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A GUIDE FOR THE POTENTIAL MICRO HYDRO DEVELOPER: MICRO HYDRO IN BRITISH COLUMBIA

by

Nicholas P. B. May

B.Sc. Geography, University of Victoria 1982

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ABSTRACT

In British Columbia, natural resource managers and potential developers of micro hydro power face a knowledge barrier. Despite the growth in the provincial utility grid, a large number of remote communities, industries and individuals remain isolated from the grid and dependent on expensive diesel fuel generators. This situation has prompted a renewed interest in developing local energy sources, such as micro hydro. However, a lack of awareness and knowledge of the subject continues to impede the development of many potentially viable micro hydro sites.

This research project provides a technical, but easily understandable manual to assist non-academic and non-technical readers in planning and installing a micro hydro system. A potential developer will then be able to make informed decisions based on power needs and the resource potential available, and to determine where expert assistance is needed to successfully complete a project. The resource manager with little previous knowledge of the subject will be informed of the technology, and be better able to assess a micro hydro proposal for environmental compliance and technical merit.

The following three subject areas are treated in some detail. The environmental impacts that must be considered as a result of project implementation are listed and a checklist is provided to assist in determining environmental issues, and for identifying key areas that may require further study. A stage by stage approach to determining preliminary project feasibility is presented outlining the important resource, technical, and economic aspects of micro hydro that must be evaluated before a decision to develop the project is reached. The final section provides a series of guides to the permits, licences, and approval procedures involved in developing a micro hydro site on federal, provincial or private land.

DEDICATION

To my parents

ACKNOWLEDGEMENTS

I am grateful for the support and guidance of my project committee members, Ann Rounthwaite and David Tanner; and in particular, the patience of my supervisor, Dr. R. B. Horsfall. I would like to acknowledge Energy Mines and Resources Canada, Indian and Northern Affairs Canada, and the Banff Centre School of Management for providing financial and research assistance to complete the program.

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INTRODUCTION AND TECHNICAL BACKGROUND

INTRODUCTION

Micro hydro development is a clean, efficient and technologically proven source of electrical energy. It is the most promising of the available provincial renewable energy resources. Micro hydro is generally categorized as a hydro electric project having an installed capacity not exceeding 150 kW.[1] A project of this capacity would provide power to approximately 45 households. In comparison, the recently commissioned Revelestoke Dam Project (1984) has an installed capacity exceeding 1,800,000 kW.[2]

Although equipment capital costs can be high, and smaller streams may exhibit highly variable flow rates, there are a number of reasons for promoting the development of micro hydro power. Specifically, it uses a renewable natural resource, is combustion free, can be relatively quick and easy to install, and is well suited for rural development, housing and light industry power demand. An even greater bonus is that there are literally thousands of small rivers and streams in British Columbia that could be harnessed to provide local power.

A key element in the renewed interest in micro hydro power has been the fact that despite the growth in the provincial utility system, a large number of remote communities, logging and fishing camps, mines, resorts, native villages and individuals remain isolated from the utility grid and dependant on expensive diesel fuel generators.[3] Due to intervening topography which makes grid connection economically prohibitive, these individuals and communities face the impact of rising diesel fuel prices and might stand to gain from implementing where possible micro hydro power. Furthermore, it is becoming more apparent that many individuals favour local smaller energy systems rather than the large dams, reservoirs and transmission lines that currently dominate the provincial landscape.

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[1]Canada, Energy Mines and Resources, 1984, "Small Hydro Symposium," (Vancouver, B.C.: (Mimeographed)), 15 p.

[2]British Columbia, Ministry of Finance, 1985, Financial and Economic Review (Victoria, B.C.: Queen's Printer), p. 126.

[3]Canada, Energy Mines and Resources, 1980, Micro Hydro Vol. 1 (Vancouver, B.C.), p. 4.6.

Discussions with interested parties in both government and private business reveals that very little is actually known about micro hydro power, least of all what it is and how it works. This lack of awareness and knowledge of the subject acts as a barrier both to the prospective developer attempting to implement a project, and to agency personnel required to assess a micro hydro proposal who know nothing about it.

The success or failure of a project can result from many other factors, however, no operation will succeed if the site location and project design are not carefully and methodically developed. For example, it is important to understand early in the project planning stage the potential for environmental impacts as a result of project implementation. If an impact study is done later, the developer could waste time and money on feasibility studies only to discover that the project would be rejected on an environmental basis. Having first established environmental compliance and the feasibility of the project, the developer can then acquire any necessary regulatory approvals. The feasibility study in turn provides agencies with solid information from which to evaluate the project, and possibly reduces the time required to review an approval application form.

The aim of this paper is to introduce the basic principles of micro hydro, and facilitate the development of an acceptable project. It is designed to educate both resource manager and developer regarding the following concepts:

- The environmental issues that must be considered;
- A method for determining preliminary project feasibility; and
- The permits, licences and approvals needed to implement a project.

Because of the small power output from these projects, this paper is restricted to the use of micro hydro at remote locations not served by the utility grid. It does not consider the option of connecting to the utility grid, due to the limited interconnection policies of British Columbia Hydro, the remote locations of many sites which make grid connection prohibitive, and because high interconnection equipment costs would make most micro hydro projects uneconomical.

1.1 BASIC CONCEPTS

Hydro-electricity can be developed at a water resource site where there is a flow of water between different elevations. This elevation difference (head) governs the amount of energy a flow of water can produce. The water flow is determined by such factors as local precipitation, catchment area, evaporation rates and soil characteristics.[4] It is important to have a good knowledge of the stream's flow rate in order to size the turbine correctly to meet power demand. The head is dictated by both the local topography and the engineering design used to transfer the water to the power house turbines. The head should be maximized where possible with the ideal situation consisting of a waterfall or section of rapids. Head can be typically categorized as follows:[5]

- Head 2- 15 m - (low head)
- Head 15 -100 m - (medium head)
- Head over 100 m - (high head)

At a given resource site, a flow of water enters an intake structure to be carried by a pipeline (penstock) to turn a turbine. The turbine rotates and the mechanical energy is converted by a generator into electrical energy. The electrical current is fed to a transformer to boost it to the voltage of the transmission system which transmits it to the household or industry site. There transformers step it down to match household appliance and electrical wiring levels.

Approximately 0.2 kW is sufficient to charge a set of batteries to run the lights, refrigerator, and small appliances of an energy conscious household. In order to supply power for an average home, a minimum of 5 kW is required for an alternating current (AC) system. Project costs for systems between 1 and 10 kW range from $8,000.00 to $20,000.00. Costs for larger systems vary from $1,000.00 to $3,000.00 per kW depending on the site characteristics, system options purchased, and the amount of site work done by the owner.[6]

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[4]M.D. Gray, (ed.) 1973, Handbook on the Principles of Hydrology (Ottawa, Ont.: National Research Council), pp. 7.1- 7.24.

[5]Interview with John McKay, Micro Power Engineer, Solace Energy Systems Ltd., Vancouver, B.C., 10 February 1986.

[6]Note 5.

1.2 TERMINOLOGY

Appreciation of the fundamental principles and concepts of hydro power requires understanding of words frequently used in micro hydro terminology.

The *capacity* of a micro hydro project to produce electricity is measured in terms of its energy output; usually in *kilowatts*. *Power* is the amount of energy (work) supplied per unit of time.

- 1 kilowatt (kW) = 1000 watts
- 1 megawatt (MW) = 1000 kW
- 1 gigawatt (GW) = 1,000,000 kW

A 100 kilowatt plant has the capacity (power output) to run one thousand, 100 watt light bulbs. *Energy* is the capacity to do work. The work done by moving water (producing electrical energy) is usually measured in kilowatt hours (kWh). The energy output of a micro hydro project will depend on the time period over which the project is operating. A 100 kilowatt project operating at full capacity over one year produces (100 kW x 8760 hours) 876,000 kilowatt hours of energy (kWh). In reality, a project will usually operate below full capacity depending on the power demand and availability of water for generation.

Additional hydropower words include *demand*, *load*, and *efficiency*. Demand refers to the amount of power needed at a site (i.e., house, farm); load refers to the rate at which the power is delivered to the site by a micro hydro system. Efficiency is divided into hydraulic and mechanical efficiency; hydraulic efficiency refers to the effectiveness of the transfer to the turbine of the available power in the water that flows through the system; mechanical efficiency refers to the friction losses in the turbine equipment (i.e., bearings), and water friction losses within the overall system (i.e., penstocks).

1.3 RESOURCE FEATURES

If a resource site is to have potential as a good micro hydro power site, it should exhibit the following characteristics:

- High Head: Sites with high head require less water to generate power, and are usually more cost effective, since higher head turbine and project works are less expensive to install than are lower head equipment.[7]
- Sufficient Flow: Sufficient minimum stream flow must be available to generate power. Upstream water which is reserved for consumptive rights, irrigation, or fish and wildlife is usually not available for power use. In British Columbia, south coast runoff is greatest during the rainy winter months and many streams exhibit high energy potential during the same period power demand is greatest. Interior and Northcoast runoff is greatest during the spring freshet, and again in mid summer due to glacial melt water. At this time storage capacity can be replenished for use in low stream flow periods.
- Lack of Environmental Constraints: Resource agencies set basic requirements for the protection of fish, wildlife, aquatic habitat and minimum flow rates. Development on a stream containing fish could require installing fish ladders, elevators and scheduling of construction and operation activities to minimize impacts. Proper powerhouse location usually involves location near the first impassable barrier to migrating fish.
- Accessibility to Land/Water: In British Columbia the developer must apply for and obtain a water licence prior to generating power. Land ownership alone does not confer the right to use water. Land is also required to locate civil features such as penstocks or powerhouse. Land tenure is required to obtain a provincial water licence.
- Access Roads/Proximity to Power Demand Site: Site costs can be reduced where the powerhouse or penstocks are accessible by an existing road. Roads can be used to route penstocks, transmission lines or where hydro, or telephones poles exist to string micro hydro transmission lines.

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[7]Note 5.

- Existing Weir: Construction and environmental disruption can be minimized at sites with a pre-existing diversion or weir. Retrofitting weirs or diversions can also be less expensive, and reduce project construction time. The weir design and safety should be assessed prior to installing any project works near or below the structure.

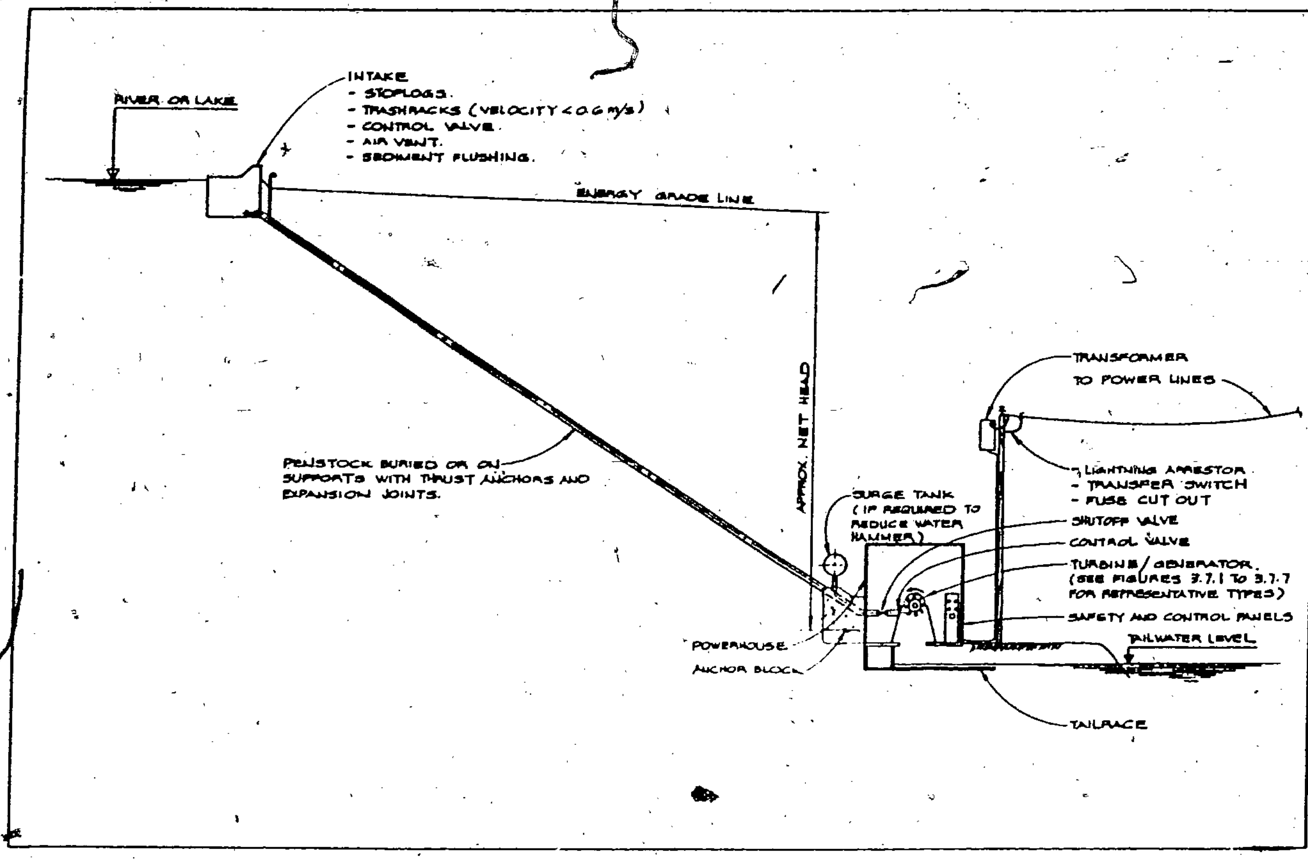
1.4 TECHNICAL ELEMENTS

The project design and overall configuration is dependant on a variety of factors including site characteristics (head and flow), technical and engineering feasibility, cost and power requirements. In general, a micro hydro project contains the following equipment and technical components:

- Diversion weir – structure to divert or impound water for storage;
- Intake system – structure to divert and permit water to enter the system;
- Penstock – pipe to carry water downhill to the powerhouse equipment;
- Turbine/generator – equipment used to generate electricity;
- Governor – mechanical or electrical equipment used to ensure that a constant rate of turbine rotation is maintained regardless of power demand;
- Powerhouse – structure to enclose and secure the turbine/ generator equipment;
- Outlet/tailrace – system to return diverted water to the stream;
- Transmission line – power line to transmit power to the demand site.

In addition, other ancilliary engineering features may include access roads for project construction and maintenance; fish ladders, guards or hatcheries to mitigate environmental impacts; and assorted electrical equipment (i.e., transformers, switchyards and load controls). (Figure 1).

Figure 1: MICRO HYDRO SYSTEM. (Source: British Columbia. Energy, Mines and Petroleum Resources, 1984.)



1.5 PROJECT TYPES

In British Columbia, micro hydro power projects include a run-of-river, mixed hydro/diesel, or a weir/storage project.

1.5.1 Run-of-river project

A run-of-river project is one whose energy output is subject to the available rate of flow in a stream or river. It requires ample water to supply the energy to drive the turbine because no appreciable storage is built into the system. These projects involve limited instream construction activity and only temporary water diversion. During winter, river ice or reduced rainfall can render such a project inoperative to meet the power demand, while in summer, drought conditions or low annual stream flow can also reduce power output potential. Energy storage (i.e., batteries) can be used during periods of low stream flow.

1.5.2 Mixed hydro/diesel project

A mixed hydro/diesel system can be used when stream flow rate is sometimes reduced, and insufficient to generate power to meet the demand. The diesel is typically used when peak demands or low stream flow (i.e., winter) occur, and is not used during the high stream flow periods. The major benefits of this system are the cost savings in diesel fuel, and the capacity to generate auxiliary power to meet peak load demand and emergency situations.

1.5.3 Storage project

A storage type project retains water in a natural lake or impoundment reservoir by using a dam or weir to augment or regulate stream flow during periods of low flow. This allows for a more constant power output, especially during low stream flow periods (i.e., winter). It also reduces the dependence on stream flow velocity to generate power which is common to a run-of-river project. The weir must be designed to withstand maximum flood conditions and stream channel meandering.

1.6 DEVELOPMENT CONSIDERATIONS

1.6.1 Advantages

The advantages of developing micro hydro include:

- The fuel (water) is a renewable resource, and rental costs are usually low for this type of project.(annual water licence charges);
- It reduces or eliminates diesel fuel costs;
- It provides an energy independence from the utility grid and diesel generator;
- It requires less maintenance than diesel generators of comparable size;
- The long term costs are low, and once built the project is virtually inflation-proof;
- It is a non-polluting source of electrical energy;
- The project can operate unattended for long periods of time; operates quietly; is unobtrusive and requires short distribution networks;
- There are a large number of sites available for development, and local power demand is usually limited (i.e., farms, homes);
- The projects have a modest water resource requirement, enabling integrated water resource use with present or future waterway users.

1.6.2 Disadvantages

A number of current drawbacks to developing micro hydro include:

- The water resource can be seasonal and highly variable; firm power capability of the stream must be thoroughly assessed to assure reliability of the project;
- The initial costs to fund feasibility studies, engineering designs, and to purchase equipment are high. Some cost reduction will occur depending on how much the developer can do himself, and when off-the-shelf or second hand equipment can be installed;
- The competing instream uses for the water resource, such as irrigation, domestic water supply, and fish and wildlife concerns could reduce the amount of water available for power generation, especially on smaller streams;
- The institutional difficulties in dealing with resource agencies and authorities concerning dam or weir construction, environmental issues, and regulatory procedures such as obtaining a

water licence can significantly extend the implementation phase of a project, increase costs, and in some cases even cause the developer to give up;

- The site must be located near the power demand as line losses can decrease power capacity while increasing project cost;
- Power demand can increase beyond the installed capacity of the existing hydro project, and require either installation of larger capacity generating equipment, or use of diesel generation units;
- Minimal technology transfer and information sharing presently occurs between developers, suppliers and equipment manufacturers. There is no provincial micro hydro association or newsletter that provides information on micro hydro (or any hydro) technology.[1]

1.7 PLANNING AND SITE EVALUATION

To ensure good results the planning and design of a micro hydro project should be carried out in several phases.

- SITE RECONNAISSANCE STUDY: the information collected during this phase is used to establish the viability of developing a micro hydro system. The study should be broad, and consist of a preliminary appraisal of the physical, technical and economic issues required to complete the project. Data collected should include identifying any major obstacles to development (i.e., environmental impacts, existing and future uses of the water by upstream and downstream users). Local topography, vegetation and hydrology should be assessed to determine sensitive areas (i.e., unstable slopes, endangered flora and fauna), and a suitable combination of stream flow rate and topography (head) for producing usable power. The study can initially be carried out as a desk study using topographic maps, air-photos, and site photography. Site visits provide an opportunity to establish the preliminary location of project components (i.e., intakes, penstocks, powerhouse), and for survey measurements made of stream flow, head (gross), and access road design. A simple plan of the project layout, equipment cost estimates, and a tentative project schedule can help the developer decide whether project analysis should be continued.

[1]For example, Idaho Energy Newsletter, "Currents", Department of Energy, Boise, Idaho. A monthly publication of energy and water technology in Idaho and Montana including information on small and micro hydro.

