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Proposals for restoration of Mediterranean watercourses in urban context

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Abstract

The increased sensitivity for the preservation of the riparian ecosystems equilibrium has guided the attention of researchers and planners towards river restoration interventions, to give a higher naturalness to watercourses. Interventions of ecological river restoration in urbanized areas require specific preliminary studies and surveys on the hydraulic compatibility of materials (both living and nonliving) and works, in order to verify the effects induced by the new fluvial settlements on the hydraulic safety of riverbed reaches and its surroundings. In this work three contexts will be identified: three representative contexts in an urban environment, and, for each of them, possible ecological river restoration interventions will be proposed.

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*Keywords:*River restoration; Embankments; Riparian ecosystem; Fiumara.

1. Introduction

The increased sensitivity and the interest in the preservation of the equilibrium of riparian ecosystems has guided the attention of researchers and planners towards the identification of more environmentally-friendly operations, able

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to combine the often opposing needs of both hydraulic and hydro-geological safety and safeguarding the natural characters of watercourses.

Although the pertaining body of laws has always contemplated the need to preserve the river environments by stimulating, in the planning phase, the adoption of an integrated river-basin-scale approach[1];only with the implementation of the Habitat Directive (92 / 43EEC) in Italy, the aims of hydrological safety and defense of environment are associated to those of conservation and improvement of river habitats conditions. The Water Framework Directive 2000/60 / EC or WFD (Water Framework Directive) also establishes strategies and key aims to achieve a "good" ecological status for all watercourses, also through river restoration[2].The Floods Directive (2007/60 / EC) suggests the adoption of river restoration intervention to achieve the reduction of hydraulic risk,giving back "more space to rivers" and ensuring "maintenance and/or restoration of floodplains" i.e. morphological requalification (Goltara *et al*., 2013).

In Mediterranean area and specifically in Southern Calabria and Eastern Sicily the hydrogeological risk assumes a paroxysmal character in conjunction with specific meteorological events. It mainly takes place in mountainous and hilly areas, where the interaction between heavy rainfall and geo-morphology (easily erodible soils and steep slopes) activates runoff and sediment transport, whose negative effects are conveyed downstream.

An interconnection between the watershed planning and urban planning is needed, in order to oppose the transfer of hydrological effects from upstream to downstream areas. This is even more relevant in the case of the Metropolitan Area of Reggio Calabria and Messina, both located downstream of morphologically complex hilly and mountainous area and crossed by several rivers. The irregular morphology of this area has always forced the populations to a continuous work of "architectural" reconstruction of the territory. The complex orographic scheme of this area, the slender coastal plains and the violent character of the torrents that flow through (known as *fiumare*, local name used to describe seasonally flowing streams which drain the mountain chains of Calabria and Sicily in Southern Italy) have resulted in the lack of real urbanizable spaces (Bombino, 2009). Thus the settlement process has been disordered, often perched on rugged slopes, and has required an arduous search for "corrective" elements (hill and mountain terraces, embankment, etc.) aimed to defend human settlements and activities from natural events.

In fact embankments have been built, in order to permanently recover farming areas (until the first half of the last century) and urban areas (in the last decades) in the slender coastal plains and along the expansion areas of rivers, and at the same time to protect them from periodic floods. (Bombino *et al.,* 2007). This implied the drastic narrowing of the riverbed, where *fiumare* had up to 1-km wide floodplains. Subsequently the changing of territorial and hydraulic conditions of drainage basins near the coast has made further engineering measures necessary.

Especially in urban areas, "hydraulic safety" has been obtained with embankments and waterproofing (made of concrete) of the riverbed, which have adjusted the reaches, increased the gradient and decreased the roughness, in order to facilitate water flow and sediment transport towards the sea. Other interventions (as in the cases of the Annunziata and Caserta torrents in Reggio Calabria, or of the Camaro and Boccetta torrents in Messina, for example) have implied the waterbed coverage and its use as a roadway. Especially in the cities of Reggio Calabria and Messina, this marked a true work of "exclusion/cancellation" of watercourses from urban areas (Bombino, 2008). For this reason if the land changes to agriculture or impervious urban lands, land development and management should be considered with care (Gyawali *et al*., 2013).

Taking into account the complex situation described so far, the present study suggests the possible restoration measures, analyzing three fluvial contexts, which are located in urban areas and with different levels of

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[1]See RD 523/1924, art. 96, letter f; Law 183/89 (repealed and incorporated in the Legislative Decree of April 3, 2006 n. 152); though not explicitly referring to river restoration, both laws include, among their principles, the soil conservation, the use and management of water resources and the improvement of waters, as well as the need to monitor the embankments during the flood events and the possibility to carry out the necessary maintenance interventions.

