

The Third Rhone Correction: Rehabilitation Despite Operation of a Power Plant?

In contrast to past corrections of the Rhone, the Third Correction, which is currently in the planning stage, will return some of the space that has been “taken” from the river. The river corridor will be widened in a number of places, which will both improve flood protection and the river’s ecological viability. The current situation is, however, rather complex. Over the past 50 years, several new hydroelectric power plants have been built in the alpine headwaters of the Rhone, which cause pronounced periodic changes in the water level of the river. EAWAG is currently investigating how the proposed broadening of the river corridor – and continuing fluctuations in water level – will affect groundwater levels and whether or not a natural ecosystem will be able to become re-established under these conditions.

“On se représente sans peine l’attitude des hommes devant le fleuve: ses grandes crues assez fréquentes devaient leur donner l’impression que le Rhone est une force contre laquelle l’homme ne peut rien.” For centuries, inhabitants of the Rhone valley have been at the mercy of a river that has produced massive flood events and caused great human loss and material damage [1]. After the dramatic flood of 1860, it was decided to force the river into a rigid structure, which was realized by the First (1863–1928) and Second (1930–1960) Rhone Correction; however, recent floods have pointed out some new deficiencies, which have led to a proposed Third Correction of the Rhone.

Third Rhone Correction

At the time of the First and the Second Rhone Correction, “hard” flood protection was the preferred method of controlling a

river. Today, river management emphasizes integrated planning, giving consideration not only to economic, social and political concerns, but also to ecological values [2]. Goals for the Third Rhone Correction include flood protection as well as measures for improving the ecological function of the river. Restoration, i.e., “reverting the river back to a natural, or at least near-natural, state” [3], will, to a large extent, remain wishful thinking. Instead, the Third Rhone Correction will rehabilitate selected stretches of the river, where a widening of the river corridor is expected to allow for improved ecological function.

Utilization of Hydroelectric Power Has Problems

The Valais is ideally suited for the operation of hydroelectric power plants due of its topographical characteristics. Over the last century, several impressive projects were realized, one of them the largest hydroelectric power plant in Switzerland, Cleuson-Dixence, with a total power production equivalent to that of a nuclear power plant. The plants produce electricity only when there is demand and are, therefore, brought on-line almost exclusively during periods of peak consumption. Water from high alpine lakes is piped to turbines situated several hundred meters lower in the valley. One consequent problem results when the water is discharged into the Rhone where it

causes transient increases in water level. This phenomenon of hydropeaking can cause the water level to vary by as much as one meter in some locations. For engineers of the Third Rhone Correction, this adds a difficult and demanding aspect to the overall problem of flood protection.

Consequences of Broadening of the River

The upcoming rehabilitation will create large riverbank zones that raise some planning questions:

- Will relocating the dam cause disturbances in groundwater levels?
 - How will hydropeaking affect the ecological equilibrium of the revitalized stretches?
- Two EAWAG projects are currently investigating these questions; some of our preliminary findings are presented in this article.

The Third Rhone Correction

has a budget of approximately 900 million Swiss Francs, spread over a 30-year period, and has the following goals: improved flood protection and enhancement of the ecological and esthetic aspects of the river corridor. In addition to the cantonal project, there is an ongoing interdisciplinary research project focusing on several specific questions, where EAWAG is also a participant. Results from these projects will give us valuable know-how for similar waterwork projects in Switzerland and abroad.

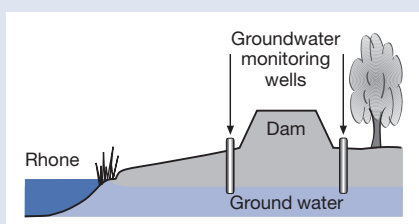


Fig. 1: Cross-section of the Rhone with dam and groundwater monitoring sites.

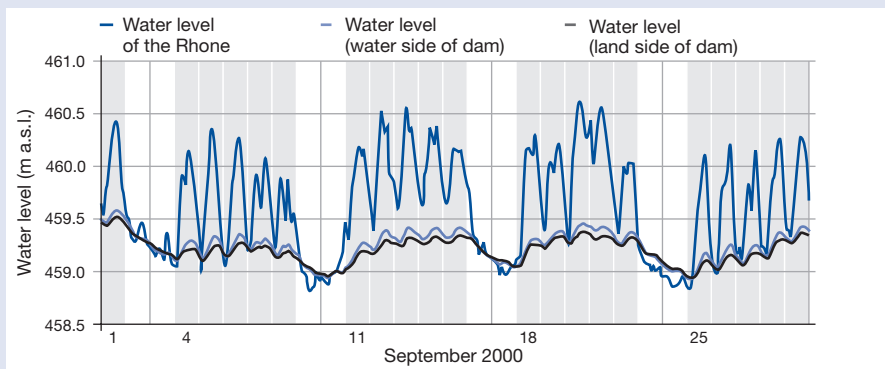


Fig. 2: Groundwater levels in the vicinity of the left Rhone dam near Martigny in comparison to water levels in the Rhone (raw data: Canton Valais/office BEG). Grey area: Monday through Friday; white area: Saturday and Sunday.