- PRELIMINARY FEASIBILITY STUDY: the preliminary feasibility study extends the reconnaissance study, and involves a detailed evaluation of the project site, layout, cost, environmental and technical features. The study's key function is to provide information to the developer so that decisions can be made concerning project implementation, and to suppliers and agencies inorder to determine equipment components (i.e., turbine, generator) and statutory requirements (i.e., water licences, environmental compliance). The study should refine critical issues identified in the reconnaissance study (i.e., environmental mitigation, status of water rights), and involve field work to gather information on electrical demand, stream flow, water and land access, equipment, configuration and cost. In most cases the developer can compile the information to complete a preliminary feasibility study at a potential site. However, consultation with an equipment supplier or civil engineer can ensure the study is structured to provide quality data, such that a decision to develop a project is made with a high level of confidence.
- PROJECT IMPLEMENTATION: the project implementation phase typically includes the following aspects:

  - Filing the applications for permits, licences and approvals;
  - Studies of environmental impacts (where required);
  - Ordering and obtaining electromechanical equipment;
  - Acquiring land;
  - Constructing and installing project;

1.8 CASE STUDY: Nimmo Bay Hydro Site

The following example demonstrates the basic technical and economic concepts involved with a micro hydro project.[9] The site selected is one which has been funded under the Canada/B.C. Agreement for the Demonstration and Development of Renewable Energy and Energy Conservation Technologies. The system is a storage type project located on Nimmo Creek, Nimmo Bay, Central coast of British Columbia. The project was designed and constructed in 1982. The purpose of the project was to implement a 35 kW micro hydro installation to replace the diesel fueled electrical

[9]Canada, Energy Mines and Resources, 1982, Nimmo Creek Hydro, Project Number F-80-11 (Vancouver, B.C.: (Mimeographed)), 1 p.

generation at a remote fishing camp. The hydro project serves all the energy needs of the camp including lights, refrigeration, hot water cooking, space and hot tub heating (Figure 2).

The project system consists of a 35 kW 1200 RPM generator with a projected annual production of 200,000 kWh/yr. The installation includes a weir/spillway and holding pond supplying a water flow of 0.065 m^3/s to a 240 m long 25 cm PVC penstock supported on wooden trestles, a powerhouse, and a stainless pelton turbine. The net head is 64 m. In addition, an electronic governor, transmission powerline, and protection systems were installed. The project costs are presented below in 1982 dollars (Canadian).

1.8.1 Project Economics

Pre-project energy costs:

- Annual maintenance costs- $1,350.00
- Annual fuel costs- $11,200.00

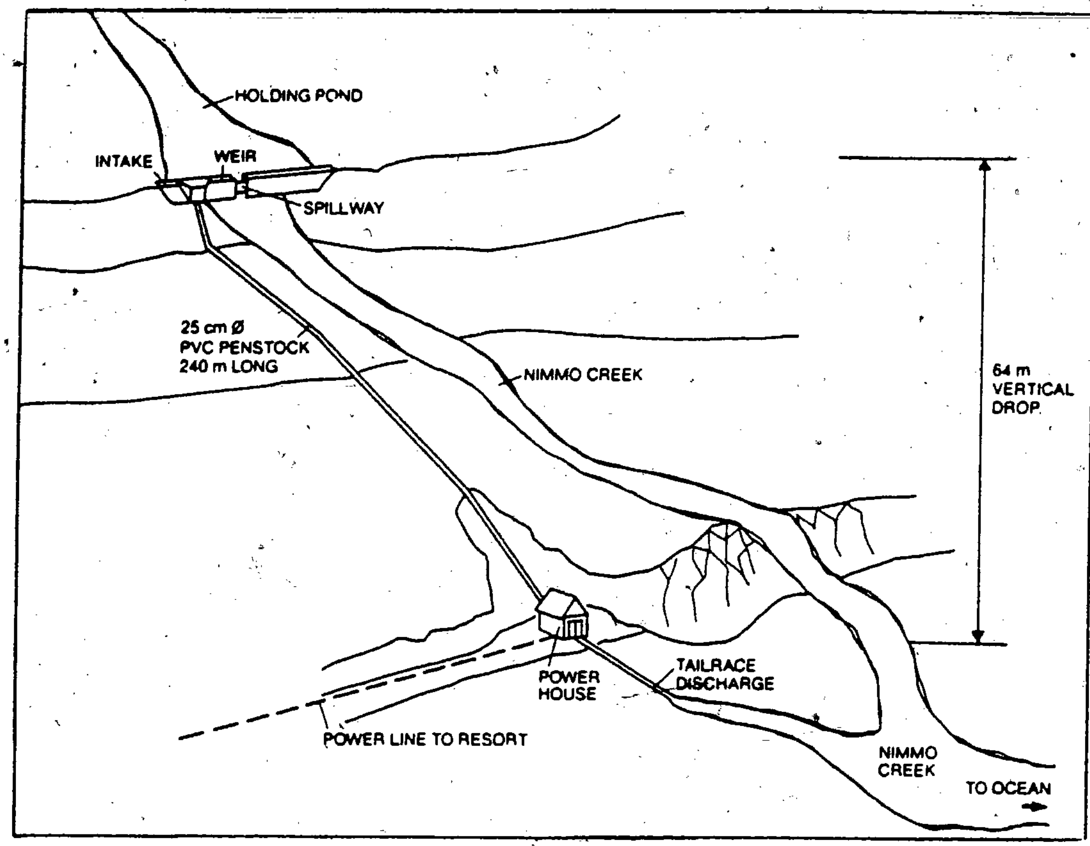
Project costs for the new hydro system:

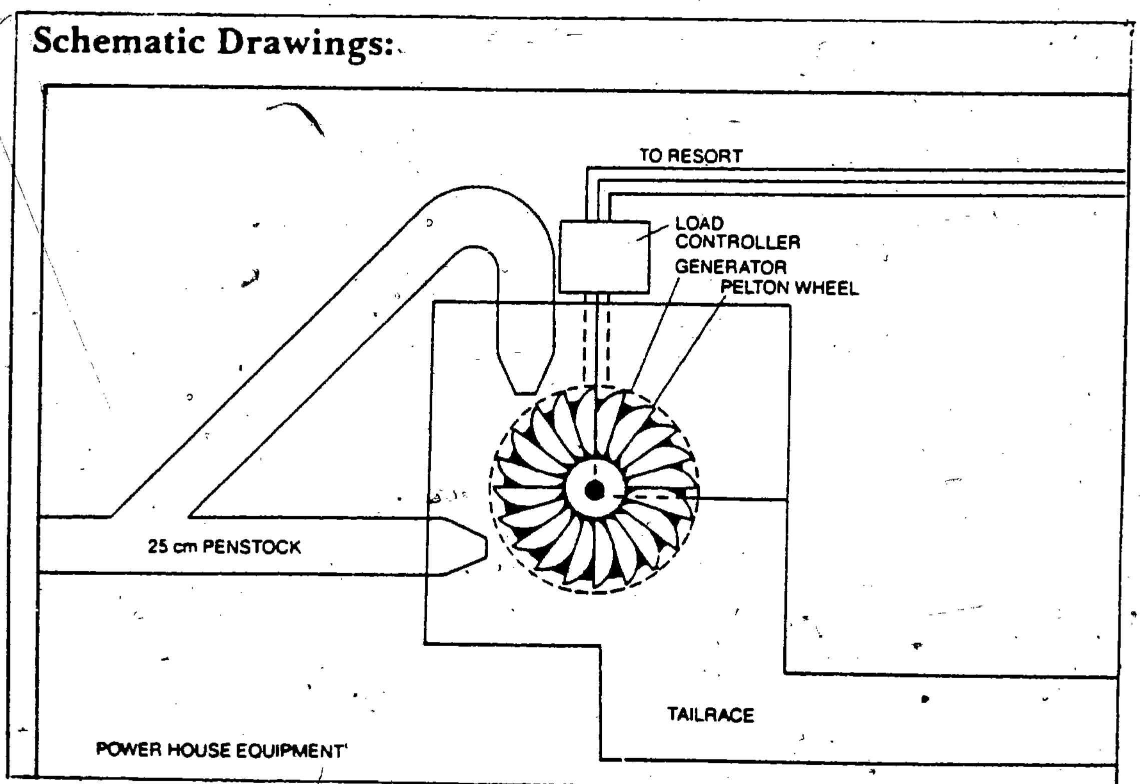
- Capital costs (equipment and materials)- $27,000.00
- Installation costs- $19,000.00
- Total installed costs- $46,000.00
- Cost per kW- $1,314.00/kW
- Annual maintenance costs- $65.00 per year
- Simple pay back period- 3.6 years

Expected benefits/savings:

- Reduction of $11,200.00 of diesel fuel per year consumption at the camp;
- Reduction of $1,285.00 maintenance cost;
- Replacement of an air pollution source.

Figure 2: NIMMO CREEK MICRO HYDRO. (Source: Canada. Energy Mines and Resources, 1982.)





CHAPTER II

ENVIRONMENTAL IMPACTS

INTRODUCTION

This chapter reviews the environmental impacts of concern when developing micro hydro. It briefly outlines where impacts could be expected to occur, and identifies key areas that may require further study. It also provides a checklist to assist the developer in determining general environmental issues before contacting regulatory agencies for approval to build and operate a project.

While the extent of environmental impacts associated with large hydro has been well documented,[10] the literature concerning small scale hydro assumes that environmental effects will be minimal, or that impacts will concentrate on the blocking of instream fish passage.[11] However, the need for water to generate electrical power from any size hydro project often conflicts with other stream flow characteristics such as water quality, quantity, recreation, aesthetics and irrigation. Therefore, to ensure that environmental quality is not irreparably damaged, it is best to consider potential environmental impacts during the design phase of the project.

The environmental impacts that originate from micro hydro can occur at two different stages of development; (1) temporary but significant effects during construction, and (2) those effects experienced during the actual operation which may be of a more permanent nature. Various types of project have the potential to create adverse impacts. Constructing a weir or dam in once free flowing water can create a more serious set of impacts than a run-of-river project having no appreciable storage capacity, causing little flooding or variation in downstream flow rate or temperature regimes. The use of an exisiting weir or dam (retrofit) can also reduce development impacts owing to pre-existing infrastructure.

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[10]C.P. Ruggles and W.D. Watt, 1975, "Ecological Changes Due to Hydroelectric Development on the Saint John River," J. Fish. Res. Board Can. 32: pp. 161- 170.

[11]G.H. Geen, 1980, "Environmental Impacts of Small Hydro." In Proceedings of the Conference on Small Hydro For Industry (Vancouver, B.C.: Crippen Engineering Ltd.), part 2.

While prediction of exact environmental impacts requires information specific to a particular hydro site, general concern should focus on fish and wildlife occurrence in the stream, location and extent of aquatic habitat, sensitive or endangered species, local vegetation, geological or hydrological factors, project type and mode of operation. Much of this information is easily collected by walking the hydro site and becoming familiar with the local environment into which the project is to be inserted. The information can then be used by both developer and resource agency staff in the following manner:

- To indicate whether any further feasibility study of the project is warranted;
- To determine whether regulatory agencies will require field studies to: assess development impacts; enforce the installation of mitigation equipment or compensation; or prevent development by refusing to issue a permit, licence or approval;
- To assist in selecting project equipment which is environmentally acceptable;
- To determine the environmental approvals necessary to operate the project, and to ensure they are obtained so the project is completed on schedule.

An *important first step* is to develop a list of the various sources of information useful for investigating potential environmental impacts of a hydro site:

- Much of the information can be found by contacting local, provincial and federal government agencies such as local municipal and regional planning offices, the B.C. Ministries of Environment, Energy Mines and Petroleum Resources, Lands Parks and Housing, and Forests, and the Departments of Environment, and Fisheries and Oceans Canada.
- In addition, local property owners, associations, societies, mining and forestry companies can provide information that might not have been readily apparent to the developer in the initial site reconnaissance study, including information concerning the last local flood or drought.

- Where possible, a developer should obtain maps, air photos and government reports on the area. They can provide information on the following environmental aspects:
    a. large scale topographic map (1:25,000) showing site elevations, streams, rivers, lakes and contour intervals;
    b. detailed air photos showing the drainage basin, vegetation cover, and land use;
    c. maps or reports of run-off and stream discharge information for the site, and drainage basin;
    d. maps of present and future land use in the project area;
    e. maps or reports detailing important historical, cultural and recreational resources in the project area;
    f. maps or reports on the soil type, geology and natural hazard potential in the project area;
    g. maps or reports taken from water wells in the project area that detail subsurface geology, groundwater levels and foundation permeability;
    h. maps or reports on sensitive areas such as wetlands, fish spawning habitat, endangered or threatened species in the project area;
    i. maps or reports on aquatic plants that could interfere with project operation (i.e., millfoil, algal blooms in impoundments).

An ***important second step*** is to develop a list of the environmental considerations that need to be addressed at the project site. The following is a general list that could be used to help structure a preliminary assessment of environmental feasibility:

- Visual aesthetics;
- Construction activities;
- Surface water quality and quantity;
- Soils, vegetation, geology, seismic activity;
- Dams, weirs and diversions;
- Fish and aquatic life;
- Birds and wildlife;
- Recreation (i.e., boating, fishing and swimming).

2.1 ENVIRONMENTAL CONCERNS

2.1.1 Visual Aesthetics

Too often, the aesthetic aspect of micro hydro is neglected by the developer because the small size implies small impacts. The developer should attempt to use some imagination and the available landscape (natural features) so that project equipment and facilities blend in easily with the natural surroundings. When constructing a weir (dam), use local materials (i.e., rocks, timber) rather than precast concrete structures. Penstocks can be painted where total concealment by vegetation or rocks is not possible. The powerhouse should conform in design and construction with other structures in the vicinity. Intake, tailrace, transmission lines and support structures can be integrated into the landscape in terms of shape, type, color, composition.

2.1.2 Construction Activities

Environmental and land use impacts are created by the improper construction of access roads and project components (i.e., weirs, penstock supports). Clearing vegetation for project facilities, or when constructing weirs or intakes within the stream channel should be scheduled to avoid harmful impacts to fish and wildlife. Access roads required to service projects located in mountainous and isolated regions should be built to prevent erosion, hillside slumping and poor overland drainage. Roads that cross streams should be constructed so as not to create slumping or erosion into the watercourse, and designed to withstand stream flood conditions. Construction activities including clearing stream banks for impoundment storage, transmission lines, blasting underwater bedrock, or washing construction aggregates can create localized soil instability and erosion. This can increase the suspended solids carried by the stream, burying and suffocating aquatic vegetation and bottom dwelling organisms, or injuring fish and marine life by abrasion. Increased erosion of sediment can also impede navigation, reduce the impoundment capacity, and increase flooding potential in downstream areas. The provision of stream side buffer strips of trees or vegetation, revegetating cleared sloping land and intercepting surface run-off at the construction site by ditches or drains to be later cleared out can reduce erosion and soil loss. It is also more appropriate to use small localized charges (explosives) during periods when no fish or marine life are in the stream. No chemicals, paints or solvents should be placed in the stream. Chemical spills (i.e., solvents, paints or oils) at the site can contaminate ground and surface water, and enter the food chain.

Construction related sediment or materials can act as a transport medium for heavy metals, oil residues or organics which can be toxic to instream fish and wildlife.[12] Designate a specific area for mixing and applying chemicals, oils or solvents, and dispose of all chemical residue away from the stream. Project safety should be paramount and involve regular project inspections during and after construction. The most catastrophic impact is, of course, the result of actual dam failure.

2.1.3 Water Quality and Quantity

The issue of instream flow should be addressed in the preliminary feasibility study. To take all of the water at a hydro site would mean drying up the stream between intake and powerhouse, a move that would be environmentally unacceptable and considered illegal. The resource agencies, including the Department of Fisheries and Oceans, Environment Canada, and the B.C. Ministry of Environment may require that a minimum instream flow be released at the point of diversion. This is to maintain fish and wildlife habitat, provide stable stream temperatures, and allow the downstream transport of dissolved nutrients and sediment.[13] Insufficient stream flow can kill fish and destroy aquatic habitat, reduce water quality, recreation and scenic values, and impede navigation. Instream barriers (i.e., rocks, stumps) that were avoidable under natural flow regimes can often become impassable with low instream flows, and impede fish, wildlife and watercraft (i.e., kayaks, canoes).

The extent to which stream flow patterns are altered is directly related to the design and operation of the project. The potential impacts on downstream aquatic habitat could range from negligible for run-of-river projects to significant in the case of storage projects. Small store and release projects operating to meet peak load can create rapid fluctuations in water levels above and below the dam. This can cause stream bank erosion, increased sedimentation downstream, exposure of the stream bed, and stranding of fish. The sudden startup of a hydro project using all or most of the natural flow may cause de-watering in the reach between the intake and the powerplant stranding fish; and may create a surge of water below the powerhouse with attendant erosion, and possible destruction of fish habitat.

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[12] J.J. Fritz, 1984, Small and Mini Hydropower Systems (New York, NY.: McGraw Hill Co.), p. 8.16.

[13] G.K. Reid, 1961, Ecology of Inland Waters (New York, NY.: D. Van Nostrand Co.), pp. 263- 287.

2.1.4 Soils, Landforms, Seismic Activity

Land clearing and vegetation disturbances for project works, transmission lines and access roads can be minimized if construction activities are undertaken in planned stages allowing for site reclamation and rehabilitation. The clearing of vegetated slopes near the watercourse can increase stream sediment load especially during heavy precipitation. Buffer strips adjacent to streams can act as stream bank stabilizers, and filter out overland transported sediment or overburden. Soil stability, geological features and vegetation type should be carefully observed near the project location to give clues to the subsurface geology, and assist in the assessment of the soil seepage, drainage and stability characteristics. Geological information can be obtained from surface observations of rock outcroppings, cracks and fractures. Vegetation in the area should be observed to provide information on soil depth, type and conditions (i.e., sand, clay or bedrock). Vegetation type can also identify a specific geologic unit, such as a fault line or fracture that could affect structural integrity of powerhouse and turbine foundations, or penstock support systems. Features such as rodent holes, fault lines, fractures, tunnels which could create a leak or breach of the weir (dam) structure should be investigated prior to project construction and operation. Examining soils and geologic features can identify areas of aggregates and borrow pits to be used in construction. Examining air photos for the presence of old abandoned stream channels will indicate the stability of the present stream channel. Instability can require engineering stabilization measures (i.e., rip-rapping, gabions or shot-crete) to prevent erosion around the intake; weir or dam rendering the project more costly.

2.1.5 Weirs, Dams and Diversions

Storage type micro hydro involving weirs (dams) and impoundments of water create environmental impacts of a different nature than do run-of-river type projects that involve only a low diversion structure to convey water to an intake. The potential for impacts is strongly dependant on the size (head) of the impoundment, because dam height controls the volume of stored water, and the subsequent extent to which upstream land areas may be inundated.[14]

[14] Note 12, pp. 5.1- 5.33.

In most cases, micro hydro power will not require the creation of large storage reservoirs with their associated ecological effects.[15] Nevertheless, any water impoundment is likely to cause some local impacts to the surrounding land and aquatic life.

The dam or weir can act as a barrier to the upstream or downstream movement of water, fish, wildlife, water craft and instream materials (i.e., leaves, logs, gravel). For migrating fish travelling upstream or downstream obstacles such as a dam can exhaust them so they are unable to reach their spawning grounds. It can impose a structural or aesthetic intrusion upon the landscape, and if fractured or breached will represent a serious hazard to downstream activities. A newly created upstream shoreline can introduce a range of impacts. The impounded water can flood valuable natural or manmade features; sites of historic, archaeological or scientific interest. The scenic qualities of a landscape can be impaired by fluctuations in water levels during impoundment drawdown periods. Riparian vegetation can be affected by either drowning or by gradually encroaching into the impoundment. Rapid water fluctuations can disrupt sensitive species in marsh or wetland areas, or by exposing incubating fish embryos to drying or predation.

An impoundment will reduce water velocity and may result in changes of temperature and dissolved oxygen levels, may trap sediment and stream nutrients, and may affect aquatic habitat because of degraded water quality.[16]

Water temperature is considered an important parameter of water quality, and much discussion of impoundments concerns thermal layering. Such a condition is normally associated with larger impoundment reservoirs, however any impounded surface waters will generally be warmer and bottom layers cooler.[17] Water temperature increases can delay the migration of many adult species of fish, accelerate the growth of fungus, disease organisms, and encourage silting of the stream bed, reducing the availability of dissolved oxygen.

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[15]G.H. Geen, 1974, "Effects of Hydroelectric Development in Western Canada on Aquatic Ecosystems," J. Fish. Res. Board Can. 31: pp. 913- 927.

[16]J.A. Kelly, 1980, Potential Environmental Effects of Small Scale Hydroelectric Development in Oregon. (Corvallis, OR.: Water Resources Research Institute, Oregon State University), p. 10.

[17]Note 15.

