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Prefeasibility studies of candidate mini-hydro sites

A methodology

NRECA Small Decentralized Hydropower (SDH) Program

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Small Decentralized Hydropower (SDH) Program
International Programs Division

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Small decentralized hydropower program

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Under the agreement, begun in May 1980, NRECA provides a broad range of technical assistance to developing countries. NRECA provides such technical assistance by--

- Designing and implementing regional workshops in Africa, Asia, and Latin America
- Scoping and managing in-country resource surveys and site assessments
- Providing engineering, design, supervision, and specialized assistance
- Developing specialized publications, such as state-of-the-art reports, inventories of manufacturers, and assessment methodologies
- Conducting special studies into subjects of finance, management, and evaluation
- Providing training services in such topics as operation and maintenance, resource assessment, management, and fabrication
- Carrying out specialized services, such as tours of U.S. manufacturing plants
- Creating specialized products, such as productive-use plans for energy from small decentralized hydropower.

For more information on the SDH Program, please contact:

Information Specialist
Small Decentralized Hydropower Program
International Programs Division

NRECA
1800 Massachusetts Avenue NW
Washington, DC 20036

Telephone: 202-857-9622
Telex: 64260
Cable: NATRECA

Preface

The National Rural Electric Cooperatives Association (NRECA), under a Cooperative Agreement with the U.S. Agency for International Development, provides technical consultation and assistance in the development of small hydropower installations in developing countries. NRECA's International Programs Division, through its Small Decentralized Hydropower (SDH) program, conducts in-country resource assessments and prefeasibility studies, provides training programs, and holds regional workshops in Asia, Latin America, and Africa.

NRECA is developing a broad range of documentary materials for the use of SDH planners, managers, and consultants involved in small hydropower programs for developing nations. Several methodological guides, of which this is one, describe simple estimating and measurement techniques, rules of thumb, and common sense approaches that can be very helpful to SDH practitioners in the field, particularly in remote or rural areas where recorded data is scarce and sophisticated instrumentation not available.

These methodological guides are intended for use by people with training and experience in water resource development and/or power generation--but perhaps with less experience in small-scale projects or in developing countries. The guidelines are derived from the field experience of the NRECA staff and consultants and from the analysis of the larger body of experience and information abstracted from the extensive literature on small hydropower development.

Contents

Preface, iii

Introduction, 1
The team, 1
The task, 3

General site description, 6

Power analysis, 8
Hydrology, 8
Powerplant head, 8
Estimate of potential electrical output, 9
Load forecast, 10

Preliminary design, 12
Turbogenerating equipment, 12
Civil works, 13
Electrical facilities, 13

Project costs, 14
Direct costs, 14
Indirect costs, 14
Recurring annual costs, 14

Environmental analysis, 15

Social analysis, 16
Social impacts and productive uses, 16
Institutional factors, 16
Related infrastructure development programs, 17

Economic analysis, 18

Level of effort for feasibility studies, 20

References, 21

Introduction

The National Rural Electric Cooperatives Association, International Programs Division (NRECA) assists the U.S. Agency for International Development and governments or organizations in developing countries in planning and implementing small decentralized hydropower projects in rural areas. This assistance often includes sending teams into the field to identify and survey sites where small hydropower projects might be located and to conduct prefeasibility studies of the sites.

This brief methodological guide summarizes NRECA's approach to performing prefeasibility studies of potential mini-hydro sites. It is intended for use by those who already have some training and experience with water resource development and power generation. Throughout this document, references to other sources of methodological guidance are noted.

The purpose of a prefeasibility study is to identify sites with enough hydraulic and economic potential to justify more detailed investigation. Prefeasibility studies are a necessary, integral part of mini-hydro development. Figure 1 shows where the prefeasibility study fits into the process.

The team

A prefeasibility analysis is best conducted by a team of experienced people whose combined backgrounds provide experience and knowledge of the major aspects of small hydro development.

