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DAM BREAK ANALYSIS OF EVINOS EARTH DAM: FORECASTING THE CHARACTERISTICS OF THE DOWNSTREAM FLOOD WAVE

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ABSTRACT

In this paper we present an assessment of the hazard involved in the potential failure of Evinos Dam i.e. we present an estimate of the downstream flood wave that would be produced by such failure .We evaluate the various hydraulics aspects of the dam break hazard for the Evinos Dam and we compute the characteristics of the downstream flood wave following the dam failure for six scenarios regarding the final width and time lapse of the breach formation. We find that although in these scenarios the base breach width varies from 80 to 230 m, the time of the breach formation varies from one to three hours, and although the maximum discharge immediately downstream of the dam varies from 11270 m3/s to 79000 m3/s (more than seven times), the peak free surface elevation (m.s.l.) 60 km downstream (village of Evinoxori) varies only from 19.1 to 16.3 m (small difference). We present drawings of the peak elevation, the max depth and the peak velocity of the flood wave as a function of the downstream distance and the time, at which max elevation occurs, for various scenarios of the development of the breach.

KEYWORDS
Dam break, Evinos Dam, flood routing, emergency action plan, DAMBRK.

1 INTRODUCTION

The Evinos Dam on the River Evinos is located close to the Agios Dimitrios Village, in the Pindos Mountain Range in Greece. Water from Evinos Dam will be transferred to Mornos Dam (some 29 km away), which is the main water supply source for Athens. The Dam crest is at +516 m, 104 m above the river bed, with Full Supply Level (FSL) at +505 m. The Max Flood Level is set at 512.1 m. The Evinos Dam is an Embankment dam, comprising a central vertical impermeable core with slopes 3:1, filters upstream and downstream of the core and sand -gravel shoulders with slopes of 1:2.3 upstream and 1:2 downstream. The total storage is 139 Mm^3, the Dead storage 25.5 Mm^3, the area 36 million m^2, and the length 6 km. The elevation of the spillway crest is 505 .0 m above sea level. A catastrophic flooding will occurs when Evinos dam (hypothetically) fails and the impounded water escapes through the breach into the downstream valley. The magnitude of the flow greatly exceeds all previous floods and the response time available for warning is much shorter than for precipitation - runoff floods. We examine the hypothetical case of Evinos dam failure, which is caused by overtopping of the dam due to inadequate spillway capacity from heavy precipitation runoff. In this paper we present an assessment of the hazard involved in the potential failure of Evinos Dam i.e. we present an estimate of the downstream flood that would be produced by such failure .We use the well known program DAMBRK to explore the various hydraulics aspects of the dam break hazard evaluation for the Evinos Dam and to compute the characteristics of the downstream flood wave following the dam failure The basic version of this program was developed by Fread (1988). The DAMBRK model predicts the dam - break wave formation and its downstream progression.

The model consists of two conceptual parts, namely: (1) description of the dam failure mode, i.e., the temporal and geometrical description of the breach; and (2) a hydraulic computational algorithm for determining the tome history (hydrograph) of the outflow through the breach as affected by the breach description, reservoir inflow, reservoir storage characteristics, spillway outflows and downstream tail water elevations; and for routing of the outflow hydrograph through the downstream valley in order to account for the changes in the hydrograph due to valley storage, frictional resistance, downstream bridges or dams. The model also determines the resulting water surface elevations (stages) and flood - wave travel times.

DAMBRK is used to develop the outflow hydrograph from Evinos dam due to overtopping failure and hydraulically route the flood through the downstream valley. The governing equations of the model are the complete one - dimensional Saint - Venant equations of unsteady flow, which are, coupled with internal boundary equations representing the rapidly varied (broad - crested weir) flow through a time dependent breach. Also, appropriate external boundary equations at the upstream and downstream ends of the routing breach are utilized.

The flow may be either sub critical or supercritical or a combination of each varying in space and time from one to other.