The quantity of dissolved oxygen is an important indicator of impounded water quality. The dissolved oxygen regime can be affected by temperature change, as warmer waters are less able to carry oxygen in solution. This can accelerate the growth of algal blooms and disease leading to eutrophication which can kill fish and marine life.[18]

The reduction in upstream water velocity can cause sediment to become trapped and deposited within the impoundment. The consequent loss in reservoir capacity will in turn result in lower power output potential from the project. The interception of bed-load gravel being transported downstream can adversely affect the quality of spawning grounds that will not receive the new material.[19] This reduction in bed-load material can cause the downstream channel to degrade over time, and become biologically unproductive, unattractive and subject to erosion. To re-establish impoundment capacity and the downstream channel can require dredging the accumulated sediment and bed-load material, or installing culverts in the weir (dam) to allow material and nutrients to pass downstream unobstructed. The periodic flushing or dredging must be scheduled to minimize effects on the downstream water quality and marine life.

Storage projects, especially those used in meeting peak power demand can create streambank erosion, meandering and impoundment bank caving problems. The scale of erosion within the impoundment is highly site specific, and depends on the streambank material and method of project operation. Engineering structures and bank stabilization techniques such as planting vegetation, and rip-rapping critical zones will be required to secure unconsolidated shorelines. A ramping rate, or gradual rate of impoundment drawdown can help reduce shoreline and downstream bank erosion.[20]

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[18]M. Monition, M. Le Nir, J. Roux, 1981, Micro Hydroelectric Power Stations (Chichester, UK.: John Wiley and Sons Ltd), p. 157.

[19]R.T. Oglesby, A. Carlson, J. McCann, 1972, International Symposium on River Ecology and Man (New York, NY.: Academic Press), pp. 263- 285.

[20]Note 12, pp. 8.1- 8.23.

2.1.6 Fish

Particular concern will exist on coastal rivers or streams that support fish. Protection of anadromous fish habitat should be viewed by micro hydro developers as an absolute constraint on the type of project and operation that can occur within a stream. Structures built in a stream channel have the potential to impede the movement of fish, sediment, and interfere with aquatic and riparian habitat and affect water quality.[21]

Six major concerns that weir or dam building may pose to migratory fish include:[22]

- Dams or diversions act as a physical barrier;
- Water currents, or lack of them may confuse juvenile fish;
- Water quality may deteriorate in the impoundment or downstream;
- Inundation of spawning grounds;
- Impoundments may harbour predator fish; and
- Fish ladder facilities may not be available or effective.

Resource agencies recommend that powerhouses be located near the base of the first impassable barrier to the passage of migratory fish. A diversion structure can cause direct mortality of fish at the intake if velocities are such that fish become trapped and are carried through the turbine system. The upstream movement of fish becomes critical if the project is designed to take all, or a significant portion of the total stream flow during fish spawning periods. This may require project operation to be shut down during this period to allow safe passage of fish through the system unobstructed. Mitigative measures to protect fish and aquatic habitat include guaranteed minimum flows downstream of the dam, controlling operation during fish spawning periods, and constructing fish ladders or mechanical lifts. Fish ladders or passages must provide for the passage of all fish species in the stream, and include resting places along the route, and anti-poaching devices (i.e., wire screen, mesh).[23]

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[21]Interview with L. Dutta, Habitat Management Division, Department of Fisheries and Oceans, Vancouver, B.C., 10 October 1985.

[22]L. Korn, 1968, "Reservoir Effects Upon Fisheries," Seminar conducted by Water Resources Research Institute, (Corvallis, OR.: Oregon State University), p. 55.

[23]Note 18, pp. 157- 160.

2.1.7 Aquatic Biology

The biota of a stream system encompasses a wide variety of organisms ranging from zooplankton and bacteria through to macrophytes and invertebrates. The operation of a micro hydro project can affect the distribution of such organisms through instream flow alteration, impoundments blocking downstream drift, loss of foodsource areas (i.e., construction) and changes to aquatic habitat.[24]

2.1.8 Wildlife

The flooding of land providing habitat for wildlife is a substantial change created by developing a storage impoundment. The extent and severity of wildlife loss will be determined by existing site conditions, wildlife species in the area and the impoundment design (depth and area). The project layout will also determine impact potential; penstock routing can obstruct some wildlife species.

Adverse impacts can include the loss of natural habitat, interference with the migration of animals, introduction of pollutants, displacement of species, and the potential for increased interaction with humans and infrastructure. Critical to some species with sensitive habitat requirements is the continued preservation and protection of a specific component of the natural environment (i.e., wetland or marshland birdlife). Extreme fluctuations in water levels can affect habitat, reproduction and survival rates of lowland and wetland birdlife. However, while marsh and wetlands are critical as nesting and rearing habitat, they can also provide hunting and wildlife observation opportunties to local residents. Favourable waterfowl habitat can accompany the formation of an impoundment or reservoir, attracting birds and wildlife to inhabitat shallow nearshore vegetation. Proper powerline and pole design can help protect migratory birds, raptors and other smaller wildlife species.[25]

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[24] Note 13, pp. 263- 287.

[25] Washington State Department of Ecology, 1985, Developing Hydropower in Washington State– A Guide to Permits, Licences, and Incentives. (Olympia, WA.: Washington State Energy Office), p. 33.

2.1.9 Human Uses: recreation

Neither micro hydro type is likely to significantly alter the recreational, aesthetic and human use of a river or stream, although potential for impacts will depend on the existing and planned uses for the area, the type of project and the present site characteristics. In some areas, micro hydro development will involve environmental tradeoffs between energy and recreation.[26] The attributes of a free flowing river encourage activities such as kayaking and rafting, and user satisfaction is directly dependant on uninterrupted stream flow velocities (flow and head to create white water). In this regard, the requirements for operating micro hydro are similiar to the requirements of a whitewater kayaking enthusiast. Unfortunately, these are two mutually exclusive water resource uses. The developer must also identify and give priority to the preservation of local historical, cultural and archeaological resources. This is especially important when locating projects within national or provincial parks.

Competition for available flow rates with other water uses can become a contentious issue, especially during low stream flow periods. Existing diversions, previously allocated water rights, and the potential for new upstream weirs or dams can diminish stream flow. In streams supporting natural runs of salmon or trophy fish, micro hydro development will be hard to justify given the already diminished quantity and quality of many runs. In this case, projects are likely to experience conflict from competition with water resource recreationalists, fisherman, and Native groups.

[26] P. Dyer, 1983. Small Scale Hydropower: How Does it Fit the Northwest Energy/ Environmental Picture? (Seattle, WA.: Institute for Environmental Studies), p. 59.

2.2 ENVIRONMENTAL IMPACTS

A summary of environmental impacts and remedies associated with micro hydro equipment and their use is presented below:

2.2.1 Intakes

- Intakes must allow for the downstream movement of sediment, rocks, objects, and fish and wildlife past the system or, (1) clogging will reduce penstock efficiency, (2) project equipment can be damaged, and (3) downstream spawning gravels, sediment and nutrients will be trapped.
- High intake velocities can trap fish and wildlife at the intake opening.

  Remedy: use screens or racks to prevent objects, fish and wildlife from passing through the system. If the intake screen size is too coarse, objects will damage equipment; if too small the intake can be blocked, reducing power output.
- Poorly designed intakes can cause air entrainment resulting in nitrogen supersaturation in the project's discharge waters causing a condition in fish similiar to the bends.

  Remedy: design intake system to avoid air entrainment by using air vents and ensuring adequate water cover at the intake structure.
- Water quantity diverted may be restricted in time of low stream flow, and the developer may be required to provide sufficient water depth during periods of upstream or downstream fish migration.

  Remedy: install water control gates or automatic shut-off valves at the intake to discontinue water withdrawl.

2.2.2 Penstocks

- Penstock leakage can destabilize slopes and lead to penstock failure, hillside slumping and erosion. The resulting sedimentation can reduce the quality of stream habitat for fish, vegetation and wildlife.

  Remedy: install water control gates or automatic shut-off valves at the intake to discontinue water withdrawl. Clear the immediate area of unstable rocks or trees that could damage the penstock system. Securely anchor the penstock system.

- Visual intrusion of penstock and support system.

  Remedy: bury the penstock, paint it a neutral color or plant low impact vegetation to conceal the penstock system. Use local topography to conceal penstock (i.e., valley, trench), and local materials where possible, such as wood or rock supports to better integrate system into the landscape. Where possible burying the penstock will reduce movement, leakage at the joints will be less likely, curious animals and humans will not usually disturb it, and landscape intrusion is minimal (once the pipeline is buried).

2.2.3 Powerhouse

- Construction activities can create erosion and sedimentation of adjacent stream.

  Remedy: provide ditches adjacent to stream channel to collect sediment.
- Flooding or stream channel meandering can undermine powerhouse foundations causing loss of equipment, and damage downstream structures impacted by floating debris.

  Remedy: securely locate powerhouse where possible on bedrock or solid ground, and at sufficient elevation to avoid flood waters.
- Visual intrusion of powerhouse structure.

  Remedy: build powerhouse using local materials (i.e., local wood or quarried rock), and paint it a neutral color. Keep powerhouse door shut during equipment operation and insulate building to avoid noise impact. Plant vegetation or berms (terraces) around the powerhouse to reduce noise, prevent flood water damage, shade and conceal the structure.

2.2.4 Outlets

- Concern with outlet operation includes (1) the violent dissipation of water energy back into the stream, (2) the entrainment of supersaturated atmospheric nitrogen in downstream flows, and (3) providing an attractant to fish that can divert or delay them from upstream migration.

  Remedy: lessening the possibility of erosion or destruction of aquatic life and habitat from water re-entering the stream can require the construction of ramps, steps or rip-rap boulders. The outlet should be screened or racked to prevent the entrance of fish or wildlife into the system.

2.2.5 Weirs, Dams and Impoundments

- A dam creates an impoundment, flooding land and altering biotic habitat. The dam interrupts stream flow, blocks bed load or sediment transport, presents a structural impediment to spawning fish, imposes a structural and aesthetic intrusion on the landscape, and can represent a hazard to downstream users. Construction activities can interfere with fish and wildlife movement, increase sedimentation in the stream, and cause stream bank erosion.

  Remedy: construct a weir or dam only when necessary and in a straight and stable section of the stream channel. Schedule construction activities in low use periods (i.e., winter) to reduce impacts on fish and wildlife. Provide fish ladders or spillways so that fish and wildlife migrate unobstructed past the weir or dam. Install culverts, gates or periodically dredge accumulated sediment and bed load material from behind the weir or dam.

- Impoundments can flood areas of historical or archeaological significance, and displace sensitive marine and wildlife species. Inadequate impoundment clearing can lead to water pollution, floating debris can create an unaesthetic appearance of the impoundment, and clog intakes.

  Remedy: relocate structures or build dikes to preserve historical or archeaological sites. Where necessary attempt to relocate species to an area of similiar environmental quality. Use mechanical algal controls to prevent stagnation and pollution of the water. Properly clear the impoundment of trees and detritus before flooding.

- Impoundment of water can decrease downstream flows destroying fish and marine life dependant on specific flow rates. Stream flow fluctuations to meet power demand can degrade downstream recreation, aesthetics, and during surges of high flow can lead to channel erosion or scour. Impoundment water fluctuations can lead to erosion of the shoreline, and an unaesthetic appearance to the impoundment shoreline.

  Remedy: regulate flow by reducing severe peaking operation of the system.. Release water slowly and over a period of time. Provide sufficient water levels in downstream channel to maintain fish and marine habitat.

2.2.6 Transmission Lines and Access Roads

- Access roads may lead to the weir (dam), transmission lines, penstock and powerhouse. Poorly designed and constructed roads can cause hillside slumping, erosion, drainage and water pondage problems, and degrade the aesthetics of an area. Transmission line systems require some land clearing for right-of-way access, excavation work to secure poles to support the wires, and an access road for operation and maintenance work. Transmission systems can pose a hazard to human and wildlife in the vicinity of transformers and transmission lines, degrade the aesthetics of an area, and lead to the increased blowdown of trees and disease from right-of-way clearance activities.

  Remedy: access roads should be build in compliance with proven industrial road engineering standards, with ditches and culverts placed parallel to the road bed and of adequate volume to transport excessive runoff. Where possible the road should be covered in a hard packed gravel to prevent erosion, excessive pot holes and water pondage. Attention should be paid to road cuts in steep unconsolidated slopes; these may require gabions or wooden buttresses to prevent downslope erosion and slumping. Transmission systems should be securely anchored, and at a distance from falling trees or vegetation. Electrical equipment components should be of such a design and standard as not to pose a hazard to human and wildlife. Secure fencing with warning signs can prevent unwanted intrusion along a transmission line system and access road. In some cases, (i.e., federal and provincial parks) burying the transmissions lines will be required to avoid visual intrusion.

2.3 ENVIRONMENTAL CHECKLIST

The purpose of the following checklist[27], is to provide a preliminary information source for the developer and the resource agency to identify potential environmental impacts from developing micro hydro. The developer can use the checklist; (1) to anticipate impacts from the construction and operation of the project, and (2) to mitigate impacts at the pre-design stage. Agency staff can use the checklist; (1) to better understand the proposal, and (2) to determine whether potential impacts are significant, and require further study.

2.3.1 CHECKLIST

A. General

- Collect existing environmental information about the site. This may require environmental studies or surveys to augment existing information as needed (refer to steps 1 and 2 outlined in the introduction). Studies may require collecting information on water quality and quantity; fish and wildife; vegetation and unstable areas; and impacts from project construction activities. Resource agencies can assist the developer by providing information on the type of study required to evaluate impacts, and how to complete it.
- Check whether any other applications (i.e., water licence, crownland permits) are pending for government approval of other projects that could directly affect the land or water required by the project.

(Information Sources: *Water Management Branch, Ministry of Environment; Lands Branch, Ministry of Lands, Parks and Housing*).

B. Land

- List the current use of the site, and the number of structures located on it, or on adjacent properties.
- Draw a general description of the site (i.e., location coordinates, flat, hilly, mountainous), and describe any unusual or significant features that exist on or near the site (i.e., historical buildings, rare trees).

[27]Checklist is based on the Department of Energy Environmental Checklist, State of Washington. Environmental Policy Act (SEPA); Chapter 43.21C RCW.

Include the following information:

a. the proposed use of the water, project size and site;

b. precise location of the site (i.e., legal description, site plan, topographic map);

c. what is the steepest slope at the site?

d. what types of soils are found in the area?

e. are there sources of fill, aggregates found in the area?

f. are there surface indications (slanting fence posts, trees) or a history of unstable soils in the area?

g. could erosion occur as a result of clearing land, construction or excavation?

Information Sources: *Lands Branch, Ministry of Lands, Parks and Housing; Mines Branch, Energy Mines and Petroleum Resources*).

C. Construction

- List the construction activities (i.e., building roads, weirs, powerhouse, transmission lines) required to complete the project.
- List new access road locations, type and construction schedule.
- List provisions (i.e., settling ponds, ditches) to reduce surface run-off, and waste material or sediment entering the stream.
- Outline the site reclamation and rehabilitation procedures to be undertaken during construction, or after the project is completed.

  (Information Sources: *Mines Branch, Ministry of Energy Mines and Petroleum Resources; Construction Branch, Ministry of Highways*).

D. Water

- List areas of high water table (i.e., swamps or marshland).
- List stream discharge patterns and indicate periods of low flow or high flows (floods).
- Indicate whether the project lies within the 10, 50 or 100 year floodplain.
- Indicate the quantity of water needed to generate power.
- Note areas of stream bank meandering or abandoned channels.

  (Information Sources: *Water Management Branch, Ministry of Environment; Engineering Department, local government offices*).

E. Vegetation

- List the types of vegetation in the project area.
- Indicate the type and amount of vegetation that will be removed or altered by construction.
- Detail measures to revegetate or landscape cleared land.
- Detail measures to preserve or enhance vegetation on the site.

(Information Sources: *Ministries of Agriculture, Forests and Lands, Parks and Housing*).

F. Fish/Wildlife

- List the wildlife (include seasonal) known to be in the area.
- List the endangered species known to be in the area.
- List measures to protect or enhance wildlife, or wildlife habitat.
- List the birdlife (include seasonal) known to be in the area.
- List the species of fish (resident and migratory) known to be in the stream.
- Detail measures to protect or enhance marine life or aquatic habitat.

(Information Sources: *Habitat Protection Branch, Department of Fisheries and Oceans; Fish and Wildlife Branch, Ministry of Environment*).

G. Recreation/Cultural

- List the designated and informal recreational opportunities that occur on the stream, and in the immediate vicinity.
- Indicate whether the proposal would displace any existing recreational uses.
- Detail any landmarks, or evidence of historic, archaeological or cultural importance known to be in the area.

(Information Sources: *Parks Branch, Ministry of Lands, Parks and Housing*).

CHAPTER III

PRELIMINARY FEASIBILITY STUDY

INTRODUCTION

To determine whether a river or stream can be harnessed to generate power requires a preliminary resource, technical and economic study. The study should provide the following:

- Accurate information of a quality such that a decision to develop or not develop micro hydro is adequately supported;
- Accurate information to present when discussing project details with equipment suppliers or resource agencies;
- Accurate information to use when later filing applications for permits, licences or approvals. In turn suppliers, or resource agencies will better understand a project, and help determine a project layout to make maximum use of the site characteristics (head and flow) and minimize environmental impacts.

A preliminary feasibility study should use a simple *stage-by-stage* approach to identify and assess resource, technical and economic constraints at a potential site. This chapter briefly outlines what is involved in each stage of a preliminary feasibility study. It also provides the type of information required, should a site appear promising, to proceed with a more refined and detailed cost and engineering study. The stages are listed below, and are linked by decisions of the developer to either stop the work, or, if the project still appears viable to proceed to the next stage.

THE SIX PRELIMINARY FEASIBILITY STAGES ARE AS FOLLOWS:

- STAGE ONE: —— DETERMINE POWER NEEDS.

- STAGE TWO: —— DETERMINE THE POWER OUTPUT AVAILABLE FROM THE HYDRO RESOURCE SITE.

- STAGE THREE: —— DETERMINE THE AVAILABILITY AND ACCESSIBILITY OF THE WATER AND LAND.

- STAGE FOUR: —— SELECT EQUIPMENT AND PROJECT TYPE.

- STAGE FIVE: —— DETERMINE PROJECT EQUIPMENT COMPONENT COSTS AND COMPARE THE ALTERNATIVES.

- STAGE SIX: —— MAKE A DECISION ON TOTAL PROJECT FEASIBILITY.

3.1 STAGE ONE: POWER REQUIREMENTS

OBJECTIVES

- Identify the total and peak energy consumption, and estimate load growth.

IMPORTANT CONSIDERATIONS

- What are the present and future energy demand requirements at the site?
- What periods during the day/month/year require small or large amounts of power?
- Is the number of individuals, households, facilities expected to increase or decrease in the future?
- Are there opportunities given the present energy consumption pattern for cost savings or energy use management at the site?
- What is the present power supply source?

INTRODUCTION

It is important to determine the amount of power required to meet the (power) demand at the site. This will help ensure that the installed hydro capacity is adequate to meet or exceed the demand. The existing power demand will later be compared to the potential energy available from the hydro project. A project capability too small to meet demand will mean utilizing a secondary energy source (ie., diesel or propane), or careful load management during peak demand periods at the site. On the other hand, oversizing a project will generally cost more than is required to effectively supply the site with power, and can destroy the projects economic viability.

The present electrical demand can be estimated by examining one or more of the following sources:

- Historical records of existing diesel generator equipment at the site;
- Utility power bills at the site;
- Survey of rated electrical capacities of the different equipment or industrial machinery located at the site;
- Preparing a detailed list of present power consumption at the site.

Typical household electrical devices, the power needed to run them, average hours of use and their energy consumption per month are shown in Figure 3. These are estimated averages and will vary depending on product and use. Energy consumption will also vary depending on the month, season, unusual weather changes, number of household members, amount of equipment and duration of operation (industry). Where diesel generators are used, it is appropriate to determine the highest demand period (i.e., winter), and demand for one period in the season that typically would have the lowest streamflows. Where no data are available, a rule of thumb is to allow an average load requirement of 1.5 kW per person, or 6.75 kW per household.[28]

Important when determining power demand are two seperate but related concepts: Total and Peak Consumption.

