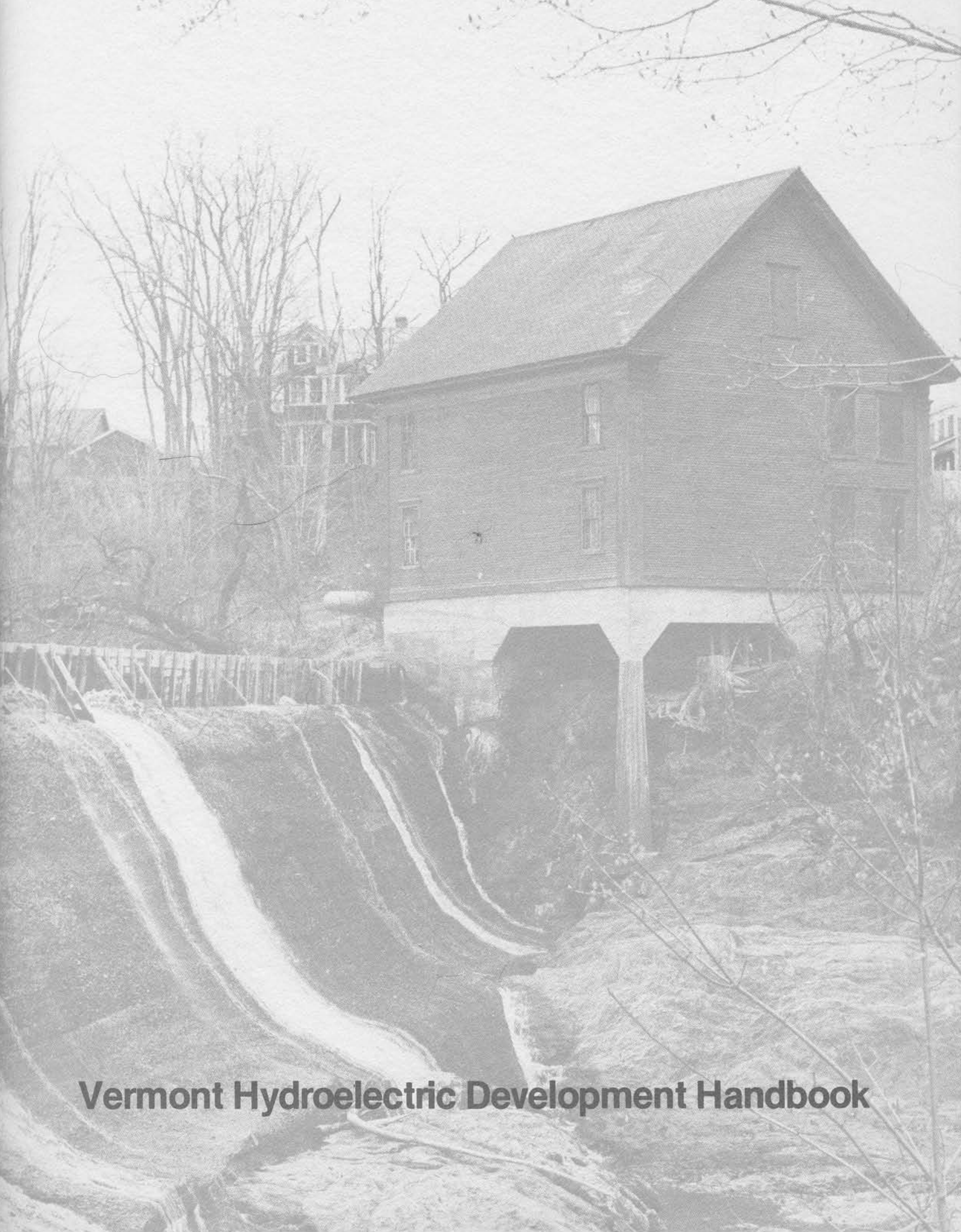

# Vermont Hydroelectric Development Handbook

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Available free upon request

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# Introduction

The use of waterpower to provide mechanical energy in New England is as old as the first settlements. Vermont's saw and grist mills of the eighteenth century used waterpower; with the discovery of electricity in the twentieth century, waterpower became a popular way to generate electricity. By 1941, Vermont hydropower facilities totalling 158,000 kilowatts (KW) capacity, produced over 90 percent of all the electricity generated in the state, and actually exported two-thirds of this power.

As fossil fuel became cheap and available after World War II, and as plants and equipment deteriorated on the older hydroelectric facilities, the percentage of electricity generated by hydro in Vermont dropped significantly. In 1979, Vermont hydro capacity totaled 91,000 KW, only 10 percent of the electricity generated in the state.

The energy crisis, stimulating interest in renewable resources, has prompted a reconsideration of hydroelectric generation in Vermont. Abandoned and undeveloped sites are being looked at by public, private, and cooperative utilities, non-utility businesses, and municipalities without utilities. If all the projects now under consideration could be built, the total installed KW capacity in Vermont would be at least 250,000 KW, an increase of almost 300 percent from the 1979 level. For purposes of comparison, the state's peak load in 1979 was approximately 800,000 KW.

It is unlikely that all these projects will be built, however. Hydropower is not, as was once believed, environmentally benign, even at existing dams. The effect of development on water quality and fisheries can be critical at some sites. To a lesser degree, a development can also adversely affect land use, historical and archaeological sites, river recreation, and aesthetics. Both the state and federal governments, through the Vermont Public Service Board (PSB) and the Federal Energy Regulatory Commission (FERC) are charged with the protection of the environment and the promotion of orderly development. Environmental and social concerns may be a factor in obtaining permits and licenses from these agencies.

Because of the complex engineering, environmental, and economic issues that might arise, a developer should hire an experienced and reputable consulting engineer as early as necessary in the development process. Chapter I explains the services that such a person or firm might be expected to perform. A list of regional consulting engineers currently offering hydropower development services is available upon request from the Vermont Public Service Board (see Appendix II). Services of a lawyer will also be necessary from time to time to determine property ownership, negotiate with utilities, and participate in hearings. It is not crucial to retain a lawyer experienced in hydropower development law.

This booklet is not a do-it-yourself handbook for developers. It is intended as an overview, written in simple terms, of engineering, environmental, and economic concepts along with a summary description of the process of developing a hydro facility for the commercial sale of electricity. Developers are encouraged to read this guidebook in order to be able to communicate knowledgeably with their consultants.

The order of chapters and parts roughly follows the development sequence, although for purposes of clarity some are taken out of order. It is important to note that many of the tasks are proceeding at the same time. Commonly used terms and concepts are explained in the text and in the glossary (See Appendix I).

# I. Consultants

Most of the firms or individuals that undertake hydroelectric development are engineering consultants, specializing in one or more of the engineering disciplines (civil, mechanical, electrical). These firms may also hire architects, designers, and environmental specialists. Often one company can provide all services, from preliminary studies to construction supervision. In some cases a developer employs two firms, one to provide preliminary investigations, feasibility studies, and financing schemes and a second to develop the final design, obtain licenses and permits, and oversee construction.

A large number of firms in northern New England and New York offer hydropower development consulting services. Many have experience in Vermont projects and are therefore familiar with the regulations. A developer should contact several firms to determine which one is most suitable. Fees may vary considerably; a firm might undertake a preliminary evaluation at little or no cost with the expectation that they would be retained for the detailed feasibility study, if the project is developable.

Fees for the preliminary and feasibility studies will depend on the size of the project and its location. There may be more concerns to be addressed in urban than in rural areas, for example. If fees must be kept to a minimum, as in a small project, the developer should consider hiring an experienced firm. Even though the fees (based on a percentage of construction costs) may appear higher initially, the firm's expertise in cost effective design and construction methods may save money in the end.

In summary, it pays to get to know a consultant well and be familiar with past work before signing a contract!

The contract between the developer and consultant should specify work to be done, time schedules for completion, and fees. The following checklist lists the exact services to be contracted for. The handbook goes into greater detail as to the nature of these tasks.

| Stage | Tasks |
|---|---|
| Preliminary Evaluation[1] | Tasks include preliminary estimate of power potential and costs, identification of critical issues, exploration of the market, and financing. Legal advice is advisable. |
| Permit & License Applications | Tasks include writing applications in proper form, coordinating meetings with government agencies and interest groups, testifying in license application hearings. Legal advice is advisable |
| Feasibility Study | Tasks include preparing engineering, environmental, and economic reports for license application. |
| Design of works | Tasks include designing plant works, writing specifications for equipment. |
| Marketing | Tasks include negotiating with chosen market source. |
| Financing | Tasks include assistance in obtaining public or private financing. |

[1]Small projects may not require a consultant at this stage

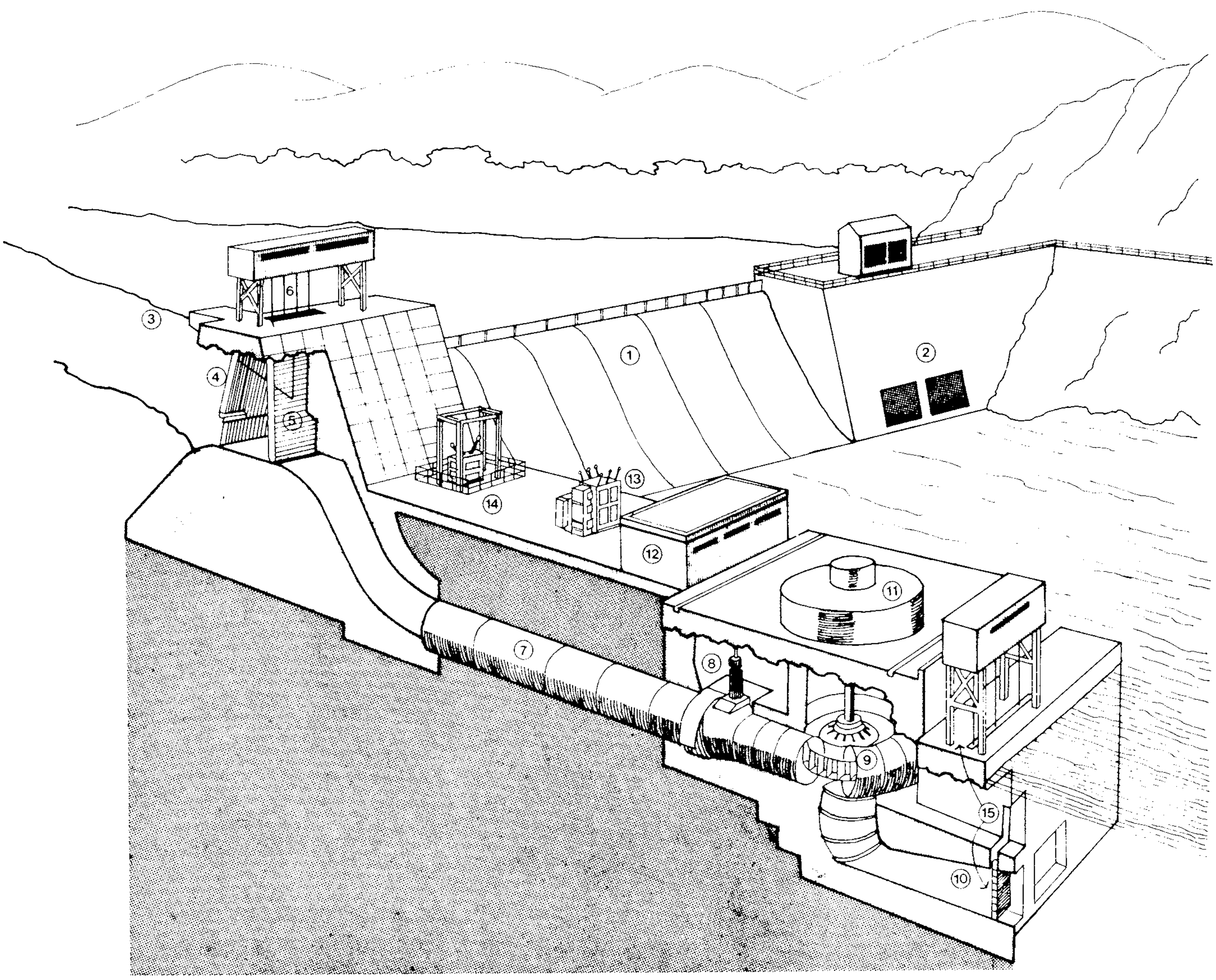


Figure 2.1 **Typical Vermont Hydropower Installation.** The walls of the powerhouse and intake structure are removed to illustrate the project works: (1) Dam with flashboards, (2) waste gates and gatehouse, (3) intake forebay, (4) trash racks, (5) intake gate, (6) intake gate hoist, (7) penstock, (8) shut-off valve, (9) turbine, (10) draft tube, (11) generator, (12) switch gear, (13) transformer, (14) circuit breaker, (15) draft tube gate and hoist.

