Technical note about the monitoring of hydromorphological management of the Avisio River (Autonomous Province of Trento, Italy)

PAT - Autonomous Province of Trento

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1. General presentation of the study sites

The Avisio Creek, is an Italian stream draining a basin of about 940 km^2 in the central-eastern part of the Alps. The average altitude of the watershed is about 1'663 m a.s.l and the land use is primarily characterized by wild areas and grazing pastures. The main course of the Avisio Creek is about 90 km long and has an average slope of 2.02%, while its watershed feeds four hydroelectric power plants.
The Avisio Creek is as an emissary of Lake Fedaia (2054 m a.s.l.), which receives the melting waters of the Marmolada Glacier. The stream runs through the valleys of Fassa, Fiemme and Cembra, and flows into the Adige River downstream from the town of Lavis (196 m a.s.l.), a few kilometers north of the city of Trento.
Along the Fassa Valley, the stream receives its first tributary, the "Ruf de Contrin" in the village of Penia, and afterwards the waters from several creeks flowing from the Sella and Rosengarten groups. Downstream from the village of Soraga, the stream is regulated by the Pezzé Dam, which has a reservoir capacity of about 460'000 m^3.
In the Fiemme Valley, several streams flow into the Avisio Creek, among which the Travignolo Creek is the main tributary. This stream originates from a glacier in the Paneveggio-Pale di S.Martino Regional Park and is dammed about 8 km upstream from the village of Predazzo, where it formed the Forte Buso lake (1450 m a.s.l.). The reservoir has a nominal volume of 32'000'000 m^3 and feeds the hydroelectric power station of Caoria, which is located outside the Avisio watershed.
Moving further downstream, close to the village of Molina the main course of the Avisio Creek is regulated by the Stramentizzo dam. The reservoir has a capacity of 11'500'000 m^3 and its water is conveyed to the hydroelectric power plant of San Floriano (Province of Bolzano) and then delivered directly to the Adige River upstream from the confluence with the Avisio Creek.
In its lower reach, the Avisio Creek flows through the characteristic porphyry gorges of the Cembra Valley, and
finally on a wide (about 1 km wide) alluvial fan deposit before joining the Adige River. The area between the town of Lavis and the Avisio-Adige confluence is a large protected area known as biotope "Foci dell'Avisio", which is characterized by high ecological and naturalistic value due to the presence of wetlands and natural and semi-natural environments.
From a geological point of view, the Avisio Creek gradually flows from the Dolomite region (characterized by limestone rocks), to the porphyritic Atesina platform (characterized by siliceous rocks), and finally to the Quaternary sedimentary formations of the Adige Valley. The different geological formations and flow regulation pressures existing in the upper and lower parts of the watershed significantly affect the hydrological regime of the Avisio Creek. In particular, the steep slopes combined with outcrops of impermeable rocks typical of the Cembra Valley make the hydrological regime distinctly torrential, with minimal flow rates of about 5 m^3/s and flood events up to 1000 m^3/s.
With regard to the climate, the whole draining basin has the characteristics of a typical alpine region, with cold and dry winters and cool and rainy summers. The mean annual precipitation for the Avisio basin is about 1000 mm (PGUAP).

Two pilot sites have been identified along the main course of the Avisio Creek, the first in correspondence of the Pezzè reservoir (46°23'2.09"N - 11°39'50.62"E - Fassa Valley) and the second in correspondence of the Stramentizzo reservoir (46°15'50.27"N - 11°22'24.81"E - Fiemme Valley). Both study reaches extend from upstream to downstream of the reservoirs. The main physical characteristics of the study reaches are summarized in Table 1, while their location is shown in Figure 1.

Pilot Sites	Avisio River – Stramentizzo reservoir	Avisio River – Pezzè reservoir
Drainage area (km²)*	765	267
Location	Upstream Stramentizzo reservoir and downstream to the confluence with Rio delle Seghe	Upstream Pezzè reservoir and downstream to the confluence with Rio San Pellegrino
Length of the study reach (km)	~ 4-5	~ 2-3
Active channel width (m)	~ 20-30	~ 15-25
Channel slope (m/m)	0,013	0,032
Planform morphology	single-thread	single-thread
Lateral confinement	Artificial and natural confined	Artificial confined
Dominant substrate	gravel-bed	gravel-bed
Main sediment sources	Active tributaries torrents	Active tributaries torrents

