

## NUMERICAL SIMULATION DOWNSTREAM ATTRACTION FLOW AT DANUBE WEIR DONAUWÖRTH

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The “Bayerische Elektrizitätswerke GmbH” BEW is the operating company of the Danube weir in Donauwörth, Bavaria, Germany. The weir did not have a fish migration bypass. To restore the continuity the BEW intend to create an artificial migration bypass at the weir. Caused by local spatial restrictions at Donauwörth, the contractor (BEW) thought about changing the standard position of the bypass channel from the downstream position of the powerhouse to the adverse bank side (gate side). 3D numerical simulations were conducted to check the influence of different bypass positions and how it is possible to connect the bypass attraction flow to the dominant flow characteristic (powerhouse outlet). The flow parameters, discharge and velocity, of the bypass were varied to get information about the required load to get a “working” attraction flow. To increase the reach of the bypass attraction flow, a small hydro power plant is planned next to the bypass entry area. In assistance to that, a groin at varying positions was investigated, too. The results show how it is possible to increase the attraction flow and optimize the position and arrangement of the bypass and attraction flow.

### 1 INTRODUCTION

To restore the continuity at the Danube weir at Donauwörth several bypass positions were investigated. Caused by the spatial restriction on site it was necessary to prove the possibility to relocate the fish migration bypass from the typical location downstream of the power house to the adverse bank side beside the weir gates. The following figure gives a short overview on the situation on site and the possible alternative positions.

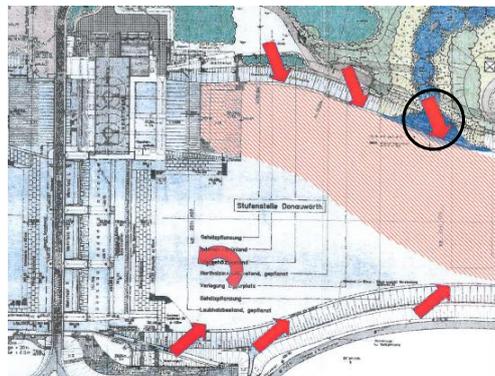


Figure 1. Overview of the situation in Donauwörth.

The flow direction in figure 1 is from left to right and the power house is located on the orographic left side. The weir on the orographic right side has three gates. The normal/standard position of the bypass arrangement is marked by the encircled arrow.

## 2 NUMERICAL MODEL

### 2.1 Digital terrain and structure model

Basing on very good input data a digital terrain model was build. Figure 2 (left) gives an overview of the measured terrain.

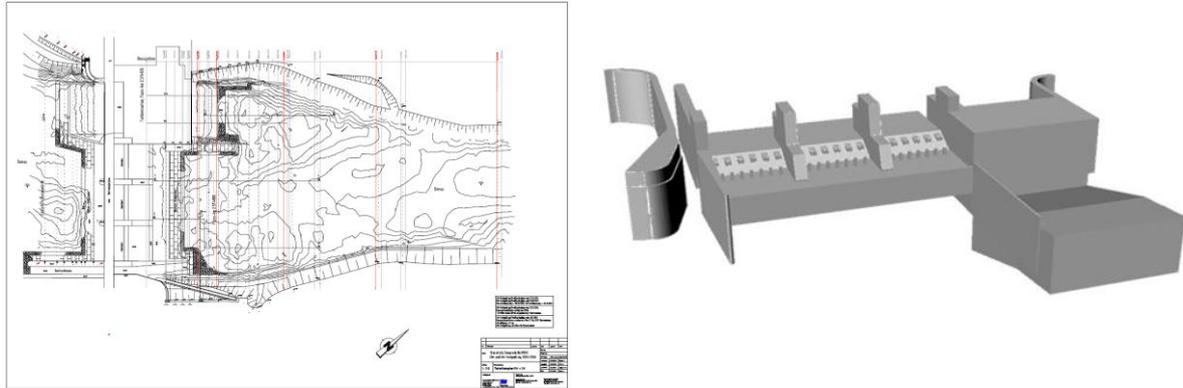


Figure 2. Digital terrain model with bed elevation measurement (left) and structure model (right)

To model the turbine outlet and the influence of the weir to the downstream attraction flow as best as possible the complete weir structure was modeled digital (Figure 2 right). In Donauwörth two turbines are installed. In a first simulation step it was important to check the influence of each turbine to the flow behavior in the tail water.