[2]According to the Centro Italiano di Riqualificazione Fluviale (CIRF) river restoration is "*the integrated and synergistic actions and techniques, also very different (from legal-administrative-financial to structural), aimed at bringing a river, with the territory closely connected to it ("fluvial system"), in a more natural state as possible, able to perform its ecosystem functions (geomorphological, physical, chemical and biological) and provided with a greater environmental value, satisfying the socio-economic objectives "*(CIRF, 2006)

"naturalness". The choice of the river restoration measures to implement needs to several preliminary investigations, concerning both the knowledge of the environmental and social context (by analyzing the hydraulic risk) and the technical evaluation of the hydraulic functionality of the works to modify.

2. Methodology

In the following work, three representative situations of watercourses in an urban environment have been identified: reaches with free sections and naturalness characters to be preserved, reaches with forced sections and no characters of naturalness, but provided with marginal areas, and finally, reaches with forced sections devoid of any form of naturalness (Figure 1).

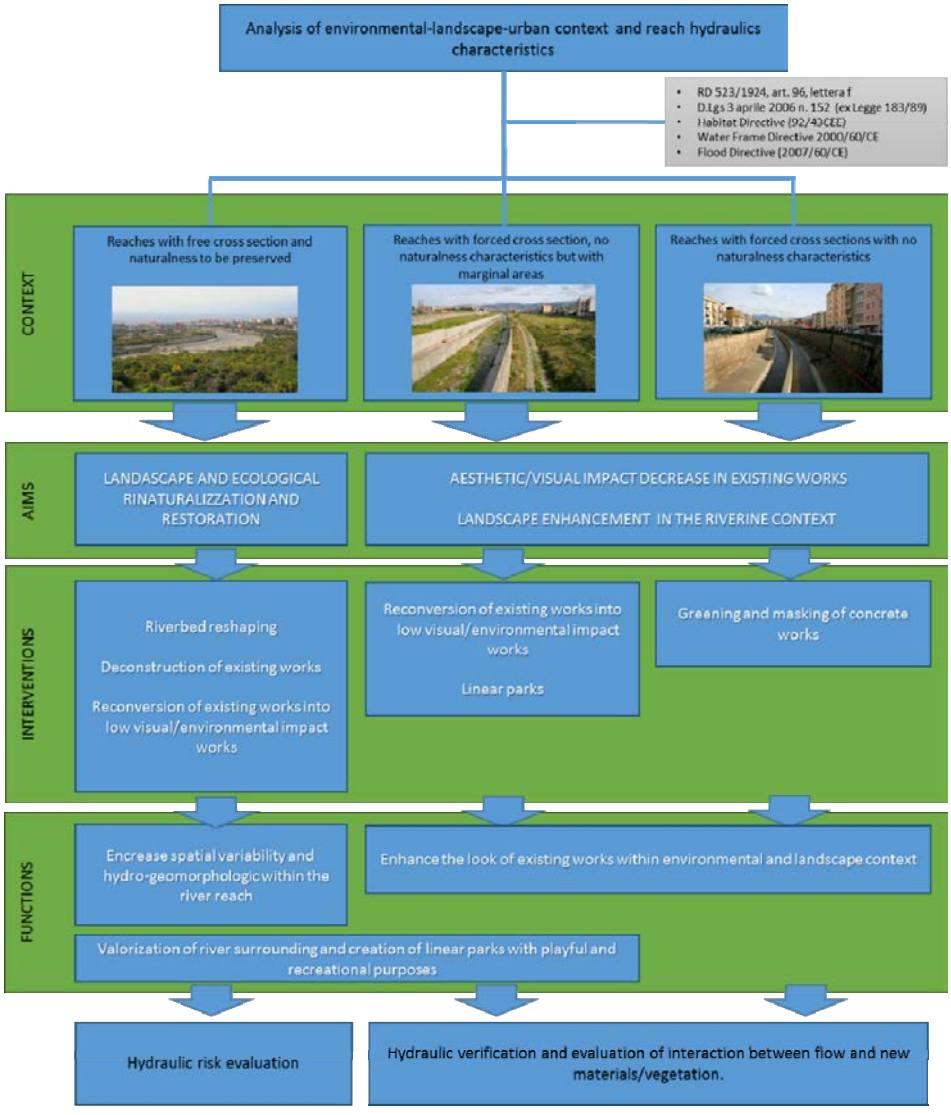

Fig. 1. Possible interventions for the enhancement of river environments in urbanized areas.