3.1.1 Total Consumption

It is usual to determine either the seasonal average demand or total power demand at the site. This will later help to establish the minimal instream flow rate required to meet the power demand. Total power consumption can be expressed as the number of kilowatt hours used in a month or year (i.e., kWh per month). A 2 kW project operating continuously for one month (720 hours) will generate 1440 kWh. However, the project will produce only 2000 watts at any given time. Average power demanded would be the total demand divided by the total number of hours during which that power is used at the site.

[28]Canada, Energy Mines and Resources, 1980, Micro Hydro Vol 2 (Vancouver, B.C.), p. 3.1.

Figure 3: POWER AND CONSUMPTION. (Source: Idaho Department of Water Resources, Boise, ID., 1983.)

Typical Household Appliance Loads

Appliance	Power Watts	Avg. Hours Use/Mo.	Total Power Consumption KW Hr./Mo.
Blender	600	3	2
Car block heater	450	300	135
Clock	2	720	1
Clothes dryer	4600	19	87
Coffee-maker	600-900	12	7-11
Electric blanket	200	80	16
Fan (kitchen)	250	30	8
Freezer (chest, 15 cu. ft.)	350	240	84
Hair dryer (hand-held)	400	5	2
Hi-fi (tube-type)	115	120	14
Hi-fi (solid state)	30	120	4
Iron	1100	12	13
Light (60-watt)	60	120	7
Light (100-watt)	100	90	9
Lights (4 extra, 75-watt)	225	120	27
Light (fluorescent, 4')	50	240	12
Mixer	124	6	1
Radio (tube type)	80	120	10
Radio (solid state)	50	120	6
Refrig. (standard, 14 cu. ft.)	300	200	60
Refrig. (frost free, 14 cu. ft.)	360	500	180
Sewing machine	100	10	1
Toaster	1150	4	5
TV (black & white)	255	120	31
TV (color)	350	120	42
Washing machine	700	12	8
Water heater (40-gal.)	4500	87	392
Vacuum cleaner	750	10	8
Shop equipment:			
Water pump (1/2 hp)	460	44	20
Shop drill (1/4", 1/6 hp)	250	2	5
Skill saw (1 hp)	1000	6	6
Table saw (1 hp)	1000	4	4
Lathe (1/2 hp)	460	2	1

3.1.2 Peak Consumption

Peak consumption is the maximum amount of electrical energy which may be required at any given time, and is the sum of the power ratings from those electrical items allowed to operate at any one time. It is normal to have a situation whereby the simultaneous use of all possible electrical items would exceed the capacity of the source of supply; however, this seldom occurs in practice because main breakers, appropriately sized, protect against a possible overload. However, a project designed to meet peak demand can mean that a developer is paying for installed generating capacity that is used infrequently. This can be both expensive and inefficient. It would be more effective to adjust present energy use through load management to fit a hydro project's power output, rather than to build a project to serve peak consumption patterns.

3.1.3 Growth Demand

Allowance should be made for potential demand growth at the site. This will also help to later determine whether the combination of flow rate, head and installed hydro capacity are sufficient to meet future demand. Where demand is expected to decline, overbuilding hydro capacity could prove expensive. The potential for demand growth can be estimated by examining one or more of the following sources:

- Historical records of exisiting diesel generating units at the site;
- Projections based on development trends using peak load demand to establish project capacity;
- Comparisons with energy data from a similiar individual or community located nearby;
- In the absence of data, a 6 percent compound growth rate is assumed.[29]

[29]Note 28, p. 3.2.

3.1.4 Summary

- Estimate total, average and peak energy consumption;
- Estimate future power requirements;
- Allow for continued use of existing source of power supply as a fill in during peak load demand and/or for emergency situations;
- Estimate power demanded at the site over a period of time, and during different days and seasons to provide an accurate representation of energy demand patterns;
- Priorize loads so that important power demand is given first priority. For example, refrigeration would be followed by lights, lights by radio, with the dog house interior light probably the least important.

3.2 STAGE TWO: DETERMINE POWER OUTPUT

OBJECTIVES

- Identify flow rate, head, head losses, equipment efficiencies, project output, and compare power output with site demand.

IMPORTANT CONSIDERATIONS

- Does the stream discharge rate fluctuate widely during the day/month/year?
- Is the stream discharge rate measurable weekly/monthly? Is there data available for the last year/ten years?
- Are there fish in the stream (seasonally or resident)? Are there spawning beds?
- Is the net head sufficient to generate energy to meet or exceed demand?
- Is the estimated hydro power output (kW) sufficient to meet or exceed demand?

INTRODUCTION

The potential power output is the product of head and flow. It is critical to have a good understanding of the available flow and head characteristics when selecting equipment of an appropriate design to meet power demand. This is because the operational efficiency of equipment will depend upon the variation in stream flow rate, head and project type. Nothing is gained by installing either larger turbine units than the resource can operate, or turbine units too small to harness the instream energy potential.

3.2.1 Stream Flow

The available stream flow rate is critical to the overall project success. When considering stream flow it is important to determine the following:

- The reliable, or dependable amount of water available;
- The minimum flow rate in order to calculate the minimum continuous power output expected from the project;
- The maximum stream flow in order to design sufficiently strong civil works (i.e., weirs, diversions), and to protect project equipment.

Stream flows can be highly variable depending on ice conditions, adjacent land use practices (i.e., logging, agriculture), precipitation, season and other water use requirements (i.e., irrigation, domestic supply). Stream flow should be monitored for a full year before a decision is made to purchase equipment or to proceed with the project. If flow rates are unknown, then at least one monthly (preferably bi-weekly) flow measurement should be made throughout the year. Where variations in stream flow are known measurements should concentrate on the few months surrounding the lowest flow periods. There are several sources available to assist in determining flow rates:

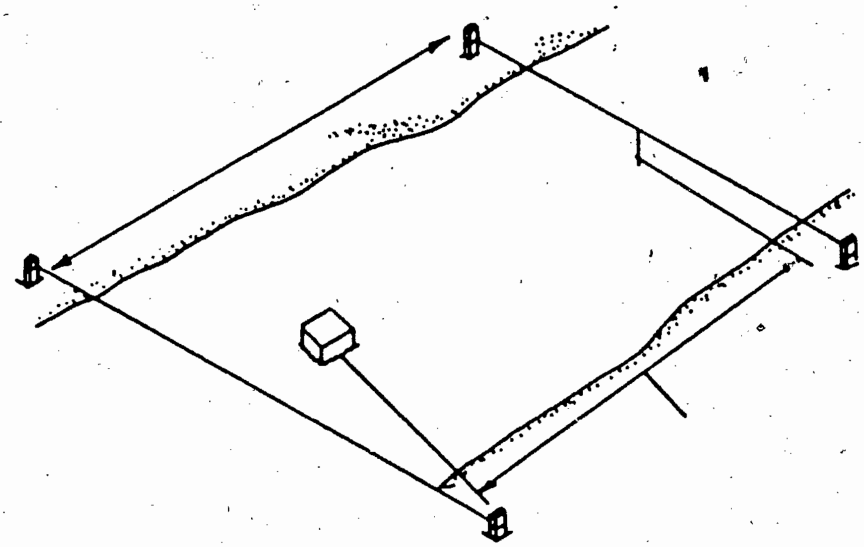
- Water survey records for the actual stream (Sources: *Ministry of Environment; Water Survey of Canada*);
- Analyzing flow data obtained from field gauges (Source: *Ministry of Environment*);
- Comparing gauged catchments of similiar precipitation and runoff characteristics;
- Hydrologic methods using precipitation, temperature and snow pack data to synthesize stream flow data.[30]

[30]Note 4, pp. 9.1- 9.22.

In the absence of data there are several crude alternatives available to measure stream flow involving the following methods:

- For very small streams, dam the water and divert it into a container of known size. Then divide the container volume by the time taken to fill it.
- For larger streams the float method requires calculating the streams cross–sectional area and velocity, and correcting for stream bed friction and channel roughness. This factor varies from 0.6 for a rocky stream bed to 0.85 for a stream with a smooth stream bed and sides.[31] Cross sectional area is determined by measuring the width of the stream and the depth (at equal intervals across the stream width), and then multiplying the width by the average depth. Stream velocity is determined by marking of a section of stream channel (i.e., 55 feet), and then timing how long it takes a float to pass between the two markers. The distance (55 feet) is then divided by the time taken by the float to travel between the markers. The float velocity is then multiplied by the correction factor to give an estimated average stream velocity. The flow rate is then determined by multiplying the cross sectional area by the average stream velocity. The flow rate is usually adjusted by the portion (percent of the total stream flow allocated for power use.

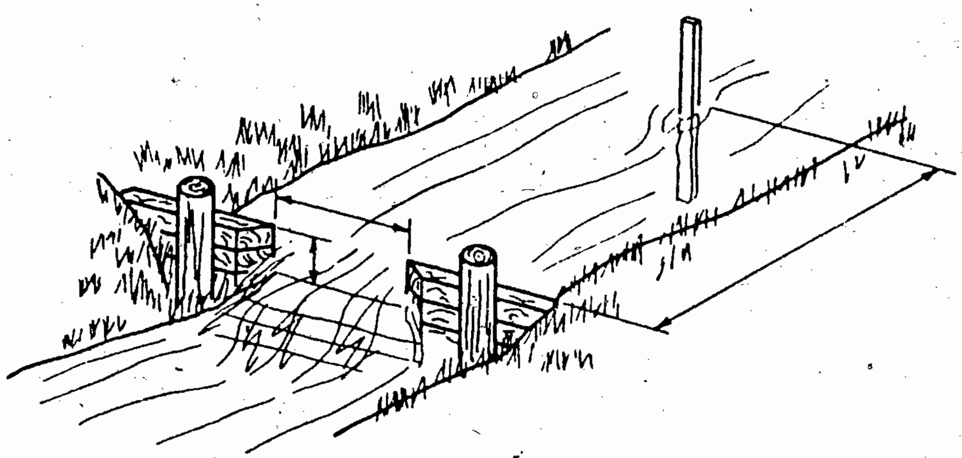
Figure 4: THE FLOAT METHOD. (Source: Idaho Department of Water Resources, Boise, ID., 1983.)



[31]see Manning Equation: T, Chow, (ed.) 1964, Handbook of Applied Hydrology (Toronto, Ont.: McGraw–Hill Co.), pp. 7.1– 7.49.

- A more accurate approach is the weir method. A temporary dam is built across the stream with a spillway located in the center section. The spillway dimensions should be sufficient to take the maximum flow of the stream during the measurements. A depth gauge is driven into the stream bed upstream (i.e., at least 5 feet) from the weir until a pre-set mark is level with the bottom edge of the spillway. The water depth above the pre-set mark will indicate the water flow rate over the weir. A weir table is required to help determine the flow rate. Estimate the depth of water over the pre-set gauge mark, and read the flow rate from the weir table. Multiply this flow rate by the width of the weir spillway to yield the stream's flow rate.

Figure 5: THE WEIR METHOD AND WEIR TABLE. (Source: NCAT Micro Hydro Handbook, Butte, MT., 1979.)



depth on stake in inches	cfm per inch of notch width
12.5	17.78
12.75	18.32
13	18.87
13.25	19.42
13.5	19.97
13.75	20.52
14	21.09
14.25	21.65
14.5	22.22
14.75	22.70
15	23.38
15.25	23.97
15.5	24.56
15.75	25.16
16	25.76
16.25	26.36
16.5	26.97
16.75	27.58

- Obtain an annual precipitation map of the province (B.C. Ministry of Environment) and note the rainfall amount in the drainage applicable to the proposed project. Compare this rainfall total with that of the nearest gauged river basin (B.C. Ministry of Environment; Water Survey of Canada). Obtain a second map of annual runoff amounts of the province (B.C. Ministry of Environment). Determine the mean annual runoff from within the gauged basin and multiply it to the ratio of the rainfall amount in the drainage and the gauged basin rainfall amount. Finally, multiply this amount by the approximate basin area where the hydro project is to be located to yield the mean annual flow in the basin.
- Additional stream gauging methods include using a current meter; gauging by chemical dilution (i.e., concentrated salt is added to the stream, and its dilution measured downstream at sufficient distance to ensure mixing).[32]

3.2.2 Head

The head is the vertical distance from the point of proposed water intake to where the water would leave the powerhouse. The head is not the length of penstock required to carry the water between intake and powerhouse. The power output potential available in the water will increase with the vertical distance the water falls. Therefore, when conceptualizing the project type and configuration, effort should be made to maximize the gradient at the site. The minimum head required to develop micro-hydro is difficult to specify because various combinations of head and water flow can ultimately provide useful power. However, sites with less than 20 metres of head are generally referred to as low head, and those with over 100 metres are high head.[33] Sites with less than 5 metres can be difficult and uneconomic to develop because of the added civil features (dams) required to augment head, the need to use precise survey measurements to determine the power output potential, and the larger physical turbine and generator equipment required to generate power. Thus, a low head site usually results in a higher unit cost of power generation than a high head site.

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[32]Note 18, pp. 30- 31.

[33]Note 1.

3.2.3 Gross Head Measurement

There are several methods available to measure the gross head at a site:

- By examining detailed maps and air photos for estimations of the vertical head difference between the proposed intake and powerhouse levels;
- By using photographic surveying in which the elevation is scaled on pictures taken at the site;
- By using a pocket altimeter to convert changes in air pressure into equivalent changes in elevation. Accuracy can be affected by a jolt during measurements or by unstable weather conditions. Measurements should be cross-checked with stuctures of a known height, and for repeatability by walking (measuring) the site several times;
- For lower head sites use a garden hose and pressure gauge. Attach the pressure gauge to the hose and fill the hose with water. Place the open end at the elevation of the proposed intake and the attached pressure gauge at the downhill location of the powerhouse. Read the pressure guage. Where the hose is not long enough, work downhill in stages;
- If the head appears to be less than 15 metres hiring a surveyor will ensure precise measurement. This can be expensive and there should be reasonable intent to carry through with the project if pursuing this option. However, it is possible to 'do-it-yourself', and requires renting surveying equipment such as, an instrument level, measuring staff and instructions how to use them. An error of 2 to 4 metres in the head measurement can have a significant impact on the type of project equipment selected and the cost estimates. This is because low head turbine and generator equipment is generally larger, requires more space to mount at the powerhouse, and involves additional civil works (i.e., powerhouse substructure of concrete).

3.2.4 Head Losses

To accurately determine the potential power output available from the stream requires calculating the net head. This is done by subtracting from the gross head various sources of fluid losses associated with the volume of water in the penstock, the size of penstock and its composition. The operating efficiency associated with turbine design and operation can also be included as a loss to the overall power ouput from the project. Turbine efficiency is largely dependent on design, range of instream flow rates, net head, operation and overall maintenance. Fluid friction losses will occur within a hydro system for several reasons:[34]

- Losses occur with high velocity water flow and in smaller penstock diameters. This results in a reduction in both the net head and potential power output;
- Losses occur at penstock elbows or bends, and so penstocks should be designed for the shortest, straightest and most direct route;
- Losses occur in penstocks of concrete, asbestoes, iron and steel. PVC piping usually offers the lowest friction loss;
- Project efficiency can also depend on the type of turbine to be selected. The majority of water turbines usually operate at between 80 and 95 percent efficiency, but this will vary depending on design and engineering refinement. Crossflow, Francis and Propellor (reaction turbines) exhibit minimal head loss. Pelton or Turgo (impulse turbines) will produce some head loss due to their design and application (vertical distance required between the jet directing water at the turbine bucket and the tailrace).

Efficiency curves are available for all types of turbines, and will usually suggest a selection of turbine types suited to a particular hydro site.[35] Micro hydro suppliers will be able to provide specific references on equipment efficiences if provided with accurate data on flow rate and head. A selection of typical efficiency ratings and turbines used in smaller (less than 20 MW) hydro projects is listed below.[36]

- Pelton .... 75 – 90 per cent;
- Crossflow..... 65 – 80 per cent;
- Francis .... 75 – 95 per cent;
- Propellor .... 80 – 90 per cent;
- Turgo .... 80 – 90 per cent.

[34]Note 12, pp. 4.10– 4.28.

[35]D. McGuigan, 1978, Harnessing Water Power for Home Energy (Pownal, VT.: Garden Way Publishing), p. 101.

[36]NCAT Micro Hydro Handbook, 1979, Micro Hydro Power: Reviewing an Old Concept (Butte, MT.: National Center for Appropriate Technology), p. 13.

3.2.5 Demand and Output Comparison

Having calculated the flow and the net head it is a simple matter to calculate the capacity in kilowatts. Given a hydro site's rate of water flow and head, capacity is provided in quantitative terms by: $P = Q \times H \times g \times e$

- Where P= capacity in kW.
- Q= flow rate in cubic meters per second;
- H= net head in metres;
- g= acceleration due to gravity (9.1 metres./s^2);
- e= overall estimated hydraulic, mechanical and electrical efficiency (0.7 for an average system);

Sample calculation: flow rate= 3 $metres^3/s$; net head= 200 metres; g= 9.1 metres/s^2; equipment efficiency (rough estimate)= 0.7.

$P = 3 \times 200 \times 9.1 \times 0.7$

Power output is approximately 3800 *kW*.

The kilowatt hours per year which may be produced requires multiplying this power output by 8760 hours per year times a firmness factor (which accounts for the times of the year when the plant will not be able to generate at full capacity due to variable stream flow). The firmness factor is derived from stream flow runoff curves and rainfall amounts throughout the province. The number will vary between 0.6 and 1.0 depending on location.[37] It is a constant which accounts for the times of the year when the plant will not be able to generate at full capacity due to variable stream flow.

Sample calculation: installed capacity= 3800 kW; firmness factor= 0.65.

Energy Potential= 3800 kW x 8760 x 0.65

kW.h/yr = 21,637,200 *kW.h/yr*.

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[37] British Columbia, Ministry of Energy Mines and Petroleum Resources, 1984, Small Hydro Power Resource in the Provincial System (Vancouver, B.C.), p. 1.3.

The final step is to now compare the power demand and the estimated (calculated) power output. For example, an average spring power demand value is 2800 kW. The power potential from the hydro source in our example is 3800 kW but should be adjusted slightly for variability in stream flow rate, season and installed capacity. However, as a preliminary assessment this indicates the stream has the potential to supply an amount of power in excess of that required at the site.

A hydro project configuration can now be selected to meet this demand. The range of flow and head combinations is from a high head option with H= 200 metres; Q= 2 m^3/s; to a low option of H=20 metres; Q= 20 m^3/s.

3.2.6 Project Output

Where a flow and head rate combination can produce a power output a decision must be made as to whether run-of-river, mixed diesel/hydro or a storage type project is appropriate to ensure reliable capacity to meet the power demand requirements at the site. The head available at the hydro site should be maximzed. The stream flow available must be considered reliable enough to provide energy to run the hydro system, and be sufficiently constant to justify constructing and operating the hydro system.

A. Run-of-River Project

Run-of-river projects will generally operate at something less than full capacity at some times during the year due to seasonal fluctuations in stream flow. This is because there are no provisions in project design to store a substantial quantity of water to augment head during low flow periods. It is not productive to construct such a plant to utilize peak flows because it will operate at less than capacity for most of the year. Sizing the project should be based on the reliable flow in order to match the installed capacity with the average daily power demand, especially during the low flow high demand winter months. Where possible some water storage should be made available to generate power to meet hourly variations in electricity demand. This can be accomplished by a simple temporary weir or wooden diversion structure placed into the stream to create a small amount of daily storage and a consequent increase in power production. The temporary weir or dam can then be removed during the higher flow rate periods (i.e., spring).

B. Mixed System: Hydro–Diesel

A mixed hydro–diesel combination can be a viable option for supplying power generation when stream flow is unable to generate enough power to meet site power requirements. However, a detailed economic and technical evaluation is required to determine the best combination of installed capacities of both systems. Advantages of this system will include stand–by emergency power, diversification of the energy source, reduced fuel costs, and an ability to meet unexpected high peak power demand at the site relatively quickly. Disadvantages are that the diesel generators can lose efficiency over time, require extensive overhaul after a low use period, are relatively inefficient during operation, and are a pollution source.