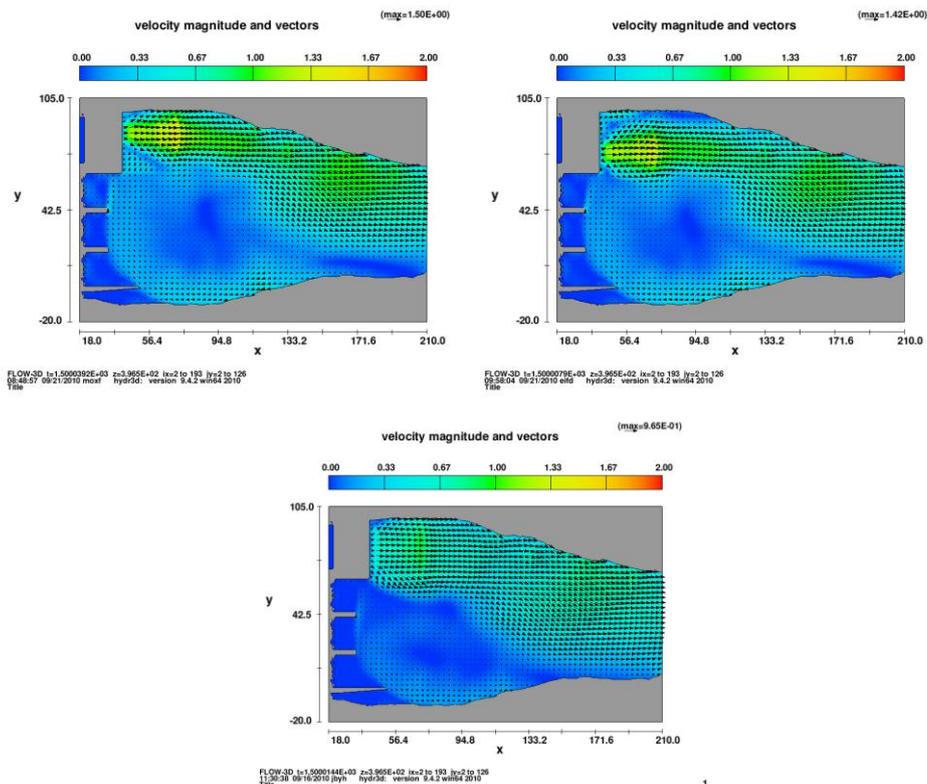


Figure 3. Influence of different load cases. Upper left picture shows left turbine with 100% load. Upper right picture 100% load on the right turbine and deepest picture shows both turbines working.

In figure 3 no significant difference between the load cases is recognizable. In all three cases the dominant clockwise turning eddy was visible and stable. So we did al further investigations under symmetric full load of the turbines.

## 2.2 Software

The used software was the commercial code FLOW3D from Flow science Inc. (Santa Fe –New Mexico – USA). Several boundary conditions can be set in this code. To model the volume influx from the two turbines two source planes were modeled at the turbines position. As downstream boundary condition a water level was set. The simulations were done with standard turbulence model (RNG) and with a cubic cell size of 50 centimeters.

## 3 SIMULATIONS

### 3.1 Reference position

To get a reference solution we investigated a bypass connection directly after the turbine outlet bottom ramp on the left bank side. Figure 4 shows four horizontal cut planes with the velocity magnitude in meter per second. The bypass was loaded with 500 liter per second and the design discharge of the powerhouse outlet was 206 cubic meter per second.

