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Raising awareness of
public policies

Why is it needed to restore river continuity?

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Ministère
de l'Écologie,
du Développement
et de l'Aménagement
durables

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3- Article R214-109 of the French Environmental Code (Code de l'environnement), defining an obstacle to river continuity.

Introduction

In France, more than 60,000 structures[1] - dams, locks, weirs and mills – have been recorded on rivers and are potential obstacles to river continuity. The European Framework Directive (EFD), the French Water Act of December 2006, the French National Eel Management Plan[2] and now the Grenelle 1 Act of 3 August 2009 with its objective of implementing a "trame verte et bleue" (green and blue infrastructure), all point towards the need to ensure biological continuity between major natural sites and within aquatic environments. In practical terms, these regulatory texts lead us to increase our collective efforts and actions in favour of restoring river continuity. The ambitious aim is to restore a good ecological status to two-thirds of water bodies by 2015.

What is river continuity?

The notion of river continuity was introduced by the Water Framework Directive in 2000 and is defined as the free movement of living organisms and their access to areas which are essential to their reproduction, growth, food or shelter, the efficient transfer of natural sediment and the correct operation of biological reservoirs (connections - especially lateral, and favourable hydrological conditions)[3].

Weir on the Maria (Nièvre), designed for the supply of drinking water in 1932 but abandoned 20 years later. This obstacle was removed in 2004.

More than 60,000 weirs and dams on rivers in France

Since ancient times, people have built dams and weirs in rivers in order to produce energy, facilitate navigation, collect and transport water for consumption, irrigation or in order to create ponds for fish farming. French rivers have thus been affected by the development of a very large number of hydraulic structures, mainly mills.
The discovery of new means of producing energy – steam engines and hydroelectric turbines – then led to their decline, with the number of working mills falling steeply at the end of the 19th century. But during recent decades, numerous hydraulic projects (river stabilisation, protection of infrastructures, etc.) have led to a sharp increase in the number of weirs, most of which are under two metres tall.
At the start of 2010, more than 60,000 structures were recorded on French rivers. According to a national inventory compiled by the Office national de l'eau et des milieux aquatiques (ONEMA – French National Agency for Water and Aquatic Environments), more than half of them do not have a recognised use.

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Moulin Marin weir on the Besbre – Allier

***A weir*[4]** is a stationary or mobile structure which blocks all or part of a main river channel. In general it is less than 5 metres in height.

© Agence de l'eau Adour Garonne

Grandval dam on the Truyère (Cantal)

***A dam*[4]** is a structure which blocks more than the main channel of a permanent or intermittent river or an original river bed*.
It almost always exceeds 5 m in height.

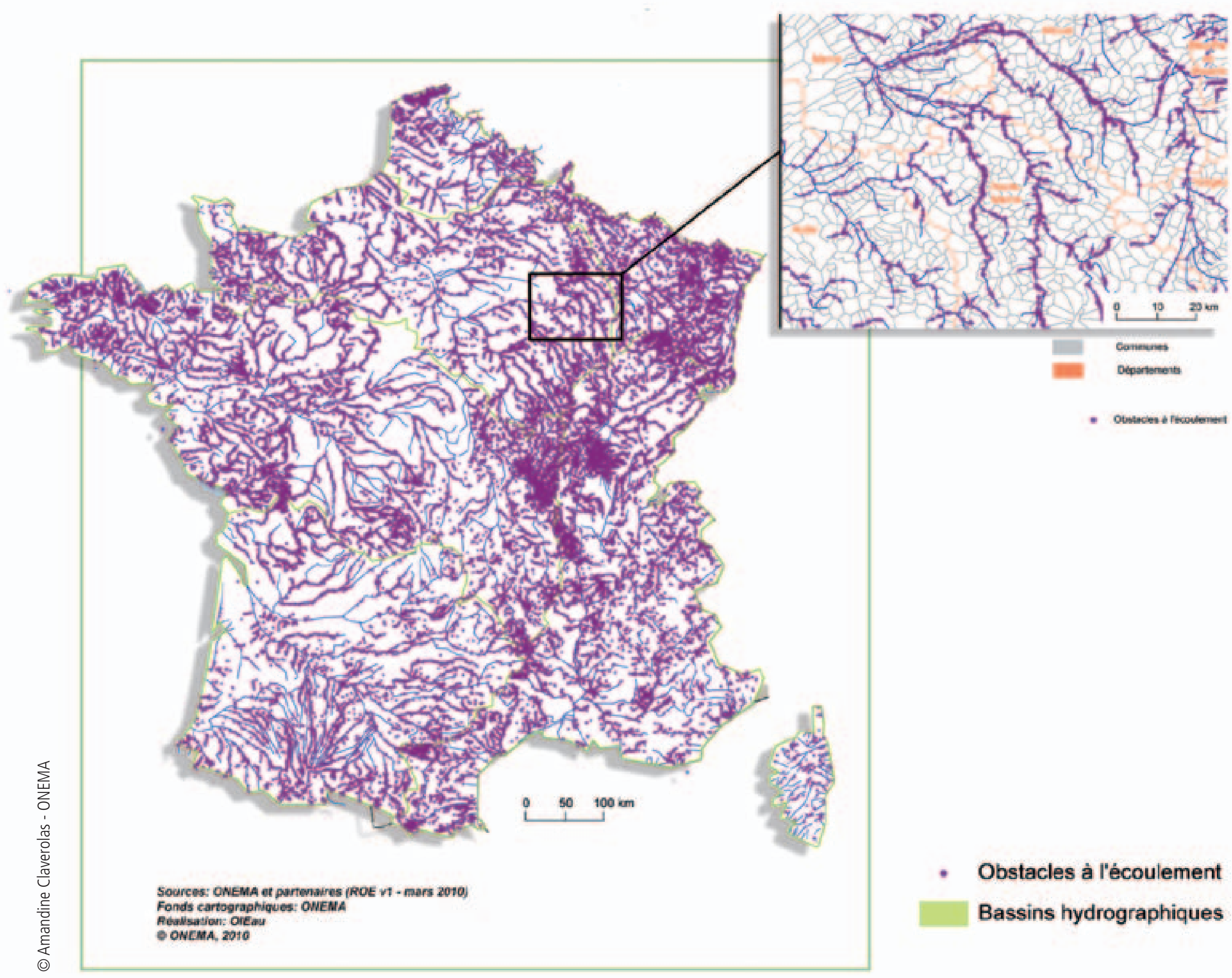
4- Defined by SANDRE (French National Service for Water Data and Reference Datasets Management)

