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3A Hy-SEE

Neste river planning & propositions for piscicultural life

Abstract

Fishes need calm and fast zones in order to hunt, reproduce and survive in the river. The Neste d'Aure is a Pyrenees' beck where velocity is the same along the bed. This characteristic is detrimental for the brown trout which is the main species present in the river.

Through several patterns proposed at different scales (small, large and intermediate), possibilities of Neste planning are studied. First, a large scale simulation is established to point out main hydraulic characteristics; then, river's plannings are proposed to create mixed zones. These buildings have been drawn, and their shape, length, and situation in the riverbed have to be determined and optimized in order to have an ideal habitat zone for trouts.

At last, laws are considered and it consists in studying what water regulations could limit the landscaping and what rules are applied on the studied river section.

Keywords

Stream, fishing river, planning, establishment of a pattern, flow, brown trout, modeling, flood, beck, local velocity, fish cover, stability

I. Introduction

There has been more changes in our environment in the last 10 years than in any time in Earth's history. Mankind has new needs and often local populations have to suffer the consequences. For instance, in the Pyrennées in France, fishes and specially brown trouts have to modify their life conditions because of the hydroelectric plants implanted in rivers.

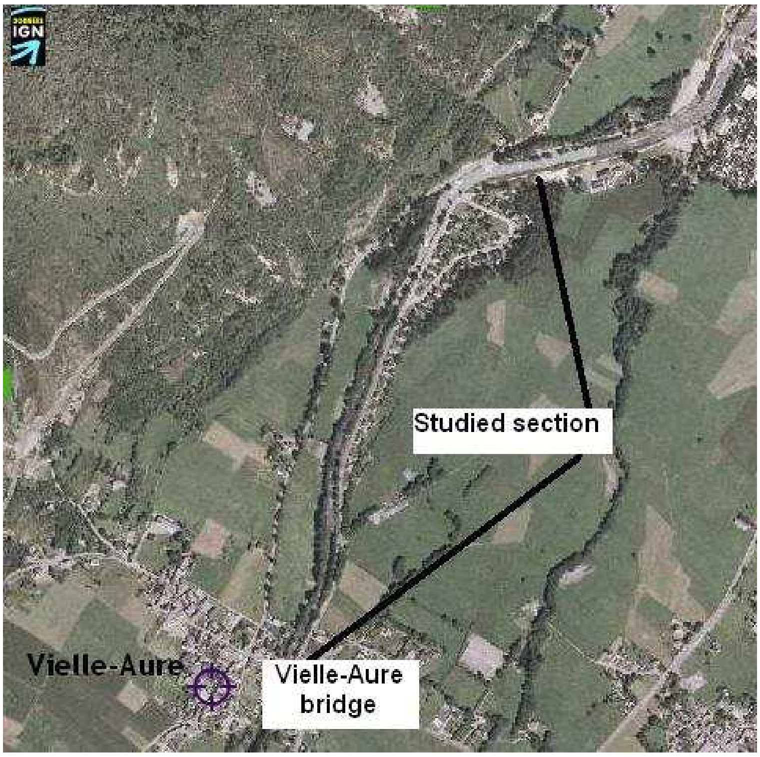
It is in this context that our school team is studying landscaping for the brown trout's development in the Neste river. This problem has been submitted by a local fishing federation and concerns many people : persons in charge of SHEM and EDF's plants, fishing and nature reserve federations, and local authorities. Our team is composed of three groups which all have specific issues to deal with. The first one works on large scale modelling while the second one investigates different possibilities of landscaping in the river for trouts, and the last one is in charge of linking our work with water regulation laws.

1.1) Geographical situation

The Neste is a river in Southern France, a left tributary of the Garonne. It rises from several sources around Saint-Lary-Soulan, in Central Pyrenees. It flows through the "Haute Garonne" and "Hautes Pyrénées" departments. Its length around 73,2 kilometre collects waters from a basin area of 906 km². Its flow is very variable because of its several sources and tributaries, but its average discharge is about 13 m3ps.

Neste d'Aure river knew wrenching floods in the past. Not only are floods torrential because of the basin area morphology and the river bed's slope, but they are also very rapid and not predictable phenomena.

We study particularly the Neste in the Aure valley, which is situated in the Hautes-Pyrénées department. In order to establish the most relevant pattern, we decide to model the river from the Vielle-Aure bridge on one kilometre long.