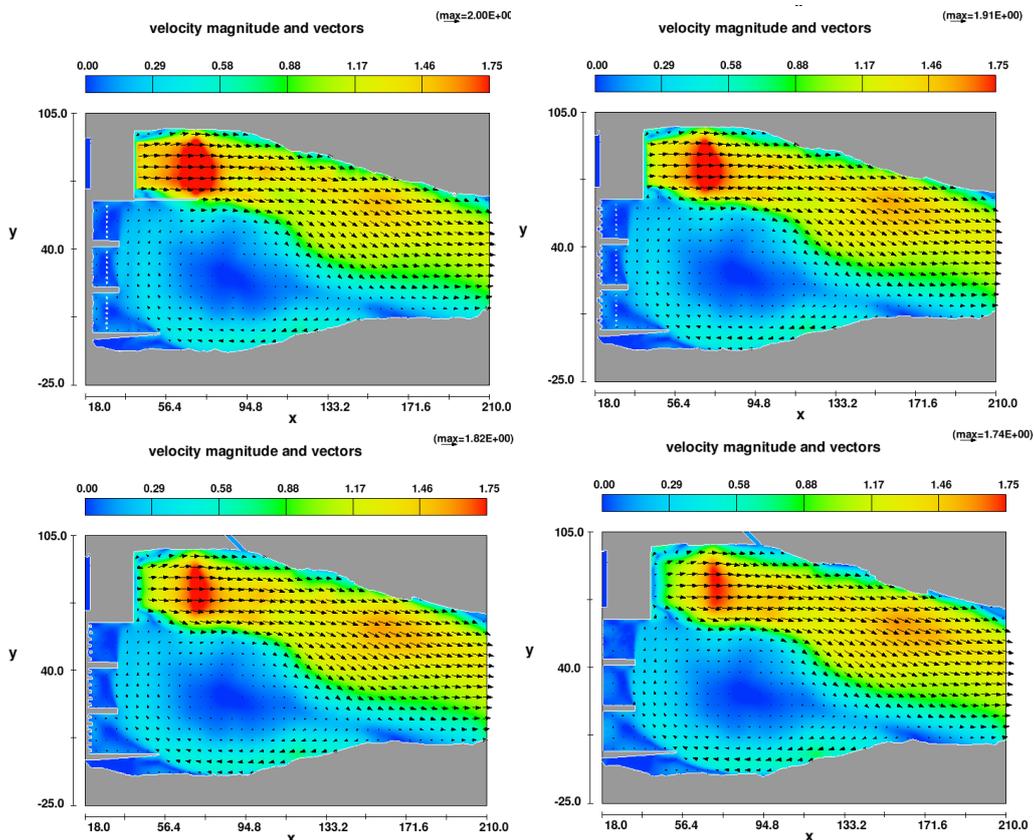


Figure 4. Horizontal cut planes with velocity magnitude in m/s. Bottom elevation is rising from the upper left to the lower right picture

Figure 4 shows clearly how vanishingly small the influence of the bypass is if design discharge is running down the river. To get a minimum of reference information a tracer were added to watch the flow.

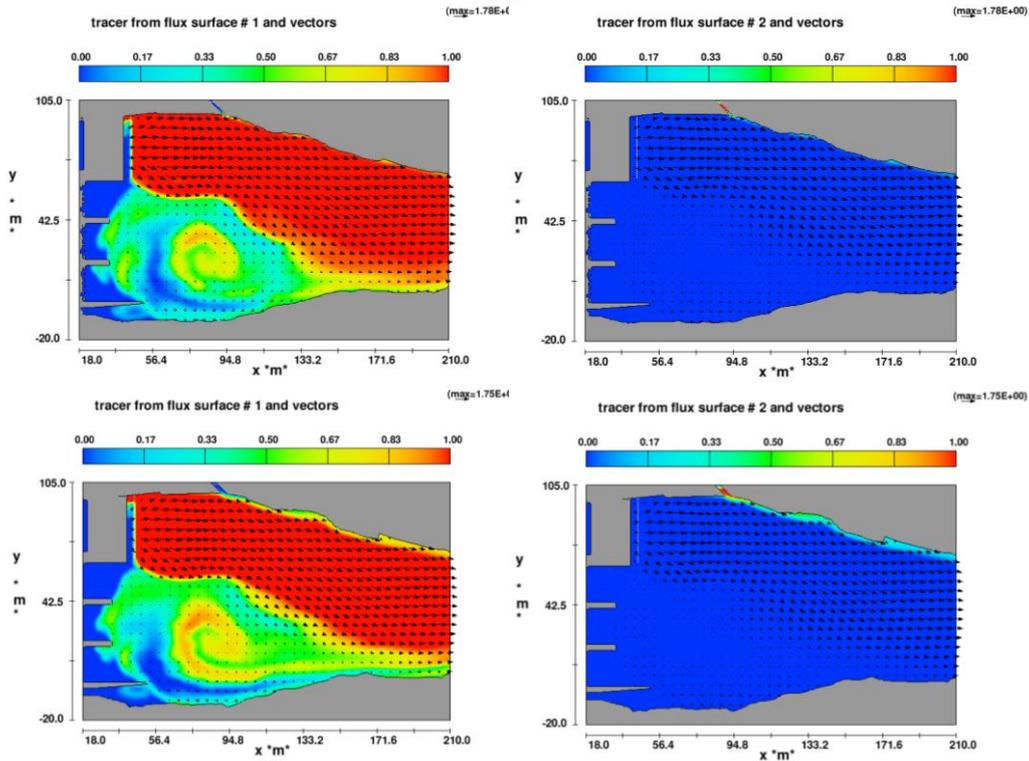


Figure 5. Horizontal cut planes. Left column illustrated a tracer from the turbine outlet and the right column shows the tracer from the bypass channel. Upper row is bottom near and the lower row is near the surface