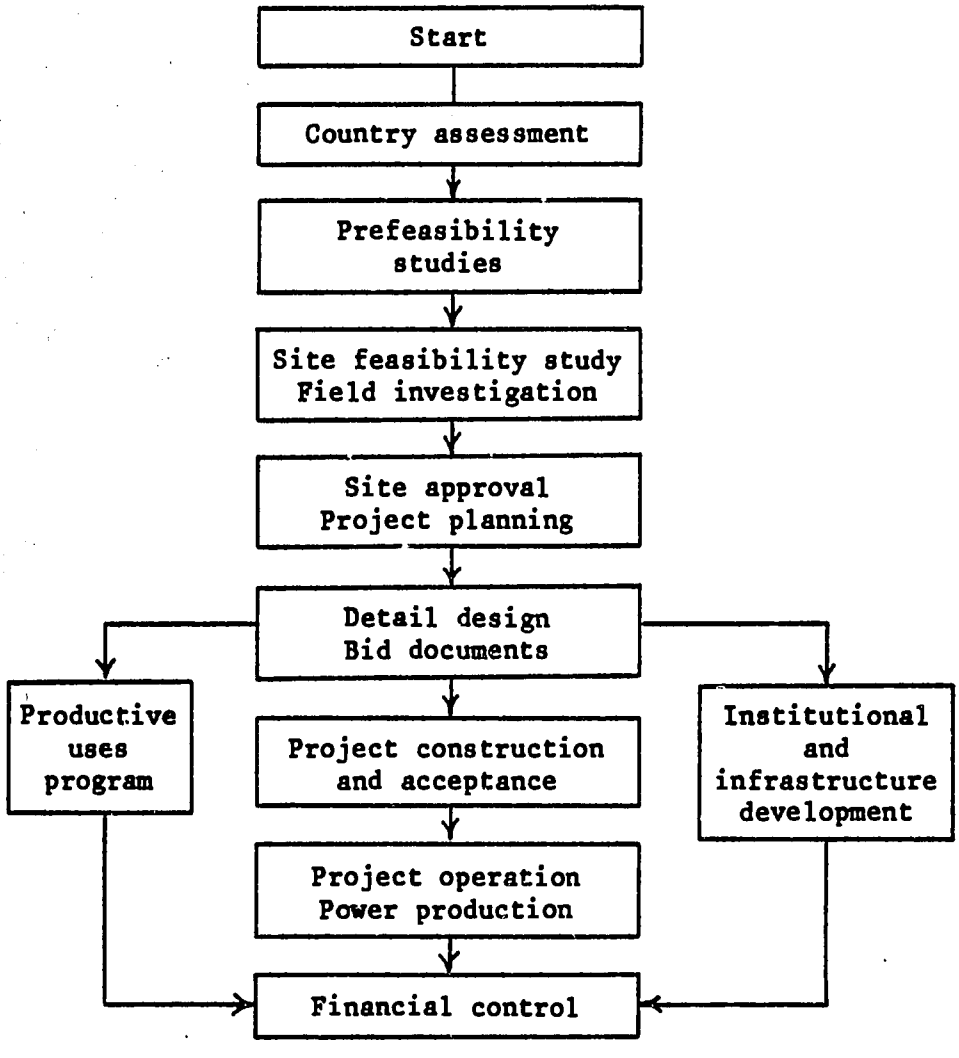
Keep the team small. Because of the great number of questions that must be addressed in a prefeasibility study--hydrology, equipment, electrical distribution, social impacts, environmental impacts, economics, etc.--it may seem that a large multi-disciplinary team is needed. But a large team is usually too costly at the prefeasibility stage. Look instead for fewer people with broader capabilities; perhaps a team leader, a general engineer, and a socioeconomist. More than four people may impose on the host country or organization a greater burden than the additional skills would justify.

Make full use of manuals. To fill any gaps in expertise that might result from using a small team, rely on field manuals and other publications that offer practical procedures, standard layouts, and simple methods or rules-of-thumb for conducting field work, especially for costing, sizing, and specifying equipment.

(NRECA has developed several methodologies to assist prefeasibility teams. See Hydrologic estimates for small hydroelectric projects (1982); Environmental methodologies for small hydropower projects (1982); and Centralized vs.

decentralized management of small hydropower (1982). NRECA also recommends several other methodological guides; see references 7, 8.)

Figure 1
Stages of project development



Assign a team leader. One person should have responsibility for the quality of field reports and presentation of the team's overall findings. He or she would be the first team member selected and should assist in selection of others. The leader will have authority to direct day-to-day activities and modify assigned responsibilities of the other members as necessary to meet unexpected situations. He or she will be the team's spokesman to host country officials. Generally the leader should be a person with broad background in energy development and small hydropower planning.