C. Storage Project

Water storage will be considered necessary where intermittent or interruptable stream flow reduces the power ouput to the site. Ideally, the impoundment would be of sufficient volume to provide storage for spring meltwaters and flood flows to provide a constant power output to the site year round.

However, annual water storage is usually only economical if an existing lake can be regulated, or a significant volume of the higher seasonal flows can be impounded with a low inexpensive dam, to provide water during low instream flow periods (i.e., winter). High dams are expensive because of high costs for engineering, excavation, civil works, large generating equipment and associated machinery (i.e., flow regulating gates, fish ladders). Determining storage volumes and reliable flow rates to size project generating equipment and civil features (dams/diversions) requires attention to drought and flood potential for the area. The overtopping or destruction of a dam can occur in severe high flow periods with subsequent damage to project generating equipment. Drought conditions will temporarily render useless a dam/diversion.

3.2.7 Summary

Steps to follow in determining the hydro power output potential at a site include the following:

- Measure the stream discharge rate, and estimate the useable flow rate over at least a one year period;
- Measure the total head (gross);
- Determine net head by subtracting friction losses from gross head;
- Calculate the theoretical power output available using the equation, P = Q x H x g x e;
- Compare the power output value to the estimated requirements at the site and decide on a project type and configuration to best meet demand.

DECISION STAGE: TO CONTINUE FEASIBILITY?

If the proposed hydro capacity is not sufficient to meet the estimated or projected power demand at the site then it is necessary to consider a number of options:

- Stop any further feasibility study on the proposal. It may waste time and money to pursue developing a project with highly variable or limited instream flows and head inadequate to meet power demand requirements;
- Select and evaluate a different water source for the required combination of stream flow rate and head characteristics adequate to meet or exceed power requirements. Two such projects combined may provide the power required at the site;
- Consider supplementing power demand requirements with secondary energy sources such as diesel generation (if not already in place), windmills or alternatives;
- Continue to STAGE 3, if confident that the available combination of instream flow, head and potential power output justify further feasibility study.

3.3 STAGE THREE: WATER AND LAND ACCESSIBILITY

OBJECTIVES

- Identify water and land availability, water licence, land acquistion, existing and future land use.

IMPORTANT CONSIDERATIONS

- Is sufficient water available from which to generate power? Who are the immediate upstream and downstream water licence holders?
- Who owns the land containing the water resource?
- Can easements for penstocks, transmission lines and roads for the project be obtained?
- Are the project works to be located on private, provincial, Indian Reserve or other federal land?
- What future short and long term land use plans are being considered on land adjacent the project, or within the upland drainage basin?

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Attention should now concentrate on regulatory and legal requirements surrounding the project site (refer to the next chapter for greater detail). Any potential water and land use conflicts, or likely environmental impacts from the project should be identified during this stage. Contact with local or district level resource agencies will confirm the continued feasibility of the project, or identify environmental or regulatory constraints that may have previously been overlooked. This early consultation will then allow sufficient time for the conflict to be either resolved by modifiying the project design, or for alternative sites to be indentified and investigated.

3.3.1 Water Availability

Contact the B.C. Ministry of Environment, Water Management Branch to determine whether the required amount of water is available for use, the names of current water licence holders on the stream, their water use and the quantity of stream water already allocated. This will help to determine whom to contact later during the licence application process. If water is available, commence water licence application procedures at a Regional Water Management Branch. The assessment of a licence application can be a long process, taking from 8 to 24 months. Filing an application will help establish a priority in time but not a priority in use. For example, hydro power generation is ranked behind domestic, waterworks, mineral, mining and industrial use for precedence in periods of low stream flow. It is necessary to have land tenure, which can include a lease in order to receive a water licence. If purchasing land near water, check if any water rights are transferred along with ownership of the property. A water licence issued for irrigation, or for mining uses does not entitle the holder to generate power. A water licence must be applied for each differing intended use of the water.

Water Management Branch staff will outline conditions that may be attached to the licence that might affect the design and operation of the project. These conditions might include fish ladders or elevators installed in a storage project. For run-of-river projects they might include intake structures to be placed in stream sections not generally frequented by fish, and limitation of flow diversion during low stream flow periods for irrigation or farming requirements. Because only part of the total instream flow is usually available for generating power, attention must focus on the quantity of water allocated for fish and wildlife requirements, irrigation and domestic supply. A good hydro resource site could be rendered useless if the stream water is fully or partially allocated for other purposes during parts of the year. Identify the water use and quantity required by current water licence holders located between the upstream intake and the downstream tailrace. Early consultation with such parties will resolve or identify conflicts, and allow time for an agreement to be reached concerning aspects of the project operation.

3.3.2 Land Availability

In some cases micro hydro developers will own the land on which the project will be located. Others will need to secure rights from a private individual or a local, provincial or federal agency. Contact the B.C. Ministry of Lands, Parks and Housing, Regional Offices if unsure about land ownership and status. Land ownership is an important consideration in any project feasibility study, because problems in obtaining land to locate an access road or civil works could later restrict project implementation. The feasibility of the entire project should be well established before any purchase, lease or licencing arrangements for land are made with private individuals or resource agencies. A developer issued a water licence does not automatically acquire any right to use or develop adjacent streamside land unless he owns that land, or has first received the permission from the landowner or managing resource agency. The developer must contact the appropriate managing provincial or federal agency before undertaking feasibility studies or locating project works within special use areas (i.e., Indian Reserve, provincial park or forest). Many of these areas are restricted to development, and may require modifying or abandoning project plans.

The developer should investigate and identify the short and long term land use patterns within the drainage. Significant impacts can occur from forestry and other related land use activities. Poorly designed access roads, logging and agriculture can increase debris and sediment loads into the stream. This will affect the operation of the project and may damage turbine and penstock equipment. Logging operations can affect the stream discharge rate by increasing peak flows and reducing low flows. Compared with pre-logging discharge flows this could now decrease the previously calculated power potential from the project.

3.3.3 Summary

- Determine availability of the water and land resource, and what quantity of the total flow is available for power generation;
- Determine and evaluate any conditions that could be placed on project design and operation, before applying for a water or land use licence or permit;
- Determine the present and future land use patterns in the drainage, and whether logging or agriculture is to be developed near the stream, or on upstream land parcels.

3.4 STAGE FOUR: PROJECT EQUIPMENT AND TYPE

OBJECTIVES

- Identify weir/dam, intake, penstock, turbine, powerhouse, generator, governor and protection/control, and transmission lines.

IMPORTANT CONSIDERATIONS

- What is the expected service life of the project given the instream conditions? Does the stream carry large amounts of silt or grit?
- Does the project require a storage weir/dam? Or is it run-of-river?
- Is the hydro site near the demand center or at a distance? Are transmission lines required?
- Is there an equipment dealer or supplier located nearby? How accessible are spare or used equipment parts?
- How much of the actual equipment installation can be done by the developer? Will it require extensive engineering or construction expertise?

INTRODUCTION

This part provides a general guide to the function and application of equipment used in micro hydro. To actually select equipment and an optimum project configuration suitable for a particular site requires a detailed cost and engineering study, and discussion with equipment suppliers. However, understanding basic information concerning equipment can make discussions about potential design, cost and installation with suppliers much easier. The photographs included in this part will help illustrate the equipment components of an operating micro hydro project. The site selected is the Koksilah Power Company (owner David Laverock), located on Grant Creek Lake, Vancouver Island, B.C. The project is primarily run-of-river with storage capability during low stream flow periods (i.e., summer). The project system consists of a 5 kW Pelton turbine, generator and governor. The installation also includes a weir, holding pond, and 100 m long 25 cm wood stave and steel above ground penstock, and a powerhouse.

3.4.1 Physical Components

Weir/Dam

Where insufficient water flow or head exist an impoundment or ponding dam is needed to capture the stream flow potential (Plate 1). Simple weirs or diversions of wood cribbing can be used for low head sites and very small installations (less than 40 Kw). Where a site requires a larger weir or diversion structure, rock filled gabions (rock baskets enclosed in wire mesh) securely attached and mounted are often used. These systems can have the advantage of being made from materials located near the site. However, they do require a layer of impervious material (i.e., butyl rubber) to prevent seepage. Where possible the weir should be anchored into bedrock by concrete or steel. The developer may need the services of an engineer depending on the stability of the stream banks, or concern for the stream environment (i.e., designing fish ladders). In general, if the height to the top of the spillway exceeds seven feet from ground level, professional assistance is required to design and construct the structure.[31] Minimum weir requirements include: (1) the weir/dam capable of surviving flood conditions, (2) the spillway adequately sized to prevent washout, (3) ensuring minimal seepage and erosion within the structure, and (4) making provision for the flushing or removal of downstream transported sediment from behind the weir. This can be accomplished by locating culvert gates in the structure to be opened for periodic flushing.

[31] Note 1.

Plate 1: WEIR STRUCTURE. (Koksilah Power Company, March 1986.)

Intake Structure

This is a simple structure located within the stream which diverts water to enter the penstock leading to the turbine (Plate 2). It should be located in the stream where the stream velocity is high and there is sufficient depth to fill the intake opening. It should never be located on the inside of a river bend, since sediment carried by the river will be deposited at the intake opening and require continuous cleaning to prevent blockage. Almost all run-of-river projects will use diversion type intakes, as opposed to the impoundments or dams used by storage type projects to augment head. Intakes are generally made from concrete and should be durable and securely anchored. During periods of low stream flow, intake submergence should be maintained. A valve or gate should be available to shut off minimal flows to prevent air and pressure changes occurring within the system, and in the event of penstock rupture (Plate 3). In addition, intakes must not be located near domestic and irrigation water supply inlets, as this can lead to 'starving' the other intakes of necessary water. The major requirement is that the intake provide a trouble-free filter for the penstock allowing grit or large debris such as logs to bypass without damaging equipment. Control of smaller debris is by screens or trashracks; for finer sediments settling tanks or ponds. Easy access is important for maintainance, cleaning out debris and removing ice when temperatures are low.

Plate 2: INTAKE STRUCTURE. (Source: John McKay, Vancouver, B.C., 1986.)

Plate 3: SHUTOFF VALVE NEAR INTAKE. (Koksilah Power Company, March 1986.)

Penstocks

The penstock is a pressure pipeline that carries the water from the intake structure to the turbine (Plate 4). There are numerous choices for penstock material including wood stave, steel, concrete, iron and PVC. No one type is best and selection must be based on particular pressure rating, acceptable friction loss, site conditions and price. Material and diameter affect both water velocity and friction loss. This is important when determining the project power ouput. As penstock diameter increases both the velocity and friction loss decline; smaller penstocks usually mean greater fluid friction loss and a smaller net head. However, increasing the diameter will also mean a higher price. The tradeoff becomes one of higher costs for greater efficiency, or lower costs and less potential power output. Other considerations when selecting a penstock are the terrain conditions near the project, availability of equipment to construct the works, and personal experience in working with a particular material. Clearing a penstock route in steep forested areas can prove to be an arduous task.

The penstock must be capable of withstanding water and pressure surges from within the system that can create cavitation and equipment damage. To minimize air pockets and turbulence the penstock route must slope continuously downhill with a minimal number of bends and turns. Thrustblocks (i.e., concrete) are used to help anchor the penstock, especially where bends are required, and where the penstock enters the powerhouse (Plate 5). This will control the direction of expansion and contraction in the penstock, prevent movement from vibration or waterhammer, and prevent the system from sliding downhill. Penstock installations may be either above or below ground depending on soil conditions. Above ground installation requires that the pipe be mounted on supports designed to provide uniform pipe support, retain pipe movement and protect the pipe from external damage. The supports can be of wood or concrete depending on site conditions. Penstocks laid directly on the ground may require a gravel bed, and protection with primer epoxy resin.[39] Below ground installation usually occurs when using PVC piping because it will degrade in direct sunlight. Buried penstocks will be better able to withstand pressure surges in the system, leakage will be less likely, and the potential for external damage and landscape intrusion minimized.

[39]Note 5.

Plate 4: PENSTOCK. (Koksilah Power Company, March 1986.)

Plate 5: PENSTOCK THRUSTBLOCK. (Koksilah Power Company, March 1986.)

Turbines

The turbine converts the potential energy in falling water into mechanical energy to be used either directly or to be connected to a generator to produce electricity. The turbine type and size selected is determined by considering the interaction between site characteristics (head and flow), load requirements, generator characteristics and cost. Figure 6 shows the suitability of various turbine types for different head and flow ranges. The figure illustrates that for most heads and output conditions the choice can be one of a variety of different turbine types. Each turbine type has limitations and offers advantages depending on the type of operation requirements.

Turbine type and speed must be selected to maximize efficiency and to avoid problems of cavitation and power surging within the system. Cavitation occurs when air or gas bubbles that form in the water collapse when they strike the turbine. This can create vibration, and cause damage to the turbine and reduce its efficiency. In order to avoid this problem, the developer should discuss with an equipment manufacturer the possibility of cavitation occurring in the turbine. In addition, selection is influenced by maintenance, cost and availability of equipment. Turbine composition is important particularly when the stream is gritty or glacial. Stainless steel is generally considered the best for extremely gritty streams. Mangenese, bronze and ductile iron are good materials for use in cleaner streams.[40] Turbine cost is influenced by powerhouse configuration and design, and ancillary equipment such as the generator. The available variety of turbine types has improved in the last ten years. This is in part due to standardization and available off-the-shelf technology.

Selecting and sizing an appropriate turbine usually involves engineering principles and fluid dynamics. Because the type selected is critical to the success of a hydro project, the developer should contact equipment manufacturers and suppliers directly for specific efficiency curves and ratings. Only broad principles of turbine design and application are discussed below.

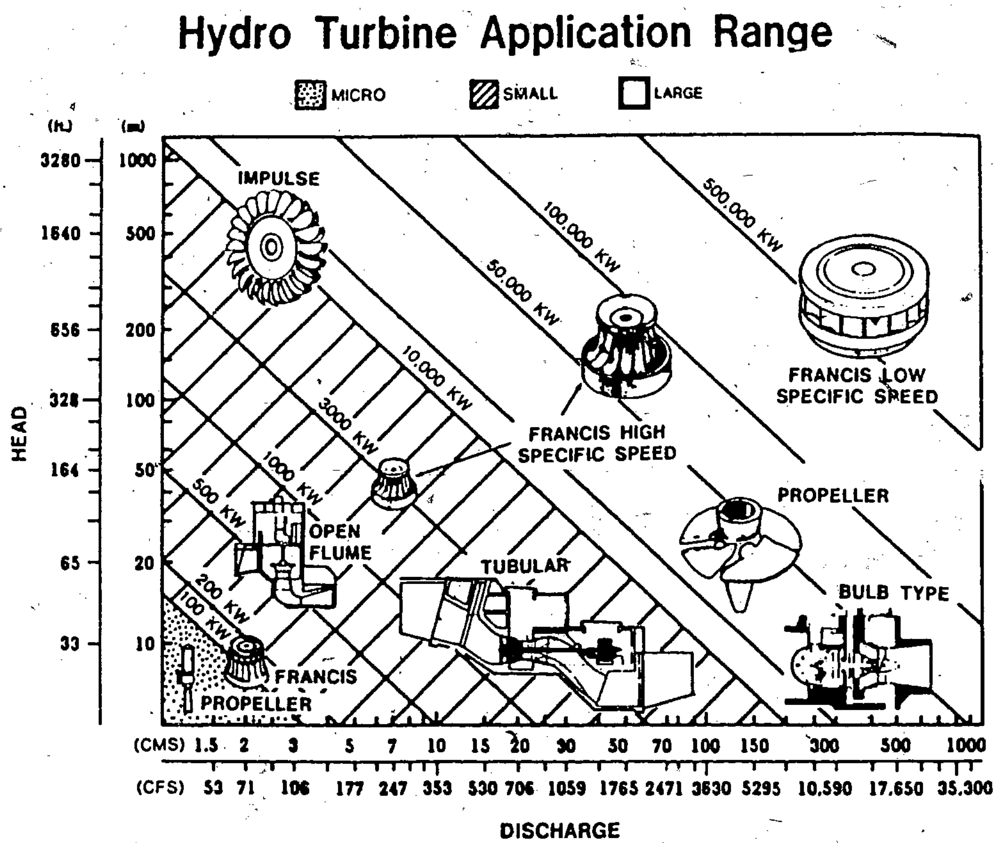
[40]Canada, Energy Mines and Resources, 1984, Proceedings of Conference on Planning, Financing and Developing Small Hydro Systems (Vancouver, B.C.), part 8.

Turbines are essentially divided into two categories. The first includes the simple and common impulse turbines used most often in run-of-river projects. They are small, simply and compact. Projects using impulse turbines convert the energy in the water into a velocity flow by forcing it through a small nozzle and aiming the water jet at buckets arranged around the turbine wheel. The water impact on the buckets turns the wheel connected either directly to machinery or a generator. Common impulse turbines are the Pelton and Turgo designs.

The second type are reaction turbines placed directly in the river. They develop power by a combination of pressure and velocity changes. These type can be found most often in low head or storage type hydro. Larger equipment components are required to utilize the lower pressure and greater volume of water. Reaction turbines can be divided into the mixed flow and the axial flow type. Common reaction turbines are the Francis, Propellor, Bulb and Kaplan. The Banki or Crossflow turbine is a transition design between an impulse and a reaction turbine (Figure 7).

The turbines often selected for medium to high head sites are the Francis, Crossflow, Turgo and Pelton designs. The Turgo and Pelton are seldom used on heads of less than 300 metres and are the most common turbine selected for micro hydro installation.

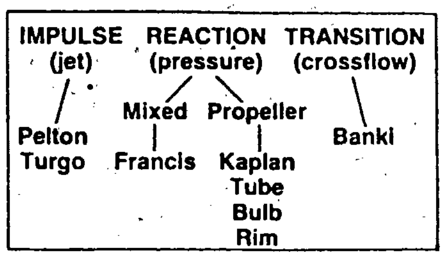
Figure 6: TURBINE CHARACTERISTICS. (Source: Washington Department of Ecology, Olympia, WA., 1985.)

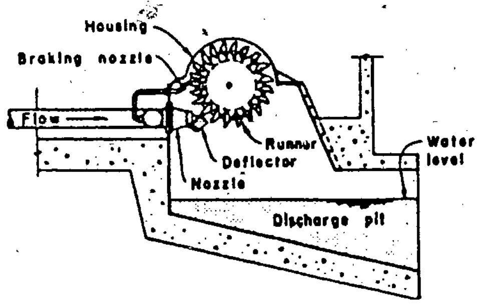


The selection of a water turbine is dictated by the head and flow characteristics of a particular site. Since its invention by Lester A. Pelton in 1880, the Pelton wheel or impulse turbine has dominated high head, low flow applications. Tube and bulb turbines are recommended for low head, high flow conditions. The majority of large projects are equipped with Francis or adjustable blade Kaplan (propeller) turbines.

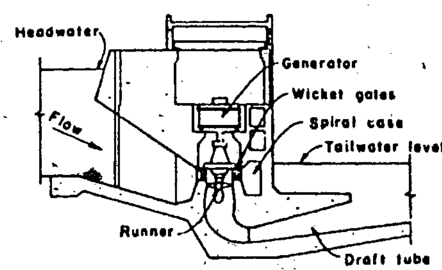
Figure 7: TURBINE TYPES. (Source: H. Hutchinson, Crippen Engineering Ltd., Vancouver B.C., 1980.)