By observing the numerical tracer a kind of attraction flow near the water surfaces could be identified.

### 3.2 First position on the right side R1

The first investigated alternative position for the bypass channels was the nearest on the orographic right side. The projected discharge of the bypass channel was given with 500 liter per second.

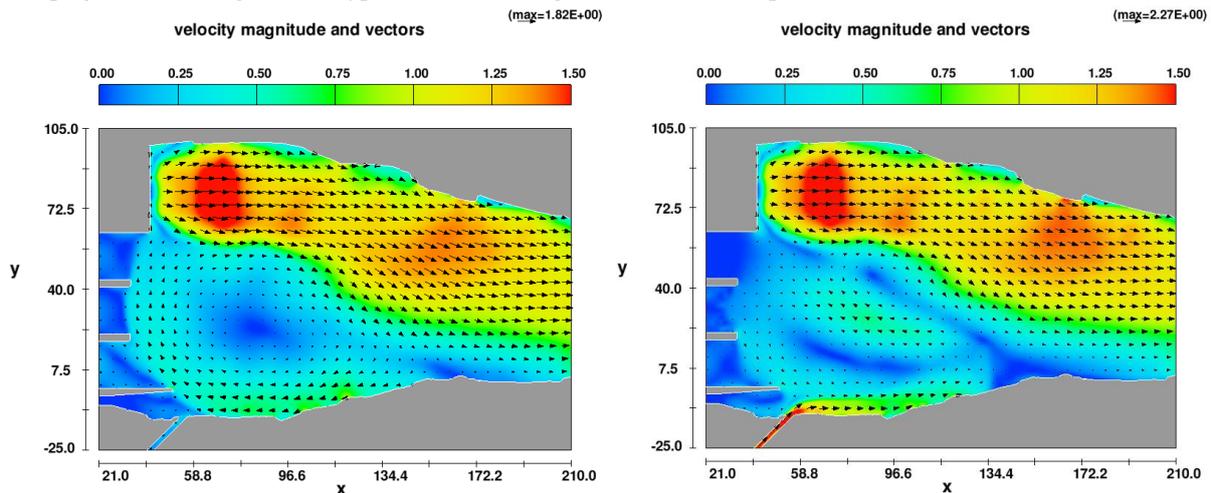


Figure 6. Horizontal cut planes with velocity magnitude in meter per second

The left picture in figure 6 shows the flow situation when the bypass channel is loaded with 500 liter per second and the velocity is fish compatible. To determine whether it is possible to get an attraction flow from this position or not, an academic load case was simulated. In this pure academic case (absolutely not fish compatible) the momentum flux was increased by 20 times. The result is shown in Figure 6 on the right picture. The simulation results show clearly that there could be no connection of the two different velocity fields from the main channel stream and the bypass channel.

### 3.3 Third position on the right side R3

If the bypass channel is moved more than 100 meters downstream on the orographic right side the situation seems a little bit better.

