The Romanche Séchilienne project, an integrated approach to river development

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ABSTRACT: In the Romanche valley, near Grenoble in France, the combined risk of a flood occurring on the river and a landslide of several millions m^3 (named the "Ruines de Séchilienne") threatens the safety of people living downstream. The SYMBHI is responsible for an operation that aims to take care of this risk, but not only : it also goes after including the other interests related to the river. This integrated project, concerning 9 municipalities and 20 000 inhabitants, thus plans developments on 10 kilometers of the river to guarantee protection of goods and people exposed, while improving environmental quality and functioning of aquatic associated ecosystems, and ensuring landscape insertion of the constructions on the banks. The project, designed by the companies Artelia and CNR, is currently in works phase. These works are scheduled to be completed by the end of 2015.

THE ROMANCHE SECHILIENNE PROJECT

The Romanche Séchilienne project, leaded by the SYMBHI ("Syndicat Mixte des Bassins Hydrauliques de l'Isère"), is a river development project, located in the Romanche valley, 15 km south-east of Grenoble. It concerns 9 municipalities, and 20 000 inhabitants. The initial basis of this operation is to ensure protection of urban areas against the centennial's flood risk of the Romanche, combined with a landslide's risk (named the "Ruines de Séchilienne", see figure 1) and its hydraulic consequences. However, the Romanche Sechilienne project distinguish by choosing to take care of these risks, integrating the best way the other interests existing along the river. This integrated project thus plans constructions of 10 kilometers of the river to ensure protection of goods and people exposed, while improving environmental quality and functioning of aquatic associated ecosystems, and ensuring landscape insertion of the constructions on the banks. It complies fully with the European framework directive aimed at achieving good ecological status of rivers.

We can summarize the objectives of this project in six major points (see figure 2) :

- protecting built-up areas and building land against the risk of a 100-year flood combined with the collapse of the Ruines de Séchilienne by constructing a coherent and secure system of embankments,

Figure 1. Photograph of The landslide "The Ruines de Séchilienne"

- restoring functional sediment transport in the embanked sections by re-mobilising fossil banks and levelling a weir in order to tend towards a natural equilibrium slope in conformity with the characteristics of the river bed and bed load materials,
- restoring the mobility of the river bed upstream of the embanked section with a view to reestablishing dynamic river conditions that will encourage biodiversity,
- designing and applying environmentally friendly techniques (mixed bank protection involving both planting and hard-surfacing techniques, rational planting of embankment sides, reconnection of tributaries to allow fish migration, recreation of wildlife corridors for small animals),
- adopting an in-depth environmental approach in carrying out the works (consideration of protected species, management of invasive plants, reuse of materials following treatment …),
- carrying out a landscape accompanying of the project, and developing leisure and access to the banks, to "give" the river back to people (this point is not developed in this article).

The amount of the project is about 28 million euros.

After a 5-year study period, during which the companies Artelia and Compagnie Nationale du Rhône, designed the project, the works have been underway since the beginning of 2013 and are scheduled to be completed by the end of 2015.