National list of obstacles to river flows: improving our understanding of obstacles and assessing their impacts

In order to improve our knowledge of the dams and weirs that fragment French rivers, ONEMA has established, with its partners, a Flow Obstructions Database (ROE – référentiel des obstacles à l'écoulement) with the aim of listing all hydraulic structures that have already been identified throughout France. The information given – unique national code, location and characteristics – will be limited but essential and common to all stakeholders in the fields of water and town and country planning. This database is published on the Eaufrance website and shows the position of obstacles on maps and aerial photographs. The data for each structure can be downloaded.

This database will be gradually supplemented by a database concerning information on river continuity (ICE – information sur la continuité écologique). In particular, it will focus on the opportunities for fish species to negotiate these structures and on the risk of impacts on sediment transport. The data required for the assessment shall be collected according to a harmonised national protocol. A methodology is currently being developed for field data collection and for impact risk assessment.

Obstacles to flows in metropolitan France recorded in the National Database



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5- http://www.eaufrance.fr/spip.php?rubrique87&id_article=54

A hindrance to river continuity

Obstacles in rivers cause disturbances and have impacts on river continuity, which vary according to their height and situation – from the mouth to the source of the river – and according to the accumulated effect of a series of such obstacles. Therefore a major impact on a river could be caused by a single, very damaging structure or the accumulated effects throughout the length of the river of a series of small structures which may individually have only a small impact. For example, the département of the Landes, which has a relatively flat topography, has an accumulated water head of more than 239 metres[6] for all of its rivers.

The alteration of river continuity should therefore be studied globally, taking account of the accumulated effects.
However, given the diversity of structures and watercourses, the impacts described hereafter cannot be generalised and do not appear at the same time, nor do they occur systematically. Nevertheless, recognising them facilitates an understanding of the different observable phenomena.

Significant modifications to hydrological regimes and flows

By creating artificial waterfalls during the construction of one or more hydraulic structures, the water level and the natural gradient of the river are modified. Running waters are thus transformed into a series of impoundments of stagnant water that may cause:

- Slowing and uniformisation of flows
- Temperature changes
- Increased eutrophication, represented, in particular, by proliferations of algae due to the input of nutrients (phosphorus, nitrogen, etc.) originating from the catchment area and the fact that there is little renewal of water.
- Diminished amounts of oxygen dissolved in the water
- Reduced quantity of water during the low flow period* due to the increased evaporation of stagnant waters in summer
- Reduced flow rate downstream of the structure (prescribed flow), or sudden flow rate variations (water releases) in the event of the diversion of water.
- Reduced[7] self-cleansing capacity of the river
- Increased depth of water upstream of the obstacle, accompanied by the immersion of banks due to the variable widening of the river according to the height of the structure.

6- M. Chanseau "La demarche mise en oeuvre par le département des Landes" Seminar: Restoring river continuity: a key strategy of the Eel Management Plan, January 2010.
7- P. Namour (1999). "Auto-épuration des rejets organiques domestiques. Nature de la matière organique résiduaire et son effet en rivière".

© Sylvain Royet - Syndicat intercommunal pour l'aménagement du Couasnon

Proliferation of aquatic vegetation due to stagnant water in an impoundment of the Couasnon (Maine-et-Loire)

© Philippe Bobel-Onema

Severe low flow downstream of a hydraulic structure on the Touyre (Ariège)

When these structures are associated with a water abstraction point or a leat supplying a mill, for example, they contribute to the uniformisation of the river flow rate at a very low level for much of the year. They also reduce the frequency of flow rate variations linked to small floods, in particular .

Immobilisation of sediments upstream of the structures

A river is a continuous flow of solid coarse or fine materials which are dislodged from the catchment area. In general, the obstacle may cause a blockage of the sediment flows and a downstream deficit, creating an imbalance in the river dynamics and affecting the bed morphology. As sediment transport and liquid transport are naturally balanced in the river dynamics, the deficit often generates river bed erosion downstream of the impoundment and causes the disappearance of substrates which are favourable to the life and reproduction of aquatic species. According to how much sediment is trapped by the obstacle, erosion and deepening of the bed downstream could lead to the undercutting of bridges and other civil engineering structures.