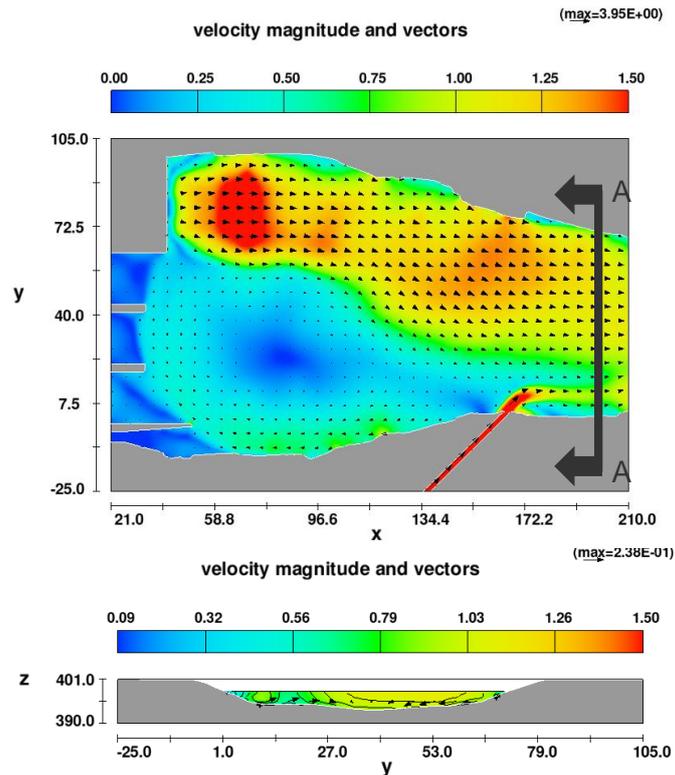


Figure 7. Horizontal cut plane with velocity magnitude in meter per second. Lower part of the figure shows the vertical cut in the A-A section

The connection between bypass channel and mean flow could only be generated under the academic load case with the maximum momentum flux. At this point of the investigation we stopped further investigations on the orographic right side, since it seems to be impossible to generate an attraction flow which is basing only on velocities and connect them to the main flow.

### 3.4 Standard position (state of the art)

To investigate the attraction flow conditions on the left bank side, which actual seems to be the “state of the art” side - we modeled the bypass channel at the position marked by the encircled arrow in figure 1. Since the preliminary simulations had shown, that the low discharge of 500 liter per second produces only a weak attraction flow under design discharge (by regarding only the velocities!) an additional small hydro power plant is scheduled to increase the influence of the attraction flow of the bypass channel. The design capacity of the new small hydro power plant is 10 cubic meter per second.

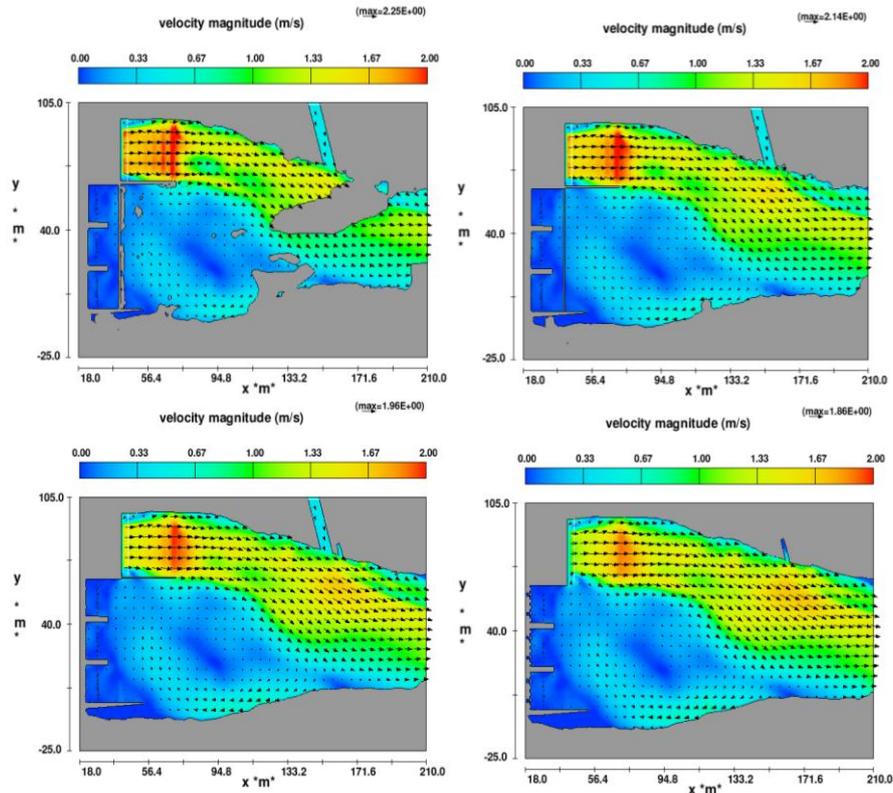


Figure 8. Horizontal cut plane with velocity magnitude in meter per second. Bypass channel and additional small hydro power plant

