

# Living with dam-break flood risk: the case of a Portuguese dam-valley system

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## Abstract

Technical risk analysis is typically based on the systematization of physical causes and effects, underlying events such as technological accidents or natural hazards. Such an effort of objectivity has the inconvenience of separating risk from its societal context, whose characteristics and dynamic usually interfere in risk severity and the probability of occurrence.

When applied to dam-break flood risk, the analysis needs to consider dam-related aspects as well as the downstream valley, namely as far as it concerns human occupation patterns and public risk perception. Risk analysis approaches of this sort imply the settlement of a research process based on an interdisciplinary dialogue between the engineering and social sciences. Through such a methodology, it is expected to guarantee a more efficient and holistic risk assessment.

The research project Dam-break flood risk management in Portugal (1995–2002), sponsored by the NATO-Science Programme (NATO PO-FLOODRISK), was an opportunity for the application of the above-mentioned approach and methodology.

This paper intends to present a short overview about essential aspects of social science research and its contribution for dam-break flood risk analysis and management.

*Keywords:* social sciences, dam-break flood risk, risk management, public risk perception, protective behavior.

## 1 Introduction

A dam failure is an example of a catastrophic situation or risk scenario associated with a relatively low-probability and potential high damage



phenomena. Risk analysis and assessment is a fundamental tool for risk management, namely as far as it concerns to emergency planning.

The concept of dam-valley system that replaced the single dam safety concept now includes, among other different components, population whose behavior and attitude towards the risk mitigation measures is very important for the valley risk management and civil protection. The main goal is to reduce the potential losses caused by a dam accident as well as to improve the quality of life for inhabitants at risk downstream the dam. By quality of life, we mean an informed acceptance of a non-zero risk scenario accompanied by public knowledge as far as it concerns to the most adequate protective behaviors to adopt, namely in case of a dam failure. Population at risk should have information and knowledge about emergency planning, land risk zoning as well as the warning and evacuation systems, for its benefit and safety. The human or social component of the integrated system under analysis implies a good cooperation between risk engineering and social sciences (sociology and social psychology among others branches). Risk communication and people's reflexivity need to be considered as an interdisciplinary challenge to risk analysis and management.

In this context, public risk perception and the quantitative technical risk analysis should not be considered as two parallel risk evaluation techniques. They need to interact in order to turn possible an approach to risk assessment in a more human frame (1) and to guarantee a more efficient and safe valley management (2).

There is no definitive solution or guidelines for this cooperation. It is a complex and continuous field of research and experimental implementation of methodologies. The Dam Break Risk Management project (NATO PO-FLOODRISK), developed in Portugal (1995-2002), made a pioneer work in that country, related to this topic [1]. This paper gives an overview about social sciences research, namely as far as it concerns to the public inquiry developed along Arade valley, the project case-study area (valley composed by two dams, Funcho arch dam and Arade earthfill dam) (Figure 1 and 2) [2].

## **2 Approaching social facets of dam break risk analysis and management**

In the context of interdisciplinary risk analysis, pursued under NATO PO-FLOODRISK project, social science specific role and contribute was directed to the accomplishment of the following objectives: Description of human occupation patterns of flood prone areas; Knowledge of public perceptions towards dam-break flood risk; Support to the design of an integrated flood emergency system.

Information about the volume of population and infrastructures at risk is fundamental for risk magnitude estimate and assessment. The circumstance of having a non-populated downstream valley turns a dam-break accident into a less severe and concerning event, by comparison with a populated one. But, the pertinence of human patterns diagnosis does not end here. It is also an important support tool for risk management purposes.