Table 1. Main physical features of the two pilot sites

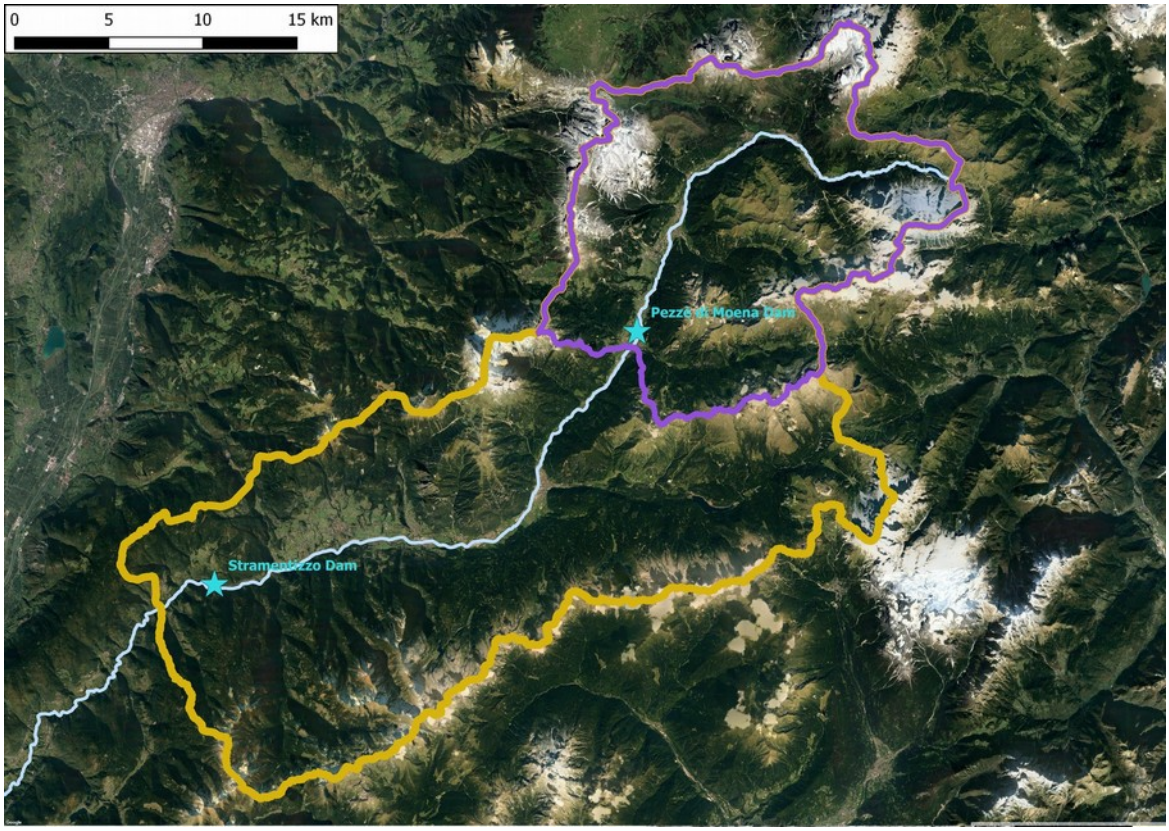

Figure 1: Location of the two case studies and their upstream drainage basins (Stramentizzo case study in orange, Pezzè case study in purple)

2. Hydromorphological restoration/management

From a hydromorphological point of view, the presence of the two dams and of the corresponding upstream reservoirs introduce an interruption on sediment transport. Currently, the management strategy of the two reservoirs does not include any efficient method to ensure sediments continuity from the reach upstream to the reach downstream

from the dam. In particular, in the case of the Stramentizzo reservoir all sediment supply from upstream is stored in the reservoir, and sediment flushing operation are typically not performed. Hence, transit of sediment occurs only during flood events with obvious environmental consequences.
The Stramentizzo dam was build between 1954 and 1955, with a reservoir capacity of 11'500'000 m^3 (of which 10'000'000 m^3 are used for regulation). The reservoir storage is used for hydroelectric power generation by the San Floriano power house located in the Adige Valley (Egna – Province of Bolzano). The average flow rate used for hydroelectric power generation is 13 m^3/s, and can increase up to 30 m^3/s. Recent studies reported the accumulation of 3,5 million m^3 of sediments in the Stramentizzo reservoir, indicating a significant reduction of its regulation capacity and potential technical and water quality issues associated with dam bottom releases .
The Pezzé dam was build in 1952, with a reservoir total capacity of 460'000 m^3 (of which 360'000 m^3 available for regulation). The reservoir storage is used for hydroelectric power generation by a power station located near the Predazzo village where the diverted water is returned to the Avisio Creek, about 10 km downstream from the reservoir. In terms of flow rate, the hydropower plant utilizes up to 7,7 m^3/s. Part of this water (around 1m^3/s) comes from the San Pellegrino Creek. From which it is diverted through a 1,2 km long pipe. The reservoir management is currently in charge of the company "Hydro Dolomiti Energia" and includes periodic sediment flushing aimed at ensuring reservoir efficiency. However, the past periodic sediment flushing did not success in ensuring optimal regulation capacity maintenance, and could cause significant problems for the river ecology and recreational use of the downstream reach (e.g., turbidity currents, sediment deposition, etc).

