Technical note about the monitoring of hydromorphological restoration/management of the Maggia River (Switzerland)

Project: HyMoCARES	
Work package: WPT3	
Activity: A.T3.1	
Deliverable: D.T3.1.1	
Status: final version	
Date: 27/03/2019	
Authors: ETH Zurich	
Revision: Irstea Grenoble	
Approval: PP1 APC_PAB	

This project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme

www.alpine-space.eu/hymocares

CONTENTS

1. General presentation of the study site

The river Maggia originates in the north-western Alps near the Cristallina mountain and flows through the Sambuco, the Lavizzara, and the Maggia Valley into Lake Maggiore between Ascona and Locarno forming a delta. The Maggia Valley, presented in Figure 1, is an alpine area of 592 km^2. Located upstream of Ponte Brolla (216 m a.s.l.) in Canton Ticino in Switzerland, the Maggia Valley lies in the southern part of the Swiss Alps and rises up to 3272 m a.s.l. at Mount Basòdino, which contains the only remnant glacier in the catchment. The geology of the catchment is predominantly composed of gneiss and granite as nearly the entire catchment lies in the Penninic basement.

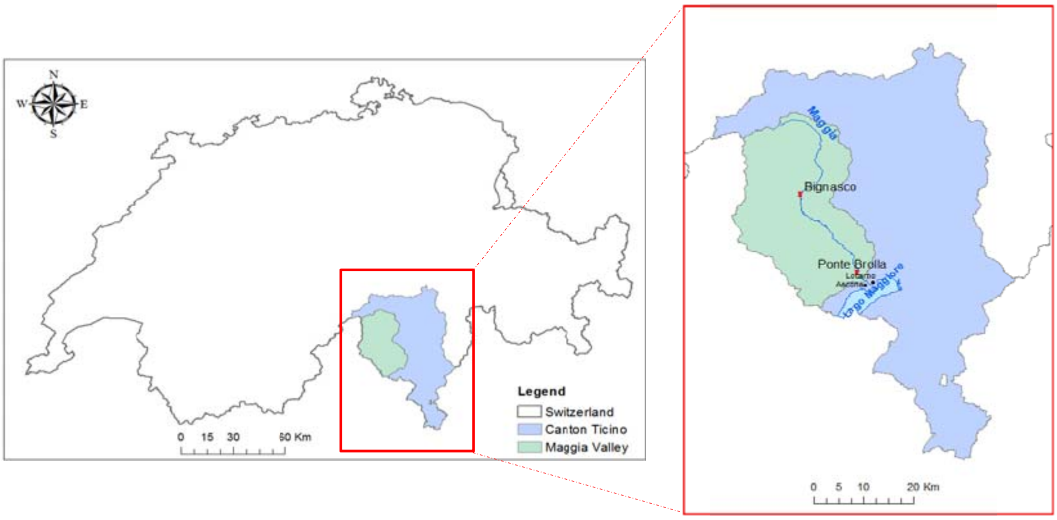

Figure 1: Location of the study area (Maggia Valley) and the concerned river section

The climate is Mediterranean with a long-term mean annual rainfall of approximately 1730 mm (Cevio, 1901-2016). Summers are relatively dry and heavy rainfall typically occurs during autumn due to the combination of warm and humid air masses from the Mediterranean Sea with deep pressure cyclones. Winter precipitation is low, occurring mainly as snow due to the high altitude. Precipitation exhibits a considerable spatial variation caused by orographic effects (Ruf, 2007). Mean monthly precipitation and temperature values over the period 1929-2003 in Cevio, located in the main valley at an alitude of 418 m a.s.l., are shown in Figure 2.

