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ORIGINAL ARTICLE

Numerical modelling of solid transport caused by an extreme flood: Case of the Hamiz dam failure (Algeria)

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Abstract Study of solid transport caused by the flow of an extreme flood such as the propagation of dam failure wave aims to simulate the hydrodynamics behaviour of the solid particles contained in the valley during the flood passage. With this intention, we have developed a numerical model which is based on the resolution of the one-dimensional Saint Venant–Exner equations by the implicit finite difference scheme. Numerical stability of liquid phase calculation is checked by the Courant number and De Vries condition for the solid phase. The model has been applied to the Hamiz dam (Algeria) which is built in the semi arid zone and presents a major risk of failure. The simulation of several scenarios of dam failure has allowed us to trace the cartography of sediment transport in the valley which is induced by the flood of dam failure.

1. Introduction

Floods caused by dam failure have taken since a long time the attention of researchers; especially where this phenomenon generates very violent flows of which its extents can be much more significant than those of natural floods. The resulting flooded zones will be noticeably very wide as well. The immersion occurs brutally of which it is very difficult to be protected. The violence of flows is accompanied by strong erosions, major modifications of the valley and destruction of its infrastructures (Capart et al., 2001). Sediment transport in the valley is possible when the training constraint exerted by the flow exceeds a critical threshold value also called critical constraint of wrenching. This threshold is well known for granular materials of certain sediments of river. It is variable according to the turbulence state of flow around the grains which can be calculated by using simple laws according to granulometry of sediment (Julien, 1995). Sediment transport begins with the bed load of which velocity of particles remains weak. If this velocity increases in consequence of turbulence, the particles reach a higher part of the liquid vein and are subjected to another type of transport, it is the suspension which concerns in general the

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List of symbols

L	constant width of dam	x	distance
h_0	initial water depth	t	time
Q	liquid flow	τ_*	the Shields parameter
V	flow velocity	τ_{*cr}	the critical Shields parameter for particle movement
h	depth of flow		
S	surface of wetted cross section	C_{MPM}	coefficient in the Meyer-Peter and Müller formula
g	acceleration of gravity	θ	time weighting coefficient
J	longitudinal gradient of energy which results from friction resistant forces	ψ	space weighting coefficients
		n	number of time step
x	distance	i	number of space step
t	time	Δt	time step
K	the conveyance	Δx	space step
R_{h}	hydraulic radius	C_{n}	the Courant number
K_{str}	Strickler roughness coefficient	μ	the courant number of sediment transport
P_{r}	porosity of bed material	C_b	bed celerity
Q_{s}	solid flow	Fr	Froude number
Bs	bed width of sediment	dq_{s}	fluctuation of solid flow per unit of width
Z	bed elevation	dv	fluctuation of velocity

fine particles maintained suspended over the bottom (Graf, 1995). Indeed, during modelling of the flow due to dam failure, in addition to the fluid component, the sedimentary component must also be modelled to hold account of erosion and transport phenomenon induced by the flood wave. Our study aims to realize a numerical model which will be used to study, after a possible failure of the Hamiz dam (Algeria), the sediment transport caused by the wave propagation due to dam failure in the valley which extends over 32 km in length.

2. Characteristics of study area

2.1. Dam situation

The Hamiz dam is built 35 km far from the SE of Algiers in the plain of Mitidja in the Arbatache Wadi which takes then the name of Hamiz wadi, it drains the Eastern large plain. It is located at 6 km of Fondouk village, at 25 km of the sea (Fig. 1). The surface of reservoir extends on 128 ha. The dam is 45 m height and 222 m width.

2.2. Dam construction

The Hamiz dam was built during 1869–1879, and five buttresses, whose establishment had been made necessary by the appearance of three cracks, were built during 1887–1889. The structure of dam was built by ordinary masonry of 38 m height; it is a gravity dam with a side outfall.

Under the action of hunting made by the bottom outlets, a basin had been formed in the downstream of the dam. This excavation was attributed to a swirl with horizontal axis which was formed under water vein leaving the spillway. We drained this excavation in 1905, foundations were not reached, but the common channel was damaged; the threatened part was supported by a surbased arches. In 1916, an additional buttress was built on left bank and works were realized on buttress of right bank. A new spillway, identical to that of 1905, was made in 1923. In 1933, the addition of a concrete solid mass

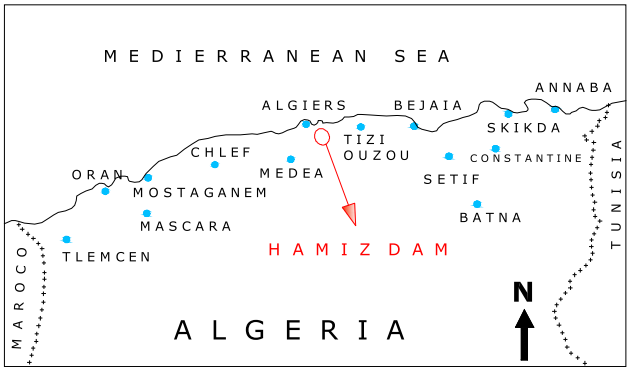

Figure 1 Study area.

was decided in the upstream of the old dam, of which the double goal was to consolidate the dam by reinforcing its profile and to raise it by 7 m, in order to increase the capacity of reservoir.

2.3. Capacity of reservoir

The capacity of reservoir was evaluated in 1935 at 22 million m^3. Silting dam, calculated with solid contribution of wadi, would be about 200,000 m^3/year. Volume of reservoir had been evaluated, in 1950, at 17 million m^3 (Durzoy, 1952). After the last bathymetric survey carried out in 2004, capacity of reservoir had been estimated at 15.4 million m^3 according to the national agency of dams and transfers.

2.4. Morphological and sedimentary characteristics of the Hamiz wadi

Water resulting from the dam failure must traverse a distance of more than 32 km to reach the Mediterranean Sea. The knowledge of the wadi characteristics in this zone is necessary