It is therefore evident that the Avisio Creek is strongly affected by anthropogenic pressures, with significant consequences on the hydromorphology and ecological health of the stream and of its watershed. The most important anthropogenic pressures are listed below:

- Damming of the river induces:
    - alteration of the hydrological regime with consequences on morphological, biological, ecological dynamics; the alteration is more critical in presence of diversions to neighbor catchments (e.g., water withdrawn from the Stramentizzo and Forte Buso reservoirs and used for hydroelectric power generation);
    - interruption of upstream sediment supply; the main consequences are an increase of erosion processes, an alteration of hydromorphological dynamics and a reduction of river ecological quality (see the comparison between Figures 2 and 3);
    - barriers to fish migration that affect local fauna;
- Artificial embankments upstream from the Stramentizzo dam induce an inhibition of the natural processes of stream morphological evolution, with a reduction of natural riparian areas;
- Massive presence of check-dams, especially along lateral tributaries, induce similar consequence as river damming in terms of sediment supply reduction;
- Periodic sediment flushing of reservoirs (e.g. Pezzé reservoir, see Figure 4) induce several ecological and water quality problems, most of them associated to the high water turbidity that decrease dissolved oxygen and destruct (e.g., through clogging) optimal habitat for breeding fish and small invertebrates organisms. In addition, turbidity currents can also cause the obstruction of downstream derivations and serious economic threats to downstream fish farms.

The main objective of the project with respect to these two pilot sites is to identify and propose efficient strategies to be implemented in the current reservoir management policies in order to preserve and improve existing ES provided by the Avisio Creek. Possible improvements include more efficient and sustainable sediment flushing procedures and the possibility of artificial sediment reintroduction downstream from the Stramentizzo dam.

Figure 2: The Avisio Creek in 1973. The Stramentizzo dam is visible in upper-right corner.