# II. Waterpower Theory & Equipment

### Theory of Water Power

In accordance with the laws of physics, water at a given elevation or under a given pressure has the ability to do *work* (see inset) if it can be passed to a lower elevation or pressure through a device that converts water energy into mechanical energy. The amount of work is directly proportional to (a) the amount of water and (b) the difference in elevation or pressure through which it passes.

The *power* created, being work per unit time, is determined from water flow (volume per unit time) and head. To produce an equivalent amount of power, a site with a "high" head will require less flow than a site with a "low" head. For example, at a site with 150 feet of head, a flow of 1 cubic foot/second (CFS) might produce 10 KW of power; if only 15 feet of head are available, a flow of 10 CFS would be needed to produce the same 10 KW.

*Flow,* the volume of water passing a specified point over a specified time period, is usually measured in cubic feet per second (CFS), or cubic feet per minute (CFM) at small sites. The flow of a stream depends on such factors as the land area draining into it, amount of rainfall, and gradient of the stream.

The *head* available at a site, measured in feet or meters, is the difference in elevation between the surface elevation of the water in back of the dam (the headwater elevation) and the surface elevation of water where it exits from the powerhouse below the dam (the tailwater elevation). The difference so calculated is termed *gross* head. *Net* head, which is used in calculating power potential, takes into account loses in water velocity due to friction of the water flowing through the intake, penstock, and power machinery. Net head is calculated by subtracting 10 percent of its value from the gross head.

### Hydroelectric Equipment

There are several basic components to a hydroelectric project with some variations depending upon particular site characteristics (Fig. 2.1). In Vermont virtually all hydropower projects incorporate a dam, the largest single component of the facility. Three types of dams are commonly found in Vermont: wooden timber crib dams, earth or rock fill dams, and any of several types of concrete dams. The timber crib construction is no longer widely used for new dams; many such dams built years ago still stand, often with added masonry or concrete faces.

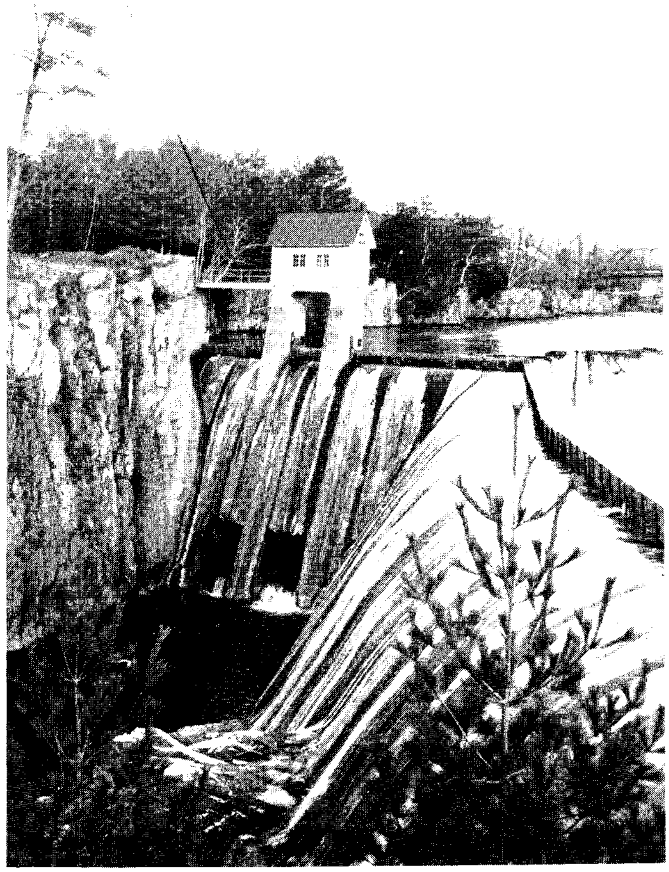

Figure 2.2 **Dam With Flashboards.** The small gatehouse contains machinery to operate the waste gates below.

Most dams have a spillway or waste gates or both designed to pass water that cannot be used for generating without excessively raising the level in the pond. In some cases, temporary flashboards are constructed on top of the spillway, raising the level of the pond and thus the available head, without changing the permanent structure of the dam. Flashboards are constructed so they will collapse at time of flood (Fig. 2.2).

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**Energy and Power**

*As it is used in this handbook,* ***energy*** *is defined as a force applied over a distance. The term work is interchangeable with* ***energy. Work*** *can be expressed in foot-pounds; one foot-pound is the work done when one pound is lifted one foot. Electrical energy is not expressed in foot pounds, but in kilowatt hours (abbreviated KWH).*

*As used in this handbook,* ***power*** *is equal to the work that can be done per unit time. Power could be expressed in foot pounds (work) per second (time). Power is also expressed in horsepower. Electrical power is not expressed in foot pounds per second but in kilowatts (abbreviated KW).*

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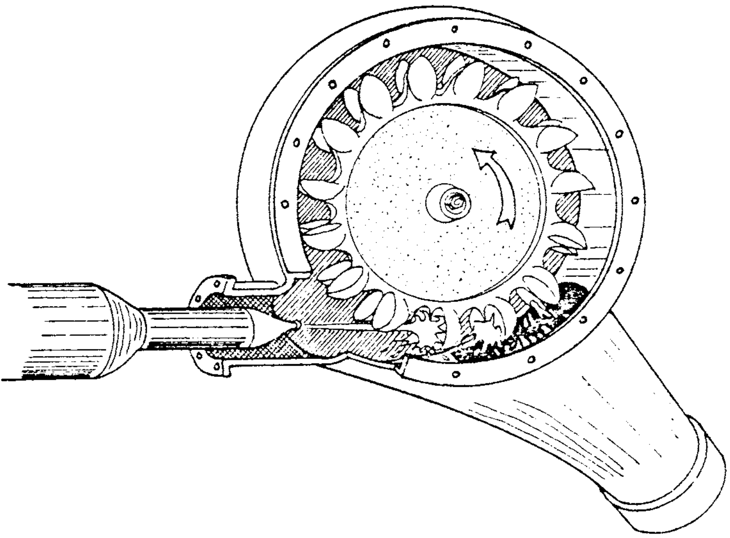


Figure A **Pelton Wheel.**

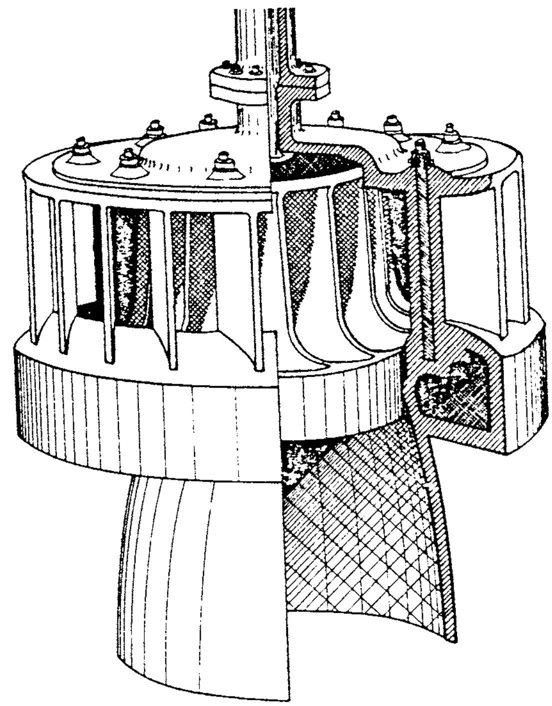


Figure B **Francis Turbine.**

### Turbines

*There are two general types of turbines, impulse and reaction turbines. Both convert energy in water into mechanical energy, but by different means. Impulse turbines direct water through a nozzle at the runner blade, converting the water energy into kinetic or velocity energy. Impulse turbines are more suitable for high head applications, since small volumes at a high velocity can turn the turbine runner at a reasonable speed. A common type of impulse turbine is the Pelton Wheel (Fig. A). Reaction turbines work on a different principle. Water flows equally over all the runner blades; both the pressure and velocity of the water cause the runner to turn. The draft tube has a vacuum in it that helps pull the water through. A common reaction turbine, now used chiefly at sites with moderate heads, is the Francis turbine (Fig. B). Propeller turbines operate on the same principle as the Francis and are used at low head sites. Propeller turbines can be installed vertically, horizontally, or on a slant (Fig. C).*

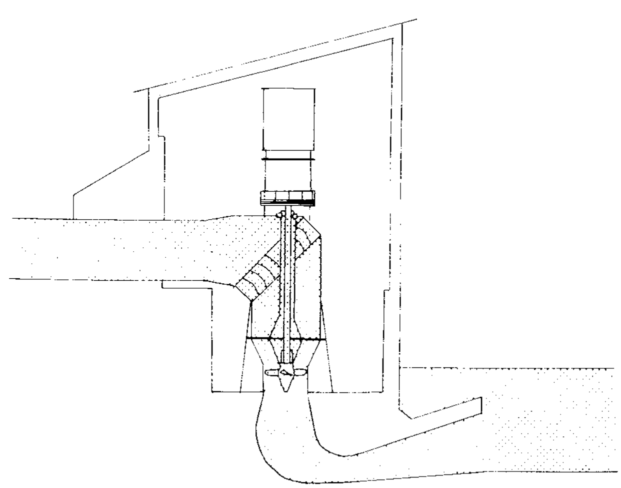


Figure C **Propeller Turbine.** This turbine may also be installed at a slant.

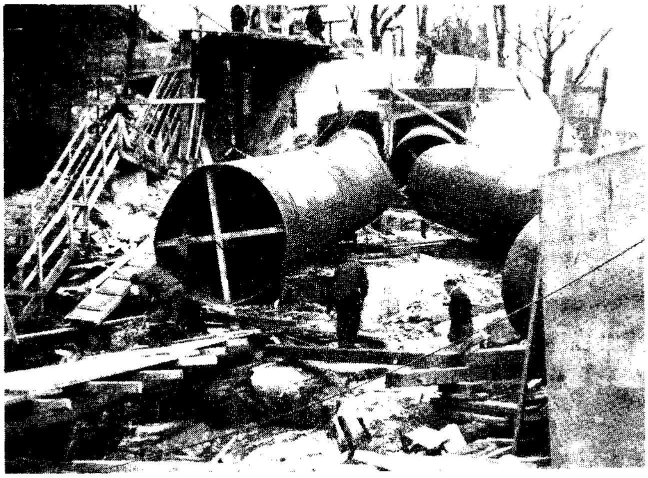


Figure 2.3 **A Steel Double Penstock Under Construction.**

The water impounded by the dam enters through an intake gate into the penstock, the pipe which conducts the water to the turbine (Fig. 2.3). The intake is protected by a barred trash rack that catches debris (such as wood, tires, and ice chunks) to prevent damage to the turbine (Fig. 2.4). The intake gates are designed to be raised and lowered, either hydraulically or manually, with a screw lift or rack-and-pinion hoist.

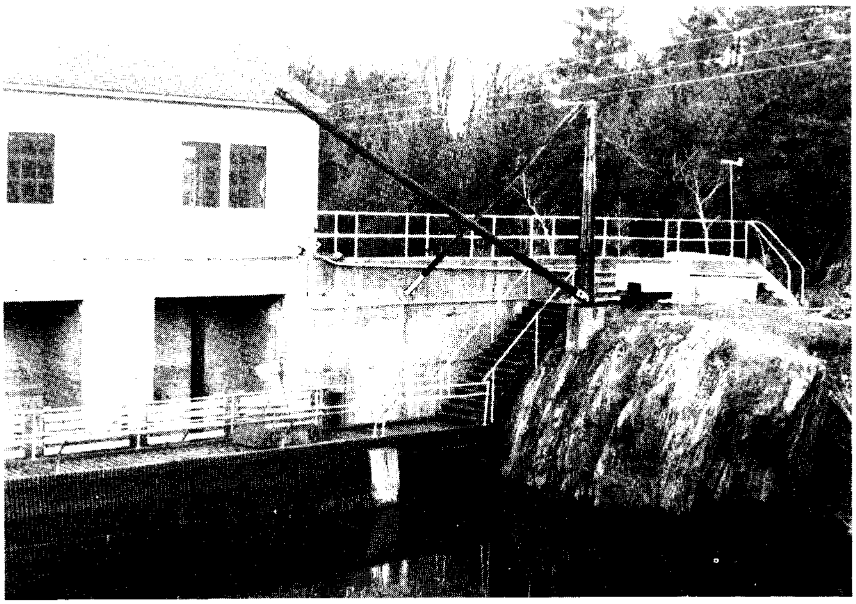


Figure 2.4 **Intake Gates.** Trash racks at the left are cleaned and debris is placed in basket on end of crane and disposed of at right. Note the screw hoist for the intake gate.

The location of the powerhouse in relationship to the dam, and thus the length of the penstock between them, depends on site characteristics and ultimately on economics of maximizing the head and minimizing the construction costs at the site. Fig. 2.5 illustrates some possible configurations. Depending on power machinery used, a long penstock may require special devices to prevent vacuums or pressure surges resulting from rapid shutdown of water flows.

