications for loans, etc. The feasibility study addresses the issues of viability, economic returns, and other benefits in adequate depth and looks at the technical design, costs, expected life, and so on.

If the investigated project can be constructed, equipped, operated, and maintained over the life of the project and does not, in any way, represent any danger or risk (except calculated risks) to the environment, the people concerned, or the public in general; such a project is said to be 'technically feasible'.

The second main criterion for feasibility is that the project is economically and financially viable. This means that the project must be able to generate sufficient income to repay the loan; cover operation, maintenance, and rehabilitation costs; pay taxes and other public expenses; and create funds for depreciation or further investment. It must be sufficiently attractive in economic terms to convince potential investors that they should invest in the project. Keeping these aspects in mind, a suitable format for the feasibility study has been described below.

4.2.1: Key Elements of a Feasibility Report

Based on studies conducted, the following are the main components to be included in a feasibility report for MMHP.

1a. Summary Briefly present all the major conclusions reached in the report; include requests for grants or subsidies; state whether or not the financial requirements are typical or exceptional and whether they conform to a general policy for financing schemes in the region; and include economic comparisons with other energy options.

1b. Key illustrations For instance, a simple sketch map of village houses/lanes and transmission lines, diagrammes of the layouts of turbines and driven machinery, etc; include simple energy supply/demand graphs.

1c. Key data

Some of the key data may be presented on the diagrammes/ sketch maps, including ratings of turbines; generators; part flow arrangements; and tables showing loan requirements, connection charges, subsidies, and so on.

2. Energy demand

Summarise the results of the supply capability and demand study. Also show the estimated future demand trends over the next five or 10 years, stating how far into the future the proposed scheme will meet the estimated demand. This should also include estimates of the competing uses of the water.

3. Water demand

Summarise the requirement for water from the hydro catchment for irrigation. Include any other uses of water, such as domestic or industrial, which may compete with MMHP. Comment on the possible multiple use of water.

4. Energy supply options

Include brief survey and costing tables of various energy inputs, including traditional fuels currently in use. Comment on the future trends in fuel supply, e.g., prospects for fuelwood replanting, kerosene price fluctuations, etc. Compare the costs of energy sources that are alternatives to hydro (or could be used as auxiliary sources in combination with hydro) - e.g., diesel, solar photo-voltaics, and biogas.

5. Management capability

Briefly reproduce the results of the capability assessment and stated interest of the recipients, e.g., to contribute towards installation costs and electricity bills, to install industries, to deal with social conflicts, to operate and manage the plant adequately, and to collect and manage the revenue. An assessment of institutional arrangements, physical infrastructure, and repair facilities in the neighbourhood should also be included.

6. Hydro potential

This section should contain a hydrograph showing irrigation and other non-hydro water demands and a Flow Duration Curve. Both graphs should have axes showing the conversion of flow to hydropower. In cases where variable flow turbines are being considered, the graph should allow for variation in system efficiency at part flow. Data sources and site measurements should be included. Comment on the effect of irrigation water requirements on the ability of the system to supply power when needed. Calculate the anticipated plant factor.

7. Plant design

This section sub-divides into civil works, penstock, turbine, generator, control equipment, and distribution system. For each part, present a design philosophy, e.g., "*the channel is constructed from local materials in order to facilitate maintenance.*" State sources of materials (names and locations of manufacturers) and include sketches that present the dimensions and characteristics of each major component. Detailed calculations and drawings can be put into an appendix. For larger plants (e.g., 50kW or above), a more detailed design may be prepared later. However, for smaller plants, the design should be complete, as far as possible, at this stage.

8. O&M costs

All aspects of O&M should be costed (e.g., spare parts, wages, and training) and a contingency sum included. If experimental (or newly-designed and manufactured) equipment is used, allow for a full replacement cost. Allow for rising prices of spare parts and transport. Include requirements for training, e.g., translation of documents into local languages, visits by equipment manufacturers, refresher courses, future training for newly recruited operators.

9. Integrated water use

Describe how management of the MMHP will be integrated into or coordinated with the management of irrigation and industrial and domestic uses of the available water supply. Detail the extent of involvement of farmers and other water users in the planning, implementation, and management of the plant.

10. Management details

How are the O&M procedures and the integrated water use procedures to be implemented? Who pays the operators and recruits new ones? How is the fund for O&M kept up, and who will keep the accounts? How are the conflicting interests of the plant and irrigation needs going to be resolved?

State what management skills are lacking and therefore which training may be required and how much it will cost. The salaries of the manager and operator should be included in O&M costs. This might include a bonus scheme for high plant availability. These problems are simplified in cases of private ownership but must be spelled out very carefully in cases of collective responsibility.

11. Schedule of operations

Provide a time chart (divided by months and years) starting with the planning and design approval stages, through to commissioning. Include the first year of operations during which monitoring and O&M training procedures will still be required.

12. (a) Costs & income

Provide a one-page cost sheet. Include running costs, contingency, plant factor, and unit energy costs (or other comparative economic indicators).

Outline the various ways in which the hydro scheme will generate revenue; for instance, via sale of energy to a mill owner or other commercial enterprises and by tariffs for fixed-wattage domestic electricity supplies. Specify what the certainty of this revenue is in each case, and how it will change over time.

12.(b) Tariff structure

The tariffs (prices paid by householders and entrepreneurs for use of electricity) to be charged should be outlined. Some justification for the tariffs should be given by detailing the outgoing costs such as loan repayments, O&M costs, etc. A request for a grant or subsidy to reduce the tariff can be made on the basis of this cash flow analysis. State in this section whether the tariff structure has been discussed with the villagers and whether agreement in principle exists. Does the tariff structure reflect the willingness and ability of all villagers to pay for the scheme? Does it include workable provisions for disadvantaged households?