Arrange to work with an in-country team. The interaction between the two groups will give the prefeasibility study team insight into the area's special characteristics and problems and allow the local group to learn how to do a prefeasibility assessment.

The task

The team's basic task is to assess specific sites to determine whether they are technically suitable and economically attractive for development. Assessment techniques should be chosen that allow the sites to be uniformly and consistently assessed, compared, and ranked in some order of suitability.

A centralized base of operations will be established, usually in the capital city, since this usually offers the best transportation and communication lies.

A generalized decisionmaking procedure is outlined in figure 2. The site report should contain the information listed in table 1. Documentation should be made of each site visited, regardless of the conclusions. This may prevent future reconnaissance teams from making the same trip only to reach the same conclusions.

The list of topics in table 1 is long, and the amount of time the team can spend at each site is limited. How far can--and should--the team go in assessing each topic? The remaining sections of this document discuss these topics; in every case, the aim is to capture the most useful information with the minimum expenditure of time.

Figure 2
Decision flow chart

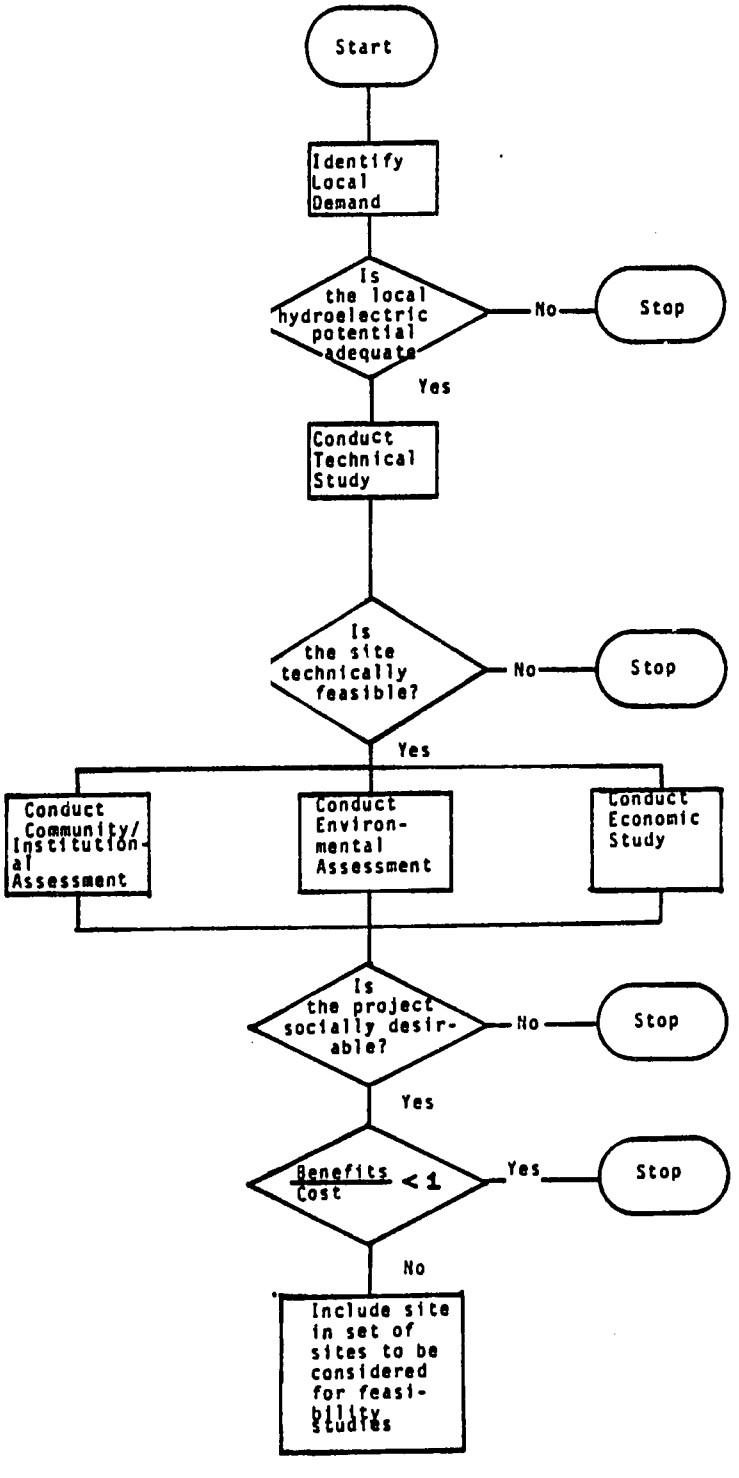


Table 1

Typical table of contents for prefeasibility study

Background

General description of site

Power analysis
- Hydrology
- Estimate electrical capacity
- Load forecast

Preliminary design
- Turbogenerating equipment
- Civil works
- Electrical facilities

Project costs
- Direct costs
- Indirect costs
- Recurring annual costs

Environmental analysis

Social analysis
- Social impacts and potential power uses
- Institutional factors
- Related infrastructure development projects

Economic analysis

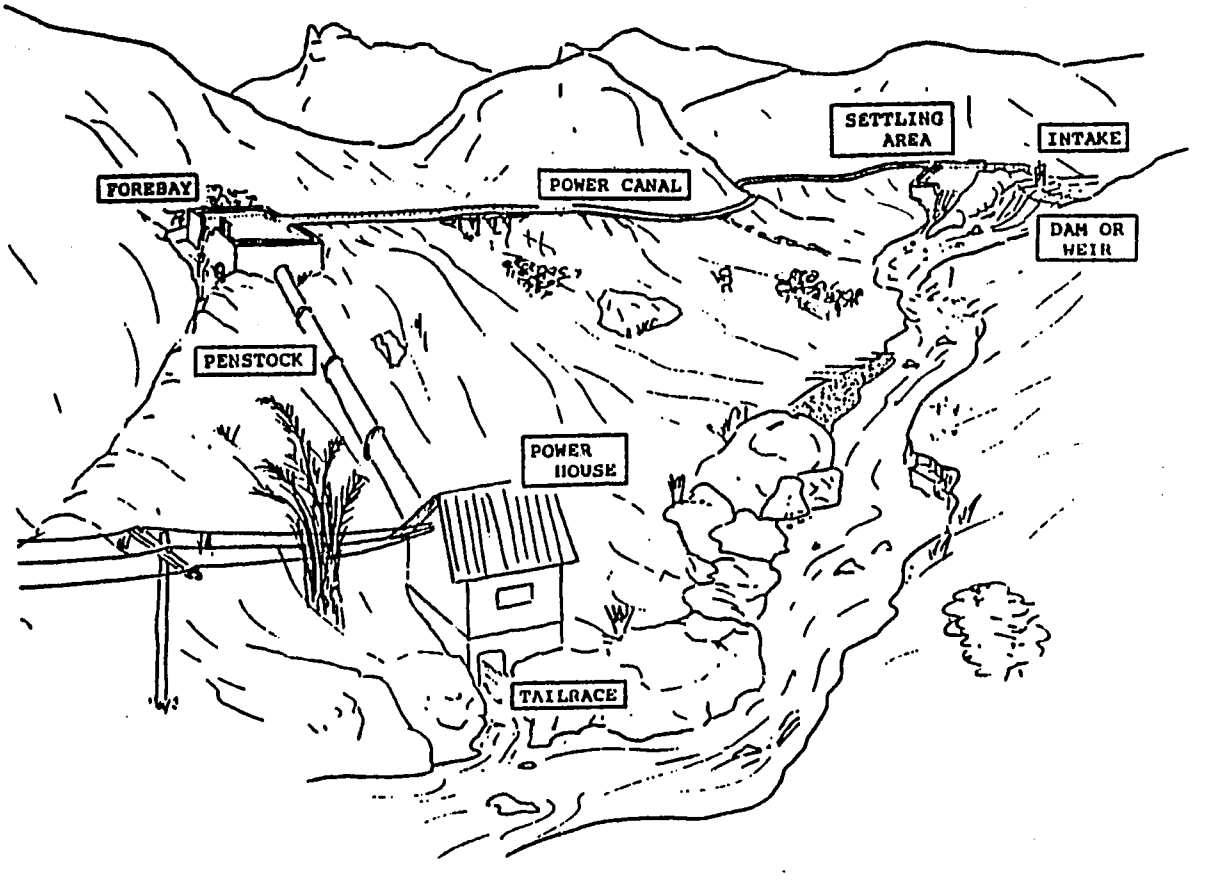
General site description

The team begins a site visit by describing the general characteristics of the site, including--

Present water use(s)
Existing electrical services
Access roads and communication facilities
Climate
Topography and geology
Local ecosystems.