2 BREACH DESCRIPTIONS

The breach is the opening formed in the dam as it fails. Evinos Dam is an earth Dam, and earthen dams do not tend to completely fail, nor do they fail instantaneously. The fully formed breach in earthen dams tends to have an average width ($\bar{b}$) in the range ($h < \bar{b} < 5\ h_d$) where HD is the height of the dam. Also, the breach requires a finite interval of time (τ) for its formation through erosion of the dam materials by the escaping water. The time of failure as used in DAMBRK is the duration of time between the first breaching of the upstream face of the dam until the breach is fully formed.

The following predictive equations are used in our study for the breach width $\bar{b}$ and the interval time τ (see Fread 1988):

$$\bar{b} = 9.5\ k_o\ (V_r\ h_d)^{0.25} \qquad (2.1)$$

$$\tau = 0.8\ (V_r\ /\ h_d^{\ 2})^{0.50} \qquad (2.2)$$

In which $\bar{b}$ is average breach width (ft), τ is time of failure (hrs), KO = 1.4 (overtopping), V_r is volume (acre - ft) (note: one million cubic meters=810.8 acre-ft); HD is the height (ft) of the water over the breach bottom which is usually about the height of the dam. Standard error of estimate for $\bar{b}$ is ± 54 % of $\bar{b}$, and the standard error of estimate of τ is ± 70 % of τ.

In DAMBRK the breach is always assumed to develop over a finite interval of time (τ) and will have a final size determined by a terminal bottom width parameter (b) and various shapes depending on another parameter (Z) .The shape parameter (Z) identifies the side slope of the breach, i.e., 1 vertical: Z horizontal. The range of Z values from 0 to somewhat larger than unity. Its value depends on the angle of repose of the compacted and wetted materials through which the breach develops. The terminal width b is related to the average width of the breach ($\bar{b}$) by the following relation:

$$b = \bar{b} - 0,5\ Z\ h_d \qquad (2.3)$$

3 SCENARIOS OF EVINOS DAM FAILURE

The DAMBRK model is dependent on certain input regarding the geometry and temporal characteristics of the dam breach. The breaching characteristics that are needed as input to DAMBRK program are: a) the ultimate size b of the dam breach (width of base of breach), b) the ultimate elevation of the base of the breach c) the shape of the dam breach d) the time that is required for the breach to develop and d) the reservoir water surface elevation at which breach begins. Thus the size, shape and time required for development of the breach is dependent on the erodibility of the embankment material and the characteristics of the flow forming the breach. The Evinos dam is classified as earthfill dam. However, in order to take in account the material (rock) used at the downstream toe of the dam, three of the eight scenarios that we run, assumed final base elevation of the breach equal to 448 meters (the base of the dam is at 418 meters). The ultimate size of the width of base of the breach varies from 80 to 230 m, and the time to maximum breach size varies from 1 to 10 hours (see Table 1). For all the scenarios the side slope of breach (horizontal/vertical) was 1.04. Evinos Dam will impound up to 139 106 m^3 of water (or 171604 acre-ft) behind an earth/rock fill embankment rising some 124 m (407 ft) above foundation level. Rockfill arising from the foundation excavations has been used for forming the main upstream cofferdam and downstream toe zone. The materials comprised hard fragments, up to 600mm in size, of sandstone and siltstone combined with finer material.

We adopt as mode of Evinos dam failure, the overtopping of the dam. We study six basic scenarios, where we vary the two basic breach parameters, the final breach width b and the time τ of formation of the breach. The most adverse conditions (Scenario 1A) are to assume the maximum probable width of the breach (which was calculated about 230 m) and the minimum probable time τ. The most favorable conditions are to assume the minimum probable width b and the maximum probable τ (Scenario 3B). The first Scenario 1A produces a maximum expected downstream flooding, while the second (Scenario 3B) produces a minimum expected flooding. The Manning n varied along the river from 0.06 to 0.09 to reflect the influence of bank and bed materials, channel obstructions, and irregularity of the riverbanks. The Manning n values often need to be increased in order to account for the additional energy losses associated with the dam - break flows.