2.1. Reaches with free sections and naturalness characters to bepreserve

In these reaches river restoration has to be connected to a series of interventions aiming at the rehabilitation and re-functionalization of *fiumara* contexts, through the "deconstruction" of existing works and the inclusion of low ecological and landscape impact works. In these contexts, the aim of these interventions is to re-create the hydro-geomorphological and ecological dynamics of *fiumare*by restoring an "ecological connection" between the river, the perifluvial areas and floodplains. Riverbank protection if present may be replaced or "masked with Mechanical Stabilized Earth (MSE) installed both inside and outside the concrete walls; which constitute subsidiary banks; as an alternative, the construction of tree-lined dams, can be positioned next to the internal embankment, (Figure 2).

In the sections with no riverbank protections, it is possible to create earth embankments on which, from the center outward, riparian shrubs, followed by woody shrubs and then by riparian trees, can be disposed (in order to recreate the natural vegetation series of river contexts). This has the dual function of increasing the naturalness of the environment and strengthening the embankments, thus helping to improve the river landscape.

In areas where the hydraulic risk is less significant, embankments can be converted into pedestrian/cycling routes through the construction of MSE, fastened to the walls foundations to ensure greater stability and durability. As an alternative, where neither the shape of the sections nor the roughness of the works are adjustable (in order to maintain a sufficient hydraulic functionality of the works), greening operations of existing embankments can be implemented, with mixed tree-species planted in the dugout, both inside and outside the concrete embankments. In sections where the riverbed is not cemented, a recalibration of the cross-section may be carried out, by shaping the gravel bed and by reconstituting a thalveg sufficiently wide to allow the flowing of low and medium flows, thus optimizing the hydraulic functionality of the watercourse. The function of these measures aims to enhance the adjacent areas for the realization of linear recreational parks.

The new structure given to these fluvial contexts involves the assessment of risk levels to which the surrounding area is subject. In particular, it is necessary to define the extrinsic hydraulic risk pertaining to floods in populated areas, evaluating: i) the elements at risk, i.e. people and properties which may be affected by natural disasters, ii) the vulnerability, that is a work's capability of resisting the stress induced by the event and iii) the natural hazard, ie the probability of flooding in a given time horizon *t*.

Furthermore, both the geometry and the roughness of the section are modified by the addition of new types of material in the water section. It is therefore important perform a hydraulic analysis on interventions, with particular reference to the evaluation of the interaction between vegetation and water flow.

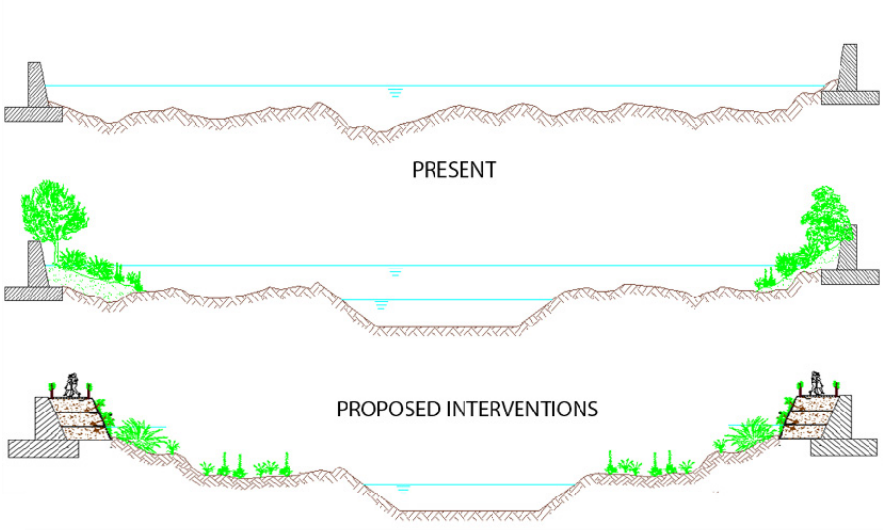

Fig. 2. Proposed reconstitution with usable areas on MSEs and cross section reshaped.

2.2. Reaches with forcedsections, no characters ofnaturalness but with marginal areas

River restoration of these contexts, although not capable of giving rise to an "ecological connection" with perifluvial areas, has the dual objective of reducing the aesthetic/visual impact of existing works and improving the landscape of the river habitat. The reshaping of the riverbed may be planned through the restoration of flow sections for the passage of ordinary and extraordinary flow rates and the consolidation of banks through the installation of structures greened with scions of local species.