© Jean-René Malavoi

Sediments blocked by the obstacle

Absence of solid materials

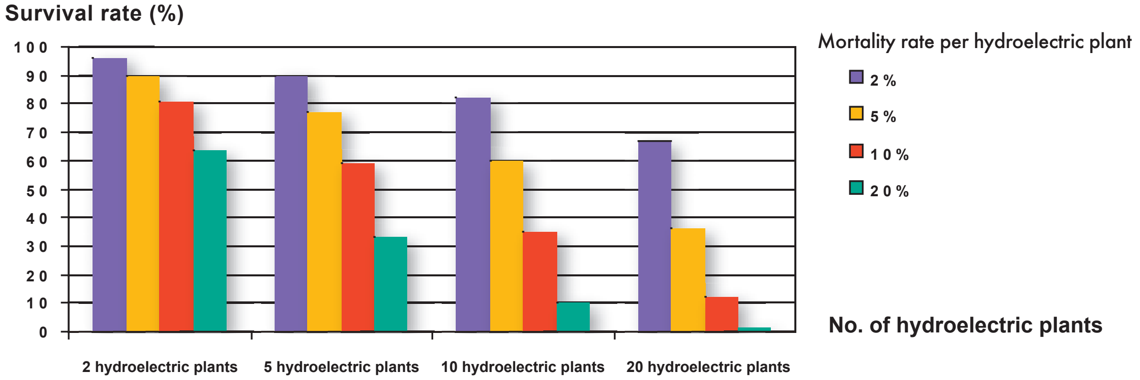
Sediments of the river (the Ardèche) are trapped upstream of the weir

Restriction or prevention of the mobility of species and access to their habitats

The opportunities for the movements of species are drastically reduced by the obstacles, which are impassable to a greater or lesser extent, and by the segmentation of rivers due to a series of obstacles.
According to estimates, hydraulic structures may be responsible for the 44% reduction in eel density since 1893, whereas the turbines of hydroelectric plants could cause a mortality rate of approximately 10% to 20%, as a best-case scenario, for eels returning to the sea[8].

In fact, all species of fish need to move variable distances along the river in order to complete their life cycle: reproduction, feeding, growth, etc. The major diadromous* migratory species: eels, salmon, shad, lamprey, etc., which may make journeys of several hundred kilometres between the estuary and the upstream catchment areas, are especially affected. Their journeys towards feeding or reproduction areas become increasingly difficult or even impossible. This results in a shortfall or absence of spawners in the spawning grounds and, consequently, a reduction in the renewal of the populations. The result is a clear drop in numbers, or even the extinction of the species. The wild salmon, which is considered to be vulnerable in France, has thus disappeared from the majority of major French rivers: the Rhine, Seine, Garonne, etc.
Finally, the fragmentation of the areas of distribution facilitates the isolation of populations. This compartmentalisation prevents any genetic exchanges between different groups of the same species, increases the risks in the event of pathologies and reduces the opportunities for escape and possible recolonisation following accidental disturbances (pollution, etc.).
These impacts influence the status of populations in combination with other anthropogenic factors, fishing-related pressures and the global evolutions of biotopes and species.

Survival rates according to the number of hydroelectric plants and the mortality rate at each of the plants



This chart clearly shows the impact of the accumulated effect of obstacles to river flows on migratory fish populations. For example, if 1,000 eels must negotiate a series of 20 turbines, each with a 10% mortality rate, only 120 eels will reach the sea.

8- French Eel Management Plan – national component – approved on 15 February 2010 in application of regulation R (EC) no. 1100/2007 of 18 September 2007, MEEDM, MAP, ONEMA: 116 p. + appendices.
9- Especially the case for the eel, sturgeon and the Rhône rock pickerel, included on the IUCN (International Union for the Conservation of Nature) endangered list for 2008.

Regulatory context at the origin for the promotion of environmental restoration of aquatic environments

All of the constraints on aquatic environments are increasingly leading to the implementation of regulations whose purpose is to achieve the European requirement of good water status by 2015.

Achieving good water status by 2015: a powerful national ambition and a target set by a European Directive

The Water Framework Directive (WFD) of 23 October 2000 sets Member States the target of not degrading rivers and achieving good river status by 2015. "Good status" is based on an assessment of the chemical and ecological status of our rivers. The ecological status includes physico-chemical and biological parameters, including the diversity and abundance of animal species – invertebrates and fish – and plant species found in our rivers.

There is, however, a significant risk of failing to achieve this good status. The inventory conducted in 2004 revealed that for 50% of water bodies, there was a risk of "failing to achieve good water status", for which the degradation of the hydromorphological conditions of rivers is often a decisive factor. This degradation, which is primarily a result of the straightening, resizing or canalisation of rivers and their fragmentation by obstacles, alters the quality of the habitats of different aquatic species. However, these habitats allow for colonisation by numerous invertebrates and plants, form refuges and are essential to the reproduction of several fish species. They are also spawning grounds for fast-water species such as salmon, trout, barbel and gudgeon. The diversity and abundance of species depend on the diversity and quality of the habitats.

However, these habitats directly depend on three major, constantly interacting parameters:

- Hydrology: quantity of water, velocity and heterogeneity of flows, seasonal variations in flow rates.
- Physico-chemical conditions: light intensity, water temperature, oxygen content, conductivity, acidity, pollutant content, salinity.
- Morphological conditions: river bed profile, heterogeneity of flow patterns* in habitats: alternating fast, still and deep waters – and the bank structure.

The improvement of hydromorphological conditions and river continuity, which is necessary for re-establishing the correct ecological process of the river, thus contributes to achieving the good water status required by the European directive and to supporting biodiversity.

Making hydraulic structures safe: a requirement of the Code de l'environnement (French Environmental Regulations)

In addition to the obligations of the WFD in relation to the protection of river continuity, hydraulic structures are subject to safety rules defined by the French Code de l'environnement (Environmental Regulations). All structures exceeding two metres in height are now concerned[10], as new provisions aiming to ensure the safety of hydraulic structures other than hydroelectric dams have been introduced.

An assessement of recent river restoration projects (aiming to re-establish a flowing river system) reveals that public safety is the main reason for removing an obstacle. However, the environmental benefits of these interventions – permanent restoration of continuity – are very regularly taken into consideration in the analysis of possible solutions and thus consolidate the decision made initially on the grounds of public safety.