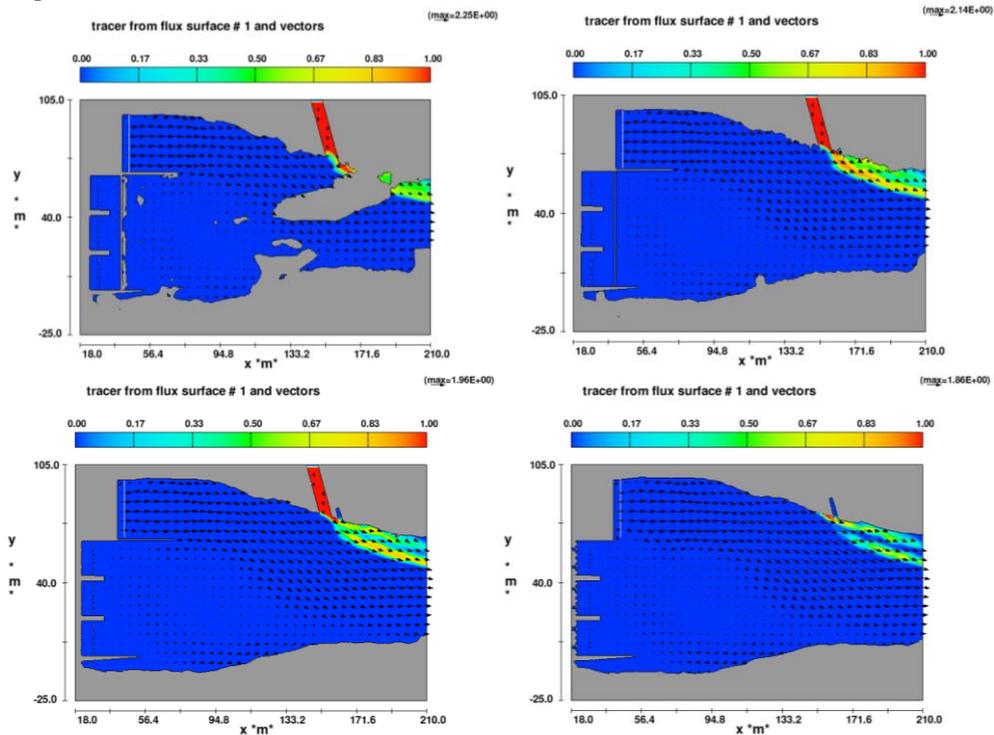


Figure 9. Horizontal cut plane with tracer form the additional hydro power plant with 10 cubic meter per second discharge and 206 cubic meter per second from the existing two turbines

Figure 8 and 9 show clearly that the additional discharge increase the visibility of the attraction flow near the bypass entry zone.

### 3.5 Optimization via a groin

To optimize the attraction near the bypass entry an additional groin was modeled. Different positions were investigated- The following figures show the best results.

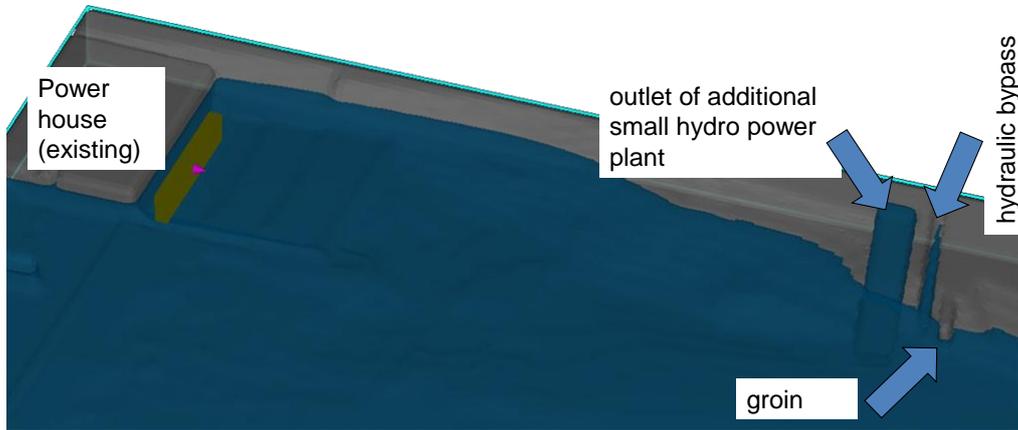


Figure 10. Perspective view of the additional hydro power plant, bypass channel and the additional groin