TURBINE TYPES

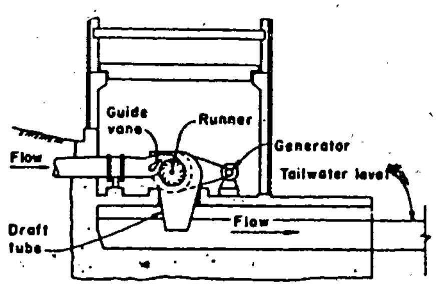




IMPULSE TURBINE (PELTON TYPE)



KAPLAN TURBINE



CROSS-FLOW TURBINE

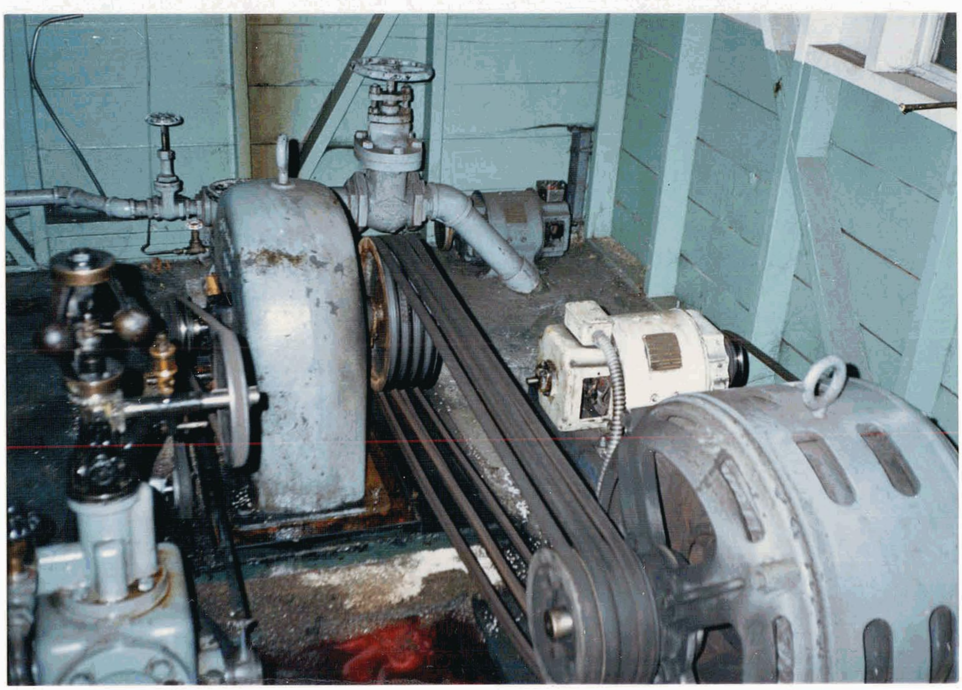
Powerhouse

The powerhouse protects the generating equipment and allows electrical equipment to be securely mounted (Plate 6). Powerhouse size cannot be confirmed until the dimensions and requirements of the turbine and generator have been established (Plate 7). The high head project powerhouse can be of a simple construction because of the turbine system employed, and water discharge is directly into an opening in the floor. Low head projects using reaction turbines require substantial substructure because of the irregular shape of the turbine package. In both types, the powerhouse is to be located near the river but at sufficient elevation to avoid damage to equipment from flood waters, and to set correctly the height of the turbine. The important considerations for a typical powerhouse are listed as follows:

- <u>Size</u>: spacious enough to work comfortably around equipment; For medium to high head plants 8 by 12 feet is acceptable. Low head sites can require larger facilities owing to equipment configuration. The powerhouse should have electricity supplied to provide light and power during system operation, and for maintanence periods;
- <u>Ventilation</u>: adequate ventilation to prevent overheating of equipment and machinery. A fire protection system of either water sprinklers or portable carbon dioxide extinguishers should be easily accessible;
- <u>Insulation</u>: to prevent icing up inside during the winter and to be able to work inside during equipment shutdown periods;
- <u>Floor drains</u>: to ensure adequate drainage in case of leaks or ruptures, and to drain condensation buildup on the penstock and turbine housing;
- <u>Chainblock</u>: to lift or re-position the generator or turbine during installation or maintanence. For the smaller plants a mobile crane can be used rather than an expensive permanent installation;
- <u>Outlet/tailrace</u>: there must be good clearance between the turbine runner blades, and the water outlet below it to avoid backwash and splashing interfering with the operation of the turbine runner blades.

Plate 6: POWERHOUSE. (Koksilah Power Company, March 1986.)

Plate 7: POWERHOUSE EQUIPMENT: Turbine and Generator. (Koksilah Power Company, March 1986.)



Outake/Tailrace

The outlet or tailrace does two things; (1) carries water leaving the powerplant back to the stream channel, and (2) keeps the turbine runner submerged during actual operation (low head systems) (Plate 8). Depending on the site and project configuration, the outlet can vary from a short unlined excavation to an elaborate concrete lined channel. If the soils are porous sands or gravel, a lining is usually required to prevent seepage, ponding and erosion of the channel bank.

Plate 8: OUTTAKE. (Koksilah Power Company, March 1986.)

3.4.2 Electrical Components

Generators

Mechanical energy is converted to electricity by a generator. Generator speed is determined by the turbine, and by the size of the generator (Plates 9 and 10). Small generators operate at a higher speed. The turbine configuration will determine the location of the generator unit, which may either be mounted adjacent to the turbine, or be designed as an integral part of the turbine. Generators will be either synchronous (self governing), or asynchronous (governed by an outside agency (utility grid)). The generator selected will depend on whether the project is for utility grid connection (asynchronous), or is independent (synchronous). As most micro hydro constructed is for independent power generation, discussion will focus only on synchronous equipment.

Synchronous

Because most household and small industry motors operate at a constant frequency of 60 Hz, generator speed must be constant. A governor unit is required to control the turbine speed and thus electrical flow to the system. The generator voltage required is dependent on the types of electrical loads being serviced. For example, if the load is mainly for lighting, 110 volts is sufficient; 220 volts or even 440 volts may be required for machinery or industrial applications. A higher voltage may be desirable if the transmission line (distance to demand) is relatively long. The generator must be of a solid design, well insulated, have its' own voltage regulator, and own excitation system because it is operated in isolation from other electrical systems (i.e., utility grid).

Plate 9: POWERHOUSE EQUIPMENT: Synchronous Generator and Governor. (Koksilah Power Company, March 1986.)

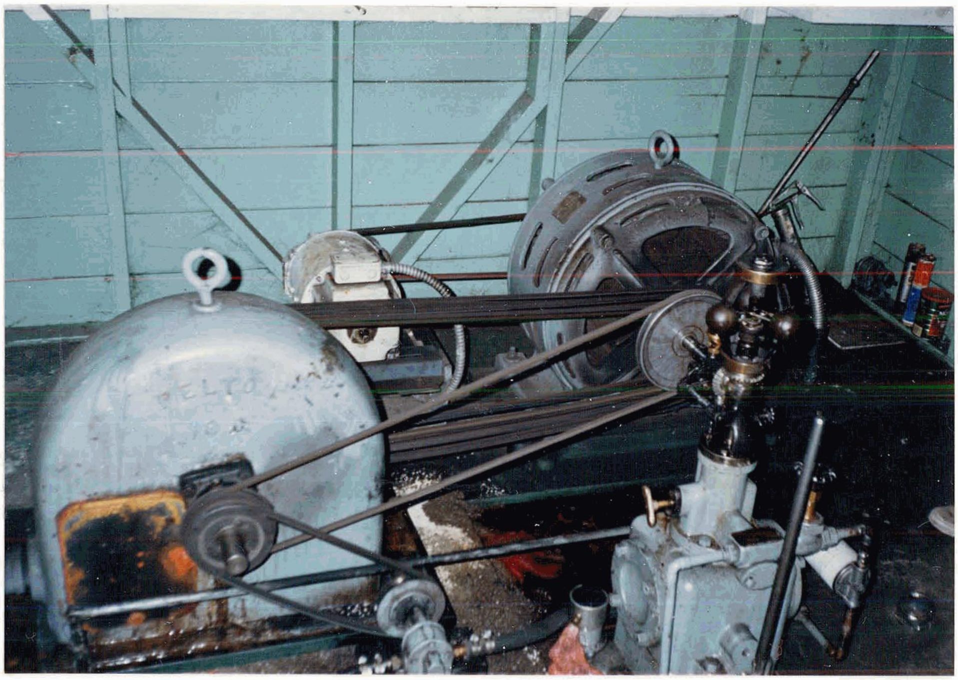
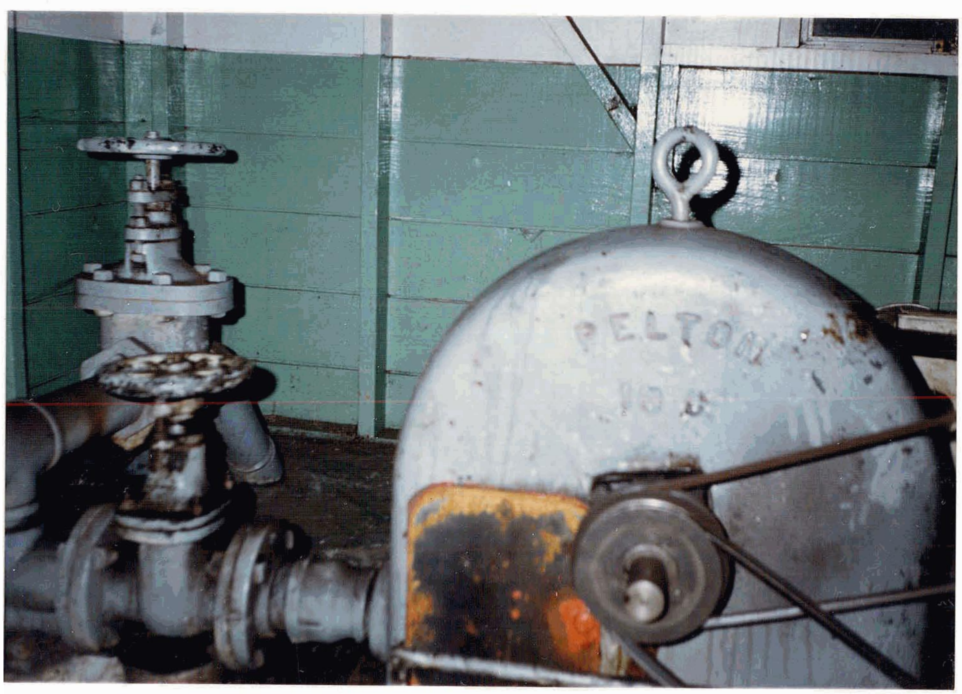


Plate 10: POWERHOUSE EQUIPMENT: Pelton Turbine Housing. (Koksilah Power Company, March 1986.)



Governors

Isolated micro hydro must use a governor to control the speed of the turbine and generator. The governor senses speed fluctuations due to load changes and adjusts the turbine speed and electrical flow to maintain the 60 Hz frequency. Governing of low head turbines is complex and expensive. For example, Francis turbine governing involves stopping water flow through the use of wicket gates. For high head impulse turbines (i.e., Pelton, Turgo) governing is efficient and straightforward because water flow can simply be deflected as load demand fluctuates. The two most common type of governors available include:

Gateshaft Governor

Generator voltage fluctuations due to changes in load activate electrical servomotors to open or close water flow control gates. This regulates the water flow onto the turbine and adjusts the generator speed to agree with the load. The equipment is complicated and expensive for small turbines, yet apparently works with great reliability and precision.[41]

Electric Load Control

Electronic sensors regulate the load on the governor and not water flow (water control gates). Therefore, systems no longer requiring complicated mechanical gates allow for simpler and cheaper turbines to be used. Advantages include a 'use priority system' in which electronic controls connected to the loads at the site turn off low priority loads when high priority (lights and cooking) are turned on. With this system, the power output from the generator is kept constant. These systems can be expensive and should be purchased from a competent electrical contractor.

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[41]Note 35, pp. 80- 83.

Protection/Control

To install protection and control systems requires a knowledge of the physical and electrical operation of the total project. Electrical protection equipment should meet or exceed Canadian electrical safety standards.[42]

Electrical protection is project specific and may include: lighting arrestors, fuses, load breakers, over and undervoltage and frequency protection to the generator. Protecting the physical project components includes: monitoring temperature, turbine speed, trash rack conditions, oil and lubricant levels. To protect machinery a range of mechanical equipment is used including intake screens to block the entry of debris into the penstock, and gates or valves controlling water flow into the turbine system. Gates and valves are available for use in a variety of situations, and are usually specialized for application in a particular project. Intake gates are used to cut off water flow into the penstocks to enable maintenance, not to regulate water flow to the turbine. Bypass valves at the powerhouse are used to divert water flow from the turbine, and allow for sediment to be flushed from the penstock.

Transmission Lines

Transmission lines are needed to distribute electricity if the power site is not adjacent to the power house. The transmission line can be an expensive component of the project depending on design, carrying capacity and installation. Most micro hydro projects require 600 volt wiring, which can be installed by the project developer. Depending on length of line and total load a simple wooden pole construction and open conductors can be used. Line losses (lower voltage) increase with greater distance transmission. The voltage drop in a wire is equal to current in amperes multiplied by the resistance in ohms of the wire. The power loss to a site can be reduced by increasing the generator voltage, and locating as close to the powerhouse as possible. A rule of thumb is that there will be a line loss of 1 percent for every 4 m travelled (properly sized overhead wire). High voltage required at some distance from the powerhouse would involve having to use higher voltage line and transformers (i.e., 25 kv or higher). This is expensive, requiring substantial equipment and machinery to locate and construct the transmission system. An electrical engineer should be contacted before purchasing and installing transmission line

[42] Electrical Safety Act RSBC, 1979 c. 104.

equipment.

Transmission line and generator voltage can be the same where the hydro plant is in close proximity to the load center (under 1 mile). This eliminates the need for stepup and stepdown transformers. Overhead power lines are efficient and inexpensive to install but vulnerable to falling trees, icing, lighting strikes and vandalism. Underground cable or submarine cable can be required in special use areas, such as a provincial park, or in navigable waters. However, it is usually not cost effective for the micro hydro developer because of the high installation cost.

3.4.3 Summary

- Determine what equipment components are required for the resource site;
- Determine the best combination of equipment components (turbine and generator);
- Determine how much of the work or installation you can do yourself;
- Contact turbine equipment suppliers or manufacturers for specific details.

3.5 STAGE FIVE: PROJECT ECONOMICS

OBJECTIVES

- Identify project component costs, capital cost, operation and maintenance cost; evaluate alternatives; case study.

IMPORTANT CONSIDERATIONS

- Is the hydro project affordable to build and operate?
- Is the unit cost of the generated hydro electricity less than the present price paid for the existing power source?
- Are there available options to finance the project?
- For how long is the current energy demand expected to continue? Will the hydro project have re-sale value?
- How much of the installation and maintenance work can be done without engineering and contracting experience?

INTRODUCTION

The economic benefits of operating a micro hydro system are the replacement costs of an alternate energy source, usually diesel or utility grid connection. Diesel fuel presently ranges between 10.0 and 20.0 cents/kW.h., and cost will escalate with inflation and with real cost increases in fuel price.[43] The cost of connection to the utility grid must also be considered by the developer when evaluating energy alternatives. If the site is already connected to utility grid power, and the water has no other uses such as for providing irrigation or fire control, then micro hydro could be difficult to justify. Present utility hook-up can cost over $40,000.00 a kilometer.[44] The current costs for a micro hydro project are in the range of $2200.00 to $3000.00

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[43]Interview with Robert Woodley, Manager, Systems Engineering Division, BC Hydro, 20 January 1986.

[44]Note 43.

per kilowatt, with cost variations dependent on site work, equipment and head.[45] Generally, the cost per kilowatt decreases as power output increases. High head projects are usually less expensive than low head projects but this will vary on site and equipment characteristics. The listing below gives approximate cost data for a variety of project sizes:[46]

Project Size and Cost

0 - 50 kW (0 - $150,000)

50- 100 kW ($150,000 - $300,000)

100 - 250 kW ($300,000 - $750,000)

over 250 kW (over $1,000,000.00)

3.5.1 Project Components

The following physical, mechanical and electrical components are considered standard for most low and high head projects with power outputs ranging from 10 kW to 2000 kW. Basic unit costs have been well established for hydro electric components and are represented by reasonably accurate cost curves.[47] A general guide as to what information to consider when assessing cost factors is given below. Specific cost information would require contacting an equipment supplier and providing accurate resource data, and price ranges. The component cost data in 1986 dollars (Canadian) below is a general estimate provided by Solace Energy, Micro Power Engineering Systems, Vancouver, B.C.

Access Roads

Costs will vary depending on the site location, terrain and overburden to be removed, and whether the developer can do much of the work himself. Generally, as the slope gradient increases, the road costs per mile will increase. Approximately $90,000.00 per kilometre for commercially installed access road and surfacing would be an appropriate estimate. However, a developer with access to heavy machinery and brush clearing equipment could reduce this cost.

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[45]Note 1.

[46]Note 1.

[47]Note 28, part 4.

When deriving a cost estimate aspects to consider include:

- the length of road in metres;
- the amount of clearing and grubbing;
- the amount of overburden to be removed;
- the type of road surface (i.e., dirt, gravel or paved).

Intakes

Costs will vary depending on the instream flow rates, intake location and the amount of power to be generated. Generally, as the instream flow rate required to generate power increases intake costs increases. It is critical for proper system operation to correctly locate and install this equipment component. Therefore, developers should have professional assistance with intake selection and installation. Approximately $1500.00 for a commercially installed intake would be appropriate in most micro hydro sytems. When deriving a cost estimate aspects to consider include:

- the discharge rates (i.e., instream flow rate);
- the amount of power required.

Penstocks

Costs will vary depending on the terrain, gross and net head, penstock thickness and weight, and the power output required. Generally, as the pipe width, length and weight increases, the cost increases. Pipe costs are approximately $5.00 a foot for 8" irrigation plastic and $10.00 a foot for 8" steel pipe purchased commercially. Less expensive spiral plastic piping used in mine operations can be installed, and is readily available second hand. Commercial penstock installation ranges from $0.50 to $15.00 per inch foot depending on terrain characteristics. Penstocks must be solidly anchored. The use of wood supports is appropriate for most installations, but the material used (i.e., concrete) will depend on terrain conditions and penstock weight.

Turbine

Costs will vary depending on turbine design, material, size and capacity. Generally, the cost is specific to a particular turbine design and its application but will increase as power output increases. Commercial prices for off-the-shelf turbines include:[48]

- low head (Propellor 5 - 25 foot head) range from $1100.00 (0.5 kW, 15 foot head) to $16,000.00 (36 kW, 20 foot head);
- medium head (Crossflow 20 - 200 foot head) range from $5700.00 (35 kW, 200 foot head) to $12,000.00 (35 kW, 90 foot head);
- high head (Pelton 200 foot head or more) range from $1700.00 (8 kW) to $56,000.00 (550 kW).

Cost estimates for a variety of capacities are illustrated: $5000.00 - $25,000.00 (0 - 25 kW); $25,000.00 - $35,000.00 (25 - 35 kW); $40,000.00 - $60,000.00 (40 - 75 kW); $75,000.00 - $120,000.00 (100 - 200 kW).

In addition, alternators are typically purchased together with the turbine and range in price from $4500.00 (10 kW) to $6500.00 (40 kW). Powerplant accessories including turbine mounting beds, flywheels, load control governor, and drive systems cost from $5000.00 to $8500.00 (up to 50 kW). Care should be taken in purchasing second hand turbines as each is designed to serve a specific head and flow rate. When deriving a cost estimate aspects to consider include:

- the type and speed;
- the associated govenor;
- the power output;
- the head and flow rate.

[48]Note 5.

Powerhouse

Costs will vary depending on the design, location, construction material and equipment components. Generally, the costs are proportional to the power output and to the turbine configuration selected for installation. Approximately $5000.00 for one 8 by 12 concrete slab plus prefabricated wood power house frame would be appropriate in most cases. A used wooden frame powerhouse would be approximately $3000.00 with cost reductions if the developer were to construct and install equipment. In some cases, a purchased stock garden shed with locking door can be an appropriate powerhouse for very small systems (i.e., less than 30 kW). When deriving a cost estimate aspects to consider include:

- the amount of excavation;
- the substructure and superstructure;
- the need for a yard, fencing and security;
- the gross and net head;
- the installed plant capacity and equipment configuration.