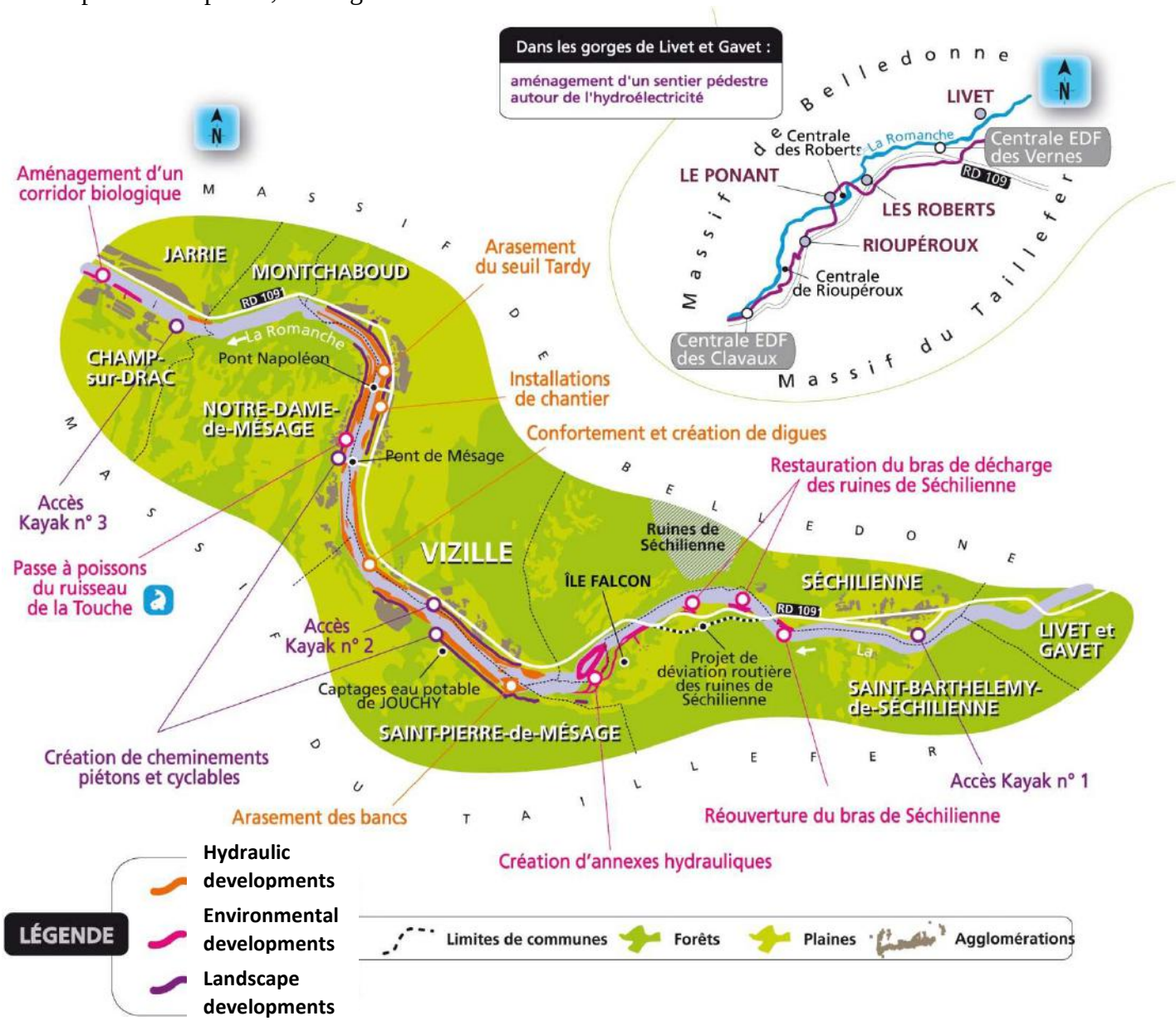

Figure 2. General map of the project "Romanche Séchilienne"

1 HYDRAULIC OBJECTIVES OF THE SÉCHILIENNE MIDDLE AND LOWER ROMANCHE PROJECT

1.1 *Hydrological assumptions*

The design flood adopted is the 100-year flood on the Romanche, plus an extra discharge of 50 m^3/s. This extra discharge, which was determined by a scale model, is associated with the erosion of a landslide at the Ruines de Séchilienne, rising to an elevation of 336 m.

Figure 3. Design flood hydrograph

The exceptional flood corresponds to an episode with a return period of 500 years (Q_{500} = 790 m3/s) occurring after the landslide at Séchilienne. This event governs the sizing of the safety structures (weirs) to be built to avoid embankment failure, and therefore the sudden arrival of water in the protected areas but it does not protect them against flooding.

