HyMoCARES

Integrating the Ecosystem Services approach in planning and operational activities affecting river hydromorphological processes

Sediment replenishment on the Buëch river (downsteam of the St-Sauveur dam)

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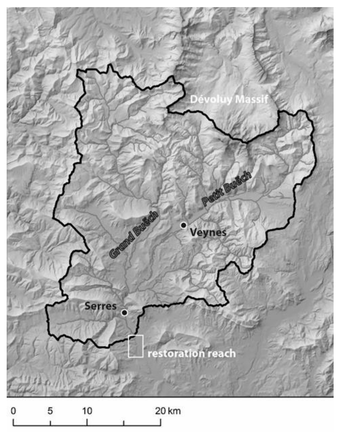
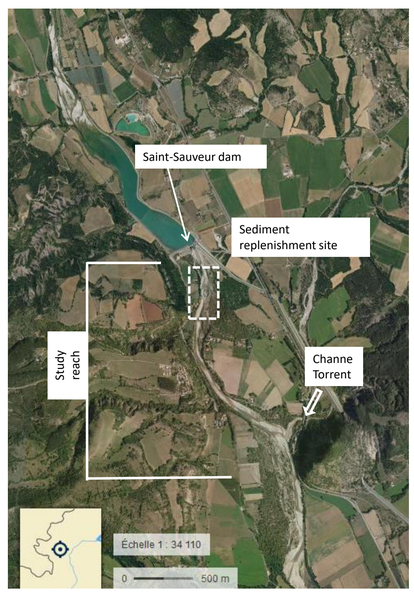
Buëch restoration site



Drainage area (in km²)	**836**
Location	44°23'48''N, 5°43'51''E
Length of the study reach (in km)	**2,2**
Active channel width (in m)	**180**
Channel slope (in m/m)	**0.009**
Planform morphology	**Braided / wandering patterns**

- Gravel mining > 3 millions of m³ in the upper catchment
- Dam built between 1991 and 1992: dredging of 600,000 m³ of sediment
- Sediment transport continuity strongly impacted
- Narrowing of the active channel
- Channel incision (marly bedrock outcrops)
- A shift from a braided to a wandering pattern



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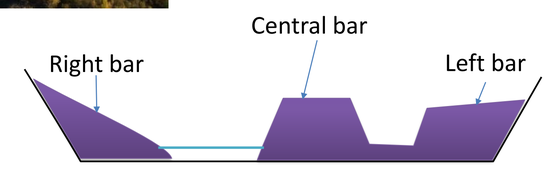
- Duration: 8 weeks from 09/2016
- Dredging the alluvial fan of the Saint Sauveur reservoir
- Sediment replenishment downstream of the dam 44,000 m³



Schematic cross section of the replenishment operation

shaping of a secondary channel

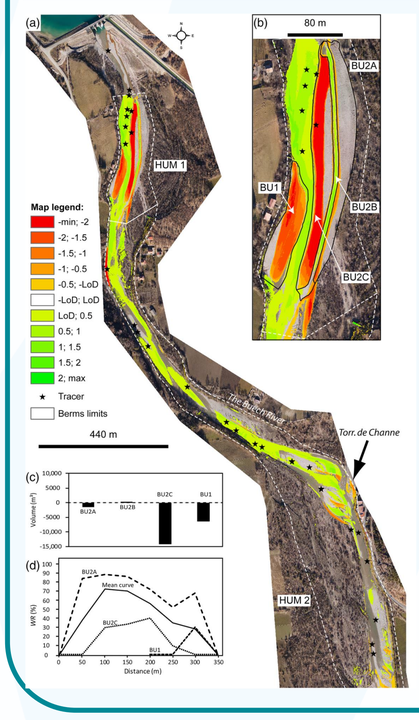
Brousse G., 2017, IAG 9th ICG

Physical monitoring

High resolution topographic surveys

Date of the survey	Type of survey	Data source	Before (B) After (A) restoration Spatial coverage
15/01/2015	Airborne LiDAR	EDF/Sintegra	B (Serres-Montrond, 6 km)
04/11/2016	Airborne LiDAR	EDF/Sintegra	A (Serres-Eyguians, 11 km)
22/12/2016	Airborne LiDAR	EDF/Sintegra	A (Serres-Eyguians, 11 km)
10-11/07/2017 24/08/2017	UAV-SfM*	Irstea	A (St. Sauveur-Montrond, 2 km)
04-05/09/2018	UAV-SfM**	Irstea	A (St. Sauveur-Montrond, 2 km)
16/11/2018	Airborne LiDAR	EDF/Sintegra	A (Serres-Eyguians, 11 km)

