Entry to the Stockholm Junior Water Prize

France 2009

Presented by Damien MAURY and Léopold NOTO, students in the penultimate year of the baccalaureate in Civil Engineering at the Souillac Technical High School in the Department of Lot

Technical lecturer (Civil Engineering): Jean-Philippe Marquié, correspondent at the High School for environmental education

Design and production of river structures:

-fish hides
-fish passages

Brown trout

There are many varieties of trout and many strains, but specialists agree that all these forms constitute a single species: the brown trout This species, originating in Europe, was introduced to North America in 1883. Today it is to be found in all parts of Europe. The typical trout has a streamlined body well adapted to life in fast-flowing water. It has a conical head and its mouth is armed with small pointed teeth.

Its back and sides, brown, gold or silver in colour, are dotted with dark, coloured spots (often red). The trout feeds on worms, insect larvae, adult insects, etc. Its average length is 30 cm and its weight between 300 and 500 g. But in some rivers and streams it can reach more than 80 cm and weigh 7 or 8 kg.

Stockholm Junior Water Prize 2009
French entry

Title: **Design and production of river structures:**
-fish hides
-fish passages

Authors: Damien MAURY (age 17) and Léopold NOTO (age 17) , students in the penultimate year of the baccalaureate in "Civil Engineering" at the Souillac Technical High School in the Department of Lot

1 – Summary

We are students in the penultimate year at the **Souillac Technical High School** in South-West France. We are training in civil engineering. A project such as river structures is not part of our course, but as practical work our lecturers have allotted us production (in the civil engineering workshop) and installation (in site training) of items such as prefabricated urban furniture For the last two years we have been working on river structures, where the technical production aspect goes hand in hand with sensitivity to environmental protection.
To this end we are cooperating with organisations and institutions which can inform us on matters of river equilibrium.
Each year, the installation of the fish hides gives us an opportunity to take part in Nature Days (at the end of the school year), organised by the Midi-Pyrénées region, in the presence of local and regional councillors and of school pupils. (primary or secondary level) An information panel is always erected near the site of operations for the benefit of the public, and outdoor snacks round off the day.
Our High School has already acquired useful experience in the manufacture of fish hides. This year we decided to go ahead with the production of an experimental fish passage. We did a lot of work on a fish-passage project with macro-rugosities and, in the end we changed the model during the school year. Installation is in progress.

2 - Contents

1 - Summary
2 - Contents
3 - Abbreviations and acronyms
4 - Acknowledgements
5 - Design and production of river structures
- **5.1 Introduction**
- **5.2 From river modifications to environmental reconstruction**
- **5.3 The fish-hide construction project**
- **5.4 Construction of an experimental fish passage**
- **5.5 A project to enter the European arena**
- **5.6 Conclusions**

6 – Annexes
- **6.1Fish hides manufacturing techniques**
- **6.2 6.2 Innovative character of the project**

3 - Abbreviations and acronyms

AAPPMA: Association Agrée pour la Protection de la Pêche et du Milieu Aquatique (Association for the Protection of Fishing and the Aquatic Environment)
ONEMA: Office National de l'Eau et des Milieux Aquatiques (National Bureau for Water and the Aquatic Environment)
EPIDOR: Etablissement Public Territorial du Bassin de la Dordogne (Public Authority for the Territory of the Dordogne Basin)
SYMAGE: Syndicat Mixte pour l'Aménagement et la Gestion de l'Eau et de l'Espace (Joint Body for Management of Water and Land)

4 – Acknowledgements

Lycée Louis VICAT.
Claude Vigié, Principal, Joël Village, Practical Studies Supervisor, Marie-Christine Osmont, English teacher, Jean-Marc Bertrand, History and Geography teacher.
Puy d'Alon Middle School in Souillac: Pierre Rouxel, Philippe Teilhet, teachers.
Financial partners:
Midi-Pyrénées Region in the framework of *Projets d'Avenir* (Projects for the Future).
Crédit Agricole Nord Midi Pyrénées in the framework of *Tickets Passion* (a bank project supporting projects of local youth).
Other partners:
Fédération des associations de pêche du Lot (Federation of Anglers' Associations in the Department of Lot), Cahors.
ONEMA Toulouse, AAPPMA Gourdon. Syndicat des propriétaires riverains du Céou (Association of owners of property beside the River Céou)
EPIDOR Castelnaud La Chapelle. Agence de l'Eau Adour-Garonne (Adour Garonne Water Authority), Rodez. Direction Départementale de l'Equipement et de l'Agriculture (Departmental Authority for Infrastructure and Agriculture), Cahors. SYMAGE, Creysse.
Inspection Académique (Schools inspectorate) of the department of Lot: Serge Ricou

5-Design and production of river structures

5.1 Introduction

From very early times, human beings have lived close to rivers and great civilisations and cities have often developed along river banks. These rivers served multiple purposes, including water supply, power, evacuation of waste and food provision via fishing. This close relationship between rivers and humans led them to make profound changes to these ecosystems, modifying them according to their needs and to protect themselves from flooding.
These modifications led to a loss of biological diversity, in particular the disappearance of certain species such as migratory fish, whose passage was blocked by the construction of dams.