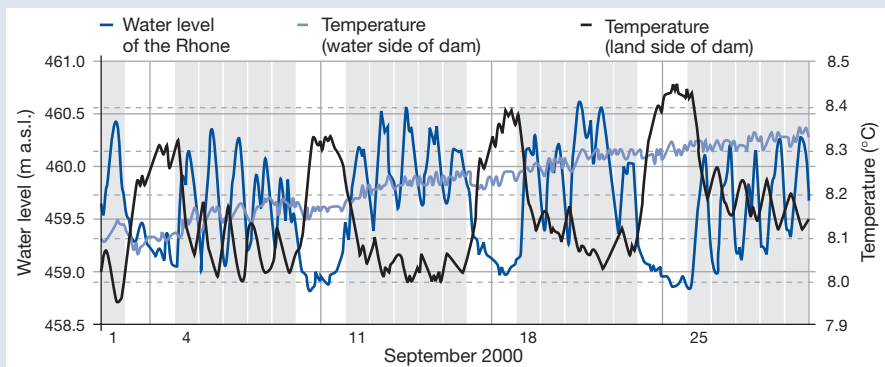


Fig. 3: Temperature profile of ground water in the vicinity of the left Rhone dam near Martigny in comparison to water levels in the Rhone (raw data: Canton Valais/office BEG). Grey area: Monday through Friday; white area: Saturday and Sunday.

How Hydropeaking Affect Groundwater Levels

In an effort to answer the question about relocation of the dam disturbing groundwater levels, water level and temperature were assessed in groundwater wells both on the water and on the land side of the dam (Fig. 1). Figure 2 clearly shows that the water level of the Rhone reflects the cycles of hydropeaking caused by operation of the power plants: Monday through Friday, this results in a daily fluctuation in water level of approximately one meter (dark blue line). The same behavior is observed in wells on either side of the dam, although the amplitude is dampened, and there is a slight time

lag (light blue and black line). When the turbines are turned off on Friday evening, the groundwater level stabilizes as does the water level of the Rhone itself.

The temperature profile on the water side of the dam (Figure 3, light blue line) does not exhibit any detectable variations. On the land side of the dam, however, a pattern corresponding to hydropeaks in the Rhone is observed (black line). Daily temperature fluctuations are 0.1–0.2 °C, and on weekends, the temperature can rise by as much as 0.4 °C. Wells located more than 100 m from the dam do not show any effects of hydropeaking. In this dam then, we can assume that the observed water level fluctuations are the result of pressure waves; however, other results (see isotope data discussed below) suggest that some water exchange is also taking place. Since it appears that there is no hydraulic connection across the footing of the dam, we maintain that water exchange occurs only below the dam.

Isotope Chemistry Yields Further Insights

Further insight into water exchange processes in the Rhone can be gained from isotope chemistry. Isotopes are atoms of the same element that differ in their total mass.

The oxygen atom in water, for example, can be the ^{16}O isotope with a mass of 16, or the ^{18}O isotope with a mass of 18.

The water cycle causes these isotopes to be released into the atmosphere and then to be re-precipitated as rain or snow. Fractionation processes in the atmosphere cause precipitation that falls at high elevations to be “lighter”, i.e., lower in ^{18}O , than precipitation that falls in the valley. The relative amount of the ^{18}O isotope is normally given with respect to the $^{18}\text{O}/^{16}\text{O}$ ratio of a reference material, the difference being reported in ‰ and denoted as $\delta^{18}\text{O}$. Streams at different elevations, therefore, have different $\delta^{18}\text{O}$ values. This “altitude memory” can be used to determine the origin of the water.

Using average $\delta^{18}\text{O}$ values (Fig. 4) of Rhone water (-14.30), of the nearby ground water (-13.71) and of the Rhone tributary Printse (-13.12), we are able to estimate whether the groundwater body is primarily being fed by Rhone water or by water originating from higher elevations. Due to a lack of data, we neglected the contributions of precipitation and of ground water located upstream of the study area. Our calculations indicate that the ground water is made up of approximately equal portions of Rhone water and high elevation water.

Reduced Diversity Due to Hydropeaking Effects

A second EAWAG project deals with the second question: how does hydropeaking affect the ecological equilibrium of a rehabilitated stretch of the river? In this project, the diversity of aquatic and terrestrial invertebrates along the banks of various streams are being monitored for several years.