These intervention also have the function of enhancing the adjacent areas, by creating the conditions for the construction of a fluvial park through linear punctual, linear and areal works (Figure 3).

Fig. 3. Channelized reach in urban area with marginal areas in the surroundings.

2.3. Reaches with forced sections with no charactersof naturalness

The high degree of riverbeds' waterproofing and the narrowing of watercourses' terminal stretches impose the implementation of requalification measures within the "rigid" existing forms and do not allow the "ecological connection" between requalification measures and perifluvial areas. Based on these elements, several project measures can be defined, e.g. those for the setting of the green shielding between hydraulic structures and eco-vegetation areas, or the non-invasive procedures for multi-purpose use of the torrent (Moraci et al. 2007).In particular, actions may provide the masking of embankments by means of walls perforation and planting of riparian plants. The action must consist of the drilling of concrete walls up to the embankment behind and the insertion, in the holes, of local plants' cuttings (Figure 4).

The proposed actions for the regeneration of the areas near the mouth are instead part of a broader design aimed at the recovery of the relationship between the city and the sea, very often canceled because of the interposition of road and settlement infrastructures. A conjunction between the coastal area and a linear fluvial park is proposed, using the planitial wood near the mouth as a biological re-connection element. The river restoration measures allow achieving the creation of both pseudo-natural areas near the urban center, and areas of biological permeability, functional for the linear park. It seems therefore important to highlight how the recovery of the mouths can occur through the planting of trees and the restoring of flow sections.

The proposed interventions do not affect the structure of the works; the hydraulic risk levels remain therefore unaltered. Variations affect the roughness of materials, for which it is important to have a hydraulic testing of interventions, paying a particular attention to the evaluation of the interactions between water flow and vegetation.

It has been generally agreed that vegetation increases flow resistance, changes backwater profiles, and modifies sediment transport and deposition (Masterman & Thorne, 1992).

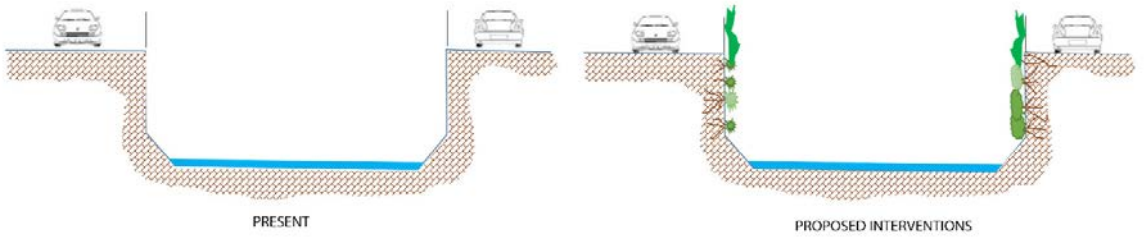

Fig. 4. Proposed masking by creeper plant in embankments walls

The net impact of vegetation depends on many complex interacting factors, including the geomorphic setting of a channel, as well as the physical properties, extent, species, age, and health of the vegetation (Masterman & Thorne, 1992).

3. Discussion and conclusion

In an urban environment, the choice of restoration measures for rivers with different levels of "naturalness" require preliminary investigations, concerning both the knowledge of the environmental and social context in which interventions need to be made, as well as the assessment of the hydraulic risk related to the inclusion of new works. In reaches with free sections and natural characteristics to preserve or restore, "deconstruction" of existing works can be made to restore an ecological connection between the watercourse and perifluvial floodplain areas,granting in the same time, the riparian ecosystem usability through the creation of linear parks. In reaches with forced sections devoid of naturalness but with the availability of marginal areas, milder interventions are to be proposed, aiming to minimize the landscape impact of existing works and/or to reconvert them, within the limits of the construction of pedestrian and/or bicycle routes. forced sections devoid of naturalness in which it is not possible to "deconstruct" the current structure of the watercourses, the inclusion of works in the urban context can still be enhanced by surface masking and greening of the embankment walls, without significantly changing the hydraulic and geometric characteristics of the section. In all cases a *post operam* hydraulic verification is essential, to assess the compatibility of interventions for the maintenance of acceptable risk levels. It seems evident that the issue of restoration of rivers in urban areas should be further investigated through a detailed analysis of the ecological dynamics, which are now interrupted by bursting urbanization.

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