5.2 From river modifications to environmental reconstruction

In the last 30 years the perception of rivers has changed. Once seen simply as a resource to be exploited, they are now recognised as ecosystems to be protected and restored so as to ensure the continued provision of a benefit essential to life—water. Major efforts have been made to decontaminate waste water and attempt to restore some species of fish that had disappeared from our rivers, such as the Atlantic salmon in the River Dordogne. These efforts have been increased under the pressure of European policies, in particular the Water Framework Directive which requires all member-states to bring all their rivers into good condition by 2015.
This good condition is based on the presence of a balance of species of both fish and invertebrates in rivers and streams. To ensure this balance, it is today necessary not only to maintain efforts in waste-water treatment but also to restore the habitats of species, that is the places where they live, while respecting their needs and providing them with the means to move between these habitats. These movements are essential for many fish which undertake long migrations, especially at breeding time. The Water Framework Directive has defined the term “ecological continuity” to require that the possibility for fish to move freely be restored.
Today then, we have to reconcile operations which are still very much in evidence on our rivers (hydro-electricity generation, irrigation, drinking-water extraction) with environmental needs, in the spirit of sustainable development. However, this reconciliation can very rarely take the form of a “return to nature", i.e. demolition of infrastructure (such as dams). So it is necessary to carry out reconstruction of rivers, in particular of habitats favourable to fish, and modifications at the location of dams so that fish can pass.
Since humans have intervened to satisfy their needs or to protect themselves, they must now use their technology for the restoration of aquatic species.
It is in this spirit that the students of our High School have devoted themselves to these projects to help the environment and the fish. What we attempted to do, during our meetings with the authorities responsible for water, rivers and fishing, was to develop our knowledge and skills around a learning project that could bring technical solutions to the restoration of the rivers.

5.3 The fish-hide construction project

5.3.1. History of the project

This project resulted from a partnership between our High School and the Lot Federation for Fishing and the Aquatic Environment, which now, in 2009, is in its third consecutive year. While reading a review on fishing and river management, our Civil Engineering lecturer, Jean-Philippe Marquié, who is also our school's correspondent for environmental education, came across a project in a river in the Pyrenees which was based on the construction and installation of artificial hides for trout. The design of these structures provided an excellent basis for learning in the field of civil engineering applied to outdoor areas (gardens, green spaces, natural environments). From initial contacts with the Lot Fishing Federation a construction and installation project emerged.

In 2007, the first initiative was undertaken on the River Céou. The action was supported by a river contract[1] governed by EPIDOR. One of the clauses of the contract targeted the conservation and restoration of its potential to support fish. The project then continued on the Borrèze in 2008 and on the Bave in 2009.

5.3.2. The objectives of the project.

The aim of this project is to reconstruct resting habitats for fish, mainly trout which are the majority species in these rivers. These habitats consist of a fixed structure functioning as a hide.

The project should enable us to:

- establish collaboration between partners who habitually work in very different areas (fish and fishing management and building construction)
- create teaching material both for the students at the High School (construction of fish hides validates the students' training), and also for pupils in middle and primary schools who have learning projects on water and rivers (sensitising these youngsters to preservation of the aquatic environment),
- provide a channel of communication between all players in the protection of rivers (information boards were produced and installed on the river banks),
- play a major role in the re-diversification of river habitats, so as to improve the potential to accommodate fish and thereby the general position of the fish.

5.3.3. Why build these fish-hides?

Fish organise their lives around three activities: feeding, reproducing and resting. To these ends, they very precisely choose places with specific environmental characteristics. The hides

[1] A river contract formalises policy carried out at the level of a river and brings together all the players in order to bring about concerted action to protect and restore rivers while respecting use of water and the catchment area.

are habitats which enable fish to shelter from the light and from the current. They use them in rest periods, but also to hide from predators (the concept of a refuge area).
The hides may also constitute zones behind which fish, especially trout, can feed while benefiting from the shelter from the current so as not to use too much energy, and from the proximity of prey drawn in by the flow of water on either side of the hide. This defines the concept of a hydraulic shelter. In a resting or refuge-from-predators situation the fish do not compete with each other. It is primarily the volume which determines the capacity of the hide. When feeding, territorial species such as trout exclude their congeners so as to benefit from better conditions.