10- Article R 214-112.2 of the French Environmental Code

Launch of the National River Restoration Plan in 2009

On 13 November 2009, the French Secretary of State for Sustainable Development announced the launch of a national action plan for the restoration of river continuity, with five main thrusts:

1 **Greater knowledge of weirs and dams,** including the implementation of the national database for obstacles to river flows, accompanied by an assessment of the impact of each obstacle on river continuity.

2 **Definition of priorities of action for each basin,** shared by all government departments and public institutions. This will be based on water management and development schemes, the Water Framework Directive programmes of measures* and local initiatives, while also taking account of the performance obligation relating to the Eel Regulations[11].

3 **Revision of the 9th Water Agency programmes and target contracts,** allowing for the release of the funding required to mobilise project owners and improve the 1,200 priority obstacles by 2012.

4 **Deployment of the Water Police (Police de l'eau):** a multi-annual programme of interventions on the most disruptive obstacles to fish migrations will be implemented in order to coordinate the actions of the water police and the incitement measures carried out by water agencies.

5 **Assessment of the environmental benefits of the measures carried out**

The restoration of river continuity concerns the full length of the river, from the first marine structures, such as tidal flaps, through to upstream hydraulic structures, and must therefore involve all public and private stakeholders affected by this important issue.

The plan will ideally aim to remove or level hydraulic structures that have no further recognised economic utility and will favour management or improvement solutions for weirs and dams that are still of use .

Upon the launch of the national plan, the Secretary of State announced the decision to remove the large dams at Vezins and La-Roche-qui-Boit on the Sélune (département of the Manche). These structures were impossible to improve in order to allow for the movement of migratory fish, whereas the river had been classified for this purpose. The removal operations will include a technical and financial support plan for the local authorities affected by the project and will be conducted in an exemplary manner with all of the interested parties.

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Barrage de Vezins (Manche).
The removal of this 36-metre tall structure was announced in 2009 by the French Secretary of State for Sustainable Development.

11- The French Eel Management Plan (Plan de gestion de l'anguille) – national component – approved on 15 February 2010, includes accessibility commitments for spawning runs* and downstream migrations* on 1,555 structures identified in the Priority Action Area (ZAP – Zone d'Action Prioritaire). Cf. paragraph VI.6.2.3: Identification objectives for the Priority Action Area (ZAP).

12- Circular of 25 January 2010 relating to the implementation by the State and its public institutions of an action plan to restore river continuity.

Improving or restoring river continuity: possible solutions

There are several ways to eliminate or at least reduce the negative impacts caused by these hydraulic structures, from their complete removal to the creation of fish passes. These solutions have very different aims; their efficiency and choice are strongly influenced by the local context.

Choosing between solutions with different aims

Removal of hydraulic structures

One of the most effective and permanent ways of helping to improve the operation of aquatic environments and the quality of water bodies is probably the removal of structures. This solution is recommended for structures that are currently abandoned, unused or without economic, heritage or scenic benefits. Indeed, this option offers many advantages in terms of completely re-establishing river continuity and being simple to manage thereafter.
The removal of an authorised[13] hydraulic structure may be envisaged, at the owner's request, if the maintenance and upgrading costs for the structure exceed the benefits to be derived from keeping it in service. A restoration of the river with the removal of the obstruction may also be envisaged by the Prefect of the département if such hydraulic structures are incompatible with environmental issues and especially with French commitments with regard to European legislation: Water Framework Directive, Eel Plan, species in critical danger of extinction and the Fauna-Flora Habitat Directive.

Example 1

Removal of the Fatou dam on the Beaume (Haute-Loire) – 2007

Built in 1907 to a height of over 6 metres, the Fatou dam was intended for hydroelectricity production. It went out of service in the 1960s and the Etablissement Public Loire became its owner. At this time, the structure was in a poor state of repair, blocked the passage of fish and prevented the movement of 6,000 m³ of sediments accumulated upstream. Given the problems of public safety and river continuity, the structure was dismantled in the summer of 2007.

© S. Nicolas – FDPPMA Haute-Loire

The Beaume, a tributary of the Loire prior to removal of the Fatou dam.

The Beaume, after removal in the former impoundment area.

13- A structure whose existence has been recorded in an administrative deed or for which full ownership rights have been established.

Lowering of hydraulic structures

Reducing the height of the structure or creating a permanent localised opening, combined with improved management, may also be considered as an alternative solution for structures which are of heritage or scenic interest. This solution may be implemented for technical reasons or as an intermediate stage with a view to subsequent total removal.

Example 2

Lowering the weir at the Moulin de Régereau on the Vicoin (Mayenne) – 2009

The Vicoin Basin Association has embarked on a multi-annual river morphology restoration programme. Following major interventions carried out on other structures in 2008, a spectacular new operation took place at the Moulin de Régerau (Origné) in the autumn of 2009. A single structure, situated far downstream, exclusively influenced fish migration throughout the entire length of the Vicoin. In order to allow fish to negotiate this obstacle, the association first contacted the owners who, proud of their heritage, were convinced of the usefulness of the project but wanted to retain the water supply to the mill. The technical solution adopted consisted of lowering the mill weir by 1.30 m in relation to a water head of 2 m. The remaining difference in height was compensated by the creation of consecutive basins. The result was an aesthetic success, which completely satisfied the owners and was also ecologically successful because since the site was refilled with water, the owners have witnessed the upstream movements of fish.

The lowering of the weir helps to reconcile river continuity and heritage conservation.

Opening of sluice gates

If a structure retains strong scenic or heritage-related benefits, the opening of sluicegates (temporarily, periodically or permanently,) according to the situation, is an interesting intermediate solution which may be specified by the regulations of Water Management and Development Schemes (SAGE – Schémas d'aménagement et de gestion des eaux).