The team should then layout the major features of the mini-hydro installation, as shown in figure 3.

Figure 3
Sketch of a typical mini-hydro site



Now the team should estimate the amount of power that could be produced at the site. This is a function of the quantity of water available, the vertical distance along which the water falls, and power plant capacity and efficiency.

Hydrology

Hydrology is a key element of the assessment since it is the basis for determining the project output and reliability and therefore its economic feasibility. A first step is to determine streamflows for a given location near the project site. The data that the team seeks is the daily or monthly streamflows, recorded at the site or at a nearby site, and the minimum and maximum flows occurring historically.

Due to the great variability in natural flows in a stream, it is necessary to use as long a hydrologic record as possible. Ideally, the record would be of sufficient length to include a representative sample of high-flow and low-flow years, show the long-term average flow, and include the critical dry period.

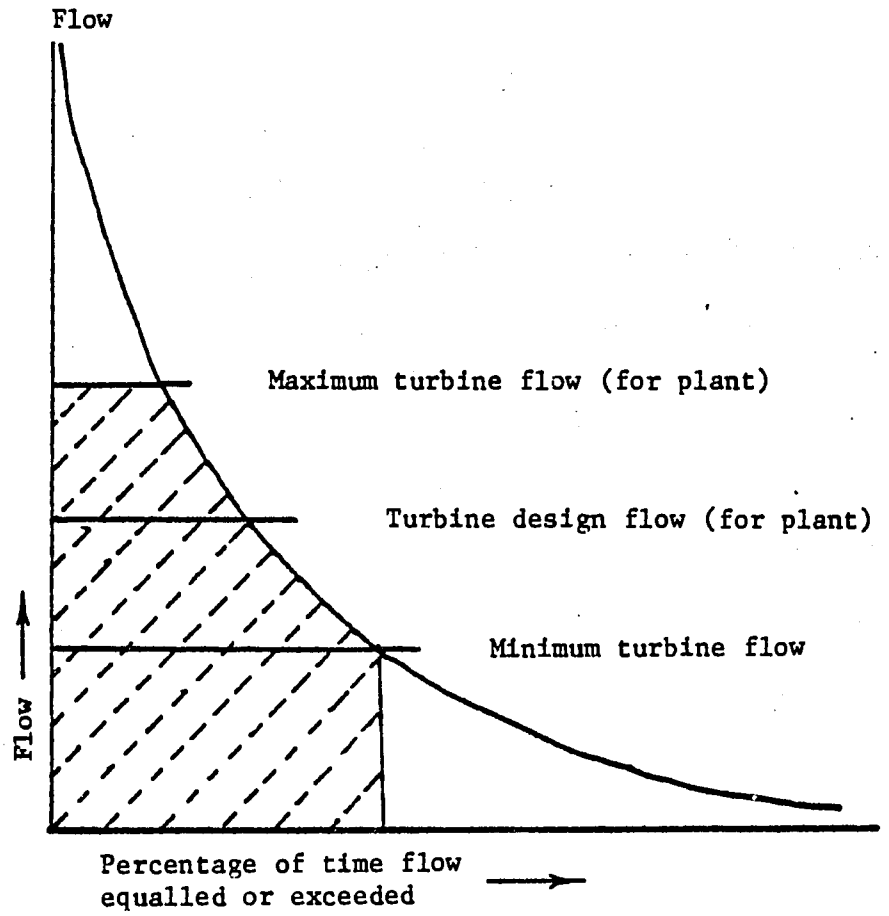
In most cases, the streamflow data will not be available in remote areas of developing countries. The team will have to estimate flows. Detailed instructions for doing this are described in NRECA's Hydrologic estimates for small hydroelectric projects (1982). This method utilizes rainfall data to estimate yearly streamflow. If sufficient information is available, the team can construct a flow-duration curve such as shown in figure 4. However, this is rarely the case.

