Plate 5.3 Influence on Rivers by Water Power Stations and Lakes

Introduction

In Switzerland, many surface waters are influenced by a variety of both construction and water management actions. Among the significant quantitative changes in the water balance are the impacts resulting from hydro-electric power production, domestic water supply and lake control. Furthermore, the quality of the water is influenced to a great extent by human activity (cf. map 7.2).

By showing the influence of power stations on rivers, this map focuses on one essential aspect of water quantity. The impact of lake control both on the lakes and on the lower water courses is also presented.

Influence by storage power stations

Between 1950 and 1970, there was an important upturn in the production of hydro-electric power in the Alps and the lower alpine regions. During this period, the rivers were increasingly influenced by the diversion and the feeding back of water.

For a period of hours, days or months, water is stored in the artificial lakes and equalising reservoirs (cf. table). From either the natural catchment or by an extensive network of conduits from remoter basins, this water flows into the artificial lakes. In the production of hydro-electric power, the temporarily stored water is later returned to the original or another river below the power plant.

The map shows all the larger artifical lakes and equalising reservoirs, as well as a schematic illustration of the water intakes and conduit systems, indicating the flow direction of the water. Thus, the courses of the water can be followed. Included are also conduit systems whose primary purpose is to supply drinking water, and only secondarily to feed water to a power station. Examples are the water supply from the upper Saane catchment to Lausanne, and the diversion of water from Lake Constance to the region of Stuttgart.

Catchments feeding the yearly storage reservoirs of the alpine region are emphasised. A distinction is made between the natural catchment of an artificial lake (green) and those regions in which water is transferred into a lake by means of a conduit system (yellow). In these catchments the rivers, for the most part, are not influenced.

In some cases water is pumped from lower catchments into artificial lakes. At night, the water is pumped back after its use. There is no depiction of this circulatory operation.

The influence of storage power stations on rivers is intelligible when considering the way these plants operate: mostly in summer, water is diverted from the rivers at high altitudes, and then fed back again in winter at lower reaches of the river system. In between, therefore, only part of the natural water supply remains. Below the points of reflux, more or less water flows than would naturally flow, depending on the season and the load of the power plant. In winter, the discharge in the downstream rivers is generally higher than the natural flow; however, it can be lower, too, for example during the night or on weekends.

Shown by a six-part gradation, the main emphasis of the map is the influence on rivers by power stations with a maximum possible generator capacity of at least 300 kw. The degree of influence is described as a percentage of the mean natural annual discharge: the smaller the percentage, the greater the influence. Thus, in the grade indicating the greatest influence, less than 20 % of the natural discharge on average remains in the channel. Rivers with a significantly increased discharge beyond natural conditions during the winter season are specially marked.

The four diagrams in figure 1 show the seasonal fluctuations of discharge (discharge regime) in both the natural and the influenced state. For this purpose, the ratio between the natural or the influenced monthly value and the natural annual value is evaluated for each month (Pardé coefficient, cf. map 5.2). The diagrams are representative for the measurement sites mentioned in the map 1:2.2 million (fig. 1), in which the discharge without and with influence of hydro-electric power plants is recorded by long-term measurements.

In smaller waters in particular, the remaining discharge amounts are subject to large seasonal fluctuations. In addition, a sudden considerable deviation from the depicted mean discharge values is possible due, for example, to flooding, when the water intakes can divert only part of the discharge and channel it to the artificial lakes. Nonetheless, this artificial storage can often reduce the flood risk in lower valleys.

Below the water feed-back sites, considerable discharge fluctuations can occur due to the response of power plants to the current demand for electricity. This in turn results in relatively frequent and sudden water level changes of up to one meter (cf. fig. 2). On the map, the sections most influenced in this way are marked accordingly. Their selection was based on water level recordings by measurement stations.

Extensive diversions of water from one drainage basin to another (cf. map 6.1) are indicated by showing their mean yearly water flow. These diversions amount up to 5 % at most of the natural flow of the basins concerned.

Method

In order to calculate the remaining part of the mean natural annual discharge, it is necessary to determine the natural discharge as well as the amount of diverted water. Since these quantities are only measured at a few sites in the hydrological network, they had to be determined by means of appropriate methods.

For each intake point, the data and methods applied in [1] were used to estimate the natural discharge. The method of estimation was developed on the basis of measurements of natural discharges and various physiographic characteristics of the catchments concerned (area, mean altitude, glaciation, precipitation amount).

The quantities of water diverted at the different intakes were calculated. In each case the sum of these water amounts corresponds to the quantity of water passing through the turbines in the power plant. The water amount can be calculated according to the data compiled in the statistics of hydro-power stations [2] on electricity production values (mean expected production in kWh) and the mean net fall (difference of altitude between artificial lake or intake and power plant minus hydraulic losses). In correlating water amount, net fall and electricity production, the total efficiency of a hydro-power station must be taken into account. Losses occurring during conversion from hydraulic into electric energy in the turbine and in the generator are included in this figure of total efficiency. A standard total efficiency of 80 % was assumed for the present calculations.

By means of appropriate methods, the figure for the turbined water amount thus calculated must be divided into the individual intakes. Then only is it possible to calculate the part of the remaining water.

This description makes it obvious that in some cases, particularly in small catchments, the calculations are subject to various errors. A check at sites where measurements of natural and influenced discharges are available revealed that in most cases the correct influence category had been determined. However, in the classification into different categories it is possible that, at the limits, an adjacent category can also be adequate.

Influence by low-pressure power stations

In the midland and Jura regions of Switzerland, many power plants exploit the medium-size and larger rivers. Two main types of plants can be distinguished. For both types, the river is dammed up by a weir. The weirs as well as the approximate extent of the block area in the river are depicted on the map. For one type, the engine room with the turbines forms an integrated element of the weir. There is always the total water amount flowing along the whole river-section. For the other type, water is diverted at the weir, led by an upper channel to the engine room and then back again to the river by a lower channel. Between the points of diversion and reflux, only a residual amount of water is flowing in the river. At power plants with upper and lower water channels, a rather complicated succession of water intakes and returns can occur now and then, for example at the lower Emme. Here as well, such systems can only be depicted schematically on the map.

Influence by Lake Control

All of Switzerland's larger lakes are controlled except for the Lake Constance and the Walensee. They have a movable weir by means of which, observing certain operating rules, lake level and downstream discharge can be influenced. Smaller lakes often have solid weirs or sills which also have a controlling effect on the lake level. Owing to the control, the fluctuation in monthly maximum and minimum levels decreased and, consequently, the number of extreme low or high water levels was reduced as clearly shown by the four illustrations in figure 3. Not only does the control influence lake levels but also the lower water flows, though only to a smaller extent. Control manoeuvres at the weir are normally visible by abrupt changes in water levels and discharges.

References

[1] **BWW (1968):** Natürliche und durch Ableitungen beeinflusste Wasserführung der schweizerischen Gewässer (Stand 1.1.1967). Mitteilung des Eidg. Amtes für Wasserwirtschaft, Nr. 45, Bern.

[2] **BWW (1973, 1990):** Statistik der Wasserkraftanlagen der Schweiz. Bern.