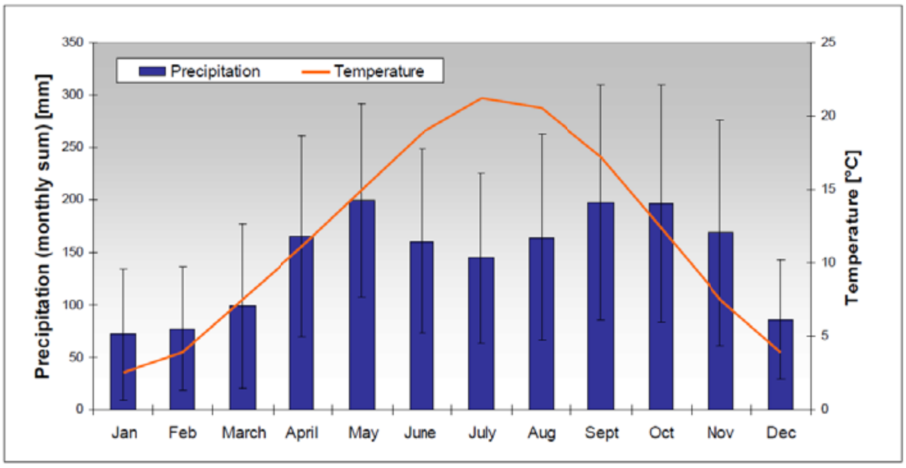

Figure 2: Mean monthly precipitation and temperature over the period 1929-2003 in Cevio (Sturzenegger, 2005)

The natural streamflow regime of the Maggia River (streamflow gauge in Bignasco) can be described as pluvio-nival with a typical snowmelt peak in June. Streamflow exhibits a high temporal variability due to the very fast catchment response to precipitation. This results from the very steep slopes, the thin soil layers as well as granite and gneiss bedrock. Streamflow varies from less than 1 m^3/s under natural low flow conditions up to several hundreds of m^3/s during extreme flood events. Largest flood peaks may reach close to 1000 m^3/s (Ruf, 2007).

The main valley, located in the lower part of the catchment (section Bignasco-Ponte Brolla) is characterized by steep rocky slopes, resulting in fast responding runoff events, and a relatively well-defined floodplain (Figure 3). After the last period of glaciation, it was filled with deep coarse alluvial material to around 150 m (Ruf et al., 2008).

Figure 3: A view of the main valley with its steep hillslopes (©Wolfgang Ruf)

The riverine corridor in the main valley, extending from Bignasco to Ponte Brolla and having approximately a length of 22 km and a width of 500 m, is the concerned river section in this project. The river bed is characterized by strong dynamics and high sediment transport rates. As a result, a braided river morphology with gravel bars and vegetated islands is observed over a length of around 7.5 km near the village of Someo in the central part of the corridor, especially after large flooding events (Figure 4).

Table 1: Main physical features of the pilot site

Pilot Site	Bignasco – Ponte Brolla
Drainage area [km^2]	592
Location of the study reach	Bignasco (46.3382° N, 8.6089° E) to Ponte Brolla (46.1853° N, 8.7528° E)
Length of the study reach [km]	22
Active channel width [m]	500
Channel slope [m/m]	0.005 (braided area) – 0.02
Planform morphology	braided/alternate bars (in the central part)

Figure 4: The braided area of the Maggia Valley (©Wolfgang Ruf)

Historical references report the wild character of the river Maggia with vast inundations and frequent relocations of the channels (Cerini, 2003). From the natural point of view, this braided area is a very active floodplain with riverine vegetation undergoing its natural dynamics of erosion, seedling, succession, and rejuvenation. The braided area has an average slope ranging from 0.5-1%, while in the upper and lower parts channel slopes reach 2%. The entire floodplain in the main valley consists of coarse material: cobbles, large gravels and sand with a pronounced armouring layer (see Figure 4).

2. Hydromorphological restoration/management

2.1 Human induced alterations of flow

The Maggia Valley with a large hydropower system (OFIMA) with many reservoirs in the upstream part of the catchment is an example of an alpine environment highly affected by streamflow regulation due to hydropower operation. Its riverine corridor, which contains one of the few remaining natural alluvial river systems with a braided gravel bed stream and a riparian floodplain forest in Switzerland, has undergone a strong reduction in flow magnitude and variability as well as a drop in groundwater levels and sediment delivery. The affected river reach is classified as a wetland of national importance since 1992.

Similarly to many alpine valleys, hydropower system construction in the 1950s led to a dramatic drop in the mean annual streamflow in the affected river reach. This change amounts to about 75% of the natural pre-dam discharge, i.e. from 520 mil. m^3 in the pre-dam period to about 130 mil. m^3 in the post-dam period. The seasonality of streamflow also changed significantly, with a reduction of the spring-summer snowmelt runoff peak due to filling of reservoirs (Figure 5 left). The imposition of minimum flow requirements in 1982 leads today to almost constant flow for most of the year (Figure 5 right). However, because the upstream reservoirs are not large in size and are not built for flood protection, they do not store flood waves and the very highest discharges in the affected reach are not significantly reduced. Thereby the geomorphic reworking of the gravel bed by large floods continues to take place.