The water courses concerned by the installation of hides (the Céou, Borrèze and Bave) are rivers which mainly have trout (1st category rivers) along with sculpins, loach, minnows and chub. Following hydraulic works aimed at improving drainage conditions in periods of high water, some sections of the rivers have been modified. The modifications consist of smoothing the river bottoms and banks, and result in a reduction in the number of hiding places for fish. In fact, in these zones the bed presents as a smooth and even sloping (>1%) bottom in shallow water (predominantly pebbles). They are very unattractive to fauna because of the lack of shelter (under banks and debris, etc.).
Restoration of good living conditions for trout, especially by installing hides, will also benefit other species of fish. By diversifying the environment, these hides will replace lost natural habitats. They thereby provide the fish with rest areas and bases for hunting. In addition, they divert the downward flow. The current speeds up as it flows past the hides, which aids the oxygenation of the water, and causes the formation of a small trench downstream.

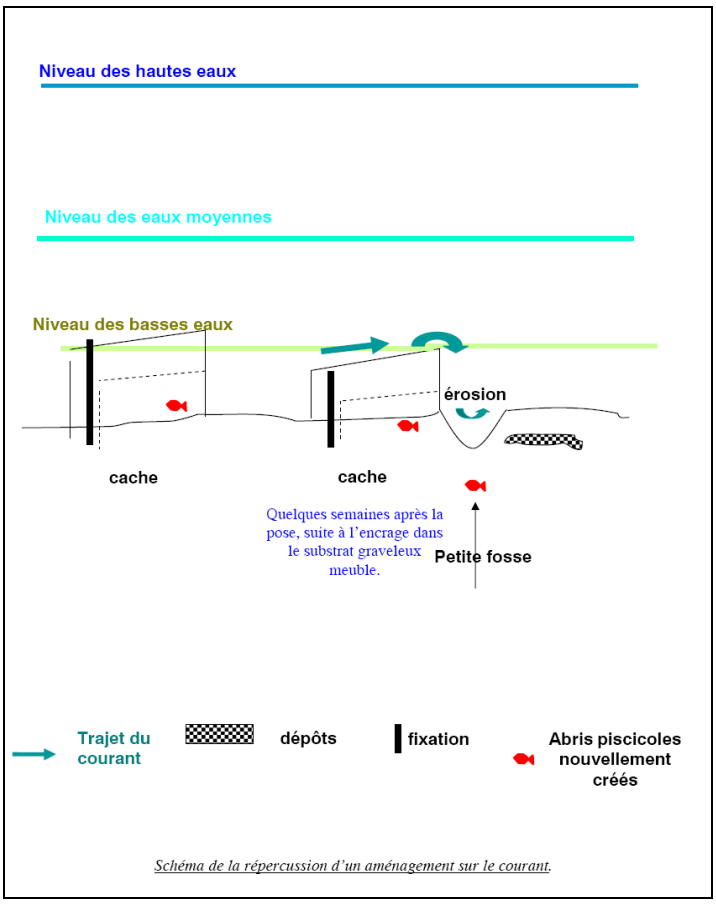


Schéma de la répercussion d'un aménagement sur le courant.

High water level

Average water level

Low water level

Hide, hide , erosion

A few weeks after installation, following anchoring in the mobile gravel substrate.
Small ditch

Trajectory of current
sediments, anchors, Newly created fish shelters
Diagram of the repercussion of an installation on the current.

Schéma du mécanisme de création d'une sinuosité du lit.

Hides in quincunx arrangement

Trajectory of current

Diagram of mechanism for creating a bend in the stream/river bed.

5.3.5. Stages in production of our fish hide model.

a) Manufacture
The hides are manufactured by us, students in the penultimate year of Civil Engineering at Louis Vicat Technical High School in Souillac. They are constructed using wooden shuttering into which reinforced concrete is poured. (See in the annexe the shuttering shapes and the details of manufacture of the wooden shuttering in the Civil Engineering workshop).

b) Appearance
The hides present a profile designed to offer minimum resistance to the current.
They are covered on the upper surface with a pebbled decoration designed to enable them to blend into their future environment as discreetly as possible.
The rear part is wide open and there are two openings on the sides to allow fish to hide there easily.