Example 3

Coordinated management of sluice gates on the Ourdon (Mayenne and Maine-et-Loire) – 2008

The Local Water Committee for the SAGE, the Mayenne and Maine-et-Loire fishing federations and the two Oudon river management associations signed a coordinated management charter for the sluice gates responsible for opening the structures during the winter period. The private owners, who were not signatories but were the intended recipients of this charter, were asked to follow the scheduled management recommendations.

Example

4

Opening of the sluice gates on several hydraulic structures on the Vence (Ardennes) – 2004

The presence of 11 structures on the Vence – a tributary of the River Meuse – disrupts the river continuity. While these structures are no longer used for hydroelectricity generation which was the original reason for their construction, they nevertheless remain of significant interest for heritage-related reasons. In light of this interest and the strong opposition to any removal of these structures, it was agreed to keep the sluice gates on several structures permanently open.

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The opening of sluice gates on a structure on the Vence, synonymous with the restoration of river continuity.

Contruction of fish passes

When the aforementioned solutions cannot be envisaged and if the aim is the preservation of continuity for fish migration, schemes allowing fish to negotiate the structure may be implemented. However, these fishways are often specific to one or more species and are only relatively effective, while demanding considerable monitoring and maintenance in order to guarantee their efficient operation. Despite the constant progress in techniques, research and development, the best schemes remain less effective than situations in which there are no obstacles.

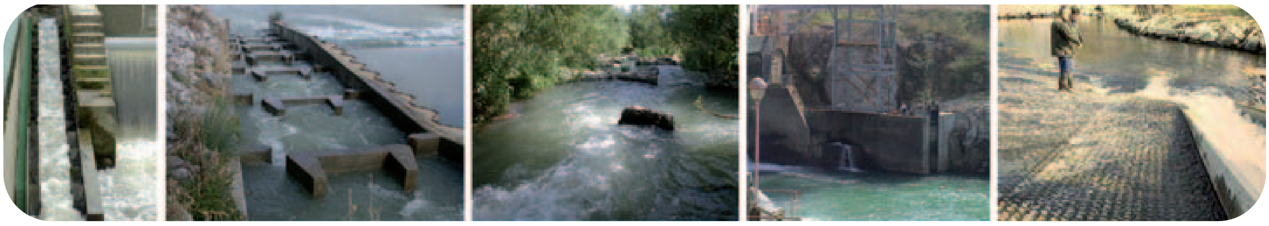
Research and development dedicated to creating technical solutions to improve river continuity

Technical solutions derived from applied research in hydraulics and in the behaviour of fish have been developed over the past 30 years by the Toulouse Pôle écohydraulique (Eco-hydraulic Centre) in order to reduce the impacts of transversal structures and their associated uses, especially hydroelectric. From the start, the schemes were dimensioned in order to allow for the passage of salmonids. They then evolved in order to allow for the passage of an ever-increasing number of species: eels, salmon, pike, cyprinids*, lamprey, cabots bouches-rondes of Réunion Island, etc. This important project, which is still underway, provides a wide range of technical solutions that can be adapted to many contexts. In accordance with the Eel Management Plan, new techniques, concerning the downstream migration of eels in particular, are currently being developed in the framework of a specific research and development programme that ONEMA has entered into with hydroelectricity producers. However, these constant evolutions do not prevent the implementation of temporary or experimental solutions (example of periods of time in which turbines are shut down during peak migration)[14].

14- P. Baran (ONEMA), F. Travade (EDF). "Présentation des actions R&D" Seminar: Restoring river continuity: a key strategy of the National Eel Management Plan, January 2010.

Techniques allowing for the upstream movement of fish

For upstream migration*, the schemes must be dimensioned in order to ensure that the hydraulic conditions are compatible with the fishes' capacities for movement (swimming, jumping and crawling). These abilities, which vary according to the species, their size, state of health, fatigue and environmental conditions, mean that a large range of solutions must be proposed. "Technical" fish passes are structures equipped either with baffles or successions of partitions and basins. "Natural" fish passes consist of structures resembling natural river riffles, i.e. ramps with rough surfaces.



1- Baffle fish pass. 2. Pass with consecutive basins. 3. "Natural" pass. 4. Fish lift. 5. Device specifically for eels on their spawning runs, allowing them to "crawl" between the studs

Techniques to reduce the risk of mortality during downstream migration and the return to the sea for diadromous* species

Technical solutions for downstream migration* are based upon fish retention devices which prevent them from reaching the turbines of hydroelectric plants (causes of death and injury), and then provide a mean of guidance downstream. The most efficient systems consist of screens with closely spaced bars, provided that the strength of the current remains compatible with the fishes' swimming abilities. Behavioural barriers, consisting of light, audible or electrical systems are less efficient and much more difficult to control and maintain. In recent years, different types of turbines have been developed in order to reduce the mortality of fish and eels in particular (fish-friendly turbines). Their principle is based on low rotation speeds and specially shaped blades.

Monitoring in order to improve technologies

The monitoring of fish at hydraulic structures provides feedback which is essential to the improvement of technologies. A summary of seven structures in France gives mean values of 120 fish per day of counting. At certain sites, 30 species of fish and over 400 fish per day have been recorded (MIGADO, LOGRAMI[15] and the Association Saumon Rhin (Rhine Salmon Association) data). The radiotelemetry approach used for Atlantic salmon and the large shad has revealed that the efficiency rates for negotiating dams vary from 10% to over 90%. These large variations are due to the hydraulic characteristics of the fish pass, its maintenance or position in relation to the dam and also to the environmental conditions (flow rate and temperature).

Doing nothing

Certain weirs may collapse naturally due to a lack of maintenance and dilapidation. It is then necessary to make sure that there are no undesirable consequences and to implement accompanying measures which will vary according to the issues at stake.

15- LOGRAMI : Association Loire grands migrateurs (Loire Association for Large Migratory Species)
MIGADO – Association for the restoration and management of migratory fish in the Garonne and Dordogne basin

Example 5

Collapse of the Vecoux weir on the upstream Moselle (Vosges) – 2000

The Vecoux weir, which is 2 metres tall and 25 metres long, was destroyed by flooding in 2000. The resumption of erosion led to the collapse of a part of the left bank. The erosion is localised in a part of the bank that is not used for any particular purpose and on which there is no riparian* vegetation. Without implementing any specific measures, the river association is merely monitoring this process.

Vecoux weir: only the lower courses of masonry remain in place on the river banks.

Prioritising a global management strategy

According to the situation, the removal of a structure may have undesirable side-effects: bed erosion or bed deepening, transport of sediment from the former impoundment which may lead to massive downstream deposits, risk of disappearance of riparian* vegetation due to the elimination of the reservoir, drying out of any wetlands connected to the former reservoir, replacement of a reservoir landscape with a river landscape, etc. However, prevention techniques may control these side-effects[16].

All of the pressures and alterations to which the river is subjected must also be considered in order to optimise the evaluation of the predictable effects of obstacle removal. The presence of flow obstructions is often associated with other bed-straightening interventions, resizing, riverbank protection, presence of other structures, etc., which could cancel out or reduce the expected benefits of the restoration operation, or extend the time required before the results are obtained.

For all cases, and as for any project in aquatic environments, it is wise to carry out a global study of the anticipated effects of the restoration and on a large enough scale to take account of the elements likely to have an impact on the desired results. The choice of the continuity restoration technique will thus depend on the aims and on the best compromise emerging from the study and the local consultation.

Example 6

Global study of modifications of hydraulic structures on the Sèvre nantaise (Vendée & Deux-Sèvres) – 2005

There are numerous mill weirs along the course of the Sèvre nantaise, hence its great sensitivity to pollution and eutrophication phenomena. In 2003 and 2004, eutrophication led to the restriction of uses on certain sections. Since then, all users and local authorities have made efforts to modify the hydraulic structures and reduce these harmful effects. An assessment of the global benefits of the structures thus led to the recommendation to lower two of the structures and open one of the sluice gates permanently, whilst studies of other structures are still being carried out. On the other hand, upstream of the commune of Mallièvre, it was decided to retain certain structures because they encouraged the diversification of wetlands, which are very favourable areas for the reproduction of pike.

Wetland on the upstream Sèvre – the retention of a hydraulic structure maintains the water supply to this environment.

16- Biotec-Malavoi (2007). Manuel de restauration hydromorphologique des cours d'eau. Agence de l'Eau, Seine et Normandie

When the river's continuity is restored: eloquent examples

Local decisions are increasingly leading public or private project owners to undertake operations to restore river continuity. The motivation for this decision is often linked to public safety for the removal of hydraulic structures, with the positive effects on river continuity being an integral part of the approach. Weir-lowering and gate-opening operations are becoming increasingly common and often correspond to the desire to restore good river status. The installation of fish passes – a technique employed for several decades – is also continuing. Certain river continuity restoration operations are worthy to be known.

Return to a natural hydrological regime and flows

Depending on the situation, the removal of a hydraulic structure may lead to:

- Restoration of the natural gradient, which allows for the re-establishment of the river's diversified flows and riverbanks, which were formerly flooded by the artificial reservoir.
- Disappearance of plant proliferation phenomena due to stagnant water in the reservoir.
- Good oxygenation of the environment provided by the renewal of water and the return to a "fast and flowing" flow pattern.
- Re-establishment of homogeneous upstream/downstream temperatures and of different nutrient concentrations.
- Recreation of differentiated habitats characteristic of the flow conditions.
- Increased volume of water during the low-flow period*, due to the removal of the reservoir and lower evaporation of flowing water.

Example 7

Opening of a weir on the Aume (Charente) – 2008

A one-metre tall weir on the River Aume was obstructing the river continuity. The impoundment thus formed was highly eutrophicated with major sedimentation and significant warming of the water, which made it extremely muddy. The removal of the wooden beams, while retaining the concrete structure, allowed for the reduction of the water depth and the restoration of fast-flowing areas. By restoring the Aume's flows, the problems relating to the eutrophication and turbidity of water have now completely disappeared.

© Syndicat Intercommunal de l'Aume Couture - 2008

Weir prior to the works: presence of an impoundment of stagnant water - 2008

Weir during the works: return to free-flowing conditions - 2008

After the works: no eutrophication problems – 2009

Re-establishment of sediment transport

The removal of a hydraulic structure allows for the re-establishment of the natural transport of sediments by the river and their temporary – but renewed – deposition downstream, thus re-establishing a greater variety of aquatic habitats. The problems of riverbank erosion downstream and/or upstream of the removed structure are usually only temporary. They diminish, or indeed disappear, after the removal. When protection is a key issue – particularly with regard to civil engineering structures such as bridges and embankments, localised actions may be envisaged. The dismantling also means that there is no need for reservoir drainage operations, which are very damaging on the environmental level and also very costly.

Example 8

Removal of the Cussy weir on the Maria stream (Nièvre) – 2004

The Cussy weir, a two-metre tall structure built in 1932, was preventing the transportation of sediments consisting of sand and gravel. In areas situated downstream of the weir – deprived of sediment inflows – the trout populations had disappeared. This is because the reproduction habitat for river trout must consist of gravel. In 2004, it was decided to remove the weir. Sediment transport was quickly re-established, thus recreating conditions which are favourable to the reproduction of trout, whose numbers have been constantly rising downstream of the weir.

© PNR Morvan

Cussy weir – materials (sand and gravel) carried by the river are building up behind the obstacle.