The team should take measurements of flow at the time of the visit. Small flow-velocity measuring instruments are available and, if possible, should be used by the team. Additional methods for estimating flow are given in Reference 9. It should be remembered, however, that these methods are less than 50 percent accurate.

Powerplant head

If the upstream water surface elevation is virtually constant, the power plant head can be assumed equal to the difference in elevation between the upstream and downstream water surfaces, less friction head loss which is generally less than 5 percent. Informal methods for measuring the head are given in Reference 8, but these methods are generally good only under ideal conditions, where distances are short and there is very little brush.

Figure 4
Flow-duration curve



It may be appropriate to use a surveyor's altimeter, if one is available. For sites with greater than 100 kW estimated potential, it may be worthwhile to use instruments such as a theodoite for accuracy.

9 Power analysis

Estimate of potential electrical output

The amount of power that can be generated is proportional to the net head and the flow. The amount of power that can be extracted from any particular flow and fall is given by the following formula:

$$P = 9.8\ Q\ H\ E$$

Where P = Kilowatts generated

Q = The water flow through turbine in cubic meters per second.

H = Power plant head in meters.

E = The over-all efficiency of the generating equipment. (.6 to .8 depending on turbine type, etc.)

The formula, P = 7QH can be used for general applications.

At this point, the team should have a good idea of the head available and the range of flows. They should now consider two possible sizes, one based upon the minimum flow, and the other based upon the average flow.

Load forecast

For installations that would connect with an existing grid, load forecasts can generally be obtained from a central planning agency. But for remote, isolated applications, the socioeconomist should observe the surrounding community or area to identify possible and likely uses of the power. (For insight into this subject, see NRECA's Evaluating electrification experience: A guide to the social evaluation of small hydroelectric units in lesser developed countries (1982).) Working with other team members, the socioeconomist can estimate future load and an approximate growth rate.

In the absence of detailed information, population load charts, such as in table 2 will be developed and used as a first approximation of demand estimates.

The potential plant capacity may be greater than the estimated future load. In this case, the site may not be developed to its full potential during the initial installation.

If the load forecast is greater than the power potential estimated, then the site should be considered for full power potential development at the level of reliability desired (which, however, usually depends on the minimum flow of the stream).

Table 2

Demand estimate

Number of inhabitants	Demand
500 - 1000	30 - 60 kW
1000 - 2000	60 - 120 kW
2000 - 4000	120 - 240 kW
4000 - 6000	240 - 360 kW

Examples of factors to be considered in making the demand survey (not inclusive):

1. Current number of inhabitants
2. Average household size
3. Average current household expenditure on energy
4. Number of projected connections
5. Number of small industrial enterprises
6. Number of commercial establishments
7. Number of schools, health centers, and other community services
8. Current and projected demand for electrical energy
9. Average monthly kWh consumption per household
10. Basic assumptions for the survey
11. Types of usage