Fish hides

c) Fish hides already installed

Since 2007, 3 sites have been equipped with a total of 36 modules

Number of fish hides installed	**Location**	**Date**
12	River Céou at Laborie weir between Saint Germain du Bel Air and Concores	May 2007
12	River Borrèze in Souillac	May 2008
12	River Bave at La Vaute downstream of Saint-Céré Opposite the Chateau du Montal	June 2009

d. Notification of environmental impact of works

In order to comply with the regulatory framework on works on water courses (Water Laws), a notification of impact was prepared and submitted to the Water Police in order to receive an acknowledgement of notification that would authorise us to carry out these works. This notification describes the initial condition of the river, the content of the project, its potential impacts, the installation procedure and protective measures taken.

e) Conditions of installation

-selection of sites for installation

The location of sites must meet certain criteria:

- sufficient depth of water to submerge them,
- relatively fast-flowing water (lotic faties)
- A substrate sufficiently mobile to secure the hides without damage to the parent rock, but firm enough to guarantee a reliable anchorage (no sandy aggradations). Gravel substrate preferable.
- sufficient bank-side vegetation to shade the river or stream.

In fact these types of zone would be able to harbour fish if it were not for the lack of habitat. These are therefore the locations where our installations will be most useful.

-securing in the substrate

Securing is by metal stems into purpose-designed openings at the front of the hides, which will stabilise the blocks. In addition, the hides will be anchored in the substrate simply by the effect of their weight on the less dense base (see *diagram of the effect of an installation on the current*).

In any case this additional fixing will ensure that they are not carried away by the current when the water is low.

-conditions of installation

We install the hides ourselves in the water course, with assistance from the staff of the AAPPMA of the department of Lot and the local AAPPMA.

The fish hides are loaded by a fork-lift truck on to the load-carrying area of the truck and unloaded by sliding them down two wooden battens with a rope restraining the weight of the hides. (Unit mass: 108 kg)

The hides are brought to the river bank and then once more slid into the chosen site.

f) Communication and biological monitoring

To confirm the effect of the installations on the number of fish, monitoring has been undertaken by the Fishing Federation. This is done through electric fishing before and after installation of the hides to observe the degree of colonisation of these habitats. The initial inventory was carried out in 2007. In 2009, a first verification is to be carried out as soon as flow conditions allow.

Electric fishing in the Céou river to establish the initial inventory before installing the hides

Communication actions were quickly undertaken with the design and installation of information boards. The site also provided opportunities to organise meetings with local partners.

The students in our class and teachers with the information panel and a fish hide ready to be placed in the water.

5.4. Construction of an experimental fish passage

5.4.1. History of the project

This project was begun in 2008 in the same context as the fish-hide project—that is: in collaboration with the department of Lot Fishing Federation, within the framework of the River Céou contract. This river, like many others in France, has a large number of quite old small dams and weirs, which are usually at the location of abandoned water mills. In the absence of any sluice gates, they have become totally impassable barriers for migratory fish. In the context of the fish-repopulation activities of the river contract, a project has been envisaged on one of the weirs of the river.

5.4.2. Why and how are we building a fish passage?

A fish passage is a civil engineering project constructed at the location of a dam which is blocking the migration of fish. The principle behind its construction is to break down the total water-level drop of the dam into a series of smaller drops whose characteristics (height, flow speed) are compatible with the swimming and/or jumping capabilities of the fish.

Zones are needed between the falls of sufficient size to enable the energy generated by the mass of water and the height of the fall to be dissipated. It is also possible to construct a ramp with a slope varying between 3% and 16% in which are placed structures (blocks, chevrons) which dissipate the energy causing flow speeds compatible with the swimming capabilities of the fish.
Depending on the species, the size and the water temperature, fish are capable of swimming at speeds of 50 cm/s (a small eel) to more than 3 m/s (a large salmon) and jumping 30 cm (a small trout) to more than 1 m (the large salmon). The civil engineering for the fish passage will therefore be dimensioned for a given flow so that the hydraulic characteristics are compatible with the physiological capacities of the species migrating in the river under consideration.

5.4.3. The objectives of the project

The purpose of the project is to build a structure to enable fish to pass at the location of a dam. This project complements the fish-hide project on the same river. The fish passage consists of a concrete structure attached to a base and fixed into the dam. The objectives are identical to those of the hides in terms of collaboration and teaching support. They differ, however, in:

- their contribution to restoring the free movement of fish,
- facing heavy constraints in a river-based public works site (isolation of the site, risk of flooding, safety, use of materials and risk of pollution).
-

5.4.4. Our fish-passage construction project

a. From the specifications of the Fishing Federation to the teaching project.

The first task was the transposition of the specifications (a fish-passage structure on the River Céou) into a teaching project (prefabricated parts followed by training site *in situ*) This task involved the production of plans and calculations based partly on the constraints of civil engineering, but mainly on the hydraulic constraints specific to these structures. This task therefore implies a basic level of knowledge in civil engineering applied to hydraulics, as well as environmental and fish-science knowledge. We have therefore used the recommendations of existing documentation, principally the works of Michel LARINIER[2] of ONEMA who is a specialist in fish passages. Our work has been constantly monitored and corrected by the specialists of the Lot Fishing Federation.

b. Our various technological choices.

