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Natural responses to changes in morphodynamic processes caused by human action in watercourses: A contribution to support management

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ABSTRACT

The economic, social and environmental conditions of various European river basins and estuarine systems have changed dramatically in the last decades as a consequence of anthropogenic effects, and they will go on changing in the years to come due to increasing human pressure. Particularly in Portugal, various river-estuary systems have undergone several human interventions, notably engineering works to restore considerable stretches of channels and river banks. A thorough understanding of responses to changes in the morphodynamic processes and new strategies are needed for the use of existing resources in watercourses in order to take into account the many-faceted aims of sustainable development. This paper describes two serious accidents that occurred in Portugal, in consequence of careless management measures that have lasted for several years. It is shown that both accidents could have been avoided if the implemented management methodologies were strictly based on knowledge of the physical processes. This paper also provides a brief description of the nature and distribution of impacts on the river morphology arising out of building and operating large dams. A technical contribution is also offered which although qualitative provides a basic record and explanation of the serious consequences of significant interventions in watercourses, especially when these are not properly assessed or other mitigating circumstances are not taken into consideration.

1. Introduction

Alluvial rivers are characterized by water and sediment transport channels that undergo constant changes. Erosion in rivers is not a serious problem as long as no human action is present. Anthropogenic activities along a river stretch disturb the natural equilibrium of the river dynamics and accelerate the rate of bank erosion. It is well known that activities such as gravel mining, sand extraction, dam and bridge construction, artificial cut offs, bank revetment, deforestation and land use changes alter the morphology and natural dynamics of rivers [1].

History has demonstrated that human activities are stronger with respect to changing river dynamics than natural events, such as floods, droughts and landslides [2]. Such activities expanded rapidly in the second half of the last century, and the effects of these activities are acutely felt today, to the point that few rivers in Portugal retain their natural state and some of the more altered rivers are becoming badly damaged. Due to nonexistent or inappropriate management guidelines, certain practices and interventions were permitted in natural systems that have strongly contributed to river weakening.

History also shows us that, rather than contradicting natural processes, cultivating a pro-nature attitude is essential, which means avoiding activities that threaten nature's tendency to establish dynamically stable configurations. Sustainability can only be achieved as a result of a developmental process based on a relationship between people and nature, combining actions designed to stimulate economic dynamism and improve people's quality of life. This should concern future generations and natural environment conservation.

Implementation of measures to stabilize the river regime has always been the focus of river regulation and management. In recent years, many targeted remediation methods have been implemented worldwide and valuable experience in maintaining river stability has been accumulated [3]; however, not all activities and management measures have been successful.

Among the many construction works and interventions carried out on alluvial rivers for various purposes, the construction of dams probably has the greatest effect on fluvial processes [4]. Dams are built for many purposes: water storage for potable water supply, livestock water supply, irrigation, fire-fighting, flood control, recreation, navigation, hydroelectric power, or simply to contain mine tailings. Dams may also be multifunctional, serving two or more of these purposes [5].

In Portugal, as in other countries, the construction of dams and the consequent creation of reservoirs not only affects the water domain but also represents a potential risk that cannot be overlooked. When the hydrological system of a river is altered by the construction of a dam,

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changes are generally caused downstream depending on how the dam is operated. The way that discharges are controlled and regulated and the seasonal variability of the major discharges are important aspects to consider.

Also of great importance are changes in the water characteristics and the mixed discharges (water and sediment) from the dam that feed the river segment downstream. The environmental impact may also extend to the alluvial plain affecting the ground water system. Changes in the water level will arise because of the reduction in the water discharge, which in turn implies changes to the rate at which the water infiltrates the soil.

The operation of these structures requires proper coordination between the various entities with responsibilities in its management, particularly in the case of construction works regarding river regulation due to the strong implications of incorrect management measures that could affect the entire valley downstream [6]. Consequently, great care is needed in river management processes.

This work focuses on the lessons we can draw from past events in terms of management practices and human actions that can compromise infrastructures and human safety, as well as leading to serious changes in aquatic communities.