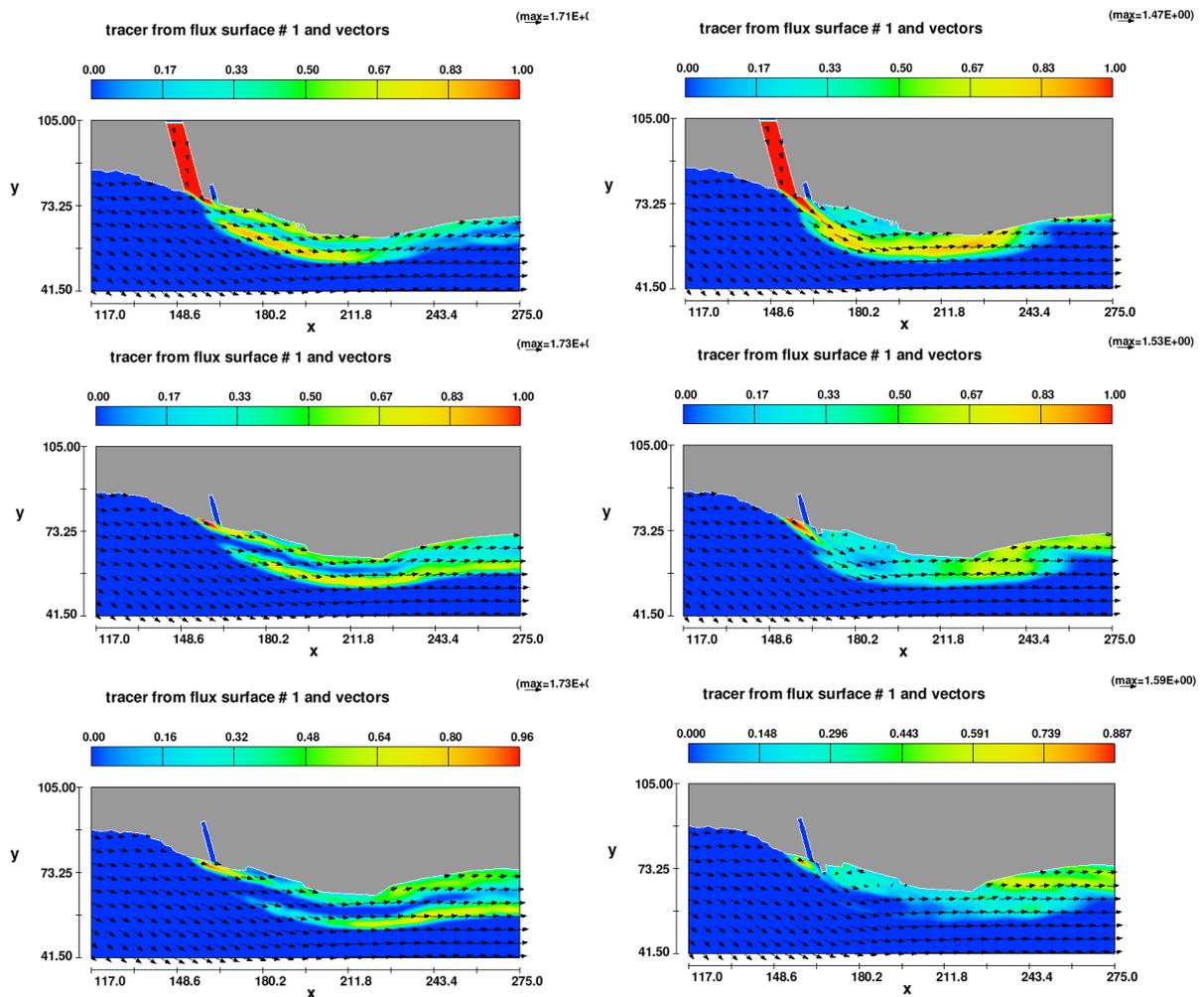


Figure 11. Horizontal cut planes with tracer from the small hydro power plant. Left column without groin as reference and right column with the additional groin