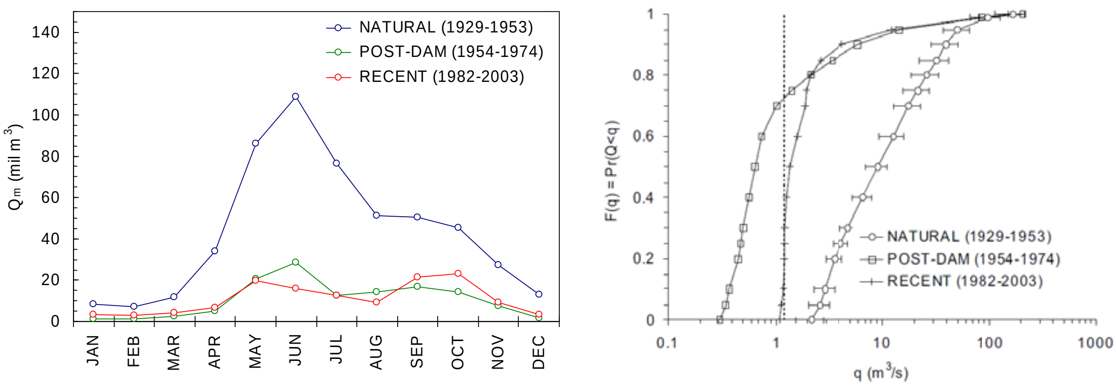

Figure 5: Mean monthly streamflow in Bignasco before and after dam construction (left) and the cumulative probability distribution of daily streamflow in the pre- and post-dam periods (right).

The environmental flow regulation (mandated minimum flow releases) was enforced in order to ensure a constant minimum flow that allows for permanent water flow throughout the entire valley (Thorens and Mauch, 2002; Cerini, 2003). Since 1982, the constant minimum release in the main valley is imposed to 1.2 m^3/s in winter and 1.8 m^3/s in summer. i.e. (Ruf et al., 2008). Currently, during dry periods, most of the tributaries from the side valleys are either diverted into the hydropower water supply system or their discharge completely infiltrates into the coarse alluvial aquifer of the main valley before reaching the Maggia River. On the contrary, under flood conditions, almost all water is released into the main channel. Consequently, the influence of the hydropower regulation on the hydrological regime is mainly limited to low and moderate flow conditions (Molnar et al., 2008).

The effects of human impacts on the floodplain aquatic ecosystem in the Maggia have two main dimensions. First is a hydrological one, where we expect that the low (and constant) streamflow and drop in groundwater levels is likely to have an effect on riparian vegetation. On a long-term perspective, the vegetation distribution should reflect the current hydrological regime, i.e. there should be a balance between vegetation destruction due to flooding and scour as well as a vegetation growth due to rejuvenation and germination on newly established gravel bar surfaces. This has been illustrated by a probabilistic model of hydrology-vegetation interactions in the Maggia River by Perona et al. (2009). Nonetheless, a strong tendency towards narrowing of the river and the exposed sediment area in the post-dam period was observed (Ruf, 2007). This general tendency occurs despite the fact that the river system is still able to rework the river bed and to erode pioneering vegetation (mostly Salicaceae) significantly after large flood events (e.g. in 1978). For managers of river systems the question then is whether hydropower operation has a significant effect on floodplain processes due to the altered surface water flow regime or changes in groundwater levels.

2.2 Human induced alterations of sediment

The second dimension concerns sediment budgets. It is expected that reservoir construction in the headwaters of the river may have significantly reduced sediment input into the affected river reach and/or shifted the grain size distribution of the incoming sediment towards coarse material. This may have significant effects on floodplain soil water storage and the erodibility of the river bed, i.e. the transportability of coarse grains. For managers of river systems there are opportunities for supplying sediment to starved river reaches and/or allowing the river system to access natural sediment sources during floods. Atlhough these actions are not envisioned for the Maggia, they are options in other rivers in Tessin (e.g. Ticio River).

The TiRiLab which is an environmental computing laboratory at ETH Zurich within the HyMoCARES project will use advanced hydrodynamic modelling in the Maggia to provide a DEMO of options focusses around the fundamental questions: (a) can we quantify the erosion/deposition rates in the river bed as well as the required flood level for a significant geomorphic work to take place?; (b) can we quantify alterations of the physical habitat, transportability of sediment, and habitat suitability for fish with respect to the pre- and post-dam period, with a view towards full ecosystem services analysis?

3. Monitoring activities

Monitoring activities in the Maggia River consist of networks covering climate and hydrology, river sediment, floodplain vegetation, and river ecology. In these networks there are both continuous as well as intermittent (snapshot) type surveys that have been (are being) conducted.