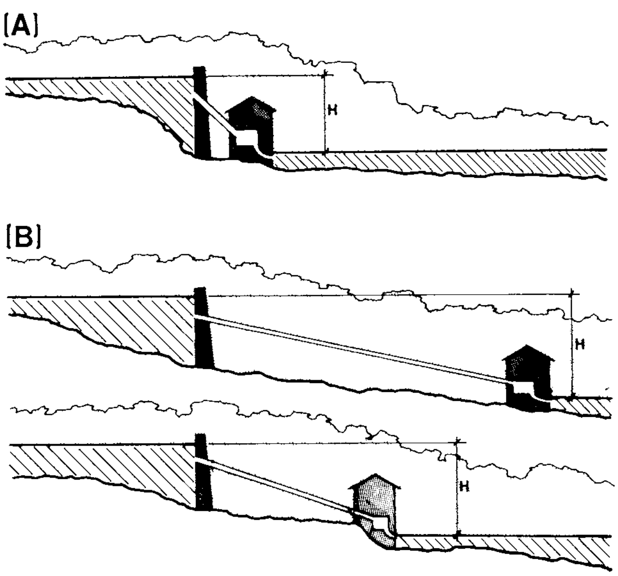



Figure 2.5 **Powerhouse Locations.** (A) a dam at a steep site with a flat gradient below. Powerhouse can be located in or near the dam. (B) a dam at a gradually sloping site. Depending on costs, the powerhouse can be distant from the dam with a long penstock, or a tailrace can be excavated to maximize head.

The powerhouse contains the power equipment (turbine, generator, governor, switch gear, etc.). The building varies in size, design, and construction depending on the size and orientation of the equipment, and aesthetic preferences of the owner and community (Fig. 2.6).

Figure 2.6 **A Modern (1950's) Powerhouse.** The power facility is an addition to a flood control dam built in the 1930's.

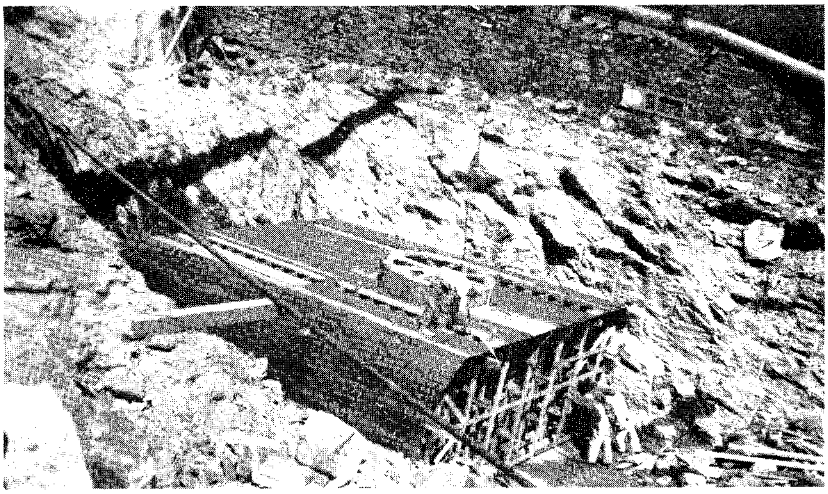
Water energy is converted by the turbine into mechanical energy, which is then immediately converted into electrical energy by the generator. The inset briefly describes types of turbines. Suitable equipment to start, stop, and regulate the mechanical energy output of the turbine are provided.

Water that has passed through the turbine exits through the draft tube, into the tailrace canal and back into the river (Fig. 2.7). The draft tube outlet is below the level of the river to form a seal; the resulting vacuum allows the head between the turbine and the tailwater to be used (in the case of a reaction turbine).

The turbine is connected by a shaft to the rotor of an electric generator, which produces electricity at its output terminals. The turbine and generator must be matched in size so that their power ratings are similar. If a turbine is too large for the generator, water may be wasted, or the generator may burn out.

Generated electricity is conducted through the switch gear and its controls before entering the substation. The switch gear, located on the powerhouse control panel, contains switches, relays and other electrical devices for connecting, disconnecting, protecting, and monitoring the generator output. The control panel may also display meters for

Figure 2.7 **Excavated Tailrace Under Construction.** The concrete form for the draft tube outlet for the powerhouse pictured in Figure 2.6. The circular section is where the draft tube will be located. The water level rises above the outlet.



monitoring water conditions, gate controls, and other necessary plant functions. The substation, usually located near the powerhouse, contains a transformer that changes the voltage to the same level as that of the utility transmission or distribution lines. The substation may also contain various switches and lighting arrestors to protect both the electrical equipment and personnel working on the equipment.

**Plant Operation**

Electrical generation facilities are operated in several different modes. These operational modes are commonly referred to as *base* load, *intermediate* load, and *peak* load operation. A base load plant runs constantly and supplies that portion of electrical demand that occurs continuously. An intermediate load plant operates during the time when demand increases above base load levels, usually during the day when more electricity is being used in homes and businesses. A peak load generator runs at certain times of the day when there are high demands. In Vermont, peak daily use occurs around morning and evening meal times, and peak seasonal use occurs in the winter months.

Some hydroelectric facilities can run in all of these modes depending upon whether water is available; few run in one mode consistently, because of fluctuations in water flow. For a plant to operate consistently at base load, the turbine would have to be sized for such a low flow that water would be "wasted" at times of high flow. On the other hand, in the spring when water is plentiful, hydro plants do supply base load. For a hydro plant to operate in a peaking mode, it must always have enough water in its reservoir to generate for two hours,[2] no matter what the flow conditions.

So-called short cycle operations, allow a facility to supply intermediate load. A facility operating on a short cycle might impound for one hour and generate for one hour.

Many dams in Vermont have little if any pondage and must be operated on a *run-of-the-river* basis, meaning that they can use for generating only that water flowing in the river at the moment, rather than being able to impound water for later use. Small projects are more likely to operate on this basis, generating when water is available and shutting down when it is not.

Flexibility is gained if a facility has an impoundment. On the other hand, a run-of-the-river operation is less damaging to the environment. A discussion of the environmental impacts of plant operation is contained in Chapter V.

[2]a standard set by the Federal Energy Regulatory Commission (FERC)

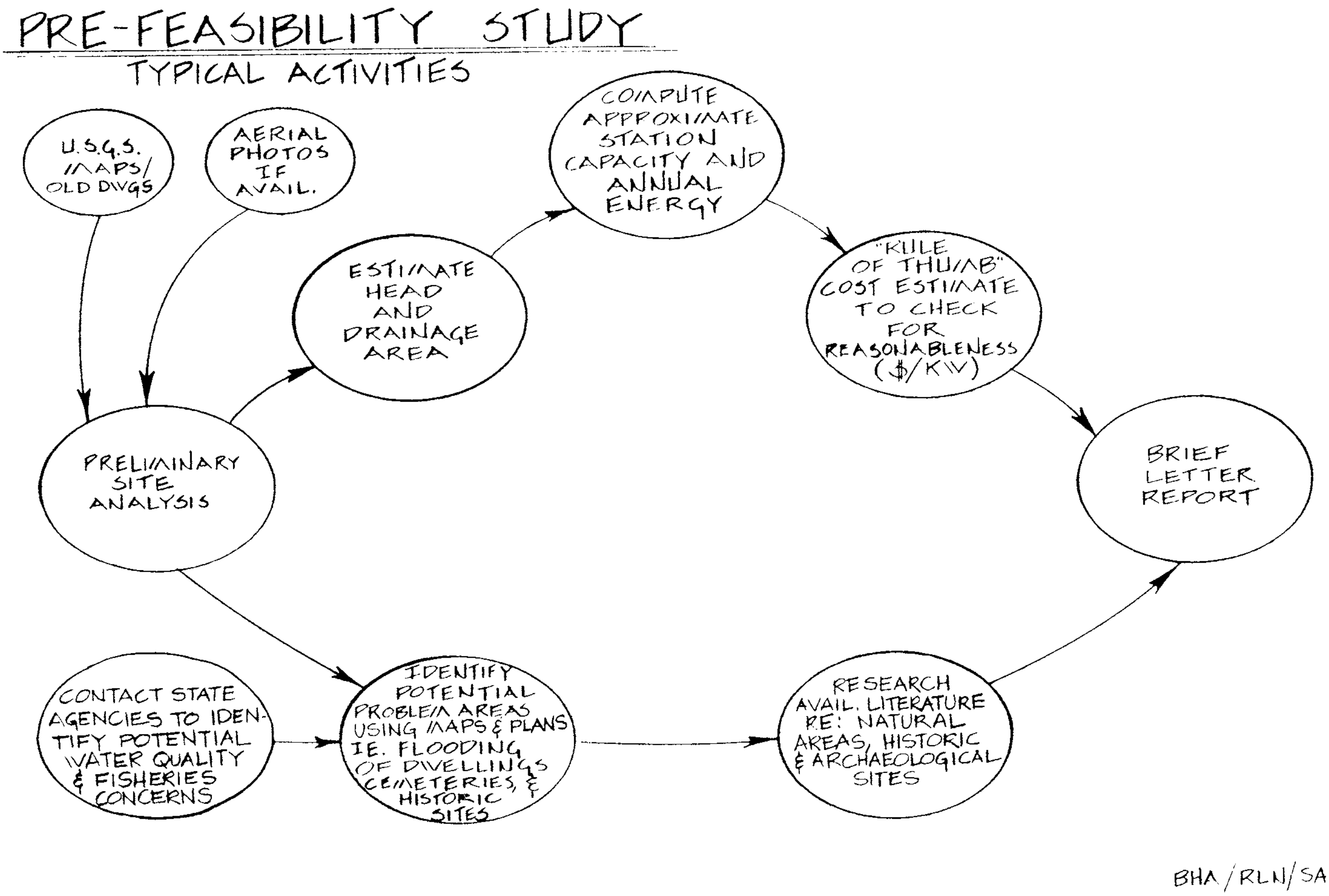



Figure 3.1 **Flow Chart.** Steps in preliminary evaluation.

# III. Preliminary Site Evaluation

A developer should be fairly sure that a development will be profitable before undertaking a detailed engineering, environmental, and economic study and applying for state and federal licenses. A preliminary evaluation should determine legal rights, identify critical environmental or social issues, and evaluate costs and benefits of development. Depending on the size of the project, an engineering consultant should be hired for the preliminary study. At the very least, a local civil engineer should be willing to check preliminary power potential calculations. Especially in projects where construction costs must be minimized, it is strongly recommended that an experienced consultant be hired at this stage. A flow chart illustrating the stages of the preliminary study is depicted in Fig. 3.1.

### Water Rights

The ownership of water rights at the site should first be determined, with the help of a lawyer. A developer must have clear title (either in fee or by lease) to any land that will be inundated by rebuilding of a dam. In Vermont, as in the rest of the eastern states, riparian water law is in effect. *Riparian rights* can be defined as the right of access to or use of water by an owner of riparian land (i.e. land located on the bank of a natural waterway). The right to use the water can be owned or sold separately from the property surrounding it. Current deeds to riparian property often do not include the water rights, and a search for owners of water rights must be made from old deeds (usually on file in the Town Clerk's office). If a breached dam is to be rebuilt, the rights to upstream land that is going to be flooded, even if it was flooded in the past and rights were acquired by the former dam owner, should be renegotiated with the current owners, especially since that land might be presently built upon or used for agriculture. If all the necessary property cannot be acquired by the time the project is licensed by **FERC,** it may be taken by eminent domain, with just compensation.

### Governmental Concerns

A developer should contact appropriate government agencies as soon as possible. The Public Service Board (**PSB**) acts as the lead state agency on hydropower matters, and should be contacted first. The Agency of Environmental Conservation (**AEC**) should be contacted concerning critical environmental issues, since satisfaction of environmental requirements may possibly prove to be costly.

Federal regulations[3] require that the federal agency funding, licensing or permitting a project determine whether any sites of historic, architectural or archaeological significance are located within the project's area of potential environmental impact. The applicant may be required to carry out this part of project planning. The State Historic Preservation Office should be contacted for information on this aspect of project planning. It may also be necessary to conduct additional research in order to obtain the information needed to fully assess the impact of the project.

The State Planning office also may have concerns about the project. If a road must be relocated, the Department of Transportation must be consulted. All agencies should be contacted by the developer either individually or in a group meeting arranged by **PSB** staff. The latter procedure is recommended since the developer can establish simultaneous contact with every agency concerned to explore critical issues and ways to deal with them. Chapter V contains a detailed discussion of possible critical issues. A list of agencies and their addresses is contained in Appendix II.

In addition to contacting state agencies, the developer should contact the local and regional planning commissions, and property owners near the proposed facility for information on local issues that must be addressed, since both planning commissions will be statutory parties to the licensing review by the **PSB.**

### Power Potential Evaluation

Determination of head and flow at the site is the first step in assessing power potential. Rough figures can be obtained by a lay person; however it is advisable to have a professional review the calculations early in the development process.

The vertical drop can be measured at the dam by two people with a tape measure, and more accurately with a surveyor's transit. Approximately 10% of the gross head thus determined should be subtracted (for intake losses) to obtain net head.

The flow data is often more difficult to obtain than head data. Information concerning the area and characteristics of drainage for Vermont river basins is available from the United States Geological Survey (**USGS**) or the Vermont Department of Water Resources. In addition, historical records of flow

[3] To comply with National Historic Preservation Act (1966) as amended and 36 C.F.R. 800: Advisory Council Procedures for Preservation of Historic Properties. This compliance is required under Federal Power Act Regulations (18 C.F.R. 4.40 - 4.51).

on a monthly and yearly basis, obtained from **USGS** river gauging stations on many rivers, are available at the Department of Water Resources.

Average annual flow data is sufficient for a rough preliminary assessment of power potential and is adequate for the very first analysis of a site. Information concerning flow fluctuations, however, is absolutely necessary for further studies, not only to more accurately predict power potential, but also to ascertain the feasibility of hydroelectric development at extremes of flow (flood and drought). If the **USGS** does not have information for flow at a site, flow data from a nearby index station can be adjusted, or index station information on a river with a similar drainage area and runoff characteristics can be used.

The bibliography contains references to manuals that explain how head and flow can be measured for a small project. In the case of a larger dam, it is recommended that: a surveyor be hired to determine head, flow data located in state files be used whenever possible, and a consulting engineer be hired to perform or verify initial calculations of power availability (installed capacity). See the inset for an example of initial calculations.

Once a theoretical installed capacity is obtained, the services of a consultant will probably be needed to calculate whether there is flow at a site enough of the time to install that amount of capacity, especially in the case of a plant that will operate as "run of the river." Using what is known as a flow duration curve (see glossary), the consultant will draw up a curve that shows the amount of energy produced annually as a function of the installed capacity. It should be easy to see from this curve a range within which an installed capacity can be chosen that will maximize energy output.

If a site is large enough, a consultant may investigate the power potential at three or four different installed capacities corresponding to a range of head and flow conditions. Corresponding average annual energy outputs will be estimated, as well as the range of outputs by month and over the years.

**Power Potential Determination**

*A simple calculation using flow and head at the project yields approximate power availability. The formula used is:*

$$P_k = \frac{Q \times h}{709}$$

where:

$P_k$ = power in kilowatts

Q = average annual flow in cubic feet per minute (CFM)

h = net head

709 = a constant derived from the density of water at 62.4 pounds per cubic foot

*Flow might be expressed in cubic feet per second or gallons per minute. Multiply CFS by 60 to obtain CFM. Divide gallons per minute by 7.48 to obtain CFM.*

*For example, a flow of 200 CFS (12000 CFM) and a net head of 25 feet would work out as follows:*

$$P = \frac{12{,}000\ (\text{CFM}) \times 25\ (\text{FT})}{709} = \frac{300{,}000}{709}$$

$$= 423\ \text{KW}$$

*The figure of 423 KW represents the theoretical power available, which is more than the generating equipment will produce, since all equipment will operate at less than 100 percent efficiency. A reasonable approximation is 85 percent efficiency for the turbine generator unit, thus:*

*423 KW x .85 efficiency = 360 KW*

*The last figure represents the power that might be available in a stream. The one or more turbine-generators installed will have approximately this power rating. The power rating is also called installed capacity.*

## Existing Facilities Assessment

If there is developable power potential, the developer and consultant should assess the dam, the impoundment, and any structures or equipment that may be at the site.

A visual inspection of the dam may reveal surface cracks, holes, leaks, and crumbling masonry or concrete. As with assessment of power potential (and other aspects of development), a preliminary review of dam safety by a layman must not be substituted for a professional examination. The State Department of Water Resources employs a structural engineer familiar with the condition of many Vermont dams and who would be willing to help assess a dam's structural integrity. The Army Corps of Engineers (Corps) has conducted dam safety inspections on numerous dams in Vermont, that data also being available from Water Resources or from the Corps.

Historic records or signs of flood damage around and below a dam may be evidence that the spillway has not been able to pass a flood (Fig. 3.2). If it appears likely that this might be a problem, the feasibility study will have to include the cost of redesign of the spillway.

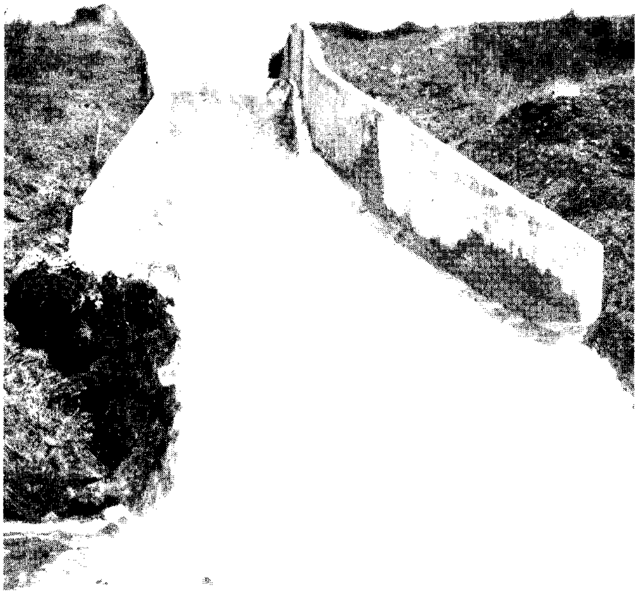


Figure 3.2 **Spillway Passing a Flood Flow.** The stoplogs have been removed from their grooves at the spillway crest.

Plans for future additions could include locating potential sites for additions of powerhouse, access road, transmission line, and substation, although final plans may change from the preliminary designs. Note should be made of areas that would be flooded by raising or rebuilding a dam.

The pond may be full of silt, gravel, and other debris deposited over the years (Fig. 3.3). Depending upon the severity of this problem, the pond may have to be desilted during construction. (See Chapter VIII for further discussion).

The consultant should be able to make a rough determination of all equipment necessary for power generation to serve as a basis for cost estimation. At this stage, the actual layout of the power equipment and choice of specific makes is not necessary. If reliable used equipment can be obtained, the cost estimate may be altered somewhat; the supply of safe and reliable used equipment is rapidly diminishing, however.

Figure 3.3 **Impoundment Siltation.** Drawdown behind the dam has revealed a quantity of Winooski River silt.

### Preliminary Cost-Benefit Calculations

Capital costs of repairs, and construction, equipment purchase, and land acquisition should be roughly estimated. The costs of measures taken to safeguard the environment, historic sites, and so forth should be added; a good rule of thumb suggests that the construction cost estimate be increased by 20 percent to take such measures into account. An additional construction contingency allowance of 15 percent should be calculated also.

Besides the construction costs, the consultant should estimate investment costs, operations and maintenance costs, and indirect costs such as engineering fees for design, licensing, and construction supervision (usually 15% of total development costs).

The benefit to be obtained is of course the amount of money made from the sale of electrical energy. The annual value of energy generated can be determined by multiplying the annual KWH generated multiplied by the price to be paid by the purchaser for the electricity. At this stage, a consultant should identify proposed purchasers and roughly estimate probable benefits. Preliminary market research is necessary in an application to **FERC** for a preliminary permit, as well as being needed to determine preliminary economic feasibility. Marketing options are discussed in detail in Chapter VI.

To be feasible, project benefits should exceed project costs. There are several ways of determining feasibility that can be discussed with the engineering and economic consultant. The costs and benefits should be compared for each installed capacity chosen.

### Financing

The cost-benefit analysis should indicate a rate of interest at which (or below which) development is feasible. Department of Energy officials should be contacted in regard to private financing or Federal grants. Chapter VII contains a more detailed study of financing.

### Report

The findings of the preliminary study should be incorporated into a short report indicating if the project seems developable. This report can be used as an exhibit to the Federal Energy Regulatory Commission (**FERC**) if and when the developer applies for a preliminary permit to develop the site (Chapter IV). It also serves as the basis for the feasibility study as detailed in Chapter V.

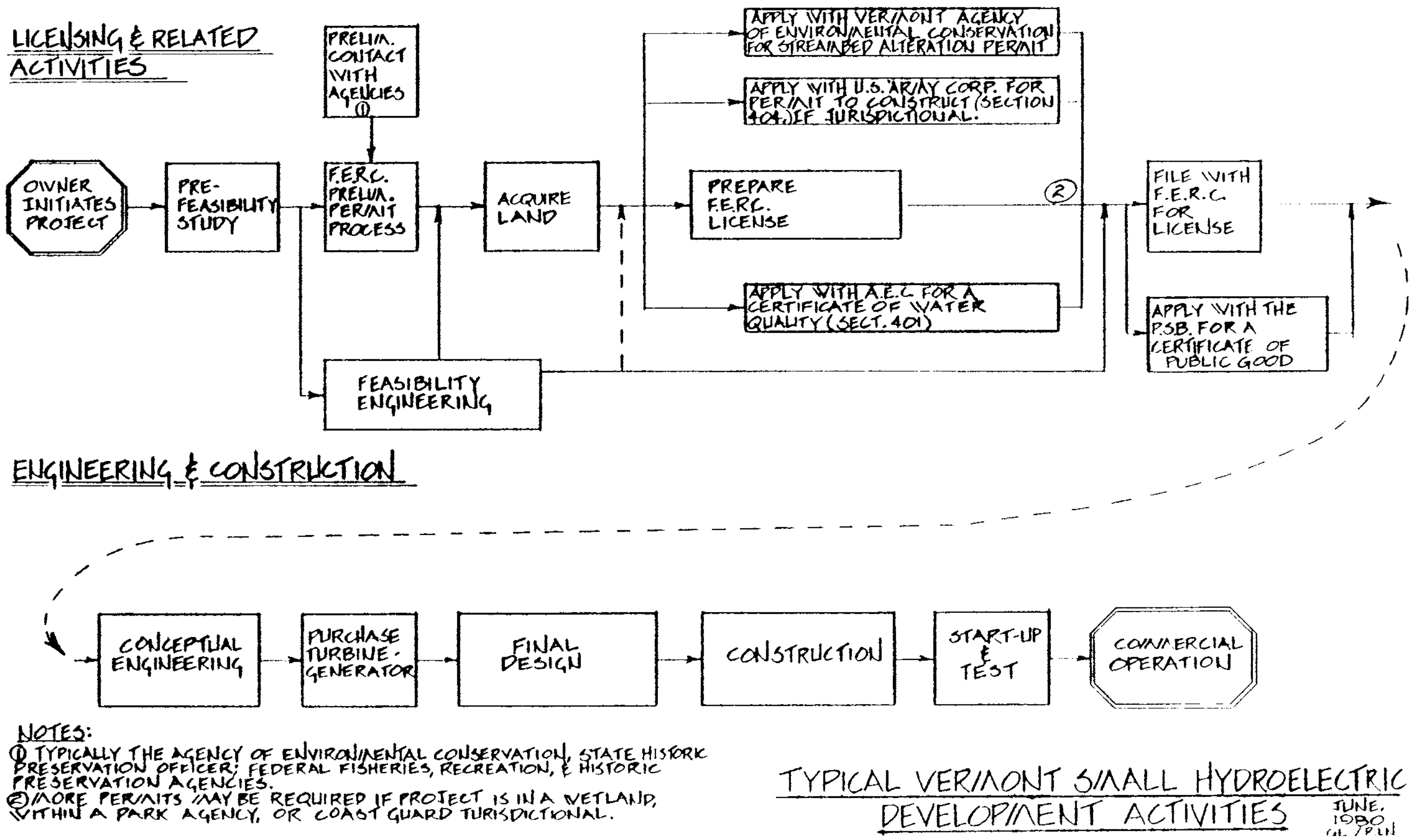



Figure 4.1 **Flow Chart.** Steps in licensing process.

## IV. Licenses and Permits

### Time and Expense

The preparation of **FERC** and state licenses can be fairly costly in time and money depending, of course, on the size of the site. The license applications for a 500 KW site, for example, might take two months to prepare with six months or more for review by **FERC** and state agencies, and might cost $3,000. For a much larger site, say 15,000 KW, the process of preparation might consume a year, review might take a year and a half or more, and the expense might be as much as $300,000.

The licensing process is intended to protect the public interest. Although the length of the process and the detail required may appear burdensome, it is necessary to ensure that all interested parties have their say and relevant issues are considered and resolved.

### FERC Preliminary Permit

Under Part I of the Federal Power Act (1935), the Federal Energy Regulatory Commission (**FERC**) is charged with regulation of all hydropower projects built on navigable streams of the United States and/or all projects built after 1935 that sell electricity into interstate commerce through the utility grid (all Vermont utilities are connected to this grid). All these projects must be licensed by **FERC**. In addition, the Act of 1935, amended by Title IV of PURPA (1978)[4], also authorizes the **FERC** to issue a *preliminary study permit* to developers undertaking lengthy feasibility studies.

The preliminary permit secures for the developer a 36-month guarantee that the license application submitted by the permittee will be the only one accepted by the **FERC.** A permit is neither a prerequisite for, nor a guarantee of issuance of a license; it does not permit construction of any type. Its purpose is to provide security for the investment of the developer in a feasibility study. In addition, federal agencies funding feasibility studies require either a permit or a permit application before monies are released.

Order No. 54 issued by **FERC** in October 1979[5] explains the purpose and procedures of the preliminary permit. This document is available free of charge from the central and regional offices of the **FERC.** The consultant hired for the preliminary evaluation should fill out the application. If no consultant was hired, the developer should follow the following suggestions.

The **FERC** requires an original and ten photocopies of the permit application, which includes a map of the project area. In the past, **USGS** topographic maps ("quad" maps) have been satisfactory, but the developer may wish to check. Officials in both the New York and Washington offices will clarify the application instructions over the phone or in writing. They will also send, upon request, a copy of a successful permit application to use as a guide. It is helpful to establish contact with one person in either the New York or Washington office who can refer one to other parts of the agency. And although telephoning is more expensive, it often produces information more immediately than does a written request.

### FERC License

A hydroelectric project cannot be constructed unless it is licensed by the **FERC.**[6] The PURPA 1978 set up a short-form or *minor* license application for all projects of 1500 KW capacity or less, and streamlined procedures in applications for a *major* license (more than 1500 KW) that use an existing dam. Rules and regulations for both are available from the **FERC.**[7]

A developer will not apply for a license until he or she is reasonably sure that the project is developable. A professional engineering and environmental consultant should be hired to prepare the license application, in fact, this should be one product of the feasibility study (Chapter V). Both major and minor applications require submission of topographic maps of the project area, with project boundaries, schematic drawings of the project works, and an environmental assessment of both construction and operation of the project. The application will also include a 401 Water Quality Certificate (see section later in this Chapter).

### Vermont "Certificate of Public Good" (Section 248)

All new electric generation and transmission facilities in the State of Vermont must obtain a Certificate of Public Good from the Public Service Board. The law requiring this certificate is Title 30 V.S.A., Section 248, usually referred to as "Section 248." See Appendix III for the text of the statute.

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[4]Public Utilities Regulatory Policies Act.
[5]Docket No. RM79-23

[6]If it conforms to the Federal Power Act mentioned earlier
[7]Order 11, Docket RM 78-9 (minor); Order 59, Docket RM 79-36 (major)

As in the case with the **FERC** licence, a developer will not file a formal application with the **PSB** for a certificate unless the project seems feasible. Before filing, the developer must send site plans and prefiled testimony to the appropriate municipal or regional planning commission, which has a 45-day period to make recommendations.[8]

Prefiled testimony consists of a written statement, either in narrative or question-and-answer form, by each witness discussing various issues of the project.

After the 45-day waiting period, a petition is filed, accompanied by the prefiled testimony and exhibits. The petition, which can be in the form of a letter, states that the applicant proposes to construct a hydroelectric plant at a certain location, and explains that the project complies with the criteria set forth in the statute. The application is designed to demonstrate that the project will not interfere with the orderly development of the region and will not have an "undue adverse effect" on aesthetics, historic sites, air and water purity, the natural environment, and public health and safety. Exhibits (see below) are available for review by various state agencies (the statute enumerates them), which make their recommendations known to the Public Service Board at the public hearing. Most critical issues involving these agencies should have been resolved before submission of the application.

It may be possible to submit the **FERC** license application as an exhibit in the 248 hearing. It is likely that the state will require additional information, especially concerning environmental, aesthetic, and social issues. In any event, the exhibits should include a map with the location of the proposed project, a project site plan, and any other charts or illustrations that will clarify aspects of the project.

If the Public Service Board does issue a Certificate of Public Good, review of subsequent detailed design plans and plant construction may be a condition of the issuance.

### 401 Water Quality Certificate

**FERC** will not issue a license until the state certifies that the project meets state and federal water quality standards.[9] This certificate, known as a "401 Certificate" is obtained through the Department of Water Resources. The consultant must prepare a letter, accompanied by exhibits, describing the impact of the development on water quality and fisheries (see Chapter V for a detailed discussion of water quality). The issuance of the certificate signifies that the Department of Water Resources is satisfied that the project does not violate water quality standards. The approval of the Department of Water Resources does not mean that the Agency of Environmental Conservation as a whole approves of the project, however, since the Agency might recommend against the project on such grounds as impact on river recreation.

### Dredging and Filling Permits

If a project involves excavation as for an impoundment or filling as for a new dam, the consultant should apply to the Army Corps of Engineers and to the State of Vermont for the requisite permits. These applications are usually made after the **FERC** license is filed and involve fairly detailed design plans.

The Army Corps of Engineers requires a "404 Permit"[10] if any fill is to be deposited in any waterway with a discharge over 5 CFS, and a "Section 10 Permit"[11] if there is to be dredging in any navigable waterway (most Vermont rivers are considered navigable).

In addition, the Protection Division of the AEC, through the District Environmental Office, requires a Stream Alteration Permit[12] if dredging or filling of 10 cubic yards or greater will be performed in a stream with a watershed of 10 square miles or more.

[8] If they do not respond within 45 days, they do not forfeit their right to to make recommendations at the hearing.

[9] According to Public Law 92-500 (Federal Water Pollution Control Act of 1972 as amended by the Clean Water Act of 1977)

[10] 33 U.S.C. 1344

[11] 33 U.S.C. 403

[12] 10 V.S.A. Chapter 41, Subchapter 2, § 1021

# V. The Feasibility Study

If a project seems developable after the preliminary investigation, the consultant should undertake a more detailed engineering, environmental and economic analysis. This analysis includes a fairly detailed design of the civil and electrical works, assessment of environmental impacts and measures taken to reduce them, along with a detailed cost estimate. The economic analysis includes market benefits balanced against costs. During the latter stages of the feasibility study, equipment manufacturers and construction contractors should be contacted. The final feasibility report should be presented in a form that can be used in a **FERC** license application and a Section 248 application. (See Fig. 5.1 for a flow chart depicting stages of this study.)

**Financing the Study**

A developer takes a significant risk in financing a feasibility and design study. Expenditures might range from \$10 to \$40 thousand with no guarantee of a return, since the project may either prove economically infeasible or may not be granted a license because of unresolvable environmental or social conflicts. Financing this study, therefore, is a difficult task.

Three possible sources of study funding include private financing by the developer and/or a group of investors, bank financing, and government financing. The first alternative is the easiest and most certain method, but can tie up money that the developer wishes to invest elsewhere. A commercial bank may make a business or personal loan to cover the cost of the study. Because the risk is considerable, the bank will require assurance of repayment, even if the feasibility study proves unfavorable. In the past, government outright grants and low-interest loans have been made to developers to finance

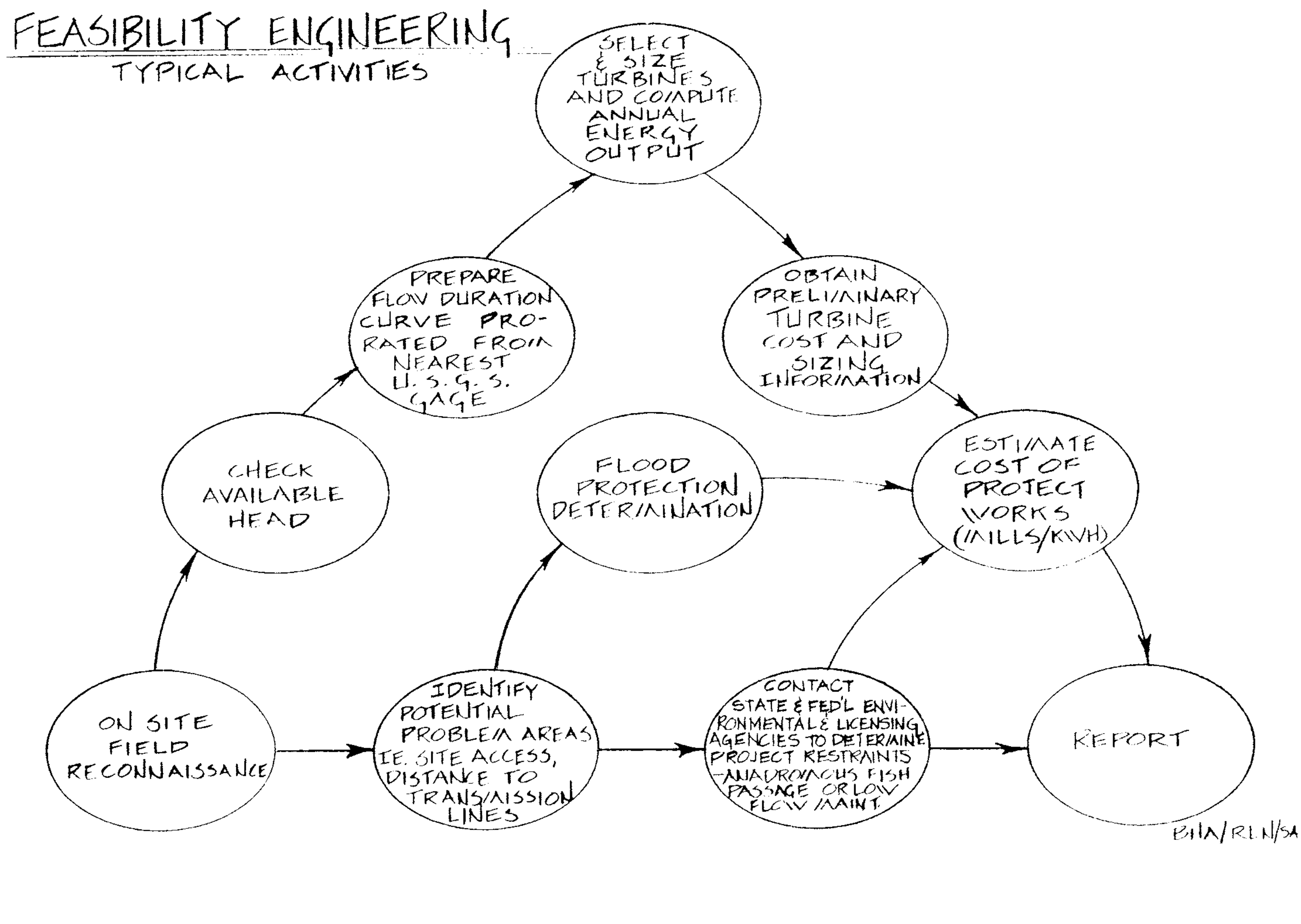


Figure 5.1 **Flow Chart.** Steps in feasibility study.

feasibility studies. Although there is competition for only limited funds, government programs are worth investigating, through the **PSB**, the Vermont Energy Office, or the U.S. Department of Energy in Boston or Idaho. Depending on the site and the source of Federal funding, a more detailed and therefore more costly study may be required, however.

### Engineering Studies

Several schemes for development will be investigated in the feasibility study. The product of the engineering study should be a plan showing the layout of all works, along with preliminary structural plans of the dam, spillway, penstock, etc. The turbine and generator should be sized according to flow variability and their layout described. A preliminary design of the electrical systems should be performed as well.

Fees for engineering and design are usually calculated as 10 to 20 percent of total development costs. The smaller the project is, the larger the fee will be in proportion to development costs, since the same number of tasks must be undertaken for small as well as large projects.

### Equipment

Although several established American firms manufacture hydroelectric equipment, most equipment currently on the market is of European design and manufacture. Several foreign firms, affiliated with U.S. companies, are planning manufacturing plants in this country. A consultant therefore, has a wide variety of equipment to choose from for a particular application.

Turbines, generators, and other equipment can be purchased in a package unit or separately. Separate components may be less expensive initially, but may prove to be incompatible in operation. The selection and proper matching of machinery, both to the site, and to the other machinery, requires the services of an experienced consultant.

### Economic Studies

Based on the preliminary cost-benefit analysis and subsequent study findings, a calculation is made of total project costs and compared with the benefits derived from selling electricity. As with any endeavor, the project is feasible from the economic point of view if costs are met and a reasonable return on investment is realized.

Total development costs include the following: capital costs (study costs, license fees, land acquisition costs, construction costs), fixed charges (taxes, insurance, depreciation, interest on loans), and operating and maintenance costs (salaries, repairs). Total development costs are usually expressed in terms of total annual costs of the project. Annual cost is determined by assuming a financial life for the project and dividing the total costs by the number of years. Twenty years is often the designated project life.

Construction costs include those for excavation, repairs, construction of new works, and the purchase and installation of equipment. In some cases, the developer is required to pay for environmental mitigation as in the construction of fishways or addition of aerators. The latter part of this chapter deals with environmental issues. A twenty percent contingency estimate is usually added to construction cost estimates to take into account unforseen price increases, foundation conditions or damage due to natural disasters or uninsured vandalism.

Fixed charges can be estimated in the course of discussions with insurance companies, lending institutions, and the listers of the town(s) to which the project will pay property taxes. Income taxes can be calculated from the predicted amount of income (see discussion below). Private developers can take advantage of income tax credits, a tax allowance for initial repairs, and accelerated depreciation allowances. These benefits should be considered in the economic studies.

Operating and maintenance costs are usually small, but should be included in total annual costs. Maintenance costs for items not directly related to operations, such as recreation areas, should also be considered. Facility operating and maintenance costs vary with the installed capacity and can be calculated by the consulting engineer.

Annual income from the sale of electricity equals annual KWH production multiplied by price per KWH paid by the utility or other customer. Price negotiations will be proceeding during the feasibility study. A further discussion or marketing is continued on Chapter VI.

### Environmental Studies

The Vermont Agency of Environmental Conservation (**AEC**) is charged with the protection and conservation of Vermont waters. The Agency, which is composed of several different departments, has concerns about hydropower development. The Water Quality Division of the Department of Water Resources protects Vermont waters from pollution and water quality degradation of all kinds. The Department of Fish and Game is responsible for the management of Vermont's fish and game resources and related recreational opportunities, and for special projects such as the restoration of once-native fishes and game animals. The Planning Division has an interest in the recreational resources of water bodies.

**Dissolved Oxygen—DO**

*The most important component of water quality is its content of dissolved oxygen (abbreviated* **DO***). Fish and other aquatic organisms need* **DO** *to breathe. Most bacteria utilize oxygen to break down wastes such as sewage, industrial discharges, and animal and plant by-products. The higher the concentration of* **DO***, the better the water quality is, and the better the conditions are for fish and most other water life.*

*Many conditions affect the amount of dissolved oxygen in the water. Dissolved oxygen is increased through aeration, as by water falling over rapids or dams. Water plants and algae produce and release oxygen as part of the process of photosynthesis during daylight hours, although at night they extract* **DO** *from the water just as animal life does. On the other hand, dissolved oxygen will decrease if water is warmed, both because water actually holds less* **DO** *as it gets warmer, and because organisms use it faster.* **DO** *concentrations will be lowered as greater amounts of organic wastes enter the water and are decayed by bacteria.*

This section of the handbook describes some of the environmental effects of a hydropower development and suggests some of the criteria that must be met before a facility is approved by the **FERC** and the State of Vermont.

Water Quality and Fish Habitat

Construction of a hydropower facility can affect water quality and fish habitat. The conversion of a free-flowing stream into a pond by building a dam may result in loss of aeration and therefore less dissolved oxygen (see inset). Concentration of nutrients in the pond resulting from the waste load of the stream flowing into it, surface runoff, and leaching may produce blooms of algae and weed growth in the pond that will also use up oxygen. Water in a pond will heat up in the summer and thus lose some of its dissolved oxygen. All these changes will directly affect the fish habitat in the pond. A developer might be required to cooperate with the Department of Fish and Game to establish fish species that are tolerant of impoundment conditions.

The downstream reach may also be affected by the higher temperatures and decreased **DO** in the pond, since the pond water will eventually flow over the dam or through the generating equipment. In addition, water which flows through the turbine will not be reaerated, as it would be if it flowed over the dam or over natural rapids. Measures to mitigate changes in the downstream reach may be required by the **AEC.**

Operation of an impounding hydro facility affects downstream water quality most critically in the summer and early fall months when natural flow is usually at its lowest and many aquatic organisms are active and reproducing. The effect of water release or non-release from an impoundment is especially felt in the downstream reach, since the potential ability for downstream waters to assimilate wastes depends on the continued release of well-oxygenated water, either through the turbines or through the dam gates. If water flow is reduced or interrupted, the river becomes shallower and less turbulent, moves more slowly and heats up—all of which conditions reduce the dissolved oxygen.

The Water Quality Division has set a standard of minimum flow that should be continually maintained or exceeded to preserve downstream water quality. This so-called 7Q10 flow is the flow equal to the average flows for the lowest consecutive seven-day period that is liable to occur once every ten years. In addition, the Agency of Environmental Conservation may request a continuous flow greater than the 7Q10, whenever it is naturally available, to prevent the degradation of habitat for fish and other aquatic life and such occurrences as drying or freezing of downstream fish spawning and food production areas.[13]

Most of these concerns will be raised when the developer applies for the 401 Water Quality Permit (see Chapter IV). If a facility does not impound at all, does not have a long penstock bypassing the stream, or is not otherwise constructed so as to degrade water quality, a certificate may be quickly granted. On the other hand, if an impoundment is to be created, the developer and consultant must demonstrate that it will not have an adverse affect on water quality, fish, or fish habitat, or must propose methods to satisfactorily mitigate environmental effects. The developer and consultant must also satisfy both the Water Quality and Fish and Game Departments that the required minimum flow will be equalled or exceeded at all times. This is a critical concern, since satisfying the flow requirements may result in decreased energy generation, which will directly affect the cost-benefit ratio.

Other Fisheries Concerns

As mentioned previously, fish population can be affected adversely by reduction in **DO** or by interference with feeding and reproduction caused either by interruption of downstream flows or flooding of upstream reaches.

[13] If a dam impounds 300,000 cubic feet or more, the Fish and Game Board may order the maintenance of a flow necessary for the propagation and preservation of salmon (10 V.S.A. § 1097).

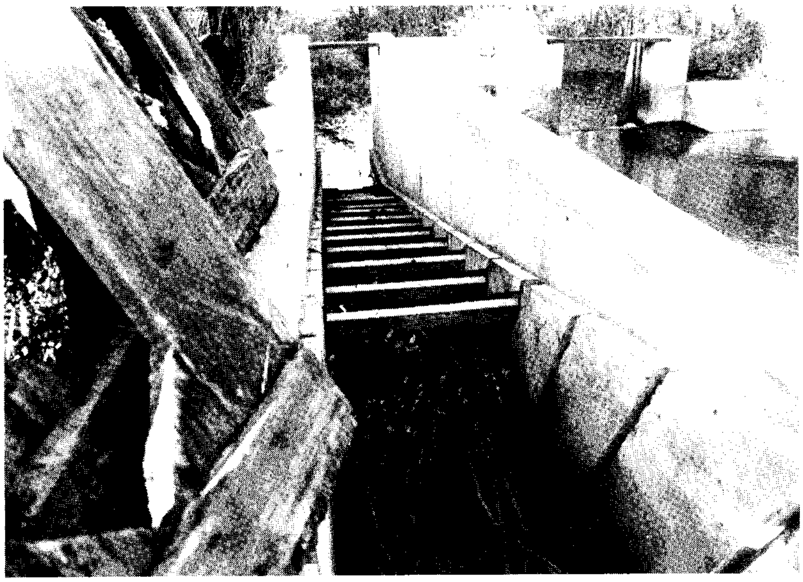

Figure 5.2 **Fish Ladder (Denil Type).** The wooden baffles removed at left fit into the grooves in the concrete.

Depending on its location, creation of a dam where no natural barrier existed before can affect the migration of anadromous fish and can block the migration of local fish species. Anadromous fish, such as salmon, some trout, and shad, travel upstream in order to spawn. The Department of Fish and Game plans to reestablish certain populations of anadromous fish, such as landlocked Atlantic Salmon, and American shad in the Connecticut River. If dams on tributaries of these bodies are substantially rebuilt, the Department of Fish and Game may require construction of fish ladders or fish passageways (Fig. 5.2). They may also require other such measures as trapping the migrating fish and transporting them by truck to above the dam. Facilities for the passage of fish migrating downstream may also be necessary.

When a hydro facility is generating, fish may be directed through the turbine despite the existence of trash racks. The magnitude of turbine mortality varies with the species and with the type of turbine. The propeller turbine is the least harmful. The Department of Fish and Game will require information on species inhabiting the river and the reservoir as well as on turbine design.

A dam is not only a barrier to fish migration, it also interrupts the flow of the current and all that it carries, causing both organic and inorganic materials (silt) to settle in the pond. Silt deposits eventually clog intakes and reduce reservoir volume and may require periodic dredging or flushing out. A sudden release of silt will increase downstream water turbidity, damaging aquatic life (fish as well as plants). Such a release might also scour the downstream banks denuding them of vegetation, thus increasing erosion potential and decreasing shady fish habitats. The Water Quality Division must be notified prior to desilting operations (see Chapter VIII).

Game Concerns

Wildlife habitats may also be affected by creation of impoundments changing wetlands to ponds. Flow regulation may also impinge on game habitats, since reservoir and downstream water levels may fluctuate independent of natural fluctuations. The principal game species most influenced by these problems are waterfowl and furbearers. Upland wildlife species such as white-tailed deer may be affected by the flooding of deer yards.

**Social Concerns**

Construction of a hydropower facility affects land and water use in dramatic and subtle ways. Such recreational use of a stream as a white water canoeing or kayaking course, for example, will be affected by impoundment. If a forested area is to be flooded, the developer will have to submit a plan for the harvesting and disposal of wood. A developer might have to bear most of the costs of reconstructing bridges and roads that will be flooded out upstream. The developer may be required to provide water-based recreation facilities if there is an impoundment (Exhibit R of the major **FERC** license).

If the Federal agency (**FERC**) in consultation with the State Historic Preservation Officer determines that properties which are included in or eligible for inclusion in the National Register will be adversely affected by the project, further planning and redesign may be necessry in order to comply with Federal regulations.

Aesthetic issues concerning the project facilities and the impoundment might also be raised. A hydro plant may require screening by plants or fences. Transmission line corridors that are part of the project must conform to the Public Service Board's aesthetic criteria.

Fluctuating water levels in a reservoir may cause some concern both on aesthetic and environmental grounds. It is normal practice to draw down a reservoir only the amount of water that can be replenished by inflow over a certain short period of time. If the project has small watershed, or if it operated during periods of low flow and high evaporation, there may be a new decrease in reservoir volume and shoreline may become exposed (the "bathtub ring," see Fig. 5.3). This is not only aesthetically unpleasant, but may destroy or impair life in the shore zone. The Agency of Environmental Conservation requires that the developer furnish them with a contour map of the impoundment and a schedule of surface elevation changes in the impoundment for the range of operating conditions so that they may predict the extent of this problem.

A discussion of dam safety and floodplain management is required by the **FERC** in a license application as well as by the **AEC** as a party to the Section 248 hearing. The consultant must also demonstrate to local and regional planning commissions that the facility and transmission lines will not interfere with the orderly development of the region.

In a section of the **FERC** license application the consultant must describe the social benefits that will be introduced with the development, such as boat launches and picnic sites. A discussion of the overall benefits of development, especially during plant construction, will also be included in the **FERC** application.

**Report**

After careful review and analysis of the issues, a final detailed report should be prepared. This report should be in a form that is acceptable to both the **FERC** and **PSB** as a license application. It should be written clearly and concisely using non-technical language, with appropriate technical details backing up the text. After publication of the report, the consultant should be available to testify before a regulatory body if necessary.

Figure 5.3 **"Bathtub Ring" In An Impoundment.**

## VI. Marketing Electricity

A private developer can sell electricity to a utility company or to a local industry. It is also possible to create a new utility to sell to retail customers,[13] but in most cases this option is not worth the effort or expense.

The PURPA of 1978 removed marketing obstacles from the path of non-utility developers. The Act requires utility companies to purchase power from and interconnect with a facility that is privately developed. In addition, the Act mandates the state regulatory authority (**PSB** in Vermont) to set a "just and reasonable price" that protects the interests of both utility ratepayers and the private developer. A detailed discussion of this follows below.

Although a developer is guaranteed a market with a utility, another option may be equally attractive. A developer can negotiate a joint ownership arrangement with a local industry or industries, for example. If the users of the power are also part owners, no state regulation is required and the developer does not need a **FERC** license. This option thus avoids a potentially time-consuming and costly process.

If selling to a utility company is the chosen option, the utility will need to know details of proposed operation in order to estimate a price. The utility will want to know the physical location of the plan, its capacity and annual energy output (KWH), and the planned mode of operation and dispatch. Location in regard to utility transmission lines is important, since the cost of lines interconnecting with the grid is directly related to their length (as well as the voltage of the transmission line). The utility also must determine whether the nearest transmission line is already being used to full capacity.

By the time the feasibility study is underway, the developer and utility should be negotiating a contract. The services of a lawyer are essential here to write a clear contract. If agreement cannot be reached over the price or terms of the contract, a developer should contact the **PSB** to discuss the difficulties. If no resolution can be reached by informal negotiations, the developer should send a written petition to the **PSB** for a rate hearing, as mandated by the PURPA. The **PSB** will define terms of a purchase power contract that hopefully, is satisfactory to both parties.

[13] Enabling legislation is 30 V.S.A. §§ 249, 251, 259.

# VII. Financing

### Lenders' Criteria

Small projects can probably be financed on the net worth of the developer alone, especially if the developer is a municipality or utility. A large project, that cannot be financed in this way, must satisfy a number of important criteria.

The projected cash flow of the project is the most important single element of a package presented to a lender. Income must suffice to pay interest and principal on the loan, and provide a reasonable rate of return to the developer, as well as have a reasonable safety margin. The lender will need to review the power contract with the buyer. The contract identifies the parties involved, price paid for electricity, length of time that the contract is valid, and any penalties to be imposed for failure to supply power. It is also necessary to obtain permits and licenses for the project before applying for financing. Often preliminary financing agreements can be made subject to the obtaining of licenses and permits.

The developer should also have a construction contract guaranteeing that the project will be built on time, on budget, and as designed. Lenders prefer a fixed-price contract to a "cost plus" contract that would allow construction cost overruns to be passed along to the developer.

Lenders may be more receptive to a project where a developer has a "turnkey contract" with a contractor, since this reduces risk to both the developer and the lender(s). A turnkey contract in brief, is one where a firm carries through the entire construction, and "turns over the key" to the owner when the project is finished. On the other hand, if a developer proposes to manage project construction, the lenders must have confidence in his ability to manage a large amount of money and coordinate all scheduling.

There are several substantial differences between a hydropower project loan and a regular construction loan. First, the net worth of the borrower usually is rather small compared to the amount of money needed for the project. Second, the project works are not useful as loan collateral, unlike an apartment house or a machine shop. The dam, water rights, the powerhouse, and even the equipment have little resale value to the lender (especially if they are custom designed for a particular site). A third difference is the leverage (debt to equity ratio) of the loan. There is less room for error in a hydropower development than in an ordinary construction project. The lender will require assurances of an adequate cash flow and of the experience and reputability of the developer and consultants.

### Short- and Long-Term Financing

Each part of the development stage may have separate financing. So-called "front-end" costs, including everything up to construction, have usually been met by the developer's own funds, by government grants or loans, or by short-term loans from commercial banks.

Project construction requires a short-term financing to cover materials, labor, and management costs. Cash must be available to cover expenses as they occur. Government loan or grant programs may be available to cover some construction costs; the Vermont Energy Office may be familiar with these. Commercial banks may provide 1- or 2-year construction loans. Another possible source of construction funding could be the turbine equipment manufacturer.

Long-term debt includes payments due on equipment as well as principal and interest on the front end and construction loans. Savings banks and insurance companies usually offer long-term debt financing, although in Vermont commercial banks may also offer this service. Long-term debt will be financed by a first mortgage on the property. Just as in a home mortgage, the lender will lend only a certain percentage of the total required amount and will expect the developer to pay the remainder. If the developer cannot pay the remainder, he may need a second or junior mortgage from another lender. The project cash flow must therefore be sufficient to pay interest and principal on both mortgages as well as provide a reasonable profit.

It is obvious that financing requirements are interrelated and related to other aspects of development as well. It is important that the developer and consultant communicate openly and often with lending institutions.

# VIII. Construction

Construction of the project is the next step in development after feasibility studies and licensing. A construction engineer, a member or subcontractor of the firm that designed the project, usually manages the entire building process (civil, hydraulic and mechanical, and electrical work) from excavation to bringing the new power plant on line. This person usually has written or assisted with equipment bid specifications, and is familiar with the intricacies of the project. Occasionally, the equipment manufacturer will provide construction supervision for the equipment installation as a condition of the guarantee. It is important that one person supervise construction from beginning to end.

The project manager puts the construction work out to bid and choses the general contractor. There are many qualified heavy construction contractors in Vermont and northern New England, although none specialize in hydro work. Contractors usually submit a performance bond with the construction bids. The bond, usually for 10 percent of the bid, protects the developer from cost overruns, delays, or errors in construction. If the bid is rejected, the check should be returned to the contractor.

The project manager is responsible for scheduling construction so that outside building coincides with dry seasons, inside work can be done in the winter, and equipment arrives at the proper time to be installed (Fig. 8.1). Delays in construction timing or equipment arrival can be extremely costly.

Public relations is also part of the project manager's concern. Since construction can involve blasting of ledge and movement of heavy equipment, such events should be timed to be convenient to area residents. Such courtesies will earn good will for the project, although it may be impossible to avoid some disturbance.

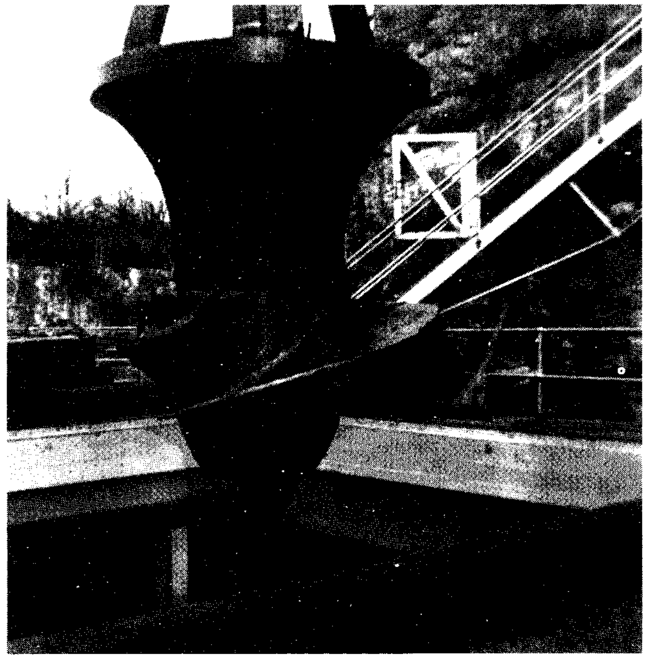

Figure 8.1 **Installation of a Propeller Turbine.**

Any activity involved in construction or operation of a plant that will violate water quality standards requires a so-called 1272 order[14] from the Water Quality Division. Examples of such activities include desilting of an impoundment, excavation of a tailrace, and release of water from a coffer dam. The order specifies dates on which certain activities cannot take place and requests notification of Agency personnel so that they can monitor operations.

Because of delays in construction or other unforseeable circumstances, construction costs may have to be cut. A developer should be careful in cutting corners, since a rushed job may cause more problems than it solves. On the other hand, unnecessary parts of the construction might be eliminated without lowering project design standards. Discussions between the developer, project manager, construction contractor, and financers could yield fruitful results in this area.

[14]Section 1272 of 10 V.S.A. Chapter 47

# IX. Operation and Maintenance

A constructed hydroelectric plant requires minimal maintenance for several decades, commonly 25 to 30 years. Power equipment usually requires only yearly inspections and periodic lubrication, but outside works may require daily or weekly maintenance.

The trash racks must be cleaned or raked at least daily, and the debris disposed of (Fig. 9.1). Ice chunks may have to be cleared several times daily in winter if a bubbler is not used. Ice buildup on flashboards is also a problem. Air bubblers can be used to keep water free near the boards, or the ice can be cut away 2 or 3 feet behind the boards with a chain saw. If flooding or ice flows are expected, part or all of the flashboards can be removed, saving the lumber and the pins for re-use when the high water recedes. (Fig. 9.2) Ice buildup inside the penstock, especially if it is above ground, can restrict flow to the turbine. If icing is a problem, the penstock can be heated by heat tape or insulated. One ingenious insulation method used by a utility is to allow water to leak into an inverted "V" shaped wooden structure covering the penstock through holes drilled in the pipe. In the spring, the holes are plugged with wooden pegs.

Inside the powerhouse, several pieces must be inspected and lubricated or replaced. The main bearings and packing glands on the turbine, especially the center bearing, require periodic lubrication. With good maintenance, they will usually last 25 years or more under normal operating conditions. The wicket gates on the turbine must be greased monthly or as recommended by the manufacturer.

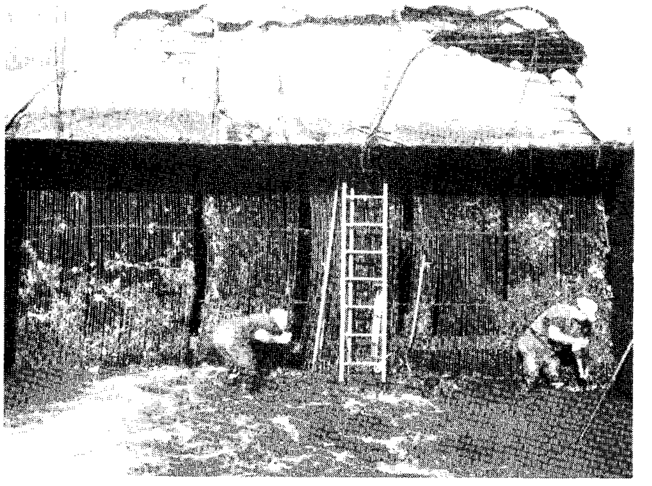

Figure 9.1 **Cleaning Trashrack After a Flood.**

The generator and circuit breakers should be inspected periodically. The generator should be cleaned and meggared during the inspection of the circuit breaker. The breaker should be checked for pitting, and if necessary the arcing contact should be filed and the main contact changed. The safety equipment, including relays, pressure switches, etc., should be tested at this time.

Figure 9.2 **Spring Ice Breakup.** Before this picture was taken, an extensive ice dam had broken, sending chunks of ice and water into the powerhouse windows and knocking out three generators.

The operation of a plant consists of starting up the generator and turbines, and synchronizing them. If the utility is dispatching the plant (switching it on and off depending on utility needs), automatic synchronizing equipment may be needed. This equipment is rather expensive and may not be necessary for the smaller projects. A run-of-the-river plant, will probably have an operator to start and stop the generator manually. Proper training for this is essential since an inexperienced operator can damage the plant equipment.

# Appendix I

## Glossary

**Anadromous Fish**—Fish that spend a part of their lives in the sea or lakes, but swim upstream at more or less regular intervals to spawn. Examples are sturgeon, shad, salmon, trout, and striped bass.

**Anaerobic**—Without oxygen.

**Base Load**—The amount of electrical power needed to be delivered at all times and seasons.

**Bulb Unit**—A unit in which a propeller turbine and the generator are a sealed unit placed directly in the water stream.

**Capacity**—The maximal power output (in KW) for which a turbine-generator or combination of turbine-generators is rated. Also called installed capacity.

**Capacity Factor**—The ratio of the actual average energy produced by a facility to the energy that could be produced if the facility could operate constantly at its installed capacity.

**Cavitation**—Formation of pits or cavities in the surface of a runner blade caused by the bursting of water vapor bubbles.

**Central Dispatch**—The instruction of generating plants, from a central system control point, to go on or off line depending on electrical demand.

**Civil Works**—All the works of a facility associated with the impounding, channeling, and emergency release of water; for example, dam and spillway.

**Crest Gates**—Gates on top of a spillway, which are opened and closed to vary the capacity of the spillway.

**Debris Racks**—See trash racks.

**Dissolved Oxygen (DO)**—Oxygen gas dissolved in water, measured in milligrams per liter. DO is one of the most important indicators of water quality.

**Draft Tube**—Tube through which water discharges into the tailrace from a reaction turbine. The bottom of the tube is submerged to create a vacuum.

**Drainage Area**—The area, usually measured in square miles, that drains through a given point on a stream or river where flow is being measured.

**Drawdown**—The amount by which the water level of a reservoir is allowed to go up and down when the reservoir is used for regulation of the flow below the dam.

**Electrical Works**—All the machinery in a facility associated with the generation, transforming, and transmission of electricity; for example, generator and transformer.

**Energy**—The ability to perform work.

**Energy Value**—The market value of electrical energy. Hydro energy value is usually based on fuel replacement costs.

**Eutrophication**—The process of aging in a lake, caused by chemical or biological enrichment.

**FERC**—Federal Energy Regulatory Commission, formerly the Federal Power Commission (FPC). An agency in the Department of Energy which licenses hydropower projects and regulates interstate transfer of electrical energy.

**Fish Ladder**—A structure consisting of a series of step-like pools that allows fish migrating upstream to pass beyond a dam.

**Flow**—Volume of water per unit time. Can be expressed in gallons or cubic feet per minute (GPM, CFM) or in cubic feet per second (CFS). See "Q" also.

**Flow Duration Curve**—Acurve which shows the percentage of time (in a certain time period) that a river's flow was equal to or greater than a given discharge. For example, it might show that over a period of a year a river flowed 500 CFS 10% of the time and 100 CFS 80% of the time.

**Flashboards**—Boards placed on top of a spillway or dam crest to temporarily raise the impoundment level.

**Flume**—A canal that conducts water to the intake gate.

**Forebay**—The enlarged body of water above the intake.

**Francis Turbine**—A reaction turbine commonly used in moderate to high head facilities. See text.

**Generator**—A machine that converts mechanical energy into electrical energy.

**Governor**—A device to control the operation of a turbine or engine, which makes the speed constant by varying the input (amount of water) to match the load. Governors can perform other functions such as maintaining a constant head pond level or automatically responding to peaks in electrical demand above a certain level.

**Historic or Archaeological Site**—A standing structure, part of a structure, or area where evidence of prehistoric habitation is found, which is listed or is eligible to be listed in the National Register of Historic Places.

**Hydraulics**—The science that deals with the laws governing water in motion.

**Hydraulic Works**—The works of a facility associated with the conversion of water energy into mechanical energy; for example, penstock and turbine.

**Impoundment**—Reservoir or artificial pond created behind a dam.

**Impulse Turbine**—A turbine that uses the velocity of water to move the runner and that discharges to atmospheric pressure.

**Installed Capacity**—The total of the capacities shown on the nameplates of all the generators in a hydro plant.

**Intake**—The structure that lets water into the penstock.

**Intermediate Load**—The amount of electrical power needed to be delivered at times when the base load does not fill demand.

**Kilowatt (KW)**—One thousand watts. A measure of electrical power (work per unit time).

**Kilowatt Hour (KWH)**—The amount of electrical energy involved with a one kilowatt demand over a period of one hour.

**Load**—The amount of power needed to be delivered at a given point in an electrical system.

**Low Head**—Sometimes defined as head 66 feet (20 meters) or smaller. Many engineers use the term to refer to a type of facility (a) that utilizes a reaction type turbine, or (b) where there is a short penstock or the powerhouse is built into the dam, or both.

**Mechanical Works**—Turbines, pumps, gatehoists, governors, cranes, and all other such equipment.

**Megawatt (MW)**—One thousand kilowatts.

**NEPOOL**—New England Power Pool, a consortium of New England utilities that sells power to each other and that dispatches (calls upon) generating stations in response to demand.

**On Line**—Generating electricity and sending it out over the transmission lines.

**Outage**—The period when a generating unit is out of service.

**Packing Glands**—Sealing devices used to provide pressure-tight joints where rotating or reciprocating shafts pass through walls from one pressure zone to another.

**Peak Load**—The maximal load in a stated period of time; for example, yearly peak and daily peak.

**Pelton Wheel**—A type of impulse turbine.

**Penstock**—A tube that conducts water from the intake gates to the turbine.

**Pondage**—The amount of water stored behind a dam of relatively small storage capacity used for daily or weekly flow regulation.

**Power (Electric)**—The rate of generation of electrical energy usually measured in kilowatts.

**Public Service Board**—The Vermont agency that regulates and licenses all utilities operating in the state.

**PURPA**—Public Utilities Regulatory Policies Act of 1978. This act requires utilities to purchase power from and interconnect with a privately developed facility and mandates the state utility regulatory agency to set a "just and reasonable price."

**Q**—The engineering abbreviation for flow. "QA" means average flow. "7Q10" is the lowest mean discharge for seven consecutive days, which occurs on the average once every ten years. Actual flow in a river exceeds the 7Q10 flow 98% to 99% of the time.

**Rate of Return on Investment**—The interest rate at which the present worth of annual benefits equals the present worth of annual costs.

**Reaction Turbine**—A turbine in which both the pressure and velocity of water cause the runner to turn.

**Riparian Rights**—The right of access to or use of water by the owner of land located on the bank of a natural waterway. Sale and transfer of these rights can be conveyed without the land.

**Runner**—The part of a turbine that turns, to which blades are attached.

**Siltation**—The accumulation of silt in an impoundment above a dam.

**Spillway**—A structure in or near a dam used to discharge excess flow not used by the turbines or stored in the reservoir.

**Stop Log**—A temporary barrier to hold back water consisting of horizontal timbers stacked up in vertical slots.

**Stream Flow Duration Curve**—See Flow Duration Curve.

**Sluice Gate**—Gates placed in passages through the lower part of a dam used primarily to pass water needed in the river below the dam.

**Surge Tank**—A device that relieves pressure of vacuums in a penstock caused by the rapid shutting off of water flow.

**Tailrace**—The exit channel of water from the powerhouse.

**Tailwater**—The water in the tailrace.

**Timber Crib**—An historic method of dam construction.

**Trash Racks**—Barred racks that prevent debris from entering the turbine.

**Turbidity**—The capacity of materials suspended in water to scatter light, usually measured in Jackson Turbidity Units (JTU). Highly turbid water appears dark and "muddy."

**Turbine**—A machine to convert the potential and kinetic energy available in a fluid into mechanical energy.

**248 Case**—An application for a "Certificate of Public Good" to build a facility for generation or transmission of electricity under 30 VSA, Section 248.

**Voltage**—Electrical potential difference between conductors or between conductors and ground.

**Waste Gates**—Gates within a dam or spillway that allow the passage of water in order to maintain a certain water elevation above the dam.

**Watt**—Rate of energy transfer equal to one ampere under pressure of one volt at unity power factor.

**Wheel**—A turbine. Also used as a verb; see "wheeling."

**Wheeling**—Transportation of electricity by a utility over its lines for another utility.

**Wicket Gates**—Gates at the entrance of a turbine, and an integral part of it, that open and close to admit water into the turbine.

# Appendix II
# State and Federal Agencies

| Agency | Subject | Phone |
|---|---|---|
| VERMONT | | (802) |
| Agency of Development & Community Affairs<br>Pavilion building<br>State Street<br>Montpelier, VT 05602 | | |
| Division for Historic Preservation<br>William Pinney, Director | Historic and archaeological sites | 828-3226 |
| Agency of Environmental Conservation<br>Heritage Building<br>79-81 River Street<br>Montpelier, VT 05602 | | |
| Fish & Game Department<br>Angelo Incerpi, Chief Fisheries Biologist<br>Ben Day, Chief Wildlife Biologist | Fisheries and game concerns | 828-3371 |
| Forests, Parks, and Recreation Dept. | Recreation concerns, forestry concerns | 828-3375 |
| Planning Division<br>Edward Koenemann, Director | General environmental concerns | 828-3357 |
| Protection Division<br>Howard Flanders, Director | Stream flow alteration permit | 828-3341 |
| Water Resources Department, Division of Water Quality | | |
| David Clough, Director<br>Thomas Willard, Environmental Engineer | Water quality concerns, "401" permit | 828-2761 |
| Peter Barranco, Dam Engineer | Existing dams, engineering and safety concerns | 828-2761 |
| Agency of Transportation<br>Administration Building<br>Montpelier, VT 05602 | | |
| Sherman J. Gage, Director Engineering | Flooding of roads or bridges | 828-2661 |
| Brookins Delano, Utilities Division | Flooding of roads or bridges | 828-2653 |
| Robert Merchant, Division of Operations | Flooding of railroads | 828-2828 |
| Public Service Board<br>120 State Street<br>Montpelier, VT 05602 | | |
| Wayne Foster, Electrical Engineer | Section 248 application, all state licensing concerns | 828-2839 |
| Gordon Stensrud, Chief Engineer | Electrical engineering, rate information | 828-2636 |
| State Energy Office<br>4 East State Street<br>Montpelier, VT 05602 | | |
| Ronald Albee, Director<br>Joseph Gainza | Government grants for feasibility studies | 828-2393 |

| | | |
|---|---|---|
| State Planning Office<br>Pavilion Building<br>Montpelier, VT 05602 | Lists of regional commissions | 828-3326 |

FEDERAL

| | | |
|---|---|---|
| Federal Energy Regulatory Commission<br>825 North Capitol Street, N.E., Rm. 41106<br>Washington, D.C. 20426 | | (202) |
| Edward Abrams, Director, Office of Licensed Projects | FERC licenses | 357-8031 |
| Ronald Corso, Director, Division of Hydropower Licensing | | 357-5321 |
| Charles Lord, Project Manager | | 357-8051 |
| Jonathan Mark | | 357-8081 |
| U.S. Army Corps of Engineers | | |
| New England Division<br>424 Trapelo Road<br>Waltham, MA 02154 | Section 10 permits<br>404 permits<br>(Conn. River basin) | (617)<br>894-2400<br>ext. 332 |
| New York District<br>26 Federal Plaza<br>New York, NY 10278 | Section 10 permits<br>404 permits<br>(Lake Champlain & Lake Memphremagog basins) | (212)<br>264-0185 |
| U.S. Department of Energy, Region I<br>150 Causeway Street<br>Boston, MA 02114 | | |
| John DeTore, Director of Assessment and Integration | Federal government grant and loan programs | (617)<br>223-5287 |
| Idaho Operations Office<br>550 Second Street<br>Idaho Falls, ID 83401 | Information and referral re funding for small hydro | |

REGIONAL

| | | |
|---|---|---|
| New England River Basins Commission<br>53 State Street<br>Boston, MA 02109 | General information | (617)<br>223-6244 |

# Appendix III

## New Electric Generation and Transmission Facilities: Certificate of Public Good (30 V.S.A., § 248)

(a) No company, as defined in 30 V.S.A. § 201, or cooperative, may begin site preparation or construction of an electric generation facility within the State, or electric transmission facility within the State which is designed for immediate or eventual operation at any voltage or exercise the right of eminent domain in connection with site preparation for or construction of any such transmission or generation facility, except for the replacement of existing with equivalent facilities in the usual course of business, unless the Public Service Board first finds that the same to promote the general good of the State and issues a certificate to that effect. The Public Service Board shall hold a public hearing on each petition for such finding and certificate in a county in which any portion of the construction of said facility is proposed to be located. Notice shall be given to the Attorney General, the Departments of Health, Agency of Environmental Conservation, Historic Sites Board, Scenery Preservation Council, State Planning Office, Vermont Aeronautics Board and by certified mail shall be given to the chairman or director of the municipal and regional planning commissions and the municipal legislative body for each town and city in which the proposed facility will be located not less than thirty days prior to said hearing. Notice of the public hearing shall be published in a newspaper of general circulation in the county or counties in which the proposed facility will be located two weeks successively, the last publication to be at least twelve days before the day appointed for the hearing.

(b) Before the Public Service Board issues a certificate of public good, it shall find that the construction:

(1) will not unduly interfere with the orderly development of the region with due consideration having been given to the recommendations of the municipal and regional planning commissions and the municipal legislative bodies;

(2) is required to meet the need for present and future demand for service;

(3) will not adversely affect system stability and reliability and economic factors; and

(4) will not have an undue adverse effect on esthetics, historic sites, air and water purity, the natural environment and the public health and safety.

(5) plans have been submitted to the municipal and regional planning commissions in accordance with this section.

(c) Before a certificate of public good is issued for the construction of a nuclear fission plant the Public Service Board shall obtain the approval of the General Assembly and the Assembly's determination that the construction of the proposed facility will promote the general welfare. The Public Service Board shall advise the General Assembly of any petition submitted under this section for the construction of a nuclear fission plant, by written notice delivered to the Speaker of the House of Representatives and to the President of the Senate. The Public Service Board may submit recommendations relating to the proposed plant, and shall make available all relevant material. The requirements of this subsection shall be in addition to the findings set forth in subsection (b) of this section.

(d) However, plans for the construction of such a facility must be submitted by the petitioner to the municipal and regional planning commissions no less than 45 days prior to application for a certificate of public good under this section. unless the municipal and regional planning commissions shall waive such requirement. Such municipal or regional planning commissions may hold a public hearing on the proposed plans. Such commissions shall make recommendations, if any, to the Public Service Board and to the petitioner at least 7 days prior to filing of the petition with the Public Service Board.

(e) However, notwithstanding the above, plans involving the relocation of an existing transmission line must be submitted to the municipal and regional planning commissions no less than 21 days prior to application for a certificate of public good under this section.

# Appendix IV
# Bibliography

American Society of Civil Engineers. *Inspection, Maintenance, and Rehabilitation of Old Dams.* Proceeding of an Engineering Foundation Conference. Available from the ASCE, 345 East 47th St., New York, NY.

A collection of papers presenting various topics related to old dams, including deterioration of materials.

Creager, WP and JD Justin, *Hydroelectric Handbook.* New York, John Wiley and Sons, 1950. Out of Print.

Probably the most useful American textbook ever published in the hydroelectric field. A copy is available at the University of Vermont Library.

McLeod, HW. "Private Financing of Small Scale Hydroelectric Projects." Speech delivered at Waterpower '79: International Conference on Small Scale Hydropower.

A recent paper on project financing, available from the Public Service Board.

National Center for Appropriate Technology. *Microhydropower: Reviewing an Old Concept.* Prepared for U.S. Department of Energy, 1979. Available from National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161 ($5.25).

A handbook designed for home hydro systems, but which contains a lot of simple technical information and a bibliography.

Tourin Musica. *The Duxbury Demonstration Project: A Feasibility Study of a Small Hydroelectric System.* Duxbury, Vermont, 1977.

An entrancing illustrated narrative, presupposing some knowledge of electronics, explaining the do-it-yourself installation and operation of a small hydro system. Available from Tourin Musica.

U.S. Army Corps of Engineers. *Feasibility Studies for Small Hydropower Additions: A Guide Manual.* Davis, CA, 1979. Available from the Institute for Water Resources, Kingman Building, Ft. Belvoir, VA, 22060.

A 6-volume technical manual explaining the feasibility study and design processes geared for someone with engineering knowledge. The volumes most useful for a layperson would be Vols. I and V.

U.S. Department of the Interior, Bureau of Reclamation. *Design of Small Dams.* Washington, D.C., 20402, Superintendent of Documents, U.S. Government Printing Office, 1977.

One of the best values in technical references available today. It covers a variety of topics of interest to the small hydro developer including project planning, ecological issues, flood design, and dam structural requirements. Each subject is dealt with in a separate chapter with an extensive bibliography.