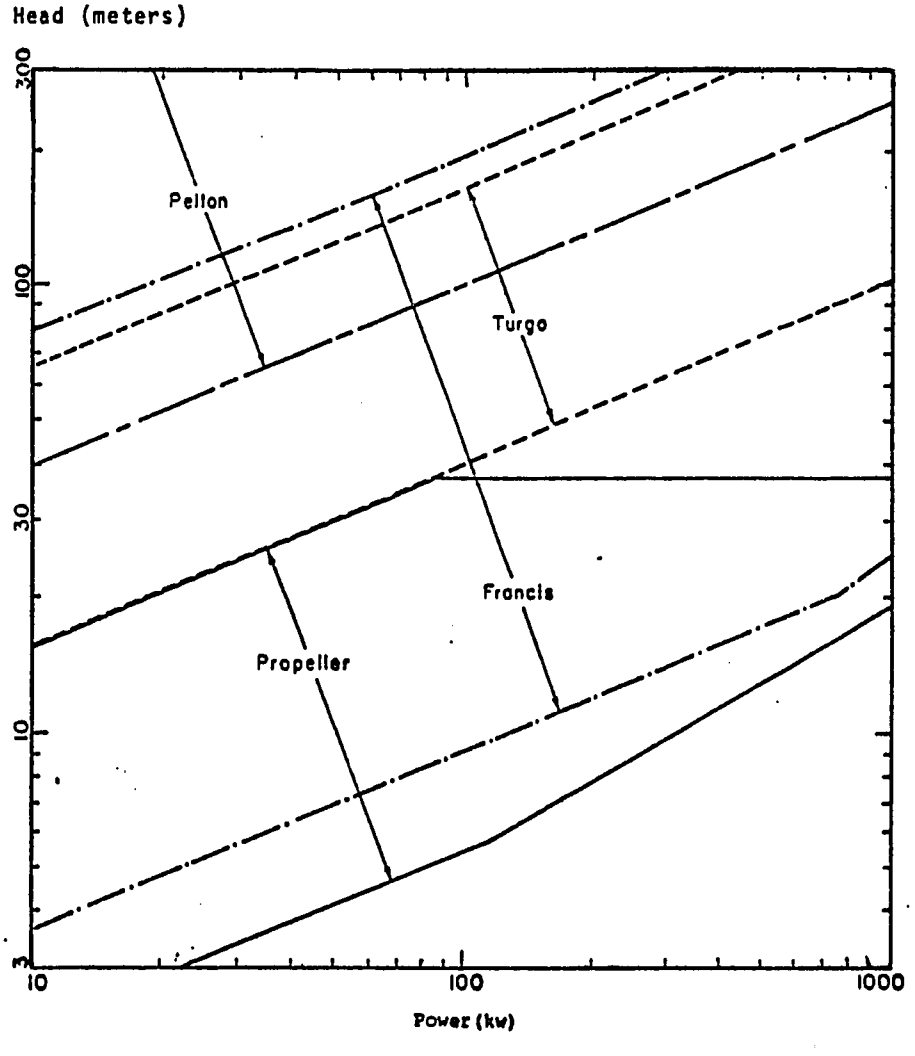
Now that the team has a sense of the capacity range and the use of the potential energy, they can determine the appropriate scale of development. If the use of the potential power is to supply a large grid, the installation should probably be scaled to full potential capacity based on a design flow greater than the average annual flow. For isolated installations, the capacity should usually be scaled to a flow value less than the average annual, but greater than the minimum and as dictated by the load forecast. Judgments based on experience in power planning are now required. What should be the design flow? If one uses the minimum annual flow, an enormous amount of potential energy is wasted. If one chooses a flow greater than the minimum, the power supply will not be reliable. How much capacity should be developed now and how much at some future date? Analytical techniques are available to address these issues, but their use is not warranted at the prefeasibility stage. The program should rely instead on the best judgment of the team members.

Once the team has a sense for the scale of development appropriate at the site, they can begin to piece together an initial design.

Turbogenerating equipment

The type of turbine will generally be determined using standard application charts such as shown in figure 5, which are based on height of head and power to be developed. The number of units depends on the flow characteristics and the service reliability desired.

Figure 5
Range of application of various types of turbines



Civil works

The civil engineer (if there is one on the team) can determine the general requirements and costs for--

Land: for power plant for reservoir (if applicable)
Access roads, if required
Penstock canal
Forebay intake structure
Powerhouse
Tailrace
Dam
Spillway

Electrical facilities

The team will have to determine the appropriate voltage level for distribution of the electric service and estimate the length and cost of the distribution facilities required. Electrical facilities will include--

Generator (size, type)
Generator switch gear and controls
Transformers
Distribution (voltage, configuration)

Direct costs

The team can now estimate the cost of the project based on generalized statistical data. Cost data based on previous projects, manufacturers' data, and unit price estimates should be used when available. Otherwise cost curves can be used to estimate equipment costs, civil works costs, and electrical distribution facilities cost. These figures will be less than 25 percent accurate, but as long as the same assumptions are used on all the sites, the sites can be ranked on a consistent basis.

Indirect costs

Indirect costs allow for engineering administration, construction management, and a contingency allowance. They should range from 20 to 40 percent of the direct costs. The sum of the direct and indirect costs is equal to the total construction cost.

Recurring annual costs

Once completed, the project will incur annual costs for--

Operation, maintenance, and repairs
Interim replacements, and
Insurance (if appropriate).

Operation, maintenance, and repair costs for mini-hydro projects are difficult to forecast, but generally are between 3-5 percent of the construction costs. Much depends on the availability of local people trained in maintenance, and on the availability of replacement parts. See: NRECA's Centralized vs. decentralized management of small hydropower (1982) and Evaluating electrification experience: A guide to social evaluation of small hydropower in lesser developed countries (1982).