We run the computer program DAMBRK for the six scenarios given in table 1 to simulate dam break hydrographs, and to route these hydrographs downstream, so that inundated areas, flow depths, and flow velocities can be estimated. The results - outputs of this model of Evinos dam failure is used for formulating the Emergency Action Plan. For the routing of the break hydrograph downstream, we used topographic maps of scale 1:5000 to construct 70 cross sections of the river, used as input to the program. The total length of the river from the dam to its outflow at the sea is about 65 km.

4 BASIC RESULTS

All the basic results are given in the following Figures 1 to 5. Figure 1 shows the flood hydrographs at various distances downstream of the Dam. Figure 2 shows the maximum depth as a function of the downstream distance and the time at which max depth occurred. Figure 3 shows the profile of maximum depth for three scenarios as a function of the distance downstream. Figure 4 presents the profile of peak velocity for two scenarios of the breach width. Figure 5 shows the profile of peak elevation (m.s.l) for three scenarios of the time to breach formation. Figure 6 shows profiles of time at which max depth occurs showing sensitivity of the time of the breach formation. From these drawings we observe the "convergence « of the peak elevation, peak velocity, and maximum depth at about 60 km downstream, close to Evinoxori for all the six scenarios. This is really striking, i.e. although the base breach width varies from 80 to 230 m, and although the maximum discharge immediately downstream of the dam varies from 11270 m^3/s to 79000 m^3/s (more than seven times), the peak elevation at the Evinoxori varies only from 19.1 to 16.3 m.

The distance of the closest village downstream of the dam, which will be partially inundate is 27 km, the elevation of the village (Dosoula) is 210-230 m, and the peak flood elevation is 215 m. The population of Dosoyla village is 38 people. The flood peak travel time is 1.24 hours. The greatest hazard potential appears to be for the villages of New Galata and Galata (distances 61.5 and 62 Km respectively from the dam), and of Ano Evinoxori and Evinoxori (distances 62 and 62. 8 Km respectively). These villages are close to each other and their total population is approximately 3000. The flood peak travel time is 3 hours. However, the time at which the flood approaches the villages is about 2.5 hours. The basic results for are given at the table 1.

5 CONCLUSIONS

The selection of breach parameters introduces a varying degree of uncertainly in the downstream flooding results of the DAMBRK model. Our results verify that errors in the breach description and thence in the resulting peak outflow rate are damped - out as the flood wave advances downstream. In Figures 3 and 4, and in Table 1 we observe the "convergence « of the maximum depth, peak elevation (m.s.l.) and peak velocity at about 60 km downstream, close to Evinoxori for all the six scenarios. Although the base breach width varies from 80 to 230 m, the peak elevation at the Evinoxori varies only from 19.1 to 16.3 m. Therefore using DAMBRK, it has been observed that variations in peak outflow at the dam are damped - out as the flood peak advances farther and farther downstream. The extent of damping is related to the size of downstream floodplain; the wider the floodplain, the greater will be the extent of damping. The results of this study are used to formulate the emergency action plan for this project.

TABLE 1 BASIC EMERGENCY PARAMETERS FOR EVINOXORI FOR VARIOUS SCENARIOS (LEVEL OF GROUND AT EVINOXORI IS 10 TO 14 METERS m.s.l)

INPUT PARAMETERS			COMPUTER OUTPUTS FROM THE DAMBRK MODEL		
SCENARIO	TIME TO MAXIMUM BREACH SIZE (HOURS)	WIDTH OF BASE OF BREACH, METERS	MAX DISCHARGE IMMEDIATELY DOWNSTREAM OF THE DAM, M3/S	MAX DISCHARGE AT THE EVINOXORI, M3/S	MAX WATER ELEVATION (m.s.l) AT EVINOXORI
1A	1	230	78875	29155	19.1
1B	1	80	67830	25160	17.6
2A	3	230	30417	21590	18.1
2B	3	80	27900	20650	17.9
3A	10	230	12212	12230	16.5
3B	10	80	11279	10988	16.3