1.2 *Improvement of flow capacity in the low-water bed*

Rather than raising the embankments and increasing the risk for residents in the event of a failure, it was decided to facilitate the flow of water in the low-water bed so as to lower the surface curves during floods. This is achieved by two types of operation:

- Eliminating the Tardy weir, which is the main obstacle to flow in the low-water bed in the downstream part of the Vizille plain.
- Clearing and lowering the banks in the low-water bed to an elevation close to that of the average inter-annual flow rate.

Figure 4. Work in the low-water bed

The combination of these two measures lowered the surface curve for the design flood by an average of 50 cm (1.5 m in certain places), thus reducing the stress exerted on the embankments in the event of an exceptional flood. Elimination of the Tardy weir and of the local lowering of the bed by 1.5 m that it has caused upstream had to be compensated for by strengthening the abutments of the bridge carrying the RN 85 road (a structure built in the 18th century).

1.3 *Restoration of the hydro-sedimentary balance*

At the present time, there are major variations in the hydraulic gradient of the bed of the Romanche in the section running through Vizille, partly due to obstructions and the existence of the Tardy weir. By restoring a more even gradient close to 0.65% and remobilising the stock of sediment formed by the banks, it will be possible to ensure the permanence of the river's longitudinal profile, avoiding the present trend whereby erosion is occurring between the banks, while they in turn are being enlarged. This is randomly modifying the hydraulic capacity of the channel between the embankments. Restoring the local hydro-sedimentary balance is therefore a prerequisite for guaranteeing the long-term effectiveness of efforts to improve flood flow conditions and the capacity of the low-water bed.

1.4 *Embankment safety*

It was necessary to ensure the safety of the embankments to avoid exposing local residents living in the protected area to a more serious hazard than slow, progressive flooding of the type that would occur if no embankment existed. This meant consolidating the existing embankments following a preliminary appraisal. Reinforcement work involved improving bank protection and resistance to internal erosion of the body of the embankment by adding a drainage layer.

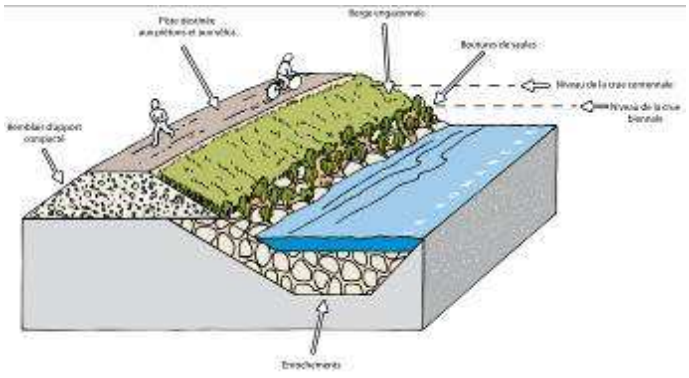

Figure 5. Embankment consolidation and widening

Five relief weirs were also created to ensure controlled flooding of the protected area for discharges higher than the design flood.

1.5 *Compatibility with hydropower production*

The Séchilienne Middle and Lower Romanche project was adapted to the existing hydropower facilities, particularly those that exploit canals in the Vizille plain. Mobile gates will isolate the network of canals against floods on the Romanche in order to avoid any risk of submersion due to water being suddenly forced back into the protected area.

2 A FEW EXAMPLES OF WORKS IN PROGRESS

2.1 *Bank levelling*

Regulations require works to be carried out in the bed of the Romanche between 15 October and 15 April, corresponding to the period when there is least water in the river. Working in the live bed nevertheless meant installing culverts to avoid construction plant having to operate directly in the current. Following preliminary clearance of vegetation, the banks were stripped and the material removed to the storage, washing, screening and crushing area.