1. Climate and Hydrology. All relevant climatic variables (precipitation, radation, temperature, wind) are being measured at two SwissMetNet sites in the valley (Cevio) and in the headwaters (Robiei) at a 10 min resolution since 1981. We have added two Sensorscope stations (Figure 6) on a single gravel bar in the central valley near Someo where also soil moisture is measured for the assessment of soil water status. Streamflow is measured at Bignasco (daily since 1932, hourly since 1980) and also at the Lodano station downstream in the valley (high resolution records since 2005). Several boreholes provide long-term intermittent groundwater level measurements. However automatic (hourly) measurements are only available for a short campaign period in 2003-2006 and currently at three wells in the Someo area since 2016.

2. River Sediment. Grain size distributions are available at a number of sites along the main valley sampled using adaptations of the Wolman count method and line sampling. Repeated surveys of cross-sections along the river are available from the Federal Office for the Environment (FOEN) and cover approximatelly the last 20 years. The most recent cross-section survey are available from summer 2016. These will be used for the determination of erosion/deposition patterns in the valley in TiRiLab. A high resolution LIDAR DEM was developed with a drone flight in the summer 2015 (HydroEnv project).

3. Floodplain Vegetation. Riparian vegetation is being monitored at three spatial scales. At the valley scale we have historical aerial photographs available since 1933 (about 10 images till 2015). These are used for the large scale mapping of land surface categories and vegetation change after large floods. At the reach scale we monitor the Someo area daily with a terrestrial camera system (Figure 6) with infrared sensitivity since 2008 (Dzubakova et al., 2015). This allows us to compute vegetation indexes and quantify the plant erosion potential of floods as well as long-term vegetation dynamics and potentially drought effects. At the plant scale we monitor the growth of vegetation by dendrometers installed on 8 riparian trees (Salix Eleagnos) in the Someo area (Figure 6). This high resolution measurement of water use is supplemented by occasional leaf stomatal conductance measurements in summer campaigns.

4. River Ecology. Macrobetnthos communities were sampled (abundance and species variety) in several ponds/pools along the Maggia valley in 2015-2017. The ecological monitoring will continue in the future.

Figure 6: Weather station, dendrometer and camera used for measurements in the main valley (©Gianluca Bergami)

References

Cerini, U. (2003). Le fond de vallée du Valmaggia entre Bignasco et Giumaglio. Faculté des Lettres. Institut de Géographie. Université de Lausanne. Diploma Thesis, p. 164.

Dzubakova, K., Molnar, P., Schindler, K., & Trizna, M. (2015). Monitoring of riparian vegetation response to flood disturbances using terrestrial photography, Hydrol. Earth Systems Sci., 19, 195-208, doi:10.5194/hess-19-195-2015.

Molnar, P., Ruf, W., Favre, V., Perona, P., Burlando, P. & Randin, C. (2008). Floodplain forest dynamics in a hydrologically altered mountain river. In: Russell, D., Broll, G. & Kaluz, S. (eds.): Floodplains – Hydrology, Soils, Fauna and their Interactions. Peckiana 5: 17-24.

Perona, P., Molnar, P., Savina, M., & Burlando, P. (2009). An observation-based stochastic model for sediment and vegetation dynamics in the floodplain of an Alpine braided river, Water Resour. Res., 45, W09418, doi:10.1029/2008WR007550.

Ruf, W., Foglia, L., Perona, P., Molnar, P., Faeh, R. & Burlando, P. (2008). Modelling the interaction between groundwater and river flow in an active alpine floodplain ecosystem. In: Russell, D., Broll, G. & Kaluz, S. (eds.): Floodplains – Hydrology, Soils, Fauna and their Interactions. Peckiana 5: 5-16.

Ruf, W. (2007). Numerical modelling of distributed river-aquifer coupling in an alpine floodplain. ETH Zürich. Doctoral Thesis. Diss. ETH No. 17534.

Sturzenegger, M. (2005). Changes in river morphology and vegetation caused by streamflow regulation: A case study in the Maggia valley. Institut für Hydromechanik und Wasserwirtschaft. ETH Zürich. Diploma Thesis, p.39.

Thorens, A. and Mauch, C. (2002). Case Study 1: Maggia Valley, EUWARENESS research project on European Water Regimes and the Notion of a Sustainable Status. Institut de Hautes Études en Administration publique (IDHEAP). Chavannes-près-Renens, p.30.

This project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme