tric feasibility studies. Under this program the St. Anthony Falls Hydraulic Laboratory is preparing feasibility analyses for dams located at St. Cloud, Granite Falls, Kettle River, Anoka, Lanesboro, Park Rapids, and Thief River Falls. These dams were selected from a hydropower site screening study of publicly owned dams that was prepared for the Minnesota Department of Energy, Planning and Development.

The Legislature has also provided for the long term leasing of publicly owned dams for hydropower and for hydropower expansion by limiting local taxes for the first five years after development. The Minnesota Public Utilities Commission is developing rules to encourage small power production — for dams, windmills, and solar facilities, for example — consistent with the protection of rate payers and the public.

Federal laws encourage hydropower by requiring electric utilities to purchase power generated by small producers. Also, changes in federal tax laws provide significant advantages to hydropower developers in terms of investment credits and depreciation.

Based on this generally favorable government climate and the need to develop additional sources of energy, it is likely that Minnesota can look forward to hydroelectric expansion in coming years.

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2. Hydropower's Unexpected Side Effect

Joseph Geis

PEOPLE VIEW hydropower as a clean source of energy — no smoke, no ash, no radiation, no environmental side effects. But fish and other aquatic life see hydropower in a different light. There is one way of operating a hydro facility that threatens aquatic life. Most people are unfamiliar with this aspect of hydropower.

The driving force of hydropower is gravity. Gravity causes water to flow from a higher to a lower level. The difference in the water elevation between the pool above the dam and the water below the dam is called "head." The higher the head, the greater the waterpower.

Dams are generally classified as either low head or high head. Heads under 60 feet are generally called low head. Most dams in Minnesota being considered for hydropower are low head dams.

The most efficient turbine design for low head dams is a propeller turbine. The propeller looks like the prop on an outboard motor, except that it is larger. The propeller is inside a tube through which water flows and is connected to a generator

by a shaft. The force of water flowing through the tube turns the propeller which turns a generator to generate electricity.

Two basic types of propeller turbines are being considered for use in Minnesota dams. One is called a fixed-blade turbine, the other a variable-blade turbine. The blades on a fixed-blade turbine are set at a fixed angle. This turbine is designed to operate with a specified amount of water passing through it and is either "on" or "off" — operating at full-load capacity or not operating at all.

The blade angle on a variable-blade turbine can be adjusted to control the amount of flow through the turbine. This feature allows the turbine to operate over a wide range of flows. As the flow through the turbine decreases, the amount of electricity generated decreases.

Operating Modes. There are several ways to operate a hydropower facility. One type of operation is called "run-of-the-river" and means that the flow out of the reservoir is equal to the flow into the reservoir. The flow in the river downstream from the dam is the natural flow of the river.

This type of operation is sometimes called "strict" run-of-the-river operation to contrast it with another definition of run-of-the-river operation which includes peaking. Peaking means that inflow and outflow are not necessarily equal. At times, some of the inflow to the reservoir is stored and released later.

These two operations are very different; it is important to know which operation is being used.

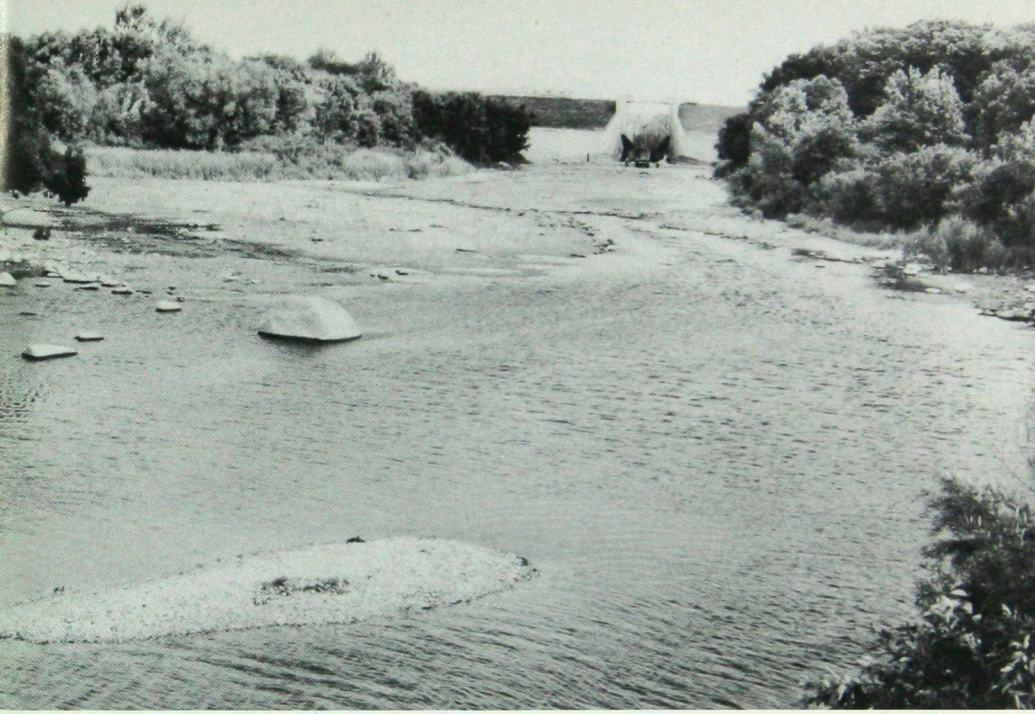
Peaking allows water to be stored in the reservoir and then released to generate electricity during peak demand periods. This mode of operation can also be called "store and release."