The first technological choice was for a macro-rugosity passage. It involved a platform with a slope varying between 3% and 8% on which were placed concrete blocks providing the rugosity necessary to reduce the energy of the current and to raise the water line. These macro-rugosities were prefabricated in the workshop. Unfortunately the specific constraints of the site did not in the end allow us to install this device at the dam (slope too great).
So we redirected our efforts towards another variant of the fish passage, a sequence of pools separated by bulkheads fitted with saddles.

---

[2] Co author of *Guide technique pour la conception des passes naturelles*, GHAPPE Report RA.06.05-V1 December 2006 by M. LARINIER, D. COURRET and P. GOMES
CSP – CEMAGREF – Groupe d'Hydraulique appliquée aux Aménagements Piscicoles et à la Protection de l'Environnement à l'Institut de Mécanique des Fluides, Avenue Camille Soula, 31400 TOULOUSE

- The work on the macro-rugosities

This is a sloping masonry structure with a lower slab in concrete and sides in blockwork. The picture below provides an illustration.

The lower slab is in exposed aggregate concrete (the exposed aggregates are visible) poured on site from a concrete-mix vehicle, using a pump.

The type of structure adopted is block macro-rugosity (13 macro-rugosities can be seen above).

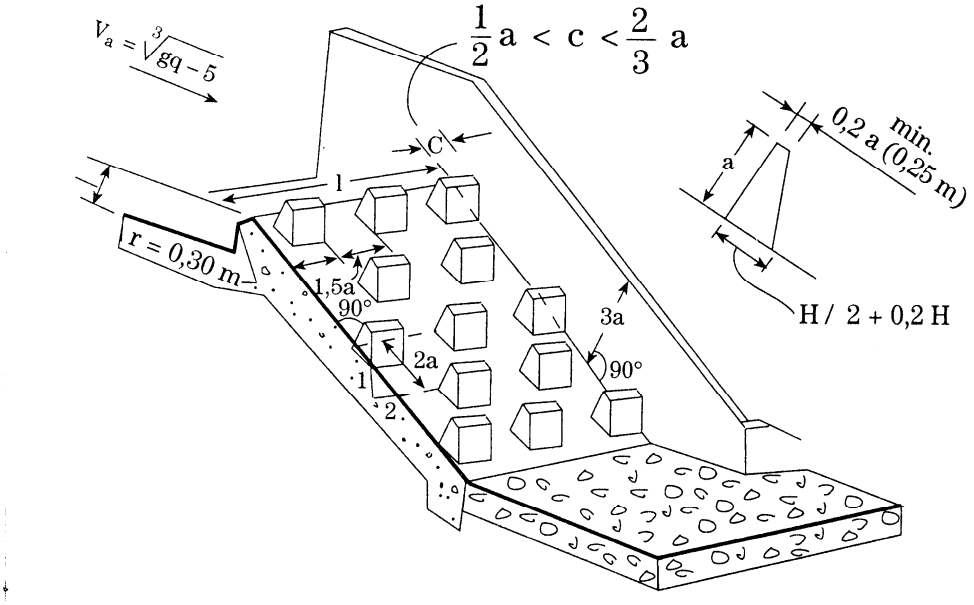
Their use is limited to low flow rates per unit width and to areas with no ice formation and where the presence of floating objects is not anticipated.

This lower slab must be fitted with PVC tubes perpendicular to the slope, 40 mm in diameter, evenly distributed, of an initial length greater than the thickness of the slab which should then be trimmed to the level of the upper surface of the slab. These PVC tubes are filled with non-shrinking mortar and a steel stem is inserted allowing fitting of the macro-rugosities which had been the subject of a specific design study. The macro-rugosities were prefabricated in the Civil Engineering workshop by students using wooden shuttering (reverse pouring, the reinforcing steel being in the upper part).

The possibility of cavitation in the blocks imposes an upper limit to the acceptable flow rate.