1.2) *Main problem of the river*

- **Brown trout :**

Species we are studying in our BEI are brown trouts or common trouts. They are Salmonidae, widespread in Europe. They are edible and that is why the fishing federation wants to facilitate their implementation in the Neste.

- **Characteristics**

The brown trout's body is slender and tall with a very small scale, and it has a big head. Its average length is 30 cm, weight from 300 to 500 g.
The brown trout can be recognized by the tiny fin placed between the dorsal and tail, the adipose fin characteristic of the Salmonidae family.

Brown trouts eat insects, maggots, worms, molluscs and small fishes. They hunt and capture preys in the flow in full or in surface water. Therefore, they need shadowy areas to provide their hunting.

They recur in winter. The female makes from 1000 to 4000 eggs on a stony nest. Fingerlings are fragile and need areas with few current to grow and find their food. If it is not enough, they become cannibal. They have a very low survival rate in their current environment. The wild population is declining and their number in rivers is maintained in an artificial way.

The brown trout likes living in fresh and well oxygenated waters. It prefers rivers and streams, but can live in lowland streams and lakes as long as the water temperature does not exceed 18 or 20 ° C.

- **Constraints**

To promote the brown trout survival in the Neste, our propositions have to offer three challenges:

- *Shadowy zones*: indeed, the brown trout hunts on the lookout and if the river is too clear, the fish will find it difficult and will tend to eat eggs and smaller fishes.
- *Quiet zones*: for the path of course, but also for younger fishes and less resistant. The brown trout appreciates low current speed areas. In fact, it appreciates natural rivers which include both flowing waters and calm waters and "chenalisation" makes this mix.
- *Non turbid areas*: when a dam is released, the current flow leads charge of sediment. Even if the adult fish hold up well to these phenomena, the young fishes are being decimated by lack of oxygen.

- **Many involved parts**

To succeed in our project, we have received the support of many people:

Fishing Federation: works on ecology and nature protection
EDF : producer of electric energy, weirs owner
SHOM : producer of electric energy, weirs owner

The mayor halls of cities crossed by the Neste
GHAAPPE : Research center about ecology and biology in water.
ENSAT : agronomy school
SOGREAH : hydraulics research and development company

Many actors are involved in this projects, and of course this results in different economic and ecologic interests.

1.3) Constraints

There are several constraints relative to the proposed development plans and to the brown trout.
On the one hand, they are first security constraints: we ought to protect the dwellings and the land registry from flood risks. Indeed, floods are quite frequent in this area because of both dams' drops and thaws. For instance, in 1982 (with a river flow of 280 m^3/s) the Vielle-Aure Bridge was totally carried along. Secondly, economically speaking, the landscaping we will propose have to be well fixed in order to resist to floods. And, in our studies, we will also have to take into account turbidity phenomena due to the dams. Viewing all those facts, we have to reach a compromise between a good fish cover, its price and frequent floods.
On the other hand, we have to respect the habitat and the reproduction conditions of the brown trout. Those fishes need special conditions to hunt, to rest and to develop. The brown trout need shadowy zones because they hunt game from a hide. They reproduce in only calm zones and they need non turbid zones to develop.
Finally, we can not propose any plans without taking care of water regulations. Since men have realised the stakes of Earth energies, laws have been enforced and the energy sources have been protected, so that water and its use are now under control.

1.4) Intended solutions

- **Fish cover in the river**

Fish covers are hydraulic plannings put in the rivers in order to help fishes. They support fishes to find food and to recur. Many fish covers exist with different sizes and forms functions of river kind and fish species. In our project, we want to create hunting zones because reproduction areas have already been made.

- **Cost**

For twenty hydraulic planning and eight days of work:
- backhoe loader location per day: 450 €
- backhoe loader driver/operator : 350 €
- hydraulic case study by a land-agency : 5000 €

We want to work with rocks from local natural environment. Nevertheless, we can easily contemplate to buy some rocks:
-1 rock : 50 €
450*8+350*8+5000+50*4*20 = 15 400 €

II. Technical realization

2.1) Flow hydrodynamic

The aim of this study is to establish a pattern of the Neste river in order to determine its different characteristics. It corresponds to a large scale modeling where precision is about few meters. We consider a section of 1 km from the Vielle-Aure Bridge, and suppose that it is a representative section of the river.
The hydraulic characteristics to estimate are principally: flow, flow depth, local velocities. We also examine the hydraulic behavior of the Neste at the moment of flood.