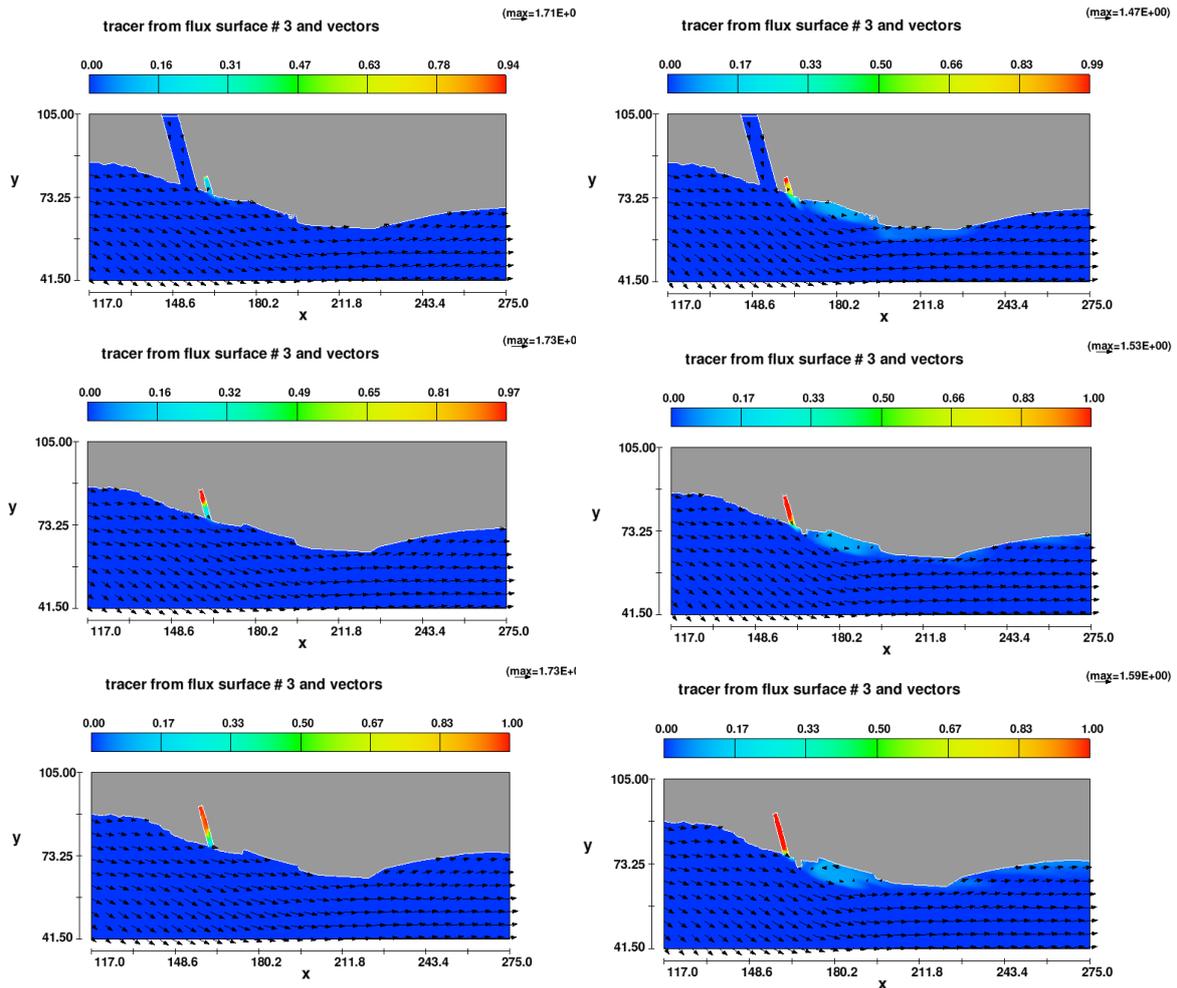


Figure 12. Horizontal cut planes with tracer from the bypass channel. Left column without groin as reference and right column with the additional groin

Both upper figures (11 and 12) show how the additional groin improves the visibility of the attraction flow near the bypass entry area.

#### 4 CONCLUSIONS

The numerous simulations which were done in this study show interesting results. Attraction flow only basing on velocities is hardly to generate guarantee under the several flow conditions in tail water. Discharges which are less than one percent of the main flow, produces nearly no attraction. Good results were generated by increasing the attraction discharge via an additional small hydro power plant which serves in this case around five percent of the total flow in the river.

One big question appeared during the numerical investigation: Is velocity the only parameter for attraction flow? Certainly not! Because if it would be the only parameter, bypass structures without any additional discharges would not produce any identifiable attraction flow for fishes, but they are working.

So we think further investigations should be conducted to check other parameters in correlation the fish migration.