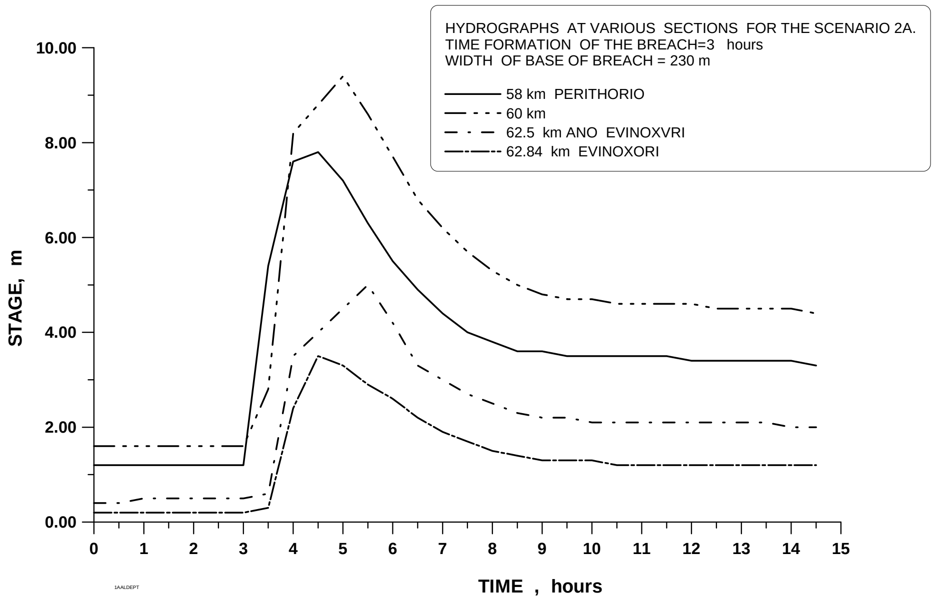

Figure 1. Hydrographs at various distances from the Dam.