- **Modeling tools**

Several softwares are used to establish the pattern but the solver is TELEMAC 2D. This software, developped by EDF and distributed by the SOGREAH Company, solves "Saint-Venant" equations (shallow water approximation) in two dimensions and permits several applications in free surface hydraulic.
We use the following modeling tools:

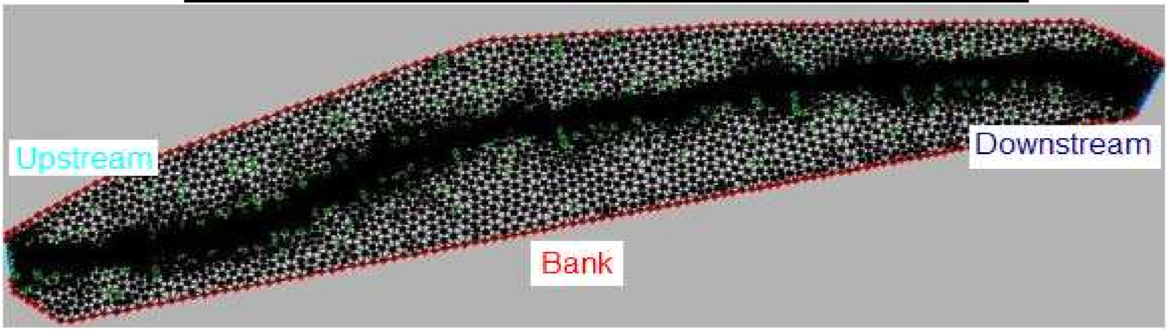
- MATISSE : mesh generator from topography and bathymetric data.
- FUDAA : project editor and roughness zoning and initialization
- TELEMAC2D : compiles program and solve problem
- RUBENS : graphic post-processor

- **Meshing and boundary conditions**

Matisse software is a mesh generator which creates a geometry file from the different data, and a boundary conditions file. After checking the imported data, we carry out the meshing. We generate two densities in the meshing: in the bed river meshes are 4 m long and outside 10 m long. We obtain approximatively 5900 points and the geometry file is generated.

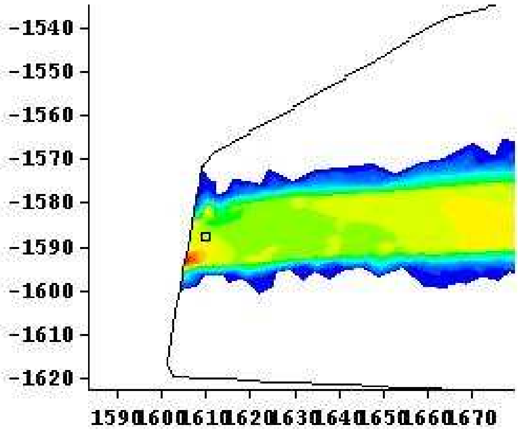
For the boundary conditions, we create 3 groups: bank, upstream, and downstream. And then 3 entities are determined with MATISSE : bank (2000 code), flow (4554 code) and free (4444 code). We associate groups and entities :

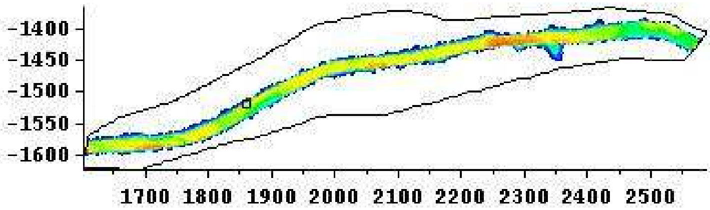
Groups	Entities
Bank (right and left banks, upstream less wetland)	Bank
Downstream	Free
Upstream (wetland)	Flow