The calculation of the dimensions of the structures for smoothing by block macro-rugosities is carried out in accordance with the diagram below. The flow per unit width, q, must not exceed 5.6 m^2/s, and the velocity of approach, Ua, must be lower than the critical-condition speed:

$$q \langle 5{,}6 m^3 / s \qquad Ua \leq \sqrt[3]{gq}$$



Optimal operating conditions are: $$Ua = \frac{\sqrt[3]{gq}}{2}$$

Minimum height of the macro-rugosities is 300 mm.
The chemical product to deactivate the non-shrink mortar and the aqua concrete was chosen to cause no environmental harm. (see product information sheets)

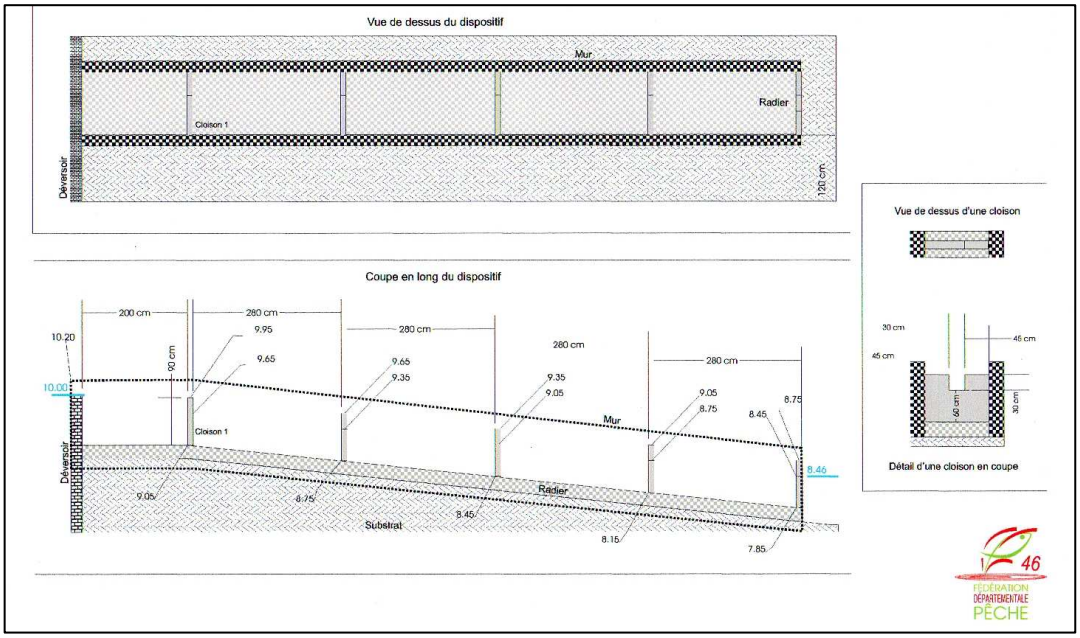
Operations sequence for the production of fish passages: (Civil Engineering)

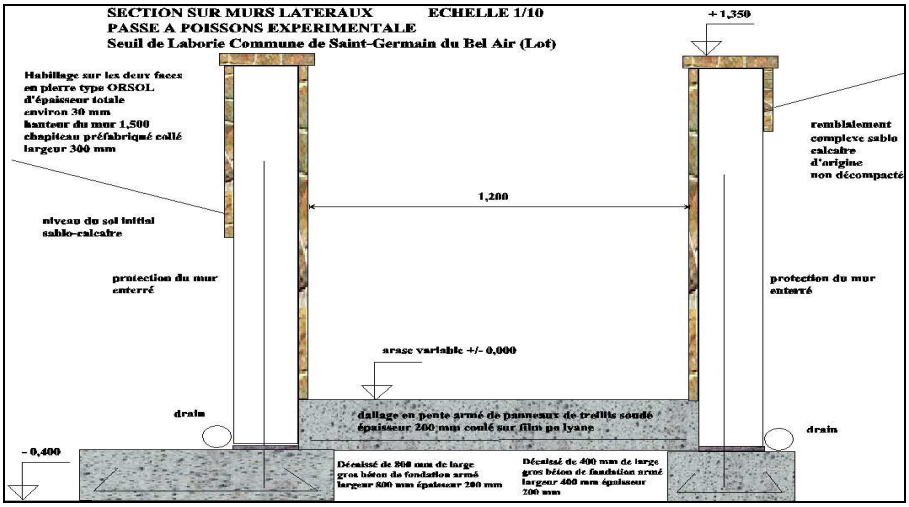
Operation No.:	Designation:
1	Stake out and outline passage and downstream wall.
2	General excavation with mini-excavator followed by compacting Lay footings 400 mm wide (side walls and downstream wall the width of the river)
3	Place reinforcement bars then pour concrete for foundations of side walls and downstream wall
4	Build side walls in hollow concrete blocks
5	Place fabric and reinforcement for sloping slab
6	Fit PVC tubes enabling macro-rugosities to be sealed
7	Pour sloping slab
8	Deactivate cement
9	Saw off PVC tubes
10	Attach stones to three sides of hollow concrete blocks (side walls and downstream wall
11	Make joints between stones stuck on side walls and downstream wall
12	Place anti-shrink mortar and pin macro-rugosities
13	Clean and tidy up

- The pool and saddle passage
The plans were proposed by the Lot Fishing Federation (ground view and longitudinal cross-section).
The Louis Vicat High School was responsible for the Civil Engineering design (Foundations, base, reinforced concrete separation items, side walls in shuttering panel, covering with artificial stones, coping on side walls, etc.).