Figure 6. Bank clearance and levelling

2.2 *Consolidation of the RN 85 road bridge and removal of the Tardy weir*

The Tardy weir was removed after a cofferdam had been built to isolate half of the bed and the bridge abutments had been secured. The retaining system consisting of an HZ-AZ sheet-pile curtain, driven to a depth of 12 m below the existing bed, will ensure the stability of the bridge abutments after the bed has been lowered and against erosion by floods on the Romanche. Instruments were installed and the bridge monitored throughout the period the sheet-piles were installed in order to detect any suspicious deformation.

Figure 7. Work on the RN 85 road bridge

2.3 *Embankment consolidation*

Fifteen homogeneous sections of embankment on both sides of the river were consolidated, making a total of more than 10 km. In each case, work began by protecting the river bank. This involved placing rockfill on the lower part the from the river bed in the protection of a cofferdam, and then placing the upper part reinforced by a 3D geogrid to protect the side slope against the main current.

Figure 8. Embankment consolidation works

Once the river side has been consolidated, the embankment is widened on the plain side if necessary by placing a drainage layer or gabion retaining wall depending on the space available. The crest is made

suitable for vehicles and both side slopes are grassed before the embankment is handed over. Once the initial accesses have been re-established, certain sections are open to the public for walking or cycling.

2.4 *Installation of a cut-off gate on the Tolentin tail race outfall*

This work was carried out to isolate a tail race from a power plant in the event of a flood on the Romanche. The gate, which is designed to remain open in normal conditions, closes automatically in the event of a flood on the Romanche. It is slaved to both the river water level and the position of the head gate at the micro-power plant.

Figure 9. Gate on the Tolentin tail race

The civil works and erection of the gate were carried out in 10 days, taking advantage of a scheduled shut-down of the power canal, which supplies a series of 4 micro-power plants on a run-of-river basis.

3 FEATURES OF THE CONSTRUCTION WORK

3.1 *Reuse of materials extracted from the bed*

The hydraulic protection works along the Lower Romanche produced an excess of material. The quantities produced by extraction from the banks, levelling the weir or protecting the lower parts of the embankment with rockfill exceeded the amounts needed for backfilling purposes. It was therefore decided to recycle the extracted materials directly on site by sending them to a storage, washing, screening and crushing area (SWSC) created in the geographical centre of the operation close to the Romanche in order to produce the fill needed to build the bodies of the embankments and drainage layers.

The facility produces 0-80mm compactable fill that is not subject to internal erosion and can be used to build the bodies of the embankments, and 20-40mm fill that can be used for the drainage layer. During sorting, larger rocks and cobbles are also produced for filling gabion cages.

3.2 *Recycling of wood from the banks and river banks*

A partnership agreement was signed with the Grenoble urban heating company, which uses fuelwood, whereby the contractor gathers cut wood in a temporary storage area, from where it is recovered for burning.

3.3 *Plugging rockfill*

In April 2013, i.e. 3 months after commencing the works, the combined effects of excavation below the surface of the Romanche accompanying aquifer and a flood on the river resulted in bacteriological contamination of water abstracted from the Jouchy wellfield to supply drinking water to the Grenoble urban area.

The same thing occurred during a second flood episode in August 2013.

Because of this disruption in drinking water supplies, the operator had to introduce temporary disinfection measures.

On the assumption that the recurrent contamination was due to inadequate filtration of surface water as it passed through the highly porous rockfill layer, the Owner decided to install a hydraulic percolation system using 0-30 mm silty gravel produced at the SWSC using materials extracted from the bed of the Romanche.

This operation, carried out on a preventive basis, was included in the rockfill placing works when they resumed in October 2013. The results obtained from a test area showed that 30% of the volume of the blocks could be percolated from top to bottom in two successive sections.

This work was exceptional in a project of this kind and was monitored on a daily basis. In addition, groundwater quality in the Jouchy wellfield was analysed each day.

It was also noticed at the time that the contamination disappeared when the rockfill was placed behind a longitudinal cofferdam but reappeared when the cofferdam was removed and the entire low-water bed of the Romanche was filled with water. The time taken to return to normal varied but was at least several weeks.