* using RGB and IR cameras ; ** using RGB camera

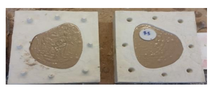


Repetitive topographic surveys of the restored reach (DEMs) are overlayed to produce change detection maps. These DEMs are derived from 3D point clouds (3D points to TIN and to DEM) from airborne LiDAR surveys and from the processing of UAV high resolution images with SfM photogrammetric technics

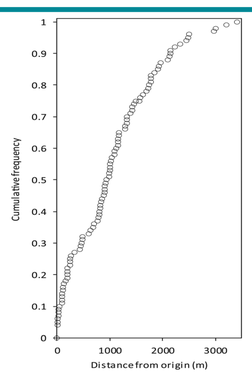
Channel change detection map following the November 2016 flood. (a) DoD after LoD subtraction and then exclusion along HUM1 and HUM2; the white dashed lines represent the surface covered by LiDAR data. (b) Zoom-in view of HUM1. (c) Sediment balance for each berm unit (PR). (d) Relative no eroded width ratio (WR). DoD, digital elevation model of difference; LoD, level of Detection
Source: Brousse et al., 2019 in RRA

Sediment mobility

A set of 148 active tags inserted in artificial gravels has been deployed upstream of the dam to evaluate the sediment transparency, and to constrain the travel distance of the reinjected gravels downstream of the dam.



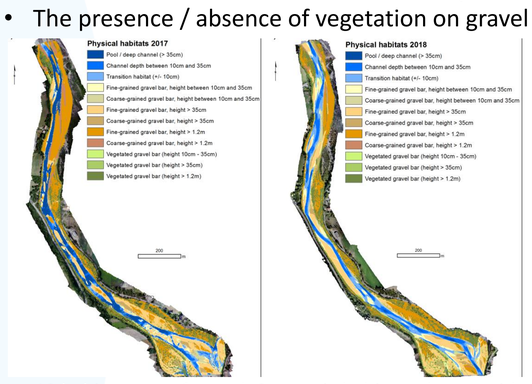
Cumulative frequency distribution of radio-frequency identification tracer transport distances during the November 2016 flood



Physical habitats mapping

Combination of 3 criteria controlling the distribution of aquatic and terrestrial species:

- The size of the substrate (2 classes: fine-medium size / coarse) based on an expert interpretation of orthophotos
- The relative elevation to the water level (6 classes)
- The presence / absence of vegetation on gravel bars (2 classes)



The distribution of these habitats were compared between 2017 and 2018 UAV campaigns with some diversity indicator (e.g., Shannon Index)

Shannon index	2017	2018
All habitats	2.97	3.04
Aquatic habitats	0.87	0.77
Terrestrial habitats	2.32	2.62

12 habitat types formed: 3 aquatic habitats classes with various water depths, 3 classes of unvegetated fine-grained gravel bars, 3 classes of coarse-grained gravel bars, and 3 classes of vegetated gravel bars (terrestrial habitats show various relative elevations to water level)

Main results

Sediment replenishment of the Buëch downstream of the St-Sauveur dam clearly improves channel morphology by reversing a long trend towards channel incision and bed simplification. There is a rapid bedload dispersion along the restored reach, and subsequently a spatially extended morphological recovery of the altered channel. However, the effective bedload input from the replenishment reach (22 650 m³) was insufficient to induce a significant shifting of the main channel during the flood, and a subsequent reactivation of braiding in the first unconfined stretch of the Buëch downstream the dam.
Orthophotos and DEM obtained from HR imagery have been successively used to produce physical habitat mapping for 2017 and 2018. Although a strong turnover rate of habitat conditions is observed, the general morphological structure of the active channel stayed unchanged during the period, and the global habitat heterogeneity of the active channel can be considered as stable over the 2-yr monitoring period. It would be interesting to extend UAV surveys during the next few years to monitor changing habitat conditions over a longer period.
As the restored reach of the Büech river is not a wide, well – developed braided channel, with very shallow channels, the automatic classification of the grain-size (as developed on the Upper Drac case studies) could not be applied, particularly under the water. This is one of the methodological limit of our work. Thus, the typology of habitats presented here is expert but is based on the same criteria thresholds to be compare through time along the restored reach.