A preliminary environmental analysis will identify problems that would make the project environmentally unacceptable, add to the project cost, or cause unacceptable time delays in project implementation. NRECA's Environmental methodologies for small hydropower projects (1982) is a useful guide for conducting the environmental assessment.

Generally, the analysis is simple and straightforward for such small projects. The major environmental impacts will in most cases be only the initial construction disturbance and the change in streamflow between the intake structure and the return flow to the stream.

The team should note any of the following potential impacts which may seem likely—

Changes in streamflow
Effects on downstream flow uses and water rights
Construction impacts
Health effects
Land-use effects
Water quality effects, and
Fish and wildlife impacts.

Social impacts and productive uses

The social scientist on the prefeasibility assessment team will survey sectors of the population in the target community, to assess—

Whom the project will benefit
Community acceptance and support for the project
The number of uses (and hookups) that can be expected
The average number of people served, per hookup
Opportunities for new productive uses and enterprises
The impact on the standard of living in the community.

This survey and analysis can be done in conjunction with the load determination. In addition, the social scientist should observe the community to reach conclusions as to the likely population growth rate, social priorities and attitudes, and the potential effect of electric power on the social welfare of the community.

The intent is to judge whether the project is socially desirable. This judgment should recognize potential direct, indirect, short-term and long-term impacts on the community. It is especially important to recognize that social/economic data collected at the prefeasibility stage can be valuable in post-project evaluation of the impact of projects, because it provides baseline data for assessment of later impacts.

For background information and guidance in carrying out preliminary social analyses, see NRECA's Evaluating electrification experience: A guide to the social evaluation of small hydroelectric units in lesser developed countries (1982).

Institutional factors

The purpose of this data collection and analysis is to provide information about major institutional requirements for development of a mini-hydroelectric project. Are existing institutions appropriate to sponsor or house such a project? Will new institutions be necessary? (See NRECA's Centralized vs. decentralized management of small hydropower (1982) for further discussion of this issue.) In general, a strong national organization interacting with a skilled local management institution is the best situation for a successful program.

Related infrastructure development projects

Electricity is a basic element in the adoption of many other technologies which can widen a community's range of possible economic and social activities. A rural electrification project

can have a synergistic effect on other development activities and projects in the area. The prefeasibility team should gather information on ongoing and planned local, national, or international development projects in the area and evaluate their possible interrelationships with the proposed mini-hydro project.

Alternative or multiple potential sites should be ranked according to their projected economic return. Dividing the estimated average annual benefit by the average annual cost gives a benefit-cost ratio. A preliminary determination of project feasibility can be made in part on the basis of the benefit/cost ratio (see figure 6 on next page).

A project will be considered economically feasible when average annual benefits exceed average annual costs. The benefit/cost ratio analysis will use a discount rate that represents a minimum social rate of return for the project. If the ratio is greater than 1.0 the project will tentatively be judged feasible and further evaluation will be recommended. If the ratio is less than 1.0 the project will still receive further consideration if it has significant potential social benefits.

The determination of these social benefits depend on--

The immediate likely impacts of electrification
The long-term, or secondary impacts of electrification
Substitution for other energy sources, or
Alternative uses for these other energy sources (for example, reallocation of dung from cooking to agricultural fertilization, reductions in deforestation, etc.

Figure 6

Sample format for calculating benefit/cost ratio

Costs

(1) Capital cost $_____

Annual cost rates:

Interest

Sinking fund ____%

Recurring annual costs ____%

Taxes ____%

Rate of return ____%

(2) Total ____%

(3) Annual cost = (1) x (2) $_____

Benefits

(4) Average annual energy _____kWh

(5) Value of energy _____ $/kWh

(6) Annual benefit = (4) x (5) $_____

Benefit/cost ratio

(7) B/C = (6)/(3) _____

Sites, local working conditions, and availability of data vary widely from project to project. It is therefore very difficult to pinpoint the level of effort required to generate an acceptable prefeasibility study for a mini-hydro site. In general terms, however, a three-person study team should be able to assemble and prepare a report in under two weeks. This figure assumes a three to four day onsite investigation and additional period of time spent at the team's base of operations in the capital city in research and preparation.

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