Weir

Costs will vary depending on the design, construction material, depth and height of the required impoundment. Generally, the cost increases as height of the weir increases. Approximately $90.00 per cubic foot (gabions) purchased and installed would be appropriate in most cases, while concrete wier/dam structures would cost $250.00 per cubic foot purchased and installed. These costs can be reduced substantially by the developer able to do all or part of his own construction. The developer should consult a civil or structural engineer before purchasing or constructing weir or dam works. When deriving a cost estimate aspects to consider include:

- the method of anchoring the weir;
- the fill materials (i.e., dirt, rocks, timber, concrete);
- the proximity of source materials (i.e., hauling distance);
- the depth and width;
- the type of impermeable barrier (if required).

Transmission lines

Costs will vary depending on the type of pole material, equipment used and the plant capacity, and distance to the load site. Generally, the cost will increase as the distance and kilowatts to be transmitted increase. Approximately $7.50 per foot installed underground; and $2.50 per foot installed overhead is applicable in most cases. For a one kilometre line $15,000.00 would be appropriate for commercially purchased and installed equipment. The developer can save expenses by brush clearing, use of wooden poles and transporting materials and equipment to the site. When deriving a cost estimate aspects to consider include:

- the poles, arms, insulator and wire type;
- the total power to be transmitted;
- the total distance of line required.

3.5.2 Feasibility Decision: Yes or No?

A. Alternatives

Fundamental to the economic evaluation is the need to compare the cost of producing hydro power to the cost of production by current means. For micro hydro developers the alternative sources are limited to utility supply or diesel generation. For the private developer the most useful indicator is the comparison of the unit energy cost, or the real cost of producing energy. The unit energy cost can be determined by amortizing (how much an amount of money paid annually is worth today) the capital costs over some period of time (i.e., 30 years) using a range of interest rates, adding the operating costs and then dividing the total by the energy production (kW/hr/yr).

B. Hydro project

For micro hydro estimates of energy demand, capital costs, operating and maintenance costs, legal and engineering costs must be calculated. Hydro will experience 'high front end' costs for equipment and machinery purchases, however, once the initial investment is made, hydro energy costs are generally inflation-proof. The operating costs of micro hydro are relatively low, and include regular parts lubrication and replacement of small mechanical parts (i.e., fuses, regulators). Allowances should be made for emergency repair costs including parts and labor. Operation and maintenance costs range from 1.2 to 2 percent of costs annually.[49]

C. Diesel plant

For diesel fuel generation the costs of diesel fuel, parts and materials, operation and maintenance, and energy demand are required. Diesel fuel costs are the main component of the economic analysis, and the price paid for energy is a linear function of diesel fuel costs. Diesel fuel costs are presently estimated at between 10.0 and 20.0 cents/kW.h., but will vary depending on generator life, efficiency rating, maintenance and diesel fuel quality. Diesel fuel prices are currently between 32 cents/l. and 43 cents/l.

D. Utility Connection

For utility power the costs include the current price paid for power and if not close to the grid the cost charged the developer for interconnection to the utility grid. Current transmission line costs can be estimated approximately using a figure of $40,000.00 a kilometre in remote locations.

It is important to be consistent in the basis for cost estimates between alternatives. An appropriate lifespan must be assumed to ensure a fair comparison of alternatives. Micro hydro is typically considered capable of a 20 – 40 year lifespan; a diesel generating plant 15 – 40 years; and utility poles 45 – 60 years. The diesel plant will typically have some salvage value at the end of that time frame. Having determined, (1) the capital costs, (2) operating and maintenance costs, (3) diesel fuel costs, and (4) method of comparison (unit energy cost) the decision whether to build or not to build the hydro plant can be made

[49] Note 5.

3.5.3 CASE STUDY: Glacier Park Hydro Project

Located in Glacier National Park is a run-of-river micro hydro system. A 150 kW Pelton turbine and powerhouse installation supplies most of the hot water and electricity for the lodge and the emergency station located at the summit of Rogers Pass. The hydraulic (net) head is 64 metres, demand flow 0.38 m/sec, penstock is a 41 cm steel pipe, 442 metres long. The mechanical equipment includes a stainless pelton turbine, and belt driven 600 volt generator. The project was built and completed in 1983.[50] Cost estimtes for this project in 1986 dollars (Canadian) are given below. They were derived by taking 1983 cost estimates and inflating them by 10 per cent per annum to 1986.

3.5.4 Project Economics

Pre-project costs:

- Annual diesel maintenance cost – $7,500.00
- Annual fuel costs – $70,000.00

Project costs for the new hydro system:

- Capital costs (equipment and materials)– $185,000.00
- Installation costs (labor) – $185,000.00
- Total installation costs – $370,000.00
- Cost per kW– $2230.00
- Annual maintenance cost – $200.00 (estimated)
- Simple pay back period – 5.0 years

Expected benefits/savings:

- Reduction of $70,000.00 of diesel fuel per year at the camp;
- Reduction of $7,500.00 maintenance cost;
- Removal of an air pollution source.

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[50] Canada, Energy Mines and Resources, 1983, Glacier National Park Hydro, Project Number F-80-15 (Vancouver, B.C.: (Mimeographed)), 1 p.

3.5.5 Economic Analysis: Option One

The cost of producing electricity in cents per kilowatt hour can be calculated for this remote site. A 30 year loan period with interest rates of 10, 13 and 15 percent is assumed. In order to calculate the real cost of producing electricity in cents per kilowatt hour, costs were amortized over 30 years and an annual operating and maintenance expense of 2 percent of initial cost included.[51] A constant capacity factor of 0.6 was used to adjust for variable stream flows through the system.[52] The hydro electricity costs range from 5.95 cents per kilowatt hour at 10 percent to 7.10 cents per kilowatt hour at 13 percent to 8.06 cents per kilowatt hour at 15 percent. These values compare with an average diesel fuel cost of between 10.0 and 16.0 cents per kilowatt hour (less inflation, and depending on location). Diesel generator maintenance costs will increase as the generator ages, and because it will become less efficient (high fuel consumption) through extensive useage.

3.5.6 Example Calculation

The following example illustrates the method used to calculate the unit energy costs outlined in the above analysis.

1. At a 10 percent interest rate and 30 year loan life the present annuity factor equals 9.426914. (this indicates how much $1 received or paid annually for X years is worth today).[53] A rough estimate of the annuity factor (perpetual annuity factor) can also be obtained by dividing 1.00 by the expected interest rate.
2. multiplying the project capital cost ($370,000.00) by a 2 percent annual operating expense equals $7400.00.
3. dividing the capital cost ($370,000.00) by the annuity factor (9.426914), and adding the $7400.00 operating cost equals $46649.30.
4. dividing $46649.30 by the average annual energy production (150 kW times 8760 times a 0.6

[51] R. Stilwell, 1980, "Economics of Small Hydro," In Proceedings of the Seminar on Small Hydro in Industry (Vancouver, B.C.: Crippen Engineering), part 8.

[52] Note 37, p. 1.3.

[53] *Refer to compounding and discounting tables; see,* J.P. Gittinger (ed.), 1973, Compounding and Discounting Tables for Project Evaluation (Washington, D.C.: Economic Development Institute), pp. 20– 21.

firmness factor) multiplied by 100 equals 5.9 cents kW.h.

5. this amount represents the real cost of producing electricity at the hydro site given a particular interest rate (10 percent) and loan period (30 years), and can now be compared to the current cost of diesel generated electricity at the site (costs will vary depending on location).

3.3.7 Economic Analysis: Option Two

The second option involves comparing the yearly expenditures on diesel fuel and operating costs (which escalate over the years) with installing a hydro system (initial capital cost) and the associated minimal maintenance costs thereafter. Yearly savings from installing the hydro system can be estimated by subtracting the operating and maintenance cost (hydro system) from the yearly diesel fuel expenditure.

For example: annual diesel fuel and maintenance costs are $3000.00. The cost of the hydro system (5 kW) is $10,000.00 borrowed from a bank for five years at 15.5 percent interest would require a payment of $2880.00 per year to amortize (pay-off) the loan. The loan would then be paid back in five years at a total of $14,400.00.[54] However, the loan payments are less than the existing annual diesel fuel expenditures, allowing for a $200.00 annual operating and maintenance expenditure budget for the newly installed hydro system. In reality, the new hydro system would require little maintenance in the first years of operation, with some increase expected in later years as machinery and parts wear out and need replacing. The savings ($200.00) could then either be re-invested in a bank account (term deposit) that would contribute capital to replace the hydro system at a later date (20-30 years), or help to pay for diesel fuel to generate electricity during low stream flow periods (winter), or in an emergency situation. After five years the loan is paid off, and the additional savings in fuel costs (excluding operating and maintenance expenditures on the hydro system) make the installation of the hydro system even more attractive.

The developer can also examine the system in terms of cost per kW.h. This requires taking all maintenance costs over the life of the project (20- 30 years) and adding them to the outlays necessary to amortize the original $10,000.00 investment.

[54]Note 53.

For example; maintenance costs beginning at $100.00 a year and increasing by 2 percent annually over 20 years equal $2400.00; amortization of the loan costs $2880.00 for five years and equals $14,400.00; total cost is $16,800.00.

Total power is 26,280 kW.h. times 20 years equals 525,600 kW.h.; Dividing 525,600 kW.h. into $16,800.00 equals 3.2 cents/kW.h.

The 3.2 cents/kW.h. compares favourably against the 10.0 to 16.0 cents/kW.h. (depending on location) the developer would pay for diesel fuel generated electricity.

3.3.8 Summary

- Determine rough estimate of equipment component costs;
- Determine and compare the cost of producing hydro power to the cost of production by current means;
- Determine the amount of yearly savings (i.e., fuel cost savings) from installing the hydro system;
- Contact bank or nearest financial institute and provide hydro proposal (equipment and operating cost estimates).

3.6 STAGE SIX: PROJECT FEASIBILITY CHECKLIST

At this stage, the developer must decide whether to go ahead and build the hydro project, or to consider other energy generating alternatives. In summary, the following points should be clearly understood and assessed before any decision is made to purchase equipment, lease land or begin construction of a project.

- Determine power requirements at the site;
- Determine hydro resource potential (i.e., head, flow);
- Determine minimum flows, fish and wildlife and other environmental requirements;
- Calculate net power output and energy available from the instream flow and site characteristics;
- Optimize the two and determine a plant size;
- Determine whether a weir or a small dam is required to increase head;
- Determine whether the water and land is accessible for development, and what constraints to power development there could be;
- Determine what equipment components are required;
- Determine rough cost estimates for equipment;
- Compare the cost of alternatives (i.e., diesel, utility).

HAVING EVALUATED EACH OF THE ABOVE COMPONENTS, THE DEVELOPER MUST NOW DETERMINE THE OVERALL FEASIBILITY OF THE PROJECT.
IF, THE PROJECT APPEARS NOT FEASIBLE FROM ANY OF A RESOURCE, TECHNICAL OR ECONOMIC PERSPECTIVE, IS REDESIGN TO IMPROVE FEASIBILITY POSSIBLE?

- If YES - Redesign and evaluate project feasibility.
- If NO - Reconsider developing micro hydro at that site.

IF THE PROJECT APPEARS FEASIBLE TO THIS POINT, THE DEVELOPER MUST DETERMINE METHODS OF FINANCING, AND DECIDE WHETHER TO BUILD AND OPERATE THE HYDRO PROJECT.

The developer must now consider the following points:

- Final design work (i.e., project layout, equipment);
- Contract for engineering work, if required;
- Final environmental mitigation requirements, if required;
- Permits, licences and approvals;
- Order equipment, machinery, and BUILD PROJECT.

CHAPTER IV

PERMITS, LICENCES AND APPROVALS

INTRODUCTION

This section outlines the local, provincial and federal approvals required to construct and operate micro hydro. The amount of time, effort and money spent to obtain an approval will vary depending on the project type, site location, agency, and the potential for environmental impacts. For example, a run-of-river project constructed for use on private land would require at most a provincial water licence, local building and electrical permit, and depending on location, minimal assessment of environmental impacts. Conversely, a water storage project inundating Crown land could require considering a number of environmental issues and involve various resource agency approvals.

Obtaining any permit, licence or approval will usually require a formal application either through filing a standard application form, or by written letter. Prior to filing any application, first contact the appropriate government agency and provide clear details concerning the planned project. This will help the developer to understand the type of information an agency will require about a project; for example, how detailed the environmental or technical studies should be, and how to correctly complete an application form. Much time and effort can be wasted because an incorrect or incomplete application form must be returned. Pre-application liason with the agency can also acquaint a developer with existing information about the resource site, and agency ideas concerning mitigation of possible adverse impacts.

The applicant can gain the following benefits from consulting with agency staff before filing any application forms:

- Be made aware of specific technical, environmental, land and water use constraints not apparent when initially considering the site;
- Receive assistance to correctly complete application forms. The staff will also clarify the time and assessment procedures required for reviewing an application form. The time factor should be incorporated into the project development schedule to avoid delay when proceeding with project implementation;
- Determine application fees and payment schedules;
- Receive input on technical and operational aspects of the project thus allowing for a modification in project design to be made in a timely manner;
- Assure that a permit, licence or approval is obtained in a minimum amount of time, and with minimum effort.

This section provides a series of individual reference guides listing the basic procedures to follow for developing a micro hydro site on each of federal, provincial or private land. The guides identify and briefly outline significant aspects of each permit, licence and approval. It must be emphasized that not every project will require every identified permit, licence and approval. The time and cost estimates provided are just that, rough estimates.

4.1 LOCAL GOVERNMENT

The extent of local government involvement with a micro hydro project will vary throughout the province; however, most proposals will encounter few municipal regulatory complications. Contacting the nearest Municipal Hall or Regional District Offices will determine the local permits, licences and approvals applicable to the project. All local governments have planning and zoning departments that will review a proposal for compliance with the comprehensive land use plan, zoning and bylaw regulations, and where required will issue building and/or burning permits. A project located within Municipal or Regional District boundaries which is not on federal or provincial Crown land (i.e., Indian Reserve, parks) must comply with local zoning and building regulations.

A project to operate on federal or provincial Crown land, will find local approval to be dependent upon the agreements stipulated within the Crown land lease or licence of occupation. Early discussion during the project planning stage with a local agency planner or engineer can assist the developer in the following manner:

- Identify the need to obtain a permit, licence or approval specific to that particular Municipality or Regional District. For example, the developer may need a burning permit, road connection approval, or a public health or safety compliance;
- Provide technical or environmental expertise to the applicant from agency staff familiar with the local area; and
- Alert the developer to the need and procedures to acquire a provincial or federal permit, licence or approval specific to the proposal (i.e., water licence, park use permit, fish and wildlife approval).

4.2 PROVINCIAL GOVERNMENT

The provincial government will issue the majority of permits, licences and approvals required to construct and operate micro hydro. The exception is where the project is located on land administered by the federal government, however, it appears that Indian Reserves must comply with all provincial regulatory procedures concerning on-reserve hydro development. On all other non-federal land within provincial boundaries, the two most important requirements are the right to use the water in a lake, river or stream, and land tenure. Water rights are vested in the Crown, and the licencing of water is regulated under the terms and conditions of the Water Act,[55] which is administered by the Comptroller of Water Rights and his administrative staff. Anyone constructing and operating a hydro site must first apply for and obtain a water licence from the regional Water Management Branch. As defined by the Act, "power purposes include the use of water in the production of electricity or other power". Anyone may apply for a water licence but may only acquire and hold licences if they have either a real property interest in land, or access through a legal Crown land tenure. Projects locating on Crown land would require at minimum a water licence and some form of Crown land tenure, such as a lease. Managing and administering the use and development of provincial Crown land is distributed amongst

[55]Water Act RSBC, 1979 c. 429.

various Crown agencies. An agency could for example, require a developer to file an application for electrical permits, a park use permit, licences or leases to occupy Crown land, to cut timber and to connect an access road to a provincial highway.

In addition, various provincial and federal resource agencies act in an advisory and technical capacity to other resource agencies. For example, as part of the ministerial referral process, notice of receipt of a water licence application is sent to the B.C. Ministry of Environment, Fish and Wildlife Branch, Dam Inspection Section; the Department of Fisheries and Oceans, and British Columbia Hydro and Power Authority (BC Hydro). These agencies can stipulate that certain conditions be attached to a permit or licence with regard to flood protection, fisheries enhancement, and recreation. Finally, although hydro projects of less than 20 MW are exempted from review by the British Columbia Utilites Commission, a private developer may require Commission approval before selling or distributing electricity to individuals, communities or industry.[56]

4.3 FEDERAL GOVERNMENT

The federal regulatory requirements are specific and limited to projects that involve fisheries (anadromous), National Parks, Indian Reserves, and navigable or international waterways. The developer has the responsibility to contact the appropriate federal agency before diverting water, constructing project works or flooding property on federal land. When uncertain about the status of the land or water at a prospective hydro site, the developer should contact Environment Canada, Land or Water Directorate (Pacific Region), providing a clear explanation of the project location, its design and configuration, and the intended use and amount of land or water required to construct and operate the project.

[56]*Note: Projects under 20 MW, when over 15 percent of the output will be sold, are subject to approval by the Commission and may include a public hearing.*

4.4 GETTING STARTED

1. Determine land availability; contact the B.C. Ministry of Lands, Parks and Housing, or Environment Canada, Land Directorate:
   a. locating on federal land (refer to the federal approvals guide);
   b. locating on private land (refer to the private approvals guide);
   c. locating on Crown land will usually require a Crown land permit, lease, or licence of occupation (refer to the Crown land guide); except in a provincial park which requires a park use permit (refer to provincial park guide).
2. Determine the water availability; contact the B.C. Ministry of Environment, Regional Water Management Branch:
   a. water use (power) on federal land (refer to federal approvals guide);
   b. water use (power) on all other provincial land would require a water licence for power generation (refer to provincial water licence guide).
3. Determine the environmental constraints; contact the Federal Department of Fisheries and Oceans, and the B.C. Ministry of Environment, Fish and Wildlife Branch:
   a. all federal and provincial water licence (power) applications are referred to Federal Fisheries and Oceans; all provincial applications go to the B.C. Fish and Wildlife Branch;
   b. provide project plans and feasibility studies to the appropriate agency staff; offer to inspect site with agency field officers;
   c. determine what fish and wildlife impacts from developing the proposal are likely to occur, and maintain the flexibility to modify original project configuration.
4. If a proposal requires constructing weirs, dams and impounding water; contact the B.C. Ministry of Environment, Dam Inspection Section:
   a. provide project plans, engineering and consultants' drawings;
   b. determine dam design and safety standards to be met or exceeded;
   c. determine environmental impacts to area; and the constraints or restrictions to be placed on dam operation (i.e., flow regulation).

5. If a proposal is to sell or distribute power; contact the British Columbia Utilities Commission, and BC Hydro:
   a. provide proposal, feasibility and engineering studies;
   b. provide evidence of safety and liability insurance coverage;
   c. ensure a secure market for the electrical power.
6. Additional provincial permits, licences and approvals will depend on the type of project and location; contact the B.C. Ministry of Environment:
   a. access roads: contact the B.C. Ministry of Highways;
   b. electrical permit: contact the B.C. Ministry of Labor (Safety Engineering Services Division);
   c. burning permit and cutting licence: contact the B.C. Ministry of Forests.
7. Compliance with local permits, licences and approvals will depend on the type of project and location; contact the nearest Municipal Hall or Regional District:
   a. requirements to comply with local approvals are usually outlined in the Crown land permit, lease or licence of occupation;
   b. building and burning permits, and local by-law compliance: contact local government offices.

4.1.1 GUIDE ONE: Obtaining a Provincial Water Licence

1. Contact the B.C. Ministry of Environment, Regional Water Management Branch:
   a. file an application form and provide information on location of the water source; quantity required; legal description of the property on which the water is to be used; evidence of tenure to the land; brief description of project works; names and addresses of landowners, right-of-way or easement holders whose property is crossed or affected by proposed works;
   b. provide a detailed diagram of the proposed hydro system, configuration, and layout describing location of intakes, penstocks, weirs and powerhouse.