Both sides of the actual stream bank are being sampled, i.e., both the flooded and the dry areas. Twelve different stream sections have been selected for this study, representing a range of hydrological and morphological conditions.

Results from the first sampling campaign are summarized in Figure 5. As expected, the hydropeaks exert a negative influence

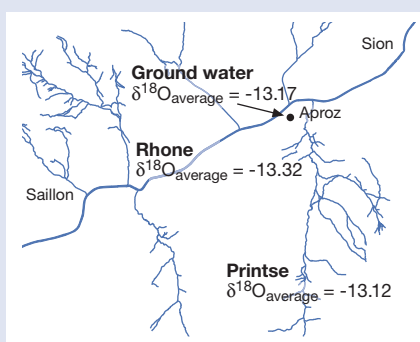


Fig. 4: Isotope data from the study area.



Discharge water from the turbines of one of the power plants of the Grande Dixence.

on diversity. The number of aquatic invertebrates in streams that are subject to hydropeaking is obviously lower than in streams with natural flow regimes. The same trend is observed, although is less pronounced, for terrestrial invertebrates (Fig. 5A). Species diversity of terrestrial invertebrates is, however, strongly dependent on the morphology of the stream bank; along artificially straightened sections of streams, the number of species is approximately 50% lower compared to stretches with natural morphology (Fig. 5B).

These results indicate that the broadening of the river corridor may improve the terrestrial fauna along the riverbank, but in order to create better conditions for natural aquatic communities, it appears that we need to adapt the hydropeaking regime.

Back to the Question...

Does this mean that rehabilitation and operation of hydroelectric power plants are mutually exclusive? According to what we know so far in the case of the Rhone, we have to answer this question with a tentative “no”. In order to secure the valley bottom, flood protection dams will be needed, even if the river corridor is broadened. According to our current assessment, replacing old dams with modern structures should not have any negative impacts on the hydrological status quo of the ground water.

Engineering Alternatives for the Third Rhone Correction [4]

- Updating of the current flood protection system by reinforcing and raising existing dam structures.
- Broadening of the river corridor and creation of a natural riverbank zone.
- Construction of a second channel, which is not immediately adjacent to the Rhone, for the absorption of high water swells.

From a biological perspective, it is becoming clear that hydropeaking will prevent the establishment of natural biotic communities even when the river corridor is widened. Additional measures, such as relief basins or diversion channels, will have to be considered. The success of the proposed correction will, therefore, depend on a combi-

nation of “hard” technical and “soft” ecological measures.

Two boundary conditions are already quite obvious: the Rhone is already heavily impacted by hydraulic structures and is intensively used for power generation, so it is unrealistic to expect that the lower reaches of the Rhone will revert to an idyllic landscape rich in fauna and flora. “*Le Rhône (...) symbole d’une force inflexible, toujours jeune et triomphante, qui descend vers le soleil, il suscite dans notre esprit des pensées vivantes*” [1] – these poetic images remain an ambitious goal.



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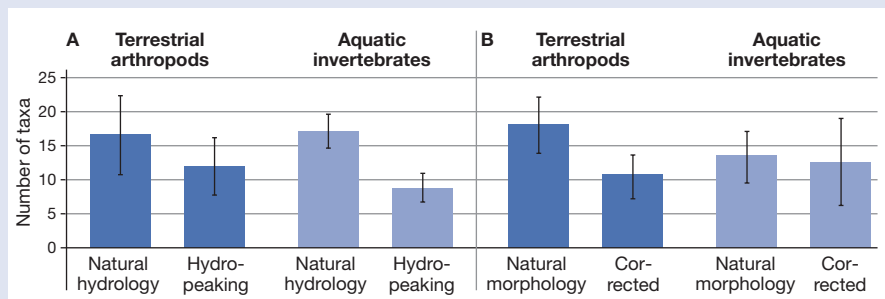


Fig. 5: Diversity of aquatic invertebrates in rivers subjected to hydropeaking and in rivers with a natural discharge regime (A). Diversity of terrestrial invertebrates along corrected river sections and along stretches with natural morphology (B).

[1] Mariétan I. (1953): Le Rhône, la lutte contre l’eau en Valais. Edition du Griffon, Neuchâtel, 22 p.
 [2] Willi H.-P. (2001) Synergism between flood protection and stream ecology. EAWAG news 51e, 26 – 28.
 [3] Friedrich G. (1986): Was bedeutet Renaturierung von Fließgewässern? – LWA-Materialien Nr. 3/86. Aktuelle Fragen der Unterhaltung von Fließgewässern, S. 23–35.
 [4] Kanton Wallis (2000): Dienststelle für Strassen und Flussbau: Broschüre zur Dritten Rhonekorrektion. See also: www.vs.ch/rhone-vs