4 4ENVIRONMENTAL ENHANCEMENT WORKS

4.1 *Restoration of the river's mobility space*

The floodplain of Alpine alluvial rivers is home to a variety of diversified and typical aquatic and alluvial habitats, which are shaped by the alluvial dynamic and are maintained thanks to the latter (secondary arms, herbaceous pioneer plants, softwood forest,

etc). Dykes have often reduced the mobility area of the river bed to the detriment of the morphological and biological diversity of floodplains. On the Romanche river, opportunities to restore this space have been integrated into the project at one site in particular.

It is located next to a former hamlet on the floodplain known as "Ile Falcon". The reduction in human challenges and the high potential for alluvial dynamic observed during recent floods (2008) make it possible to envisage restoration of the Romanche river's mobility area on this site. A geomorphologic analysis, based on old aerial photographs and topographical survey performed using remote laser detection (Lidar), was carried out to outline the restoration options and determine the actions to be undertaken. This analysis method was developed on the Rhône to reactivate the alluvial margins (Collilieux et al., 2007). Along a 1.3km stretch, the Romanche's riverbed extends along the valley's northern flank. Reduced to a single channel with a width of fifteen metres upstream, it gradually evolves towards a braiding area downstream with a width of a hundred metres (see figure 10). The floodplain mainly extends along the right bank, to the south-east. Upstream, a former dyke with a length of 265m blocks the bed's mobility on the left bank. By orientating flow towards the right bank and by promoting incision of the bed, it also limits scavenging opportunities in the downstream area without a dyke. To restore the mobility area on the left bank, the project plans for this dyke to be dismantled and the clearing and digging of two former secondary channels landed in the wooded plain. With lengths of 650 and 700m, the width of these arms will be 15 and 7m at the bottom. The slopes of the banks will be steep (1H/1V) and no revegetation will be carried out so as to encourage erosion. These channels will be fed by flooding at a frequency of around 10 days per year. In order to further encourage the shifting of the Romanche, a slight raising of the riverbed will take place using the alluvial materials from digging of the arms. The volume of excavated material for the reopening of these former arms is estimated at 12 000 m³.

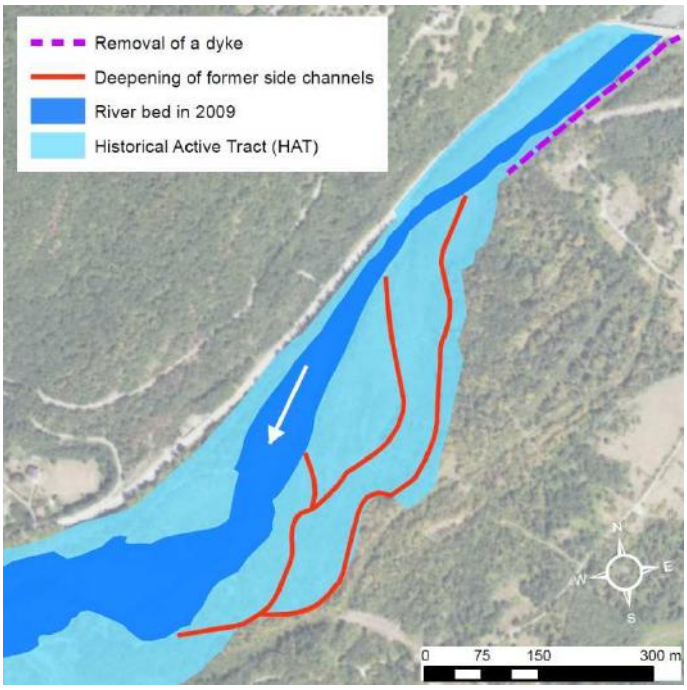

Figure 10. Mobility area on Ile Falcon and location of the project (opening of the arms and removal of the dyke).