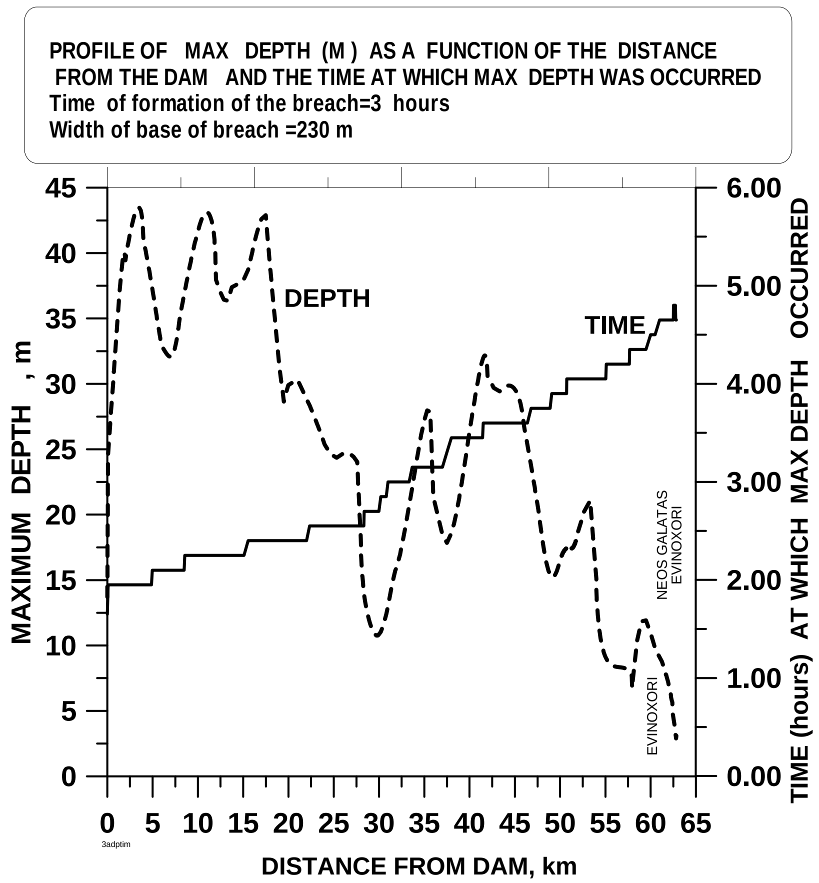

Figure 2. The maximum depth as a function of the downstream distance and the time at which max depth occurred

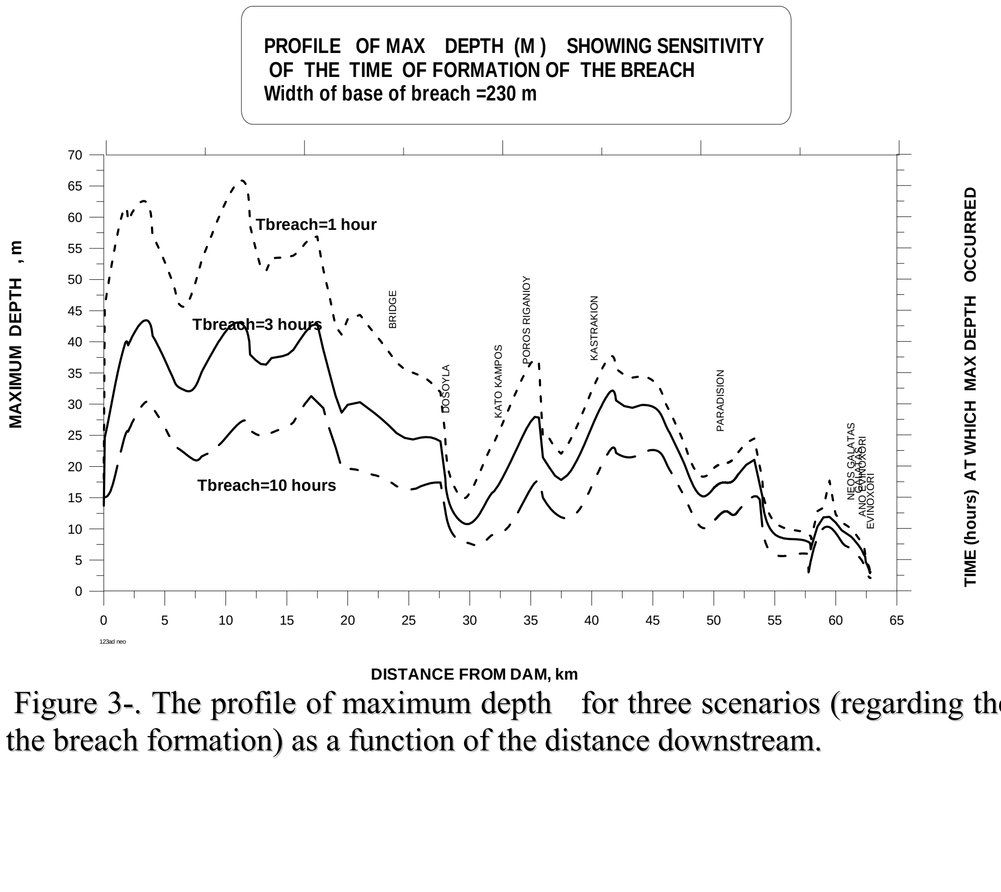

Figure 3-. The profile of maximum depth for three scenarios (regarding the time of the breach formation) as a function of the distance downstream.