© Jean-Christophe Baudin - Onema

The Maria stream five years after the removal – a return to the free movement of sediment – 2009.

Example 9

Weir lowering and removal operations on the Vicoin (Mayenne) – 2008

The River Vicoin is obstructed by a large number of weirs built on its course, which prevent sediment transport. Consequently, the impoundments are regularly affected by siltation problems. This was the case for the Saint-Berthevin recreational reservoir. Confronted with the need to perform a cleaning operation every six years, and given the prohibitive cost of such a clean-up (€110,000), the local stakeholders, who wanted to restore the continuity of their river, decided to dismantle the weir. This operation was carried out in 2008 and the success of the project had a "snowball" effect: projects adapted to each situation were instigated for 26 other hydraulic structures suffering from similar siltation problems.

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Silted reservoir

© Jean-Christophe Baudin - Onema

The river after removal of the weir: there is no longer any need to perform cleansing operations in order to remove sediment from the reservoir.

Habitats once again accessible to living organisms

The removal of the structure allows the movements of all living organisms to be restored. These organisms can now regain habitats that were formerly inaccessible or hard to reach, especially areas which are essential for reproduction. Populations of diadromous* migratory fish are the most obvious beneficiaries of the restoration of the free movement of the river. However, other aquatic species also benefit (pike, trout, otter and beaver), as several obstacle removal projects in countries such as France and the United States have shown. Furthermore, the removal of a structure allows for the genetic decompartmentalisation of species.

Example
10

Removal of the Maisons-Rouges dam on the Vienne (Indre-et-Loire) – 1998

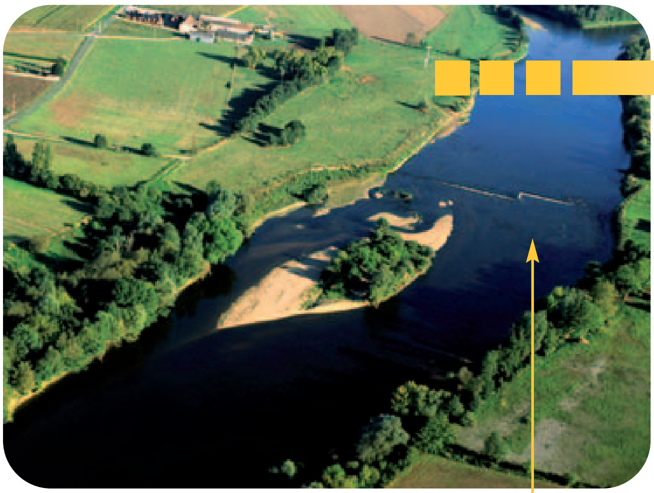
Since its construction in 1923, the Maisons-Rouges dam had been blocking the movements of migratory fish and also preventing access to reproduction sites. After its removal in 1998, the results[17] concerning the recolonisation of the Vienne and its tributaries upstream of Maisons-Rouges were remarkable.

By the following year, shad had recolonised the newly accessible 35 kilometres of river. The results were even more spectacular for the sea lamprey, as spawners had moved in to most of the newly available spawning grounds*. For salmon, which had only been seen sporadically upstream of the dam since 1920, 9 spawners were counted in 1999, followed by 54 in 2004. An entire section of the river and all of its tributaries have thus been quickly and intensively recolonised by large migratory species. Both on the Vienne and its tributary – the Creuse – recolonisation was prevented further upstream due to the presence of other dams. Nevertheless, it is continuing progressively thanks to different fishways: at Châtellerault dam in 2004, the Bonneuil and Saint-Mars weirs on the Vienne in 2009 and the Descartes dam on the Creuse in 2007.

poissons © Nicolas Dieu – 1998

Aerial view of Maisons-Rouges dam – the dam restricts or even prevents the movements of fish.

© Gilbert Cochet



The site after the removal of the dam

position of the former dam

17- P.M. Chapon, Conseil supérieur de la pêche, délégation régionale de Poitiers, cellule Migrateurs, 2001, "Éffacement du barrage de Maisons-Rouges – Etat de la recolonisation du bassin de la Vienne par les poissons migrateurs", Le Courrier de l'environnement n° 42, INRA.

Other advantages due to these interventions

The ecological benefits of the re-establishment of river continuity may be accompanied by other advantages which are likely to benefit local authorities and residents.

Improved conditions for white-water sports enthusiasts

Example 11

Removal of a weir on the Corrèze (Corrèze) – 2008

In 2008, the creation of a canoeing route initiated a project to restore continuity to a section of the River Corrèze. This concerned four weirs at the town of Tulle. After analysing the results of the global impact study, it was decided to remove one of the four weirs, which had a water head of three metres. This removal improved the fish passage, sediment transport and the quality of habitats. Of the three other weirs, two are already passable by canoes and the last one, situated downstream and posing the same river continuity problems, will be modified, allowing for the subsequent extension of the route. The town of Tulle's kayaking club was heavily involved from the start of the project. The canoeing-kayaking route was thus opened on a section of the river formerly blocked by an obstacle.