4.2 *Restoration of biological connections*

The lateral and longitudinal connectivities of the aquatic and periaquatic environments have been altered by successive developments on the Romanche.

In the very urbanised Champ-sur-Drac crossing, the biological corridor is altered, even interrupted, for land species over a length of around 600m. The banks are artificial (riprap, sheet piling) and riparian vegetation is almost non-existent. In order to restore a periaquatic corridor, 3 revegetated low berms with a width of around 10m and a length of between 100 and 170m will be constructed with alluvial material at the toe of the bank. Considering the sector's significant hydraulic stress (long and thin section, high speed), their edge will be fixed by a line of ripraps. Revegetation will take place using bundles of willow branches and cuttings thereof. Restoration of the biological corridor at this level is a major challenge involving the connection of two areas with significant ecological concern: the Drac confluence downstream and the Notre-Dame-Mésage and Ile Falcon sectors upstream.

Immediately upstream of the Tardy weir (removed in the context of the project), the lateral connectivity with an effluent, the Touche stream, is interrupted. This effluent, with an average flow of 100 l/s, houses spawning grounds for trouts (*Salmo trutta fario*). The project plans for the reestablishment of the connectivity through the restoration of an old pool and traverse fish pass. Four new pools downstream will be created and 6 existing pools will be restored. The head height between each pools will be 24cm. The inter-basin cross-walls will

be equipped with unaligned notches measuring 0.5m in height and 0.3m in width. These cross-walls will also be provided with a bottom opening, and the bottom of the pools will be rough to facilitate passage of the sculpin (*Cottus gobio*).

5 ENVIRONMENTAL INTEGRATION OF HYDRAULIC STRUCTURES AND BIOLOGICAL ENGINEERING WORKS.

5.1 *Adapting the levelling of the bars*

Levelling the gravel bars, which are mostly wooded, in the context of the hydraulic structures, temporarily alters the riparian and biological connectivities. In order to limit this incidence without altering hydraulic gains from the work, the clearing project was subject to alterations. The latter consists of maintaining a woody fringe with a width of 5 - 10 m on the river bank (see figure 11). These fringes concern a total length of 650m and a surface area of around 6 000 m² of wooded banks conserved, that is to say 6.6% of the razed surface area. In addition, these adaptations allow for the conservation of some unique habitats: a secondary arm and a wetland area rich in aquatic plant species.

Figure 11. Maintaining the forested areas on the razed banks.

5.2 *Plant engineering techniques*

Planned hydraulic developments involve the removal of afforestation present on the banks and the dykes to be reinforced. In order to reconstitute a shrubby strata quickly (compatible with the project's hydraulic objectives), the facings of the rip-rapped dykes will be revegetated through the planting of willow cuttings in the interstices over a total length of 6km. The latter will have been filled with sandy-gravelly materials beforehand from the project's waste. The species used are typical of the Romanche river: *Salix eleagnos, S. daphnoides, S. purpurea and S. viminalis*. Another technique will be used to restore the biological corridor at the Champ-sur-Drac crossing: the planting of bundles of willow branches (to revegetate the banks). The advantage of this technique is that it generates very dense plant coverage very quickly.

6 OVERALL ENVIRONMENTAL MANAGEMENT OF THE PROJECT

6.1 *Management of non-native species*

Several introduced species are present within the project's scope: *Fallopia japonica*, *Buddleia davidii*, and more marginally, *Ambrosia artemisifolia* and *Oenothera biennis*. Said species are given special attention during the workshop to avoid their dissemination, neutralise the mobilised contaminated materials and limit colonisation after works on the reworked ground. Cleaning areas with a water recovery system are planned for the machines leaving the work sites for the road network. Before the works, the introduced plant sites located in and close to the work site will be mapped and evidenced by markings on the ground. Dense sites will be cut back and isolated plants uprooted manually. The products of the cutting and uprooting will be taken to an approved landfill and then incinerated. Monitoring will take place throughout the site for a 2-year period after the works, which may give rise to new interventions. The Japanese knotweed (*F. japonica*) is distinguished from the other three species by its very effective method of vegetative reproduction. Its underground parts form a dense network (see figure 12) reaching a depth of 1.3m in the work sites. Its rootstock is very persistent and has a strong power of producing new plants.