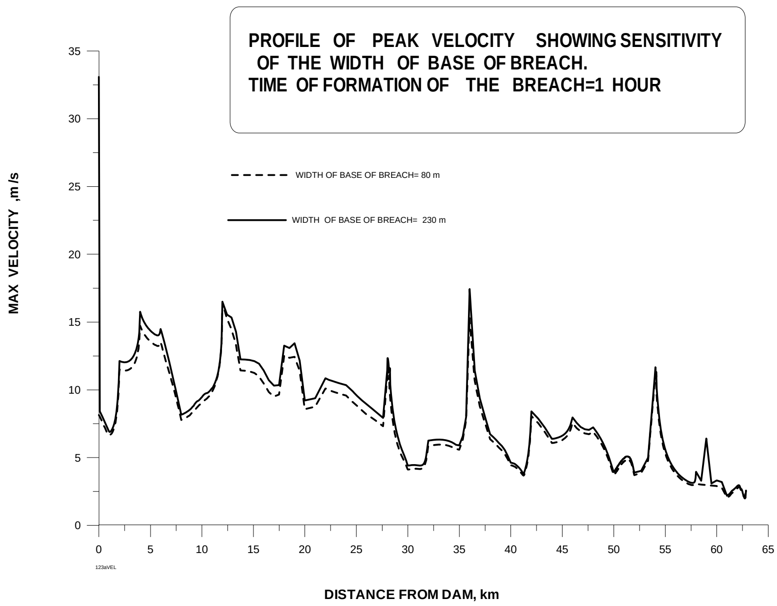

Figure 4. Profile of peak velocity for two scenarios of the breach width.