In this regard, two events of high severity that occurred in Portugal in the winter of 2001 are described below. The first accident was caused by less appropriate management measures for a dam that led to serious economic and social damage. Then, the physical processes that were neglected and the human actions that led to the collapse of a century-old bridge killing 59 people are described. To explain and to prove more clearly the reasons that led to the collapse of a pillar of this bridge, a computational model for the simulation of the involved physical processes is described and applied.

Finally, based on all the information collected, management guidelines for decision making are suggested.

2. Brief descriptions of watersheds and the events

2.1. The Mondego River catchment and flooding of 2001

The Mondego River is the largest Portuguese river with a catchment area of approximately 6670 km^2 and a medium altitude of 375 m, with a mean annual precipitation of 1130 mm. The river flows for approximately 227 km in an E-W direction from the *Serra da Estrela* mountains (1547 m) through a very narrow valley until it reaches *Coimbra* town, where the valley spreads to form a vast alluvial plain, reaching the Atlantic Ocean at *Figueira da Foz* (Fig. 1).

Fig. 2. Picture of a flood in the Lower Mondego, downstream of Coimbra (Adapted from [8]).

In natural conditions, the hydrological regime of the Mondego River was very irregular, with discharges that could be less than 1 m^3/s for several days in a year, and flood discharges up to 3000 m^3/s. The river presented torrential characteristics due to the precipitation regime and the strong slopes of the river basin [4]. Over several centuries, the lower part of Mondego River basin was subject to periodic flooding (Fig. 2) and many attempts were made to regulate and channelize the river.

To protect the population and increase the agricultural potential of the downstream flood plains, a large river regulation project was implemented in the 1970s. This project entailed the construction of three large dams, Aguieira, Raiva and Fronhas, to control the flood discharges, and a significant training of the river in the lower, flat area of its basin, with an opening of adequately designed channel flanked by unsubmersible embankments over a distance of approximately 36 km [4,9].

When designing the alluvial bed river training, the main objective was to define a dynamically stable channel. It was designed for a modified 100-year flood of 1200 m^3/s at Coimbra, resulting from the retention of a maximum flow of 1800 m^3/s in upstream dams, associated with the 25-year flood of the Lower Mondego tributaries.

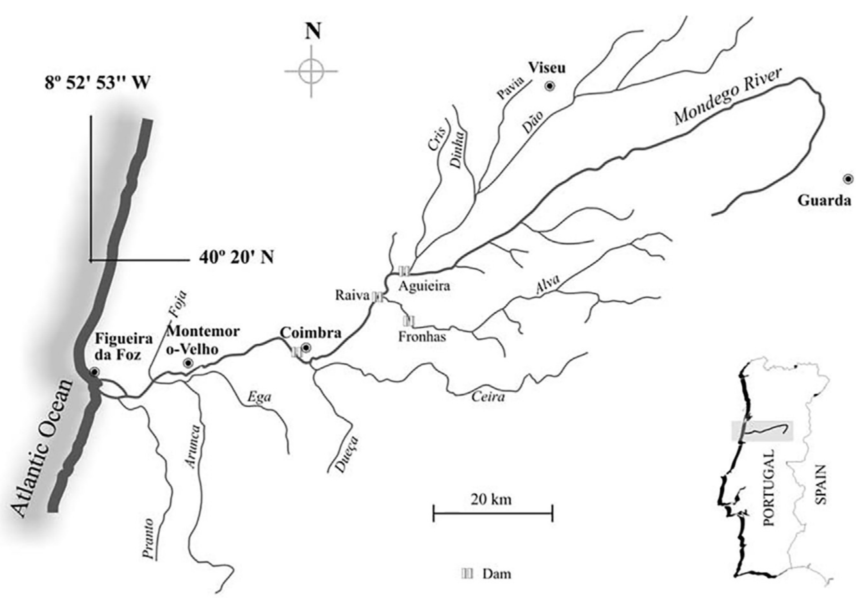

Fig. 1. Map of the Mondego River drainage basin, identifying the main urban centres and dams (Adapted from [7]).