Pool-type fish passage. Treshold "Laborie" on the Céou river

1-Document of the Fishing Federation.





2-Draft cross section made by Louis Vicat students showing the levelled upper surface of the poured concrete and details of the facing in ORSOL artificial stone.

The terracing work on bedrock was supervised by Nicolas BORDES of Onema Toulouse and Laurent FRIDRICK of Lot Fishing Federation. This is a complex work under the water line.

5.5 A project to enter the European arena

We envisage a European educational project, as we already have European partners interested:
In Finland: www.salpaus.fi our contact is Ulla Pantsar email ulla.pantsar@salpaus.fi
We have already registered a Leonardo Da Vinci project together and they have a Natural Resource Management Department.
In Iceland: www.fsu.is our contact is Ulfur Bjornsson email ulb@fsu.is
In Austria: www.hak-ibk.tsn.at our contact is Barbara Ditterich email b.ditterich@tsn.at
The above contacts were made at an eTwinning seminar on climate change at Roskilde in Denmark in March 2009.
They are interested in the project

5.6 Conclusions

This work on river modifications has enabled us to put our knowledge of civil engineering into practice in resolving practical problems, from the planning and design, stage through prefabrication of concrete items in the workshop, to on-site installation.

It was also an opportunity to discover, together with our partners in the operation, the problems in maintaining biodiversity in the rivers of the Lot department, to link this issue to the wider issue of preservation of water quality, and more generally to grasp the importance of environmental protection, in both our professional and personal lives.

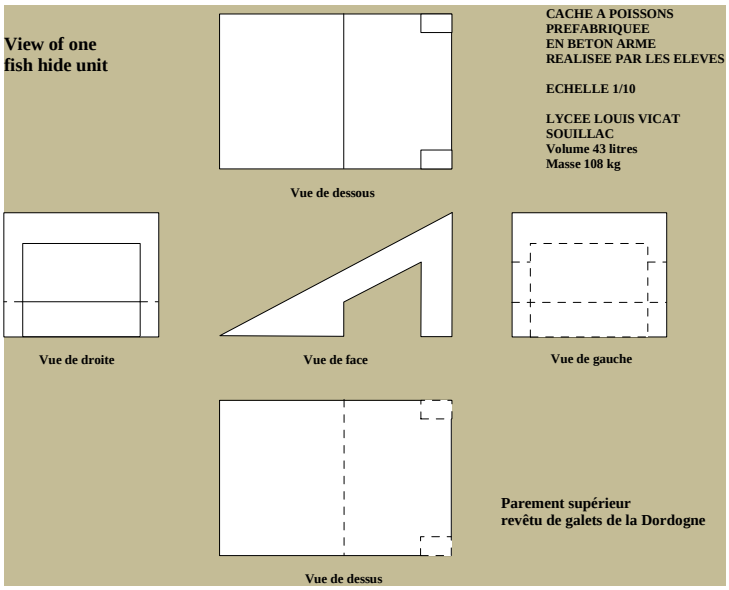
Our many exchanges with specialists, councillors and activists have made us aware of the need to approach every question from several angles, in order to construct a final solution combining them all.

Finally, the most gratifying aspect of our project was without doubt the opportunity to pass on our newly-acquired knowledge to younger pupils in primary and middle schools, along with taking part in Nature Days which made us the ambassadors of a great cause, backed by our technical knowledge, to the general public.