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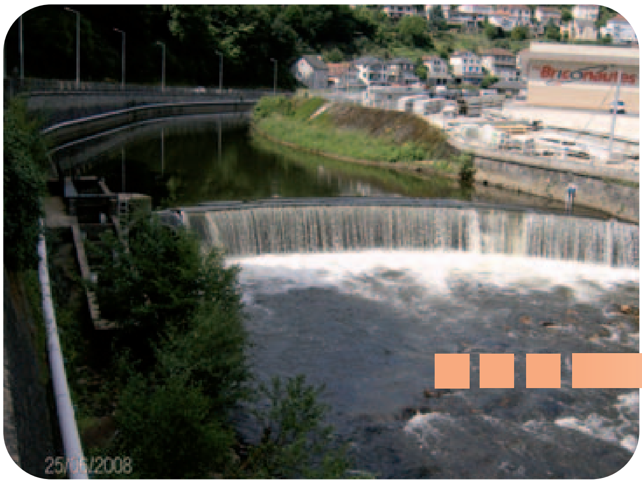


The Corrèze prior to removal (June 2008)

© Service départemental de Corrèze - ONEMA

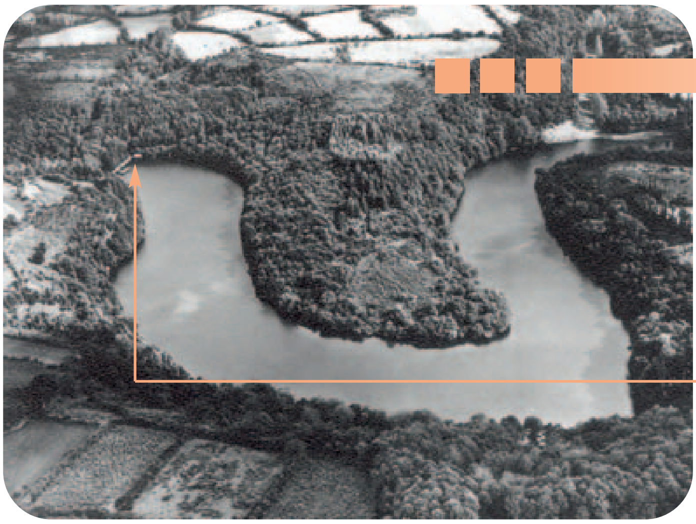
The Corrèze after removal: extension of the kayaking route (Dec. 2008)

Recovery of land made available by the draining of reservoirs

Example 12

Removal of Kernansquillec dam on the Léguer (Côtes d'Armor) – 1996

On the banks of the River Léguer, after the removal of a 15-metre tall dam in 1996, 12 hectares of land were restored over a length of 2 km along the river. The Kernansquillec site has become the largest natural public area in the Léguer valley. Seven hectares of land are now used as summer pasture by two organic farmers, with extensive grazing thus helping to maintain the site.



Recovery of riverbanks for footpaths

Example
13

Removal of the Kernansquillec dam on the Léguer (Côtes d'Armor) – 1996

Following the removal of the dam, footpaths were created on land that was formerly underwater. This project received extensive media coverage. The routes are listed in hiking trails and have been described in numerous publications as some of the most beautiful footpaths in Brittany. The operation has been a success and today, the site is a very popular destination for walkers.

© Association du Léguer - 2009
© Corinne Forst


*Footpath alongside riparian vegetation**

Footpath in the former impoundment of the Léguer

Renewal of recreational fishing

Example
14

Removal of the Moulin du Viard Mill weir on the Orne (Calvados) – 1997

In 1997, the 1.7-metre tall weir of the former Moulin de Viard mill was removed on the River Orne, 30 km from the sea. Ever since, the newly liberated flows and the return of physical activity in the river have been rapidly recreating a wide variety of flow patterns and habitats. The natural profile of the Orne is re-emerging: the fastest-flowing areas, which are the preferred spawning grounds* of migratory salmonids and sea lamprey, are accompanied by large runs with abundant beds of aquatic vegetation and alternating deeper areas.

The fishing federation of the département of Calvados, which is the project owner, now has the satisfaction of witnessing different types of fishing being actively carried out on the newly restored sector, which offers spots for fly-fishing (sea trout) in addition to fishing for small species (gudgeon), coarse fish and carnivorous species. In recent years, a new type of recreational fishing has developed using surface lures being moved through the water within the beds of river vegetation and offering the chance to catch numerous species (perch, chub, and even trout and pike). The initial fears, expressed by visitors to the former impoundment, of seeing the disappearance of fish, have definitely been allayed.

© JF Jolimaître

Angler using a surface lure at Val de Viard - Orne

Glossary

Cyprinids: family of freshwater fish including carp, gudgeon, roach, etc.

Diadromous: refers to fish that live alternately in freshwater and saltwater.

Downstream migration: downstream movement of migratory fish in a river in order to reach a marine environment.

Flow pattern: homogenous characteristics of gradient, water head, current speed and substrate particle size throughout any section of a river.

Hydromorphology: study of the morphology of rivers, i.e. of the form of the bed and banks which is shaped by the hydrological regime of the river.

Low flow period: corresponds to the period of low flow rate, generally the summer for rainfall regimes.

Original bed: line at the valley bottom along which the water flows.

Programme of measures: programme that specifies the measures to be carried out in order to conform to the provisions and targets contained within the SDAGE (Water Management and Development Master Plan) and the good status of the WFD (Water Framework Directive). The measures may be of a regulatory, financial or statutory nature.

Riparian vegetation: plant formations which develop on riverbanks.

Spawning ground: area of reproduction and of deposition of fish eggs.

Upstream migration: upstream movement of migratory fish towards the reproduction areas situated upstream from the mouths of rivers.

Publication of a collection of examples

ONEMA (French National Agency for Water and Aquatic Environments) has published a collection of around sixty examples of the restoration of rivers in all French catchments. It brings together the knowledge accumulated by ONEMA and the French Agences d'eau (Water agencies).

The restoration examples are divided according to the type of restoration operation: remeandering, reconnection of side arms, partial or total removal of dams or weirs, reopening of culverted rivers, elimination of ponds, etc.
These examples can also be consulted on the Internet:
http://www.onema.fr/Hydromorphologie,510

For further details, please visit: www.zones-humides.eaufrance.fr, go to the Agir (Acting) section /Actions concrètes réalisées (Concrete actions carried out) / Retours d'expériences (Feedback)

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