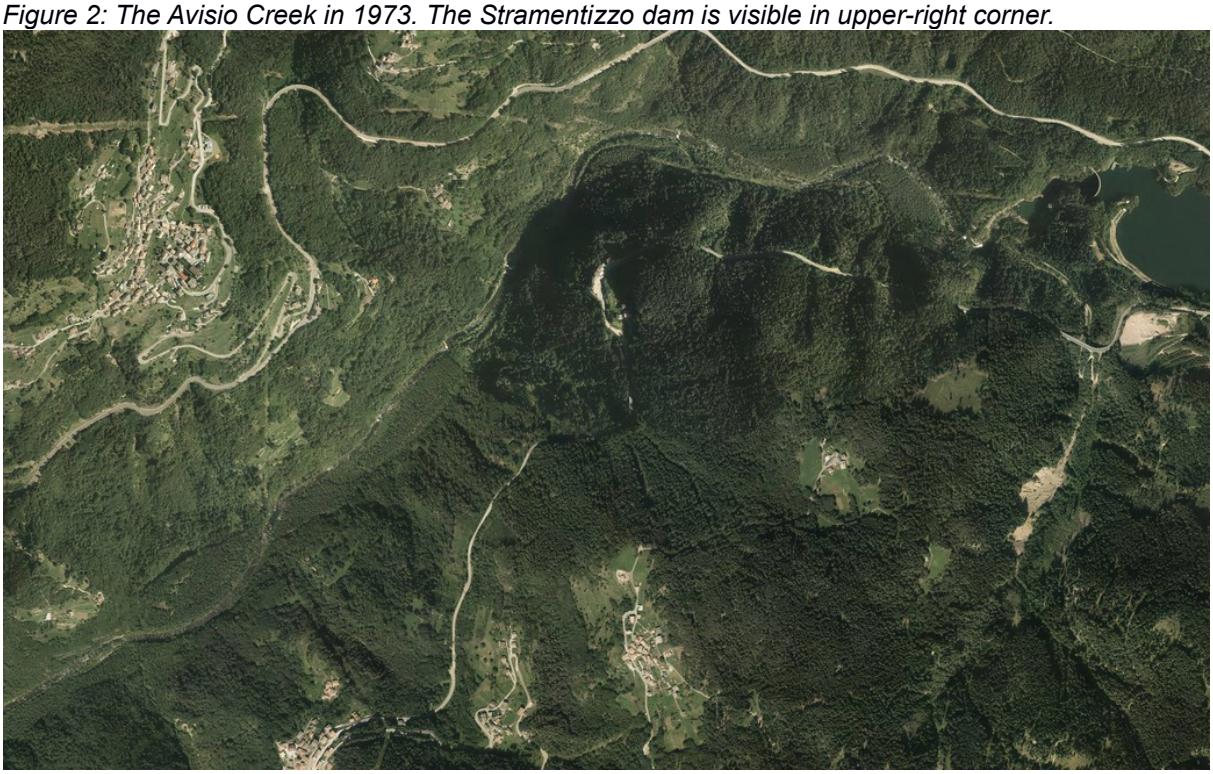

Figure 3: The Avisio Creek in 2016. The Stramentizzo dam is visible in upper-right corner.

Figure. 4: The Pezzè reservoir during sediment flushing operations.

3. Monitoring activities

3.1. General objectives of the monitoring program

The aim of the monitoring activities is i) evaluating the consequences of sediment disconnection and ii) identifying the main actions that is possible to develop in order to improve reservoir and river management policies.
In particular, the objectives are:

- estimate the upstream sediment supply to the study reservoirs;
- estimate the sediment amount present in the reservoirs;
- evaluate the composition of sediments deposited in the reservoirs;
- estimate the consequences of sediment transport disconnection, especially downstream of the dams, in terms of fauna, flora, stability of flood defense structures and more in general in terms of ecosystem services;
- estimate how the stream hydromorphological dynamics is affected by sediment transport disconnection;
- estimate the ecological response to reservoir management operations as e.g., sediment flushing;
- evaluate the technical feasibility and possible consequences due to an artificial reintroduction of sediments downstream from the Stramentizzo dam

3.2. Physical monitoring

Concerning the Stramentizzo reservoir, the follow specific activities will be carried out:

- data analysis of the bathymetric surveys performed over the past years, in order to gather information about the sediments volume present in the reservoir and, by

combining this information with the data of historical relevant floods and significant events, estimate the sediment supply over the years;

- cross section topographic survey downstream from the Stramentizzo dam with a combination of GPS and Total station techniques, in order to collect data to be used for morphodynamics 2D numerical modeling. A detailed topographic map will be obtain by combining the in-situ survey results and the existing topographic data (DTM). The terrain model is the first step to estimate the bed level degradation, the channel units and the general river morphology configuration. This information, combined with historical images and others information can be use to evaluate morphological adjustments following dam construction;
- after the topographic survey will start an analysis on river morphology condition with a specific focus on sediment budget. In particular the sediment transport upstream of the dams and the transport capacity downstream will be estimated in order to understand if and how artificial sediment reintroduction can be done. The analysis will be performed combining field survey (gravelometer, sediment traps, passive integrated transported (PIT) or similar techniques) and numerical modeling.

As for the Pezzé reservoir the follow activities will be carried out:

- in order to compare turbidity values during sediment flushing operations and during natural floods a water quality monitoring station will be located which will collect data in continuous during the entire duration of the project. The monitoring station will measure water turbidity, PH, conductibility, temperature and oxygen (see Figure 5). Another turbidimeter will be located upstream from the reservoir;
- during and after the sediment flushing operations (planned in summer 2018) the downstream deposition area will be sampled in order to obtain a map of the most affected areas where more analysis can be done.

Figure 5: Water quality monitoring station installed downstream from the Pezzè reservoir (February 2018)

Physical and ecological analysis results, in particular a comparison between natural and artificial events, could be use to confirm or change the current methodologies of sediment flushing operations in order to minimize the negative effects on river environment.

3.3. Ecological monitoring

In order to estimate the ecological response to the river management, the monitoring activities will focus on:

- ecological response to sediment flushing operations downstream from the Pezzé reservoir, with a focus on hyporheic fauna and fish fauna and relative habitats, the specific analysis on site will be done in summer 2018 (during the scheduled sediment flusheing);
- analysis on sediment composition in the Stramentizzo reservoir;
- vegetation, fauna and habitats analysis downstream from the Stramentizzo dam (using the software MesoHABSIM) in order to verify the ecological consequence of sediment budget disconnection and the response after sediment reintroduction.