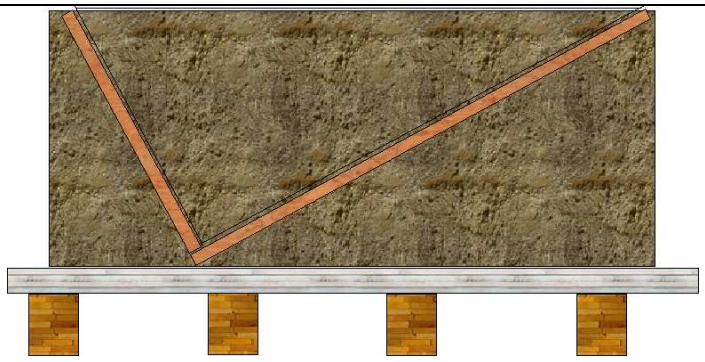
6 – Annexes

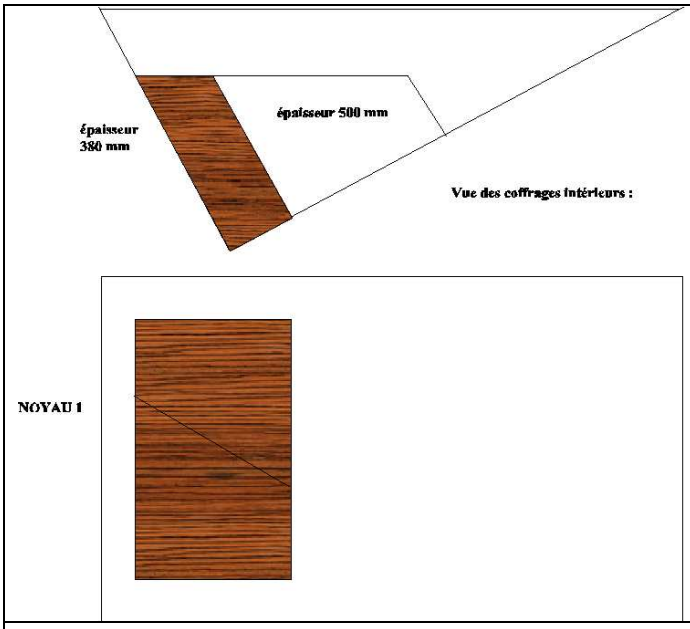
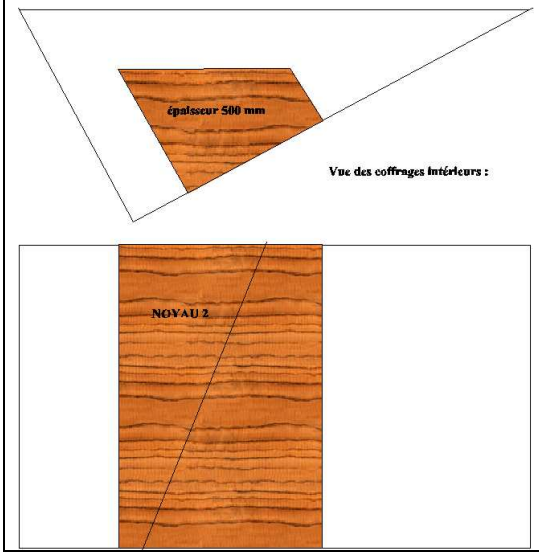
6.1Fish hides manufacturing techniques

a) Shuttering designs for a fish hide.



b) detail of the fish-hide shuttering

	Design of wooden of fully-removable double shuttering by two teams of students. Number of reuses = 5 The base is in grey. The cross panel is dark and the lower shuttering panels are light-coloured.
	The problem of de-shuttering was solved by designing two bevelled pieces of wood (removed laterally). Here is an example of core 1 (dark colour) between the two feet of the fish hide.

	
	Detail of core 2 (light colour) across the entire width of the fish hide. De-shuttering by lateral movement of two sections (bevelled shuttering).

6.2 Innovative character of the project:

Over and above the unusual partnership between future professionals in the construction industry and a Departmental Federation in charge of fishing and protection of the aquatic environment, the innovative character derives from the fact that this is a unique global action on a water course, which starts with an analysis of an existing fish population in order to carry out modifications to favour a protected heritage species. the brown trout

The actions undertaken have followed a scientific logic, associated with technical skills in civil engineering, **resulting in practical constructions which can be an example to other areas and a reference in issues of fish management**.

Very practical measures were taken before and during the project which will serve as a basis for measuring the effectiveness of the modifications carried out, for example:

- a diagnostic study of the catchment area of the
- audit of the initial status of the environment and populations by electric fishing and inventories of fish **with participation of students**,
- **relations established with various technical and administrative partners** in order to carry out the program in a concerted fashion (Adour Garonne Water Agency, ONEMA, DDEA, Midi Pyrénées Regional Council, Lot Departmental Council, St Germain du Bel Air local authority joint board, Céou river contract administered by EPIDOR, etc.),
- the pedagogical aspect of the operation via Midi- Nature Days and contributions by ecology specialists in class.
- Monitoring evolution of the environment and fish populations by electric fishing over several years,
- In the case of the fish passages, monitoring their efficiency will be carried out by marking fish downstream of the constructions and fish inventories will be carried out upstream in subsequent years, in order to establish the effectiveness of the constructions and their real value in aiding re-establishment of fish populations in the environment upstream, Migration can be monitored by capturing "wild" fish downstream of the constructions, and removing their adipose fin,
- In addition, one of the major issues in the Céou is quantitative management of water. The owner of the construction on which the fish passage has been installed has participated in remaking the weir gates in order to guarantee a stable water level over several hundred metres and in this way to provide a refuge zone for fish in periods of severe low water levels, at the same spot where the fish hides and fish passages have been installed.