Ecological monitoring

Based on the existing ecological data collected by the different river managers, an evaluation protocol has been applied along the Buëch restoration work area. Different compartments have been investigated, at different scales (station, restored channel, river), compared to a witness site. The following table shows the data used for the Buëch assessment before/after restoration work :

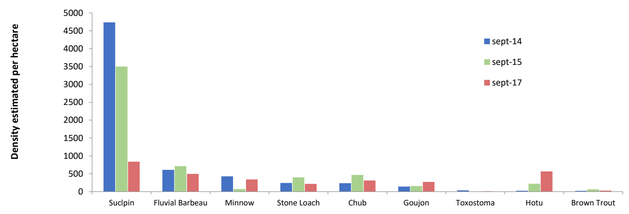
Ecological monitoring	EDF / Gay Environment 2017 to 2019	Département des Hautes-Alpes 2018 and 2019
Hydrobiological monitoring	Characterization of the benthic invertebrate fauna on 3 stations (downstream from the St Sauveur dam, Montrond, Ribiers) according to the WFD method (summer 2017, 2018 and 2019) 3 fish inventories during summer low-flows (2017, 2018 and 2019) according to De Lury's protocol	Water quality assessment by monitoring benthic invertebrate fauna according to quantitative and qualitative methods Analysis of AFB data on fish inventories
Hydrology	Two gaugings of water discharge for each of the four ecological flow periods (between 2017 and 2020) on 9 stations between the Saint Sauveur dam and the confluence with the Durance	Four gaugings of water discharge on 4 stations (Serres, Méreuil, Ribiers and Sisteron) per year
Thermal monitoring	Monitoring of thermometers installed by EDF downstream of the St Sauveur dam - 3 stations	Aerial thermal investigation during low-flow periods to define refugia zones for aquatic species using a method developed by the CNRS + continuous monitoring directly in the restored area (Méreuil)
physicochemical parameters	Punctual surveys of physicochemical parameters (T °, O2, conductivity and pH) on 3 stations (downstream of the St Sauveur dam, Montrond, Ribiers)	Punctual surveys of physicochemical parameters (T °, O2, conductivity and pH) on 3 stations (Serres, Méreuil and Ribiers) each year + continuous monitoring of those parameters at the control station and in the restored area
Riparian habitats and dynamics	No investigation	mapping of the riparian habitats from Pléiades satellite images and aerial photographs

Hydro-biological results

Two stations in the study area are being monitored by the Département des Hautes-Alpes, BUEC0700 and BUEC0800. The main conclusions are:

- ✓ Faunistic changes are observed between upstream and downstream stations of the Saint-Sauveur reservoir, the main cause of which seems to be the hydrological and thermal modifications induced by the reservoir in this sector
- ✓ The "habitat quality" factor is difficult to interpret in a modified hydrological and thermal context, whose influence seems to dominate the stand structure.

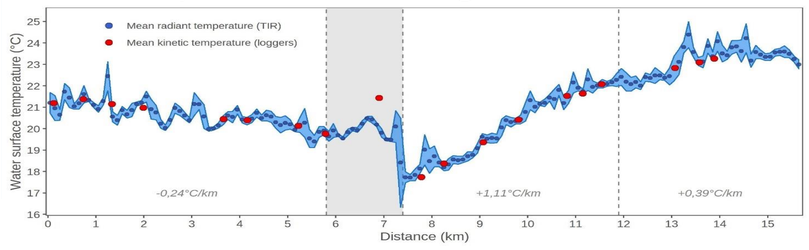
Evolution of the fishes population



Riparian environments

The diachronic analysis of SPOT satellite images over the period 2014-2017 and a field campaign in 2018 made it possible to map and study the evolution of the different functional units. Concerning the impacts on the riparian vegetation strip, the active strip has been revitalized and the bio-geomorphological processes have been (re) activated on the site of works but also further downstream. A functional break between the fringe and outer band is still marked. Intermediate strata (herbaceous and shrubby) do not provide the successional relay that characterizes the typical facies of a riparian forest in dynamic equilibrium with its recording medium (Gramond D., 2018).

Water Physical Monitoring



The restoration of Buëch River downstream of the Saint-Sauveur dam has had no impact on the quality of the water. Surface temperature is more influenced by the presence of the Saint-Sauveur reservoir.

European Regional Development Fund

SUPPORT FROM THE EUROPEAN UNION: € 2.103.452,92

Acknowledgments: The authors want to thank the people who contributed to this poster with their data, field work, or founding: UAV team at Irstea (Eric Mermin, Frederic Ousset, Pascal Tardif), Morph'eau Conseil, local water authority (CLEDA), University of Lyon UMR 5600 EVS, french agency for biodiversity (AFB), french water agency of the Rhône basin (Agence de l'Eau RMC), the Hautes-Alpes fishing federation, the regional water preservation association (MRE)

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