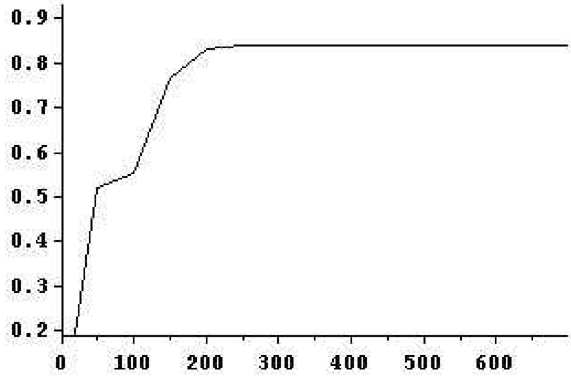


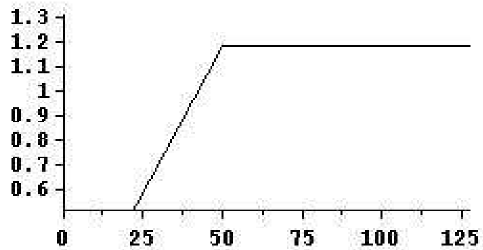
- **Results**

First we run the model for a constant flow of 15m^3/s and 30 m^3/s in order to visualize results in steady regimes. We notice the steady regime on following drawings :

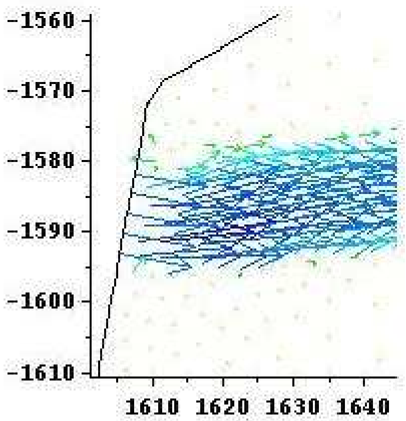


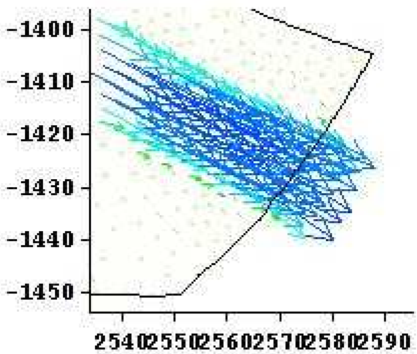






We also check input and outflow velocities:



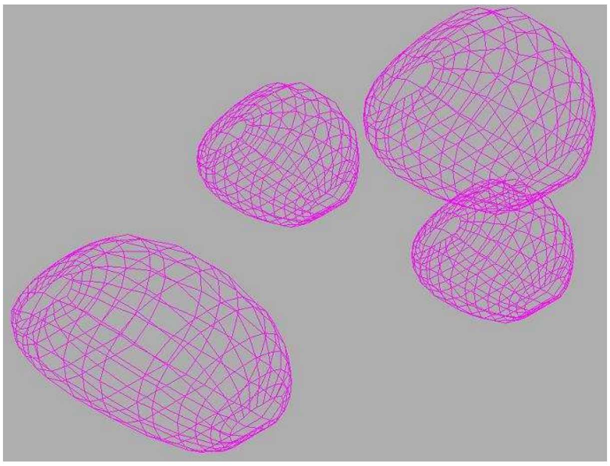


2.2) Environmental planning for the brown trout

For practical and aesthetic reasons, we have chosen to study hydraulic plannings which would be made with natural materials coming from rocks and pebbles of the river.
During the visit on site, we found that rocks of large diameter (approximately 1m) are resistant to floods.
It consists of four blocks of size between 60 cm and 120 cm. The geometry seen on site is presented below. We already know that the brown trout appreciates this type of structure, by observation of the natural environment.
In our model, these blocks will be placed against the shore.

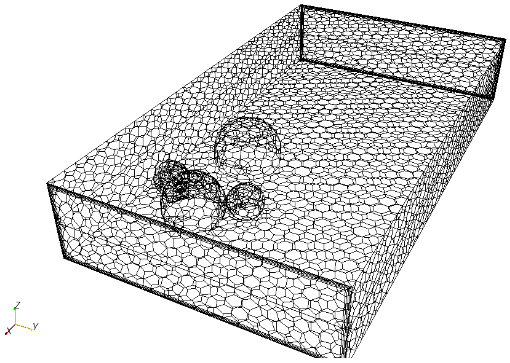
- **Plan of high definition modelling**

To begin, we have drawn our first idea with design software.



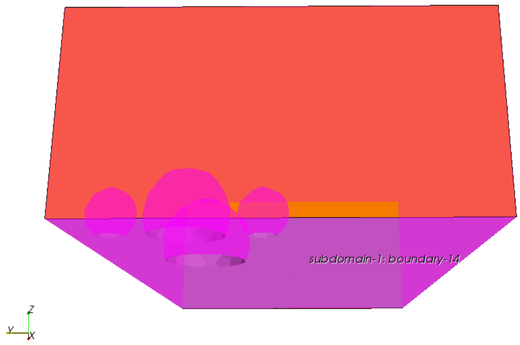
First Patting

In a second step, we have created the geometries corresponding with Star Design and we have chosen meshing characteristics.

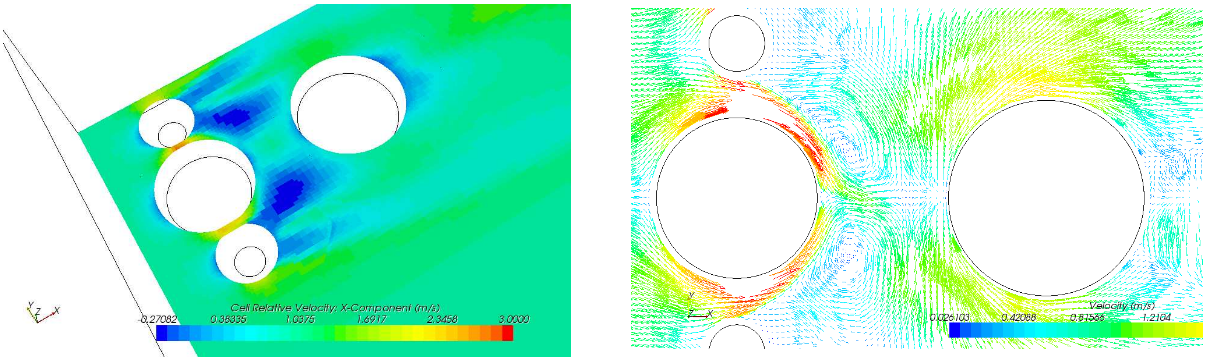


Geometry and Surface Meshing with Star Design

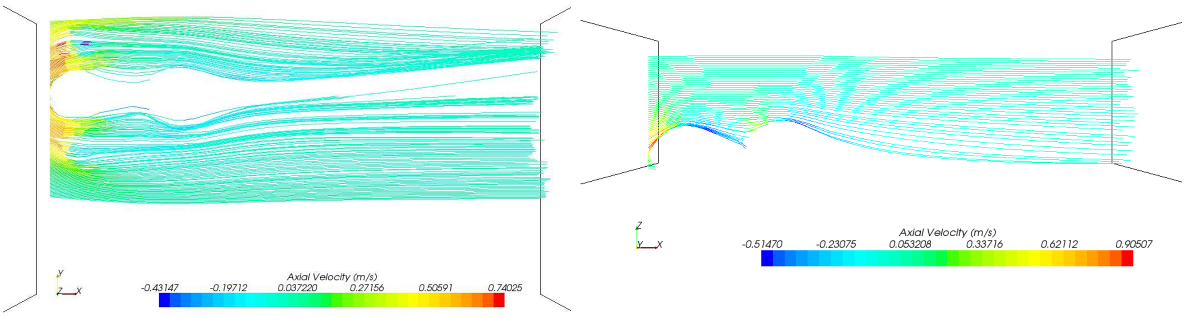
Then, we have simulated the flow around fish planning with StarCCM+ under different conditions after setting the boundary conditions.



Boundary Conditions with StarCCM+: red= inlet, orange= outlet, purple = wall



Results: Presentation of speed



Streamlines

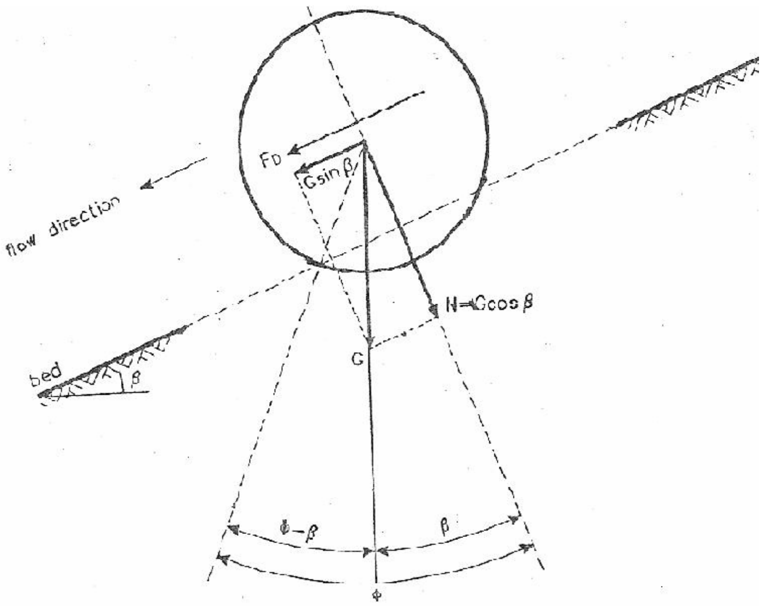
We have begun to model the second part of our planning by a sphere for easiness but in the future we are going to work with a cylinder because the zone is more isolated and darker. Now, we are trying to work with free surface, when the draft is under the planning height. These studies allow us to support the choice of a hydraulic planning for the trout development in the studied section of the Neste.