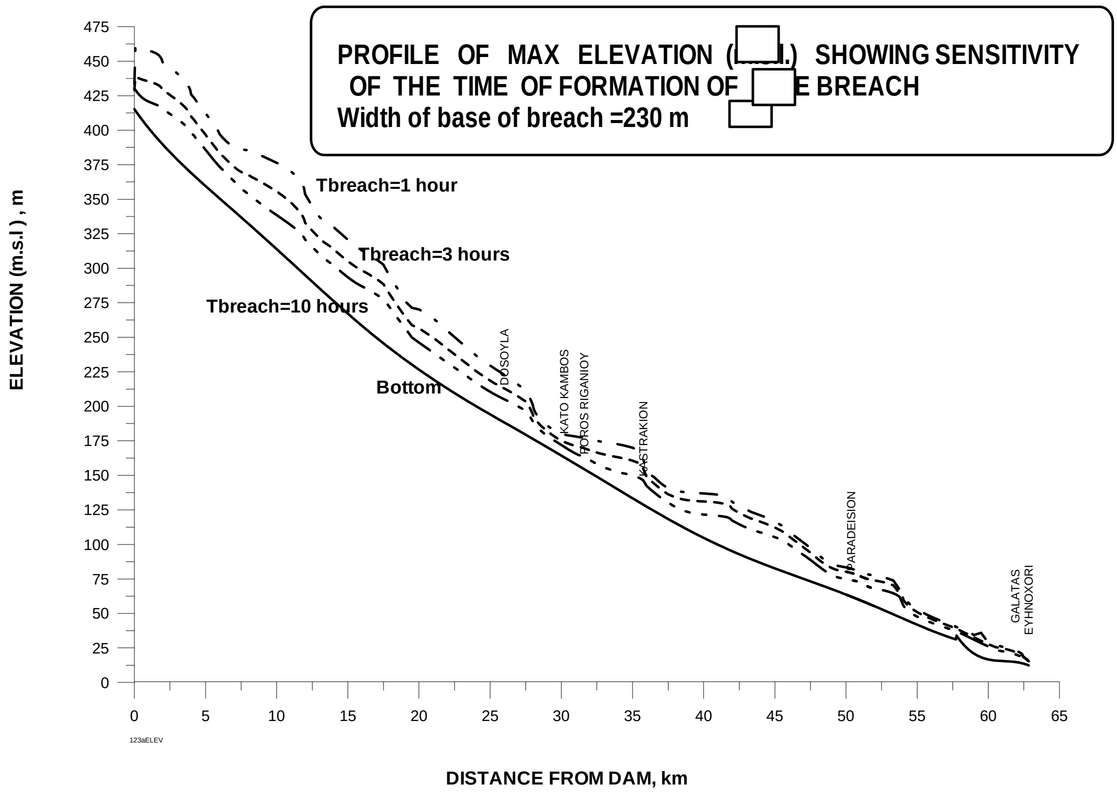

Figure 5. Profile of peak elevation (m.s.l) for three scenarios of the time to breach formation.

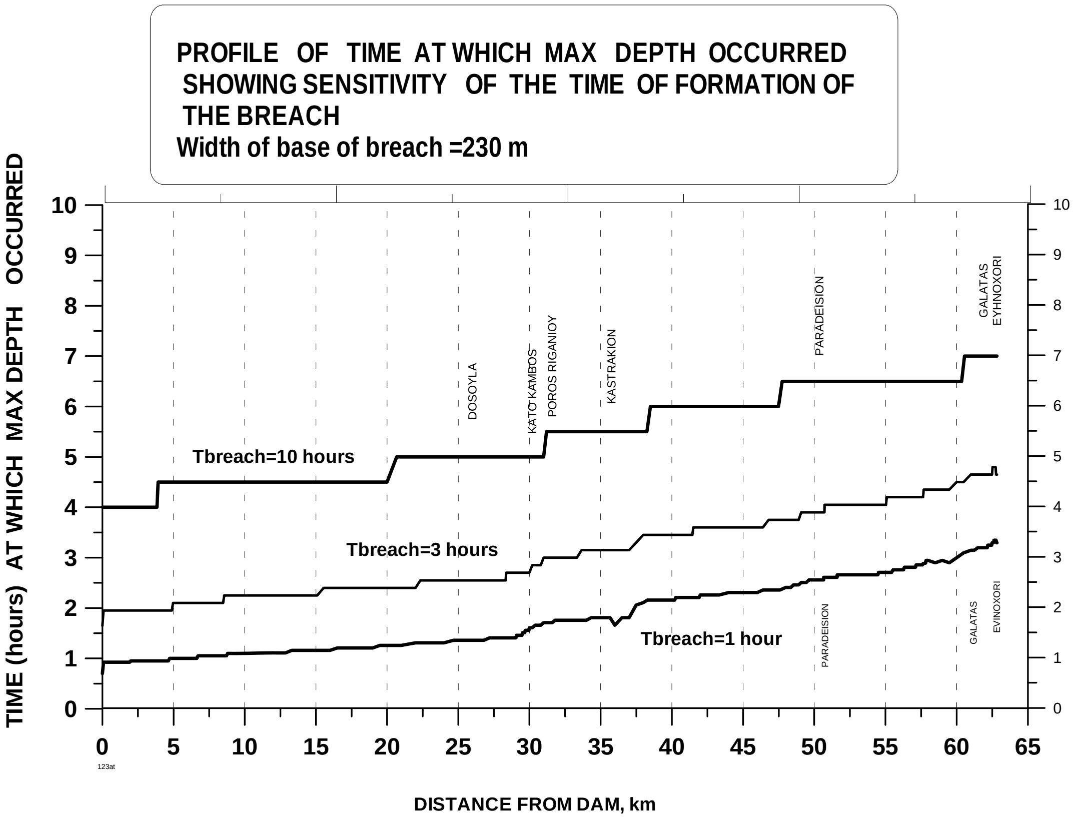

Figure 6. Profiles of time at which max depth occur showing sensitivity of the time of the breach formation.

ACKNOWLEDGEMENTS
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