   Note: Water licence applictions are referred by the Regional Water Management Branch to other resource agencies for review and comment, for example, the Department of Fisheries and Oceans, the B.C. Ministries of Environment; Fish and Wildlife Branch, Lands, Parks and Housing, and BC Hydro. This referral and review process can take longer than 12 months before a decision is made by the Water Management Branch to issue, or not issue a water licence.
2. Projects that involve water storage (weir/dam):
   a. the water licence application is referred to the Dam Inspection Section, the B.C. Ministry of Environment;
   b. the developer must detail on the application the approximate quantity of water to be stored; amount of land to be inundated; location of works;
   c. project works are to be approved by the Dam Inspectors before a water licence is issued;
   d. project works (weirs) are inspected during construction and on a regular basis thereafter.
3. The developer must post the water licence application:
   a. two copies of the application must be posted, one at the point of water diversion or storage, and another in a conspicuous place near the powerhouse or building where the power is to be used;
   b. posting the application should occur soon after filing the original application at the Water Management Branch;
   c. this will establish the priority of the licence if and when issued.

4. Notifying other water users:

   a. the developer is required to inform persons or agencies that would be affected by the proposed works, or are below the proposed point of water diversion or storage;
   b. this must be done within 90 days of posting the application.
   c. the developer will be advised by the Water Management Branch of licenced water users or applicants at the same point of diversion, or downstream from the intake who must be served notice;
   d. where more than ten persons are affected the developer may be directed by the Regional Water Management Branch to publish the application in a local newspaper or gazette.

5. Proof of posting application and serving notice:

   a. within 120 days of posting the application at the site, the developer must file with the Regional Water Management Branch a sworn declaration (see a lawyer or Notary Public) as proof of posting and serving notice to other licensed holders;
   b. failure to comply with this requirement will cause the application to be cancelled.

6. Application fees and rentals:

   a. the developer is assessed the fees and rentals at the time of application, but these may be adjusted at a later date if the size of the project is altered.

7. The developer can file an application for a Crown land permit with the Regional Water Management Branch:

   a. this permit is in most cases for small 1 to 3 acre parcels on which to locate penstocks, powerhouse and transmission lines;
   b. an application fee and annual rental charges are required similiar to the water licence rental fees;
   c. various conditions relative to the rights granted under the land permit include; prior to cutting trees the permittee must obtain a licence to cut timber from the Regional Forest Manager; if the water licence is suspended or cancelled the Crown land permit will also be suspended, and the permittee can be ordered to provide the Regional Water Management Branch with a detailed land survey of the area.

   - <u>estimated</u> time to receive a permit is 1 to 2 months; estimated annual rental charges range between $25.00 and $100.00.

8. The Conditional Water licence is issued and will contain certain requirements that must be met within a specified time period, or the licence can be cancelled. These include:

   a. completing the works;

   b. making beneficial use of the water;

   c. measures to mitigate against such environmental impacts as may be identified by the resource agencies (i.e., providing fish ladders, releasing specific water flow rates for maintaing spawning habitat).

9. As long as the water is used beneficially, according to the terms and conditions of the licence, the licence stays in force regardless of who owns the land (the licence is transferred with the property):

   a. if water is unused for three years or more the right to use it may be cancelled; however cancellation generally only occurs when there is some imperative reason, such as another person is in need of the water;

   b. a water licence does not guarantee a constant supply of water, and will be regulated according to the priority in use and in time criteria (date of application).

Total Cost

Approximate cost per year will vary depending on the hydro project category and installed capacity.

Approximate micro hydro water licence charges are $100.00 per year.

Time Frame

Approximate time to receive a water licence is 12 to 24 months.

4.4.2 GUIDE TWO: Locating Hydro on Crown Land

1. Present project plans to the B.C. Ministry of Lands, Parks and Housing, Regional Offices:
   Note: The B.C. Ministry of Environment can issue a Crown land Permit in conjunction with a provincial water licence. The permit authorizes occupation of small Crown land parcels, but can be superceded by a Crown land lease, or licence of occupation (refer to provincial water licence application guide).
2. Where a more secure tenure (longer time frame) is required the developer should seek the advice of a Ministry Officer, and if necessary obtain a land lease or licence of occupation:
   a. Land lease: the developer must survey the land and provide plans to a Ministry land office; application is referred to other resource agencies for extensive review and comment; tenure is of longer term (20 to 30 years); the fees and annual rentals are expensive; usually issued for larger land developments;
   - estimated time to receive a lease is 12 to 14 months; estimated cost ranges between $400.00 and $1000.00 per year depending on the project.

   a. Licence of occupation: the developer must post notice of intent at project site; application assessment involves agency referrals (i.e., B.C. Ministry of Forests, if timber cutting is involved); tenure is of a shorter renewable term (10 years); most micro hydro projects would obtain a licence of occupation;
   - estimated time to receive a licence is 4 to 6 months; estimated cost will range between $200.00 and $400.00 per year depending on the project.
3. Concurrent to filing a Crown land lease or licence of occupation, the developer should file an application for a provincial water licence (refer to provincial water licence guide):
   Note: This is a "Catch 22" situation, in that an applicant must either own land, or have lawful tenure to land in order to receive a licence. Water licences are normally granted appurtenant to the land on which the water or power will be used (i.e., the homesite).

4. Obtain Electrical Safety permit:

a. contact the District Electrical Safety inspector or electrical contractor;

b. install only CSA, or government approved electrical equipment;

- estimated time to receive a permit is 1 to 2 months; estimated cost varies depending on equipment and installation.

5. If the project requires connecting access road to a provincial Highway or secondary road:

a. contact the Regional Highways Offices;

b. present project plans, and file an application for a permit;

c. the permit will specify road design, cover materials, hours of use and where to locate warning signs;

- estimated time to receive a permit is 1 to 2 months; estimated cost ranges between $10.00 to $50.00.

6. If the project requires cutting trees on Crown Forest land:

a. contact the Regional Forestry Office;

b. present project plans, and file an application for a licence to cut timber on Crown land;

c. project plans should include the location of the land area to be cut, amount of timber, method of cutting and removal;

d. when cutting a timber volume of less than 300 m^3 a short form licence application is used; most micro hydro projects will not require the clearing of more than 300 m^3 of timber;

e. the developer must also provide proof of some form of land tenure, either from the Crown, or the private rights to property, before being issued a licence to cut;

- estimated time to receive a licence is 15 days; no fees are assessed.

7. If the project requires burning slash, stumps or garbage from project construction:

a. contact the Regional Forest Manager;

b. present the project plans, and file an application for a burning permit;

Note: if the project is located within Municipal, city or village boundaries contact local government offices to determine whether a burning permit is required..

c. the developer must comply with all conditions attached to a permit (i.e., fire configuration, fire fighting equipment standing by, site preparation (clearing, digging trenches, fire ditches), proximity to water source, and burning on a specific day);

- estimated time to receive a permit is 15 days; fees will range between $5.00 and $40.00.

8. Local government approvals:

a. contact Municipal or Regional District Offices to determine whether a local building permit is required before constructing the powerhouse. Checking the Crown land lease or licence will help determine whether local government regulations will apply to the construction and operation of the project, and whether local land use or zoning by-laws could affect the operation. In most cases developing micro hydro will not conflict with local by-laws;

- estimated time to receive a building or burning permit is 10 to 25 days; fees are assessed depending on the type of structure erected.

Total Cost

Approximate average cost per year for a land lease is $400.00; licence of occupation $200.00 (does not include water licence charges for installed capacity).
Approximate cost per year including water licence is between $300.00 and $500.00.

Time Frame

Approximate time to receive all approvals is 18 to 24 months.

4.4.3 GUIDE THREE: Locating Hydro in a Provincial Park

1. Present project plans to the B.C. Ministry of Lands, Parks, and Housing, Regional Parks Office:
   a. provide feasibility studies, environmental impact assessments and engineering plans (i.e., weirs, diversions);
   b. provide the financial evidence of the ability to post a sufficient performance bond (bank statement);
   c. provide the evidence of filing an application for a provincial water licence;
   d. the developer could be required to perform field studies in the park to determine environmental impacts from project operation (i.e., park flora and fauna, endangered species);
   - <u>estimated</u> time for review and decision from Parks Office is 9 to 12 months.
2. Apply for a provincial water licence (refer to provincial water licence guide):
3. Submit a performance bond to the Regional Parks Offices:
   a. the performance bond amount can range between $25,000.00 and $250,000.00;
   b. the performance bond is used for the reclamation or rehabilitation of park environment in the event of poor project construction and operation;
   c. the performance bond is returned in whole or in part when the developer is issued a Park Use Permit.
4. Obtain a Conditional Park Use Permit issued from the Regional Parks Office:
   a. if the project proposal has been accepted by the Parks Office (including deposit of performance bond) a one year renewable Conditional Park Use Permit is issued; no fees are assessed with this permit;
   b. this permit allows for project construction, but not for the final operation; it sets conditions for the construction activity (i.e., time and day) that must be strictly followed by the developer;
   c. Regional Parks Officers will monitor construction for compliance with the conditions outlined in the permit, and have the authority to suspend or cancel a permit.

5. Obtain Electrical Safety permit:

   a. contact Electrical Inspector or electrical contractor;
   b. install only CSA, or government approved electrical equipment;
   c. electrical installations must comply with park use regulations (i.e., transmission line loads, number of plug outlets per building, positioning of wires (buried) and hydro poles);
   - estimated time to receive a permit is 1 month.

6. If the project requires connecting access road to a provincial Highway or secondary road:

   a. contact Regional Highway Office;
   b. present project plans including road engineering plans;
   c. agency staff may specify road grade, type of cover, hours of use, signs and warnings to be erected;
   - estimated time to receive a permit is 1 to 2 months; estimated cost ranges from $10.00 and $50.00.

7. If the project requires burning slash, stumps or garbage from project construction:

   a. contact Regional Forest Manager;
   b. present project plans including location of burn site, water access, and the time and day required for burning;
   c. District Forest Manager may specify conditions to be attached to the permit (i.e.; having firefighting equipment nearby, preparing the site (clearing and trenching), and reclaiming the site after burning);
   - estimated time to receive permit is ten days; estimated fees range from $5.00 and $40.00.

8. When all required permits, licences and conditions have been met to the satisfaction of the Regional Parks Office, a 10 year (average) Park Use Permit is issued;

   a. the developer must comply with all attached conditions and obligations (i.e., stream flow regulation during low flow periods, planting buffer vegetation near penstocks);
   b. the permit can be cancelled for failure to comply with conditions and attached obligations;

c. the permit is renewable after the 10 year expiry date of tenure;

d. the permit is not transferable, and is issued for the permitted project only;

e. additional conditions, restrictions and obligations can be attached to a permit at any time if considered appropriate by Parks Officers.

Total Cost

Approximate cost per year $300.00 (does not include water licence charges for installed generating capacity).

Time Frame

Approximate time to receive a Park Use Permit 18 to 24 months.

4.4.4 GUIDE FOUR: Locating Hydro on a Native Indian Reserve

1. Contact Indian and Northern Affairs Canada, Regional Offices, and the applicable Band Council Office and members:
    a. provide project feasibility studies, engineering drawings and a financial statement (project costs) to the Band Council and Indian Affairs Officer.

    Note: in most cases non status Indians would not develop micro hydro on reserve lands, but would locate the project either on adjacent Crown land or private land, and distribute power to the community. Status Indians would be given preference for developing micro hydro on reserve land.

2. Obtain a land lease or certificate of possession:
    a. this is authorized by the Band Council and Indian Affairs;
    b. no fees are assessed;
    c. to receive authorization can be time consuming, due to limited land area available for development, and the Band Council's land allocation system;
    - estimated cost is undetermined; estimated time can exceed 18 months.

3. Obtain a provincial water licence:
    a. (refer to provincial water licence guide);
    b. no fees or rental charges are assessed water users who are Indians on Reserve land;
    - estimated cost is variable depending on hydro category and installed capacity; estimated time is 16 to 24 months.

4. Obtain an electrical permit:
    a. contact a Electrical inspector or electrical contractor;
    b. install only CSA, or electrically approved equipment;
    c. installation must conform with Indian Affairs electrical installation standards;
    - estimated cost depends on equipment costs and installation charges; estimated time to receive permit is 1 month.

5. Obtain structure (building) approvals from Regional Offices of Indian and Northern Affairs:
   a. provide Indian Affairs and the Band Council with powerhouse, weirs and penstock support plans;
   b. provide evidence of having received a provincial water licence, electrical permit, and Band Council permission to continue the development of the project.
6. Build project:
   a. Indian Affairs engineers will inspect and approve project;
   b. Band Council Members and Indian Affairs Officers can stipulate certain conditions that include hours of operation, water regulation and extent of power distribution.

<u>Total Cost</u>

Approximate total cost is $300.00.

Approximate average yearly cost is $150.00.

<u>Time Frame</u>

Approximate time to receive all approvals is 18 to 24 months.

4.4.5 GUIDE FIVE: Locating Hydro in a National Park

1. Contact the Parks Canada Office (Western Region), and the Park Superintendent managing the specific park:
   a. Parks Canada and the Park Superintendent must each be presented with project feasibility plans, engineering drawings, environmental impact studies, and a financial statement detailing project costs;

      Note: the developer must apply for and obtain permission initially to study a water course in a park for hydro power development. Having received permission, the developer can then undertake a site assessment and feasibility study.
2. Apply for a park land lease:
   a. the developer must apply to Parks Canada and the Park Superintendent for a land lease. A lease is only issued to a development considered beneficial to the park environment;
   b. a lease issued to another development does not imply a lesee can construct and operate a micro hydro project;
   c. a lease is issued for a renewable 10 years, and annual fees will vary depending on the use of the land;
   - estimated cost is $400.00 to $500.00 dollars annual payment but will depend on the structure and the amount of land required; estimated time to receive a land lease is 6 to 12 months.
3. Environmental Impact Statement:
   a. hydro developments require an environmental impact assessment study;
   b. the developer and Parks Canada Officers may be required to fund and undertake an impact study;
   c. this can require extensive field studies and data collection;
   - the time required to perform impact studies can exceed 12 to 16 months depending on project complexity and location.

4. Obtain a federal water use permit:

   a. this permit is separate from a licence issued by Provincial Water Management Authorities;

   b. the permit is issued only after the environmental impacts have been assessd and mitigation decided on by Parks Officers;

   - permit fees and rentals depend on the amount of water used and will vary considerably depending on the hours of project operation; estimated time to receive a permit is 12 to 18 months.

5. Deposit performance bond:

   a. the amount can vary between $250,000 and $1,000,000 depending on design and construction complexity of the project;

   b. the bond is used for reclamation and rehabilatation of the site in the event of damage to the local environment;

   c. the bond is returned if the project is constructed in compliance with all conditions stipulated by Parks Canada Officers;

   d. Parks Officers will regularly inspect the project during the construction phase, and have authority to suspend or cancel a project because of poor construction and operation.

6. Obtain an electrical permit:

   a. contact Electrical safety inspectors, or an electrical contractor;

   b. install only CSA, or provincially approved electrical equipment;

   c. the installation must conform with Parks Canada safety and electrical regulations;

   - estimated cost will vary depending on the structure and installation charges; estimated time to receive a permit is 1 month.

7. Build the project:

   a. Parks Canada Officers must inspect and approve project structures (i.e., penstocks, powerhouse, weirs);

   b. inspections occur during the construction phase and during each year the project is in operation;

   c. maintenance of access roads would be the responsibility of the developer, and must conform in design and standard to Parks Canada regulations.

8. Final approval:

   a. the developer must comply with all conditions and obligations attached to the land lease and water use permit;

   b. failure to comply with any of the conditions or obligations will cancel the lease and use permit;

   c. the land lease and water permit is not transferable, and is issued to the land and the civil works located on it.

<u>Total Cost</u>

Approximate cost per year is between $300.00 and $650.00.

<u>Time Frame</u>

Approximate time to receive all approvals is between 16 to 24 months.

4.4.6 GUIDE SIX: Locating Hydro on an International River

1. Contact Environment Canada, Inland Waters Directorate:
   a. provide feasibility plans, engineering drawings, and a detailed financial analysis of project costs;
   b. include a description of the river, location of the proposed project, details of the project works, and a brief economic analysis of any direct or indirect benefit and costs resulting from the project;
   c. include copies of any permits, licences or approvals issued by the appropriate provincial or local authority (i.e., licence to cut trees, water licence).
2. File an application form:
   a. the application form is to be filed with the Inland Waters Directorate, (Pacific Region);
   b. no application fees are assessed;
   c. the application can be then referred to other federal and provincial agencies for review and comment. Each agency can attach specific conditions and obligations to the final licence.
3. Interim licence to be issued:
   a. when all above information has been received an interim licence is issued usually for a period not exceeding two years;
   b. this allows for project construction to be completed and evaluated for compliance with the environmental or operational conditions attached to the licence.

   Note: the developer is required to conform with all local and provincial regulatory approvals applicable to the project. These may include for example, a Crown land permit, lease, or licence of occupation, electrical permit, and a licence to cut timber. If the developer has obtained all necessary local and provincial approvals then a final licence is issued.

4. Final licence:

   a. a developer having complied with all conditions provided in the interim licence is issued a final licence for a renewable term of fifty years;

   b. the licence details the terms and conditions under which the project may be constructed, operated and maintained;

   c. a licence can be suspended or cancelled where a developer has failed to comply with the terms and conditions of his licence;

   d. projects are inspected for compliance with terms and conditions of a licence annually.

<u>Total Cost</u>

Approximate cost is $100.00, with minimal yearly charges ranging from $10.00 to $100.00.

<u>Time Frame</u>

Approximte time to receive a permit is 6 to 12 months.

4.4.7 GUIDE SEVEN: Locating Hydro on Private Land

1. Provide project plans to the Regional District or Municipal Offices:
   a. include feasibility studies, engineering drawings;
   b. the project must conform with local zoning by-laws;
   c. the developer may be required to obtain a building permit.
2. Apply for a provincial water licence (refer to provincial water licence guide).
3. Obtain electrical permits;
   a. contact an Electrical Safety Inspector, or a local electrical contractor;
   b. the developer can do his own work if under 600 volts; for over 600 volts an electrical contractor should be consulted;
   - estimated cost depends on whether the developer or contractor installs the equipment; for a single family dwelling fees are based on twice the value of the materials; for a contractor the fees are based on the total value for all labor and materials; to receive a permit takes approximately 1 month.
4. If the project requires burning slash, stumps or garbage:
   a. contact the Regional Forest Manager, or local government offices;
   b. provide project plans, including location of the burn site, water access, and the time and day when burning is to take place;
   c. conditions or obligations can be attached to the permit including site preparation (land clearing, digging fire breaks, ditches), locating firefighting equipment nearby, and proximity to water.
   - estimated cost of a permit will vary between $10.00 and $40.00; estimated time to receive a permit is 10 to 15 days.

Total Cost

Approximate cost per year will vary depending on hydro project category, and installed capacity. Approximate costs would not exceed $150.00 annually.

Time Frame

Approximate time to receive approvals would be 12 to 18 months (water licence).

SUMMARY

As more small industries, communities and individuals isolated from the utility grid realize the advantages in being self sufficient in the production of hydro electricity, and because oil is a nonrenewable resource, micro hydro installations could dramatically increase throughout British Columbia. However, the present lack of awareness and knowledge of the subject acts as a barrier to the developer striving to exploit the potential of a water source, and to the natural resource manager who knows nothing about it, and is required to assess a proposal.

This report discusses the majority of the decisions faced by the potential developer of micro hydro, and provides guidelines for project assessment and implementation. It stresses that consideration should first be given to the environmental impacts as a result of project implementation. Having established environmental compliance, the developer can then focus on doing preliminary feasibility studies and acquiring necessary regulatory approvals. The feasibility study provides equipment suppliers and resource agencies with information from which to evaluate the project, and to determine the appropriate regulatory approvals.

Because developing micro hydro is a site-specific technology, it is important that both developer and resource manager give objective thought to the availability of the resource, environmental impacts, technical and economic considerations. The developer must determine what he can do himself, and what requires professional expertise. The resource manager must be able to assess a proposal for environmental compliance and technical merit. In this way, an acceptable project can be developed with minimal delay and cost.

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