The storage capacity of reservoirs created by dams considered for hydropower development in Minnesota is small. A portion of the flow into the reservoir is stored from the end of the peaking period on one day until the beginning of the next peaking period, usually the next day. Some water must be released from the reservoir at all times to maintain flow in the river downstream from the dam.

Peaking operation results in fluctuations of flows downstream from the dam which can affect aquatic resources and recreation. Peaking also causes water level fluctuations in the reservoir. Probably the greatest environmental impact associated with hydropower development at existing dams results from manipulation of water levels — peaking, or store and release, operations.

Peaking Risks. Peaking greatly increases the number of times low flow occurs in a stream. Low flow periods are critical for fish. Portions of the productive riffles in a stream are no longer covered with water. Riffles

Ottertail River near Fergus Falls, Orwell Dam (top) and Friberg Dam, at low water. Aquatic organisms on and under gravel and rocks die when exposed to sun; fish are deprived of food supply and spawning places.



are places where most of the important aquatic invertebrates live and grow. Both large and small fish eat these aquatic organisms and, in turn, the larger fish eat the smaller fish.

If portions of the riffles are without water for part of a day, rocks and gravel on the bottom dry off. The organisms which are attached to the exposed surface of the rocks and gravel also dry out and die. Organisms that can move will crawl under the rocks where it is moist. But if the area is exposed too long, even these places will dry out and the aquatic organisms will die. The result is less food available to fish.

In addition, low-flow periods reduce living space available for fish. During high flows, fish disperse over larger areas. During low flows, they crowd together into pools. Reproduction may also be lowered during these periods because the amount of spawning area is reduced.

Crowding and reduced food supply put fish under stress. Most fish can survive crowding for a short period. However, if the crowding condition persists, there will be competition for available living space, particularly by species which are territorial.

If the low flow period occurs in summer, water temperature rises in the river. As the flow in the river reduces, water stagnates in pools. Stagnant water warms faster than flowing water. Also, less heat is necessary to warm a small volume of water during low flow than to warm a larger volume of water during high flow.

Fish are cold blooded. They cannot regulate their body temperature. As water temperature increases, their body's temperature and metabolic rate increase. A fish then needs more food to maintain itself. Thus, if low flow occurs during summer, water temperature increases, raising a fish's body temperature which in turn increases the amount of food the fish needs to maintain itself. At the same time, food production in the riffles decreases because of the low flow.

Reproduction may also be inhibited by reductions in food supply or periods of no feeding. If food is scarce as a result of low flows, or if fish quit feeding for extended periods because of elevated temperatures during low flow periods, the number of eggs produced by females may be reduced or the eggs may be of such poor quality that hatching success will be reduced.

Recreation. In addition to the impact on fish and other aquatic organisms, a peaking operation can also interrupt people's recreational use of the river for fishing and canoeing. Water level and water flow below a hydropower dam increase rapidly when a turbine is turned on, a potentially dangerous situation to wading fishermen or fishermen in an anchored boat.

During non-peak periods, low

flow often makes it difficult to float the river for fishing or canoeing. In addition, developers propose to store water on weekends for peaking during the week when there is a higher demand for electricity. Recreational uses such as fishing and canoeing are higher on weekends than weekdays. Weekend storage would be in direct conflict with these other water uses.

So, from the point of view of fish and other aquatic life, hydropower using the peaking method of operation poses definite risks. However, there is an alternative mode of operation which minimizes the hazards of peaking. It involves run-of-the-river operation using variable-blade turbines with one turbine designed to operate at low flow.

By using both a large and a small variable-blade turbine, it's possible to generate electricity over a wide range of flows without the need to manipulate the flow. Thus, electricity can be generated at all times except during extremely low flows. Generation during these extremely low flow periods would not occur with a peaking operation either. Why? Because the flow into the reservoir would be insufficient for storage.

There are some other environmental risks associated with hydropower development at an existing dam: fish mortality from passing through the turbines; pollution from dredging during construction and disposal of dredge-spoil; changes in flow distribution in the tailwaters — the area immediately below the dam; and the loss of upland wildlife habitat if the water level in the reservoir is raised. However, these injuries are generally much less severe than those resulting from water-level manipulation with a peaking operation.

If hydropower is going to increase in Minnesota, people should know the environmental trade-offs associated with various designs and operating modes of hydro facilities. Although hydropower is a clean, non-polluting source of electricity compared to fossil fuel and nuclear plants, it doesn't produce electricity without environmental cost. It's important to minimize these environmental impacts through proper design and operation of each hydropower facility. □

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Biggest Fish in Minnesota? Smallest?

MINNESOTA'S FISH come in all sizes, tiny to huge. The largest is the lake sturgeon, which reaches six feet and occasionally exceeds 200 pounds. The smallest, the least darter, attains a length of about 1½ inches. So small is the least darter that it can escape through the mesh of ¼-inch seine. (Reported by Gary L. Phillips, William D. Schmid, and James C. Underhill in *Fishes of the Minnesota Region*. See report in "Star Points," page 66.)