13. Financial analysis

This section presents the financial future of the scheme, for example, by a cash flow analysis and by presenting economic indicators. It answers the question, is the scheme economically viable or not?

14. Sources of finance

This section states the recommended basis for financing the scheme. It may recommend a level of subsidy along with suggestions concerning where a subsidy or grant may be available. Also note whether the recommendations are in line with current government policy and whether or not a similar approach has been successfully adopted elsewhere.

15. Welfare

Comment on the potential of the MHP scheme in increasing the economic security of the village as a whole; in introducing new jobs and in bringing benefits to the less wealthy members of the community. Also comment on possible dangers; for instance, the creation of dissent due to unequal distribution of advantages and opportunities offered by the MHP plant and possible loss of existing jobs due to substitution of fuels. Propose methods to ensure welfare benefits and protect against disbenefits (for instance, some members of the community may be provided with electricity without payment of connection charges because they do not have cash income; people due to lose jobs may be chosen for new jobs associated with the MHP installation).

16. Monitoring

Describe how the proposed structures will be monitored and what alternative ownership, management, and O&M provisions could be made should these structures prove to be ineffective in forthcoming years.

4.2.2: An Example Explaining Applicability

Let us assume that an isolated MHP scheme is considered for construction to supply electricity to one village in a particular location. A well-informed village leader has realised the need for such an installation and started contacting other villagers, financiers, and manufacturers. A nearby stream is considered to be an adequate source for power generation. Finally, a contact is established with an expert development agency (GO/NGO/Consultancy) to look into the possibilities of establishing such a plant, investigating and analysing the various relevant parameters, and taking decisions[7]. The first task for the expert agency would be to determine the level of interest of the applicant/beneficiary community; their willingness to contribute in cash as well as in kind; and their capacity to collectively undertake the management, operation and maintenance of the plant, distribution of electricity, fixation of tariffs, and collection of revenue. Then, an initial site survey and measurements are undertaken and power estimates made. Thus, a prefeasibility study is initiated, including assessment of the demand and matching it with the available power. The first design of the plant is prepared, including a map of the layout. Costs and projected yearly expenditure are estimated to attempt a financial analysis (Chapter 7). If the Internal Rate of Return (IRR) or Benefit Cost Ratio (B/C) are adequate then the project is viable. Some environmental aspects may also be given due consideration, e.g., possibility of floods and resulting damage or landsliding due to construction of the channel, forebay, and penstock. Based on this study, the project may be rejected if any of the following can be foreseen.

- The capabilities and interest of the recipients are inadequate
- Costs are too high
- Technical viability (including geological considerations, water availability, etc) is suspect
- The current (estimated) demand is much higher than the available power.

However, if the results of the above prefeasibility study are positive, two things can be done.

a) A decision is taken to construct the plant and more accurate information from the site is collected from the recipients, investors, manufacturers, etc to improve design, economise on costs, and provide for future extensions. In this way, a more formal and expensive feasibility study is avoided; especially if the plant is small (say under 20kW in capacity) and is to be used mostly for agro-processing.
b) A more comprehensive feasibility study is authorised for larger plants, particularly for electrification, since their technical, operational, and economic aspects can be more complicated and problematic.

When a feasibility study is to be undertaken, the details can be adjusted according to the size and importance of the plant. The amount of detail in each of the elements (Section 4.2) should be matched to the size of the plant. For a scheme below 30kW, many elements will obviously be amalgamated or not required at all; for example, items No. 9, 14, and 16 can be dropped altogether in this case, while some parts of items 4, 6, and 11 can be ignored. Perhaps some aspects, e.g., 5, 12, 14, and 15 have been adequately covered in the prefeasibility study. For a one MW plant, even more details will be required than mentioned in the preceding section.

4.3: The Geographical Information System (GIS)

A relatively new method of carrying out 'desk studies' involves the **Geographical Information System (GIS)**. It deals with information that is predominantly geographical in nature. GIS can be thought of as representing a model of the real world which can serve as

[7] The procedures followed in different countries are usually different. In Nepal, for example, a manufacturer would be contacted to undertake the technical feasibility study and the plant/layout design, while the ADB/N would be approached to approve a loan and subsidy. The above example, therefore, is a desirable course of events. In some countries, e.g., Pakistan, a procedure quite close to the one described here is followed.

a test bed for anticipating the possible results of proposed actions. GIS can be technically defined as "a system of hardware and software and procedures designed to support the capture, management, manipulation, analysis, modelling, and display of spatially referenced data for solving complex planning and management problems." In short, it is "a computer system that can hold and use data describing places on the earth's surface."

GIS is a powerful tool for resource managers and planners dealing with map making and integrating other data therein. Its applications are limited only by the quality, quantity, and coverage of data that are fed into the system. Some of the standard GIS applications are integrating maps made on different scales, overlaying different types of maps which show different attributes, and identifying required areas within a given distance from map features, e.g., administrative boundaries, roads, and point locations.

GIS can be used for many applications such as planning rural infrastructure, identifying market towns, assessing and managing forests, designing irrigation systems, and so on. In MMHP also, GIS can be used for site identification, estimation of potential, and indication of demand from the neighbouring villages. GIS is not being used at present for this purpose, mainly due to the lack of quality data and expertise. However, its applicability holds considerable potential for the future.