2.3) The reorganized Neste river

To complete the previous study (see 2.2), we have decided to work on the stability and the viability of the proposed development plan. First of all, to have an idea of the resistance of the landscaping, we propose a stability analysis on it, and once we find that the solution is correct, we can integrate it in our modeling scheme.

- **Stability : balance forces**

We will first discuss if the structure can resist to the Neste flow conditions, that is to say, counting on the slope, the velocity, the substratum, are the forces applying on the block in equilibrium?



Forces on a block (longitudinal bed slope) according to Von Rijn

The forces applying on the block are:

- Weight : $\vec{P} = m\vec{g}$
- Substratum reaction : $\vec{R}$ corresponding to friction between the block and the river soil
- Drag force : $F_D = \frac{1}{2} C_D \rho_{water} S.U_f^{\ 2}$ due to the flow
- Lift force : $F_L = \frac{1}{2} C_L \rho_{water} S.U_f^{\ 2}$ due to the flow

- **Modelling with TELEMAC**

The previous approach helps us to eliminate the bad propositions. We now integrate the block to the river. First, we have to change the bathymetry of the river with MATISSE. In this part, we are focusing on the flow around the block at river's scale. Hence, it should be possible to see if the studied landscaping is dangerous, i.e if it can raise the draught or entail turbulent zones. At this stage, we did not begin this study yet.

2.4) Laws and water

Environmental law is a body of law, which is a system of complex and interlocking statutes, common law, treaties, conventions, regulations and policies which seek to protect the natural environment which may be affected, impacted or endangered by human activities. Particularly, since the 1970's in France, a Environmental Code has been established. It is composed of : books, titles, chapters and finally sections. The "Book 3" is dedicated to wildlife (fauna and flora), and it contains the "Title 3" codifying fishing in freswater and fish protection. In our project, we are most interested in the "Section 2" of the "Chapter 2" of the previous references of the Code. Indeed, it refered to fish habitat protection. The L432-5 article imposes a minimal flow, equivalent of the tenth of the stream's specific flow ('*module*'), when every structure is built in a stream. Then, the L432-6 article sets that every structure has to be composed of plans for migratory fishes traffic. According to this point, we have to preserve enough flow in the river and propose landscaping in accord with the environment.

III. Conclusion and outlook

Through our work, we have shown the importance of habitat structures for trouts. Indeed, the Neste river is missing mixed water zones, which are in, the same time, calm and quick velocities areas. As we explained in the report, trouts need calm zones to rest, and flowing waters to bring their preys. At this stage, we have not validated our model yet, neither our global simulation, but we have a precise idea of good structures which have to be built and the consequences for hydrodynamics of the Neste. Our study results in choosing a particular geometry for fish covers : three spherical blocks following by a cylinder-shaped block two meters downstream. This landscaping will keep calm zones just behind the first three blocks ,and, meanwhile, create faster velocity waters aside. Besides, its stability study shows that it can easily resist to usual conditions (i.e flow, velocity) on the Neste. Nevertheless, we did not design the structure for 30-year or 100-year floods but for 10-year flood. The proposed building material and the shape of fish covers were chosen in order to be easily (no important costs) replaced in case of great floods (like in 1982).
Finally, we want to emphasize that we worked for the trout's habitat in the river bed. Studies on optimization of structure's shape remains undoubtedly to be done. For instance, comparing different shapes, with constant volume or constant surface, and their consequences on the global flow could be a future project for the Neste. Furthermore, when we visited Vielle-Aure, we saw the fishing federation working on a new project: they have reestablished a brook to allow trout natural reproduction. This can be another point to focus on.

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