Figure 12. Underground network of *F. japonica* in the Romanche's project site.

This biological specificity requires scrupulous management and the use of treatment methods for the contaminated cleared materials. The excavated materials, over an average depth of 1.3m, under the previously treated sites, will be removed to a treatment platform. They will then be sieved using a high-performance rotating sieve (5.5m trommel, 2m diameter) to separate the rootstock from the fine substrate (sand and silt). The sieving waste, containing rootstock and, where applicable, coarse material (gravel) will then be spread over a thickness of 30cm then milled using a stone mill to fragment and alter the rootstock. The milled materials will then be deposited on a clean platform then covered (plastic cover), on the deposit. The aim of this last stage, expected to last 1-2 years, is to speed up the putrefaction of the rootstock. In the long-term, the neutralised materials will be removed in a traditional manner (landfill or reuse).

6.2 *Consideration of protected species*

The course of the Romanche river level with the project houses a large number of plant and animal species, some of which are protected (regional or national level). Naturalist inventories were carried out jointly during the development phases (Tereo, 2012a, b) as well as during the start of works by the companies through ecological engineers.

Three protected plant species have been located in the project area: *Inula helvetica* (170 roots), *Allium scorodoprasum* (75 roots) and *Anacamptis coriophora* (1 root). Changes were made to the development area to avoid the 1 root *A. coriophora*, 52 % of *I. helvetica*, 91 % of *A. scorodoprasum* roots. Favourable sites were found close to the project for the transplantation of sites that could not be avoided. In addition, areas where traffic is prohibited have been defined in a 5m radius around the protected plants located close to the site. These areas will be marked in a sustainable manner by a fence.

Fifty-nine protected animal species were recorded on the Romanche and its floodplain level with the project (fish, birds, amphibians, reptiles and mammals). One of the most symbolic is the Eurasian beaver (*Castor fiber*), which is very active in the area. Three lodges were located in the riverbed's clearing area. Adaptations of digging areas to conserve the forested fringes on the edge of the banks also help to avoid these.

In addition, measures to reduce incidences, in the design phase, of the protected fauna have been defined (training/awareness among personnel, rescue fisheries, etc). Finally, a global compensation programme for the impacts on fauna has been established. It considers the positive effect of the project's environmental developments on the fauna's habitat conditions as well as additional restoration measures: the protection and restoration of 21ha of alluvial forest and the renaturation of the deserted area of a former road covering a surface of 1.6ha.

CONCLUSION

The Romanche Séchilienne project was born from the will to protect an inhabited valley from the flood risk, generated by natural rising of the water level in the river, combined with hydraulic consequences of the collapse of the “Ruines de Séchilienne”. However, once it was initiated, the reflection on the project has been intended to be open and global. This was translated into an important consultation phase, which permitted to identify all the interests and uses existing on the river. With the objective to lead a protection operation against floods, in the interest of people and all activities (industries, transport, tourism …) present downstream, but also in the interest of the river itself. That’s why this operation, beyond pure protection constructions, is also constituted of environmental promotion actions, from mobility area restoration of the river, to protected and invasive species management, including biological connections recreation. Without forgetting landscape accompanying for the different protection constructions, in order to integrate them the better way in their environment, and to avoid the artificialisation of the banks. Leisure development actions and access to the banks, not detailed in this article, were also carried out, for the recovery of the banks by the people. They contribute to the social acceptability of the project. To conclude, the Romanche Séchilienne project is a river development project, whose basis repose on protection against floods, but has a truly integrated approach. That means taking advantage of the opportunity of a project impetus to have a general reflection. This gives a global project, which rather than imposing itself to the river, is also made to its benefit.

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