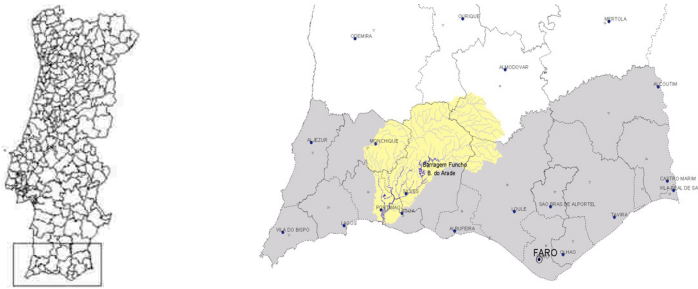


Figure 1: Arade river basin in the Algarve region.

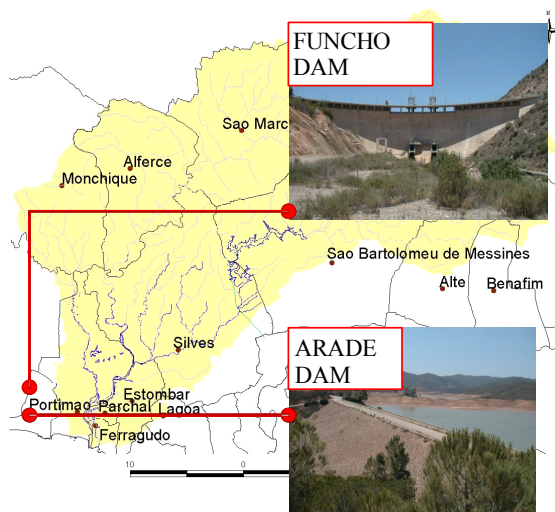


Figure 2: The Funcho and Arade dams.

Pre-disaster *preparedness* is one key-component of risk management process. It is under this component that experts and organizations structure *response* to an eventual accident, namely as far as it concerns to warning and evacuation procedures. One key feature for the success of *preparedness* and *response* is its adequacy to target-territory idiosyncrasies. Previous knowledge about population at risk helps decision-making about a great variability of issues, as for example: how to warn, whom to evacuate first, what will be the needed means, where to evacuate and what would be the expected first-aid needs and temporary sheltering.

Several studies [3] demonstrate that certain demographic or individual related traits may influence the efficacy of warning and evacuation. We refer more specifically to parameters such as age, gender, level of school attendance, length of time on the neighborhood, ethnic or migrant condition and socio-economic status. In general terms, older persons are less likely than others to hear warnings

and to evacuate. Newcomers or those who do not have a plain knowledge of the place or the country language are less likely to hear warning and to personalize threat. The rhythm and fastness of return to normality will be slower among the poorer social groups and families [4].

Besides, diagnosis of population at risk is also crucial for risk communication aims. Certain public campaigns fail on their aims because of their inadequacy to target-population characteristics. It is, as for example, inappropriate to stand a campaign mainly written materials (i.e. prospectuses) for scenarios marked by low levels of school attendance or high percentage of elderly.

The higher or lower propensity to take proper protective behaviors, namely in the sequence of a warning, depends of a combination of individual related traits. Besides the above-mentioned ones, it is important to have into account individuals' pattern of attitudes towards risk.

In general terms, risk means different things for different people [5]. Indeed, this was one of the first conclusions of initial studies developed around the subject. These ones also revealed that differences are particularly evident between experts and laymen. While the first stand their judgment on scientific models and probabilistic reasoning, the second value other risk facets. We refer more specifically to the catastrophic potential that individuals ascribe to a certain risk; to the degree of familiarity of phenomena in question; and the belief on individual or/and societal capacity to control risk and its effects, among others aspects.

Besides, lay individuals also produce their own cost-benefit assessments. Several studies [6] reveal that when benefits of a certain technology or territory — also a source of risk — are perceived as being high for the individual, risk acceptability will tend to increase.

Given this, as Otway [7] puts it, analysis and comprehension of public perceptions towards technological risk implies to have into account public views about the facility. Usually, the root of public unacceptability is not on the risk *per se* but on the facility as a whole (i.e. nuclear power plant). Similarly, high public acceptability towards a certain risk, as for example dam break risk, may not stand solely on the view individuals have about such risk, but also on the (benevolent) way they envisage the facility and its benefits. Related with this, Krinsky and Golding [8] emphasize the importance of trust on the organization and experts responsible for facility' management, for public acceptability enhancement. High levels of public trust have be ability to mitigate eventual stress or anxiety feelings, induced by risk awareness.

In Portugal, dams are globally perceived as benevolent and beneficial facilities. Dam-break flood risk is not usually at the origin of controversy and public opposition, when this one happens. Dam-building projects have been object of an increasing public debate and opposition. But, at the center of such debate are mainly issues related with local historical heritage and ecological preservation. Apart from this, it is common to find local governments and populations favorable to dams because of their water storing capacity, their ability to control floods and their role on regional development.



Overestimation of benefits can, under certain circumstances, shadow risk awareness and willingness to take precautions. Usually, such attitude is accompanied by risk underestimation or disbelief on the possibility of something wrong to happen. Scenarios of this sort turn risk management and public risk communication difficult to pursue, due to the low levels of local enrolment they provoke. Some authors [9, 10] view such disbelief as inducer of what they call as false sense of security, proper from those who live or work bellow dams.

One may see a contradiction on this issue. Factors underlying high levels of acceptability (i.e. overestimation of benefits, trust on technology and experts) may also contribute for risk public unawareness and disbelief. How then to promote safety and public risk awareness, avoiding at the same time insecurity feelings and public acceptance decrease? This is indeed an important questioning, for discussion and answering.

Social science research developed under NATO PO-FLOODRISK project — and briefly synthesized in this paper — has no definite answers for the above-mentioned questioning. Nevertheless, it was our aim to produce knowledge and to inform decision-making about most appropriate routes to follow.

### 3 Method

Knowledge of *who* is at risk and *how lives with it* stood on a methodological framework composed by several data collection techniques and procedures, which will be briefly synthesised.

This study target-area was the territory objectively exposed to an eventual flood caused by a dam-break accident. Given this, our first methodological concern was the delimitation of the so-called risk areas, using them as a basis for human occupation and public risk perception study.

The above-mentioned delimitation was pursued through a procedure of overlapping dam break model and scenario, developed within the project [2], to census cartographic and alphanumeric database. This was done with the support of GIS, a tool that had the advantage of providing higher precision to the overlapping process.

Afterwards, it was found as pertinent to establish risk zones, according to the degree of proximity with the dams. They were as follows:

- *Risk zone 1, red zone:* Area between Arade dam and the point of the valley where the flood wave is expected to arrive within a period of 30 minutes. This area is markedly rural and with a disperse pattern of occupation. Around four little villages fall into this zone, all of them immediately downstream the dam.
- *Risk zone 2, yellow zone:* Area between the frontier of the preceding zone and the city of Silves, corresponding to the part of the valley where the flood wave arrival time is high than 30 minutes, but less than 90 minutes. Apart from Silves, settled at approximately 9 km downstream the dam, this risk zone is also rural and composed by a few small villages.
- *Risk zone 3, green zone:* Area between the frontier of the preceding zone and the end of Arade River, when this one joins with the Atlantic Ocean. In this



area, the flood wave is expected to loose strength and cause minor direct impacts. A set of villages is located along Arade River and within this area. At the end of Arade River it exists an urban area, called Portimão.

Knowledge of human occupation patterns was pursued on the basis of this risk zoning procedure. The analysis stood on several demographic dimensions (i.e. volume and density of population at risk, number and type of families, school attendance levels, patterns of economic activity) and building related dimensions (i.e. volume of buildings, functions and uses, year of construction).

As far as it concerns to the study of public perception towards dams, this one stood on two interdependent empirical stages, as follows:

a) *Exploratory stage*: First approach to the field and research aims. This one rendered concrete through the conduction of semi-directed interviews with individuals living in flood-prone areas, along Arade River, as well as representatives of local government, local civil protection and water board. Afterwards, interviews were object of content analysis.

b) *The survey*: Second approach to the field conceived to deepen knowledge and to extend public inquiry. Such approach rendered concrete through the application of a questionnaire to a sample of individuals living along the valley and within risk areas. The sample was conceived, respecting the weight of population in each risk zone and demographic criteria (age structure and gender). At the end, 300 individuals answered to the questionnaire.

Still concerning the survey, it is worth to mentioned that it was found as pertinent to consider a criteria concerning urban *versus* rural type of area. Such criteria obliged to base sampling procedure and data analysis on a set of four risk zones, instead of the above-mentioned three.

## 4 Results

In this section, a synthesis of main results will be pursued, starting by the ones concerning the human occupation patterns. Afterwards, we will pursue with a synthesis and discussion about the way individuals live together with dams, its risks and benefits.

### 4.1 Arade valley patterns of human occupation

Flood prone area of Arade valley comprises some small rural villages (< 2000 inhabitants) as well as some parts of two cities. We refer more specifically to Silves downtown, located 9 km downstream Arade dam, and to Portimão riverside area, located along the river estuary.

As Table 1 shows, the higher volume of population at risk is at risk zone II — a total of 7522 individuals and 2593 families. The nearest zone from dams, risk zone I, concentrates 336 individuals and 128 families. Risk zone III, the one that is geographically more distant from dams, has 2544 individuals at risk and 880 families.

In spite of the low volume of population at risk, Zone I contains some specificities that shouldn't be disregarded, especially when emergency planning



is at stake. Being this zone classified as an *immediate safety area*, the most appropriate scenario would be to have a population as much autonomous and sensitized as possible. Nevertheless, such autonomy may be endangered, due to the existence of a non-negligible volume of elderly individuals.

On the other hand, the high percentage of individuals revealing low levels of school attendance may force the use of non-written and two-way risk communication methods (i.e. public meetings, door-to-door campaigns), instead of the written ones (i.e. pamphlets).

Table 1: Main demographic characteristics, by risk zone.

Dimensions	Variables	Risk areas		
		Zone I	Zone II	Zone III
Volume	Nº of resident individuals	336	7522	2544
	Nº of families	128	2593	880
Gender	Male	170	3856	1221
	Female	166	3914	1323
Age structure (%)	Individuals with less than 4 years	3.9	5.7	6.9
	Individuals with age between 5-9 years	4.2	6.7	7.4
	Individuals with age between 10-13 years	3.3	5.9	5.4
	Individuals with age between 14-19 years	6.0	9.2	8.4
	Individuals with age between 20-64 years	<b>51.4</b>	<b>57.6</b>	<b>59.1</b>
	Individuals with more than 65 years	<b>31.3</b>	14.5	12.7
Education (%)	Illiterate individuals	<b>25.3</b>	18.0	<b>15.2</b>
	Individuals with 4th grade	<b>23.0</b>	<b>21.1</b>	<b>26.3</b>
	Individuals with 6th grade	3.3	3.8	5.9
	Individuals with 10th grade	8.3	11.2	9.8
	Individuals with professional course	0.3	1.1	0.6
	Individuals with college degree	0.3	2.0	1.8
Family Structure (%)	Families composed by 1-2 persons	<b>54.0</b>	42.7	42.0
	Families composed by 3-4 persons	39.0	<b>46.6</b>	<b>47.6</b>
	Families composed by more than 5 persons	9.0	10.8	10.3
	Families with children (bellow 15 years old)	23.4	38.4	40.0
	Families with elderly (above 65)	57.0	31.5	27.8

Another aspect that should not be disregarded concerns the dispersed type of land-use occupation and the high volume of families composed by one or two members. Some studies on disaster preparedness indicate that these traits can disfavour warning spreading. Family members and neighbours are usually a source of warning confirmation as well as of stimulus for evacuation. If they are too far away from each other, it turns harder to take advantage from such informal networks.

#### 4.2 Ways of coping with dams: perceived risks, benefits and safety

Funcho and Arade dams are globally viewed as highly beneficial facilities, being dam break flood risk globally perceived as a low probability risk or even inexistent. Such trend indicates that dams, especially the older one (Arade dam), are infrastructures that enjoy from great public acceptability.

Benefits tend to be more strongly emphasised by those who live near dams, decreasing as it decreases physical distance from those infrastructures.



Agriculture is the sector perceived as the one who benefited more with those hydraulic infrastructures. In fact, this sector is particularly strong in the area between the dams and Silves city. Here, a market-oriented agriculture co-exists with subsistence agriculture.

As already mentioned, dam break flood risk is globally perceived as a low probability event. Nevertheless, there are specificities that should be taken into account.

As Figure 3 shows, approximately 42% of those living in the nearest areas from the dams (Rural 1) classify dam break risk as something “not possible to occur”. Although not so salient, the same attitude can be found on the remaining areas.

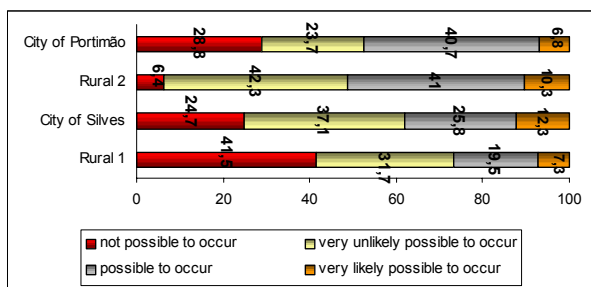


Figure 3: Dam break subjective estimates, by risk area (%).

Such attitude of risk denial is a cognitive strategy of coping with risk, very common on scenarios of high exposure to threat. The discounting of the possibility that anything serious will ever happen to them (or their possessions) helps individuals to better control eventual feelings of anxiety or stress [3].

When confronted with questions related with their area and dwelling degree of exposure to a disaster induced by dam break, approximately a half of the interviewees state their house would suffer damages. The feeling of personal vulnerability is especially salient among those living in Rural 1 and Silves. In the remaining areas, the opposite pattern prevails, meaning that individuals living in these areas do not feel endangered by an eventual disaster, induced by dam break.

In spite of the above-mentioned trend, we shouldn't disregard the percentage of individuals (27%) that, although living immediately downstream the dams, believe that their house won't be damaged, in case of a disaster.

Both attitudes of risk denial and feeling of personal invulnerability can be tricky. First, they may induce on lack of motivation to get involved on risk management programs and receive information about risk and protective behaviours. Secondly, they may provoke indifference towards warning messages, in case of an impending accident. Third, risk denial and disbelief may provoke personal resistance to evacuation, in case of need.



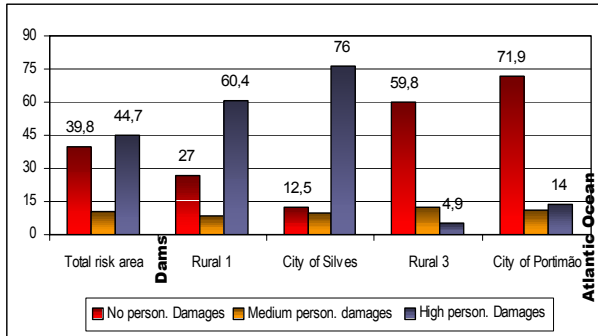


Figure 4: Perceived personal vulnerability to a dam break, by risk area (%).

As far as it concerns to dams' perceived safety, two attitudinal patterns emerged. We refer, on the one hand, to the high belief on those structures safety and, on the other, to the expression of lack of knowledge around this issue. As can be seen through Figure 5, the first-mentioned attitude is particularly salient among individuals of Rural 1 and Silves. Individuals living on more distant areas from the dams mainly expressed ignorance towards its safety.

Such geographical discrepancy is mainly a consequence of the type of relationship individuals and localities maintain with those hydraulic infrastructures. In fact, the fieldwork revealed that those dams are completely internalised in Silves and Rural 1 inhabitants' daily lives. There is even some kind of local knowledge around those infrastructures and the way they function. Such local knowledge tends to dissipate as we go down on the river and arrive to Portimão.

Nevertheless, the above-mentioned local knowledge is not immune to biases. One of the most salient concerns the belief that Arade dam is safer than Funcho dam.

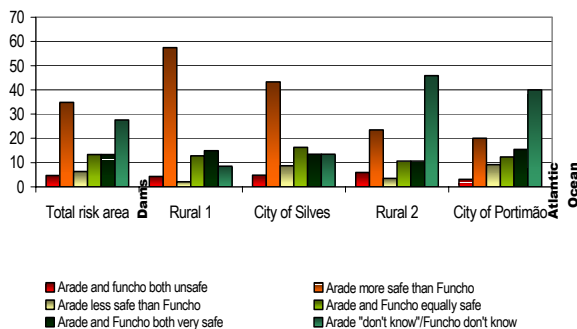


Figure 5: Arade and Funcho dams, safety perception, by risk area (%).

Indeed, for some individuals the older Arade dam is safer than Funcho, constructed approximately a decade ago. This lay perception contradicts

engineering science, according to which the greater is the age of a dam the higher will be the possibility of hydraulic problems and structural fragilities. In other words, it seems that lay feeling of safety increases as it increases the need for high expert vigilance and monitor.

Besides the above-mentioned bias, public inquiry revealed other two, as follows: the higher confidence on Arade earthfill dam, based on the type of construction and high width of its wall (The Funcho arch dam with thinner (concrete) wall is envisaged as a signal of higher fragility); the belief that in case of upstream Funcho dam break (this is concrete arch dam is located 5.6 km upstream Arade dam), Arade dam would have capacity to mortise the flood.

Such biases may mislead individuals from taking the most appropriate protective behaviours in can of threat. Its dissipation implies an investment on adequate risk communication programmes, where experts and lay individuals interact and advise about protective behaviours is pursued.

Still concerning dams' safety issue, it is found as pertinent to mention that individuals' belief on those infrastructures safety also stood on high levels of trust on experts, more specifically the ones charged of dams' management and periodical monitor. Lay trust is a key feature for the success of a risk communication process. The credibility that experts enjoy among lay public lessens the possibility of anxiety and stress, induced by risk awareness. Organizations and governments should not risk losing it, because when lost, lay trust is very difficult to re-establish.

## 5 Conclusion

As expected, Arade and Funcho dams enjoy of high levels of public acceptability and are globally envisaged as benevolent and beneficial infrastructures.

Furthermore, research also revealed that there is a sort of local wisdom around those structures (i.e. ways of functioning, their benefits, their risks and safety). Generally, personal estimates about dam-break flood risk are not unrealistic. Indeed, we are in face of a low probability but potentially catastrophic type of risk and public risk perception goes on such direction.

But, local wisdom is not, as Otway puts it [7] immune to biases. Public inquiry revealed some biased beliefs that, if not dissolved, can be demobilizing. We refer more specifically to the unwillingness to get involved on risk management process, namely as far as it concerns to risk communication initiatives. Besides, as already mentioned, biases can induce on inadequate patterns of behaviour, namely in case of warning of an impending disaster an evacuation. Disbelief and risk denial is probably among the trickiest biases, which should be object of concern and action.

But, disbelief is not an exclusive problem of lay individuals. Freudenburg [11] raises the question of risk disqualification among experts and organizations, stating that low probability risks are particularly prone to such type of attitudes. This reluctance on "putting risk on the agenda" atrophies proper risk management processes, namely as far as it concerns to pre-disaster preparedness.



NATO PO-FLOODRISK project revealed that dam-break flood risk was not immune to risk disqualification syndromes on the part of who is engaged on dam-downstream valley management. Such trend puts inter-organizational issue on the top of the agenda for further research.

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