

WORKSHOP
ON
BENEFITS AND CONCERNS ABOUT DAMS – CASE STUDIES

DAM RISK MANAGEMENT AT DOWNSTREAM VALLEYS AN INTEGRATED PROJECT AND CASE STUDY

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Abstract

One of the concerns about future and existing dams is its safety and the possibility of serious accidents including the dam failure. This concern is particularly important for people living along the valley downstream the dam. Contemporary safety legislation and technical guidelines impose the consideration of dam failure scenarios and the valley inundation maps, zoning and the preparation of civil protection procedures, namely emergency plans, warning systems and exercises.

In open societies, where public information and participation is increasing, this concern is very important. In fact despite the increasing safety of dams due to better knowledge and engineering quality, a full non-risk guarantee is not possible and an accident can occur due to abnormal environmental factors, inadequate operation, change of hydrologic conditions or just because the dam is loosing strength capacity due to its age.

In order to develop an integrated and advanced technology to solve problems related to valley risk management and dam safety, the “Laboratório Nacional de Engenharia Civil (LNEC)” and the “Technical University of Lisbon (UTL-IST)” are being working in a NATO Project (Science for Stability Program) since 1994.

The paper includes remarks about dam risk concerns and on the need for public participation and shared responsibility including dam owners, safety authorities and public.

The paper also describes the main developments achieved by this NATO project including the preliminary conclusions of the first sociological field study on dam break risk perception on an european valley, so far.

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1- Introduction

Dams and reservoirs have a main positive role within the water management strategies and give a strong contribution to the society life quality improvement. Being a complex human technical achievement, dams are also a potential danger for downstream valleys: whatever the cause and the probability of occurrence, a failure in the water retaining capability is always possible.

New large dams projects are under the public fears and the critics from environmental groups: old dams and densely populated valleys are a growing threat. Environment, safety and public opinion about dams are now a major factor of decision and pressure all over the world: the open society and the media power have changed the decision-making methodologies. Benefits from technological progress are now less obvious and seems to be more risk for the common citizen.

Present safety regulations and guidelines require a more deep consideration of the valley safety as well as a more efficient interaction between dams and valleys safety management. A new integrated dam-valley safety includes a broader spectrum of problems and methodologies: the local social behaviour and land management effects, the public perception to technological risk and acceptance of safety restrictions and response to emergency preparedness. Emergent new problems and new solutions to overcome them are a challenge for those involved in dam safety.

Past catastrophic dam failures have occurred and can occur again. Among the effects of such a kind of accident, the megaflood caused by the reservoir drainage, through a dam breach, can be a very dramatic event in what concerns loss of life and property. The horror of a concentrated death tragedy gives a special importance to dam-break flood risk at downstream valleys.

A large effort has been done during the last decades in what concerns dam safety concepts. ICOLD and several national dam safety organizations promoted reports of failures and accidents, regulations and guidelines (e.g. ICOLD, 1995, 1998). Large dams will benefit from very qualified and skilled engineers and the society will obviously be more careful about its safety. However, we need to be also careful with safety aspects concerning:

- the ageing of dam structures and the modifications of their environmental and hydrologic conditions;
- the increasing number of small and medium dams with limited funds that can not afford detailed studies.

No matter how sound is the dam design and constructions, severe abnormal or evolutive factors can induce a potential state of failure that will threat the downstream area. Should an unsafe dam condition be detected and, according to most of the recent safety regulations, an emergency plan should always be prepared in order to notify or to evacuate the residents in downstream flooding zones under risk.

Downstream safety evaluation is a very delicate subject because it is very site specific and involves human lifes and emotional reactions. In order to

improve the protection of the population in dam-break flood risk prone areas in Portugal, a research project, funded through the NATO Science for Stability Program, is under development. This project, entitled Dam-Break Flood Risk Management in Portugal, or NATO PO-FLOODRISK Project, is also supported by the Portuguese water and dam safety authority “Instituto da Água” (INAG), the main Portuguese power company “Electricidade de Portugal” (EDP) and the “Serviço Nacional de Protecção Civil” (SNPC).

In this paper a brief description of the main concepts and methodologies of the project are presented.

2- Safety of Dams and Valleys

2.1- Integrated Safety Concept To improve the guarantee of water benefits, the human technology creates large dams and reservoirs along the valleys. The concentrated water (and energy) behind each dam can be considered as a new risk factor to downstream valley. Dam structure and operation will introduce into the valley a new uncertainty factor inducing potential abnormal catastrophic floods.

Fortunately, the advances in science and in engineering have dramatically diminished the expected rate of failure of new dams. However, the incremental risk induced by these structures are differently perceived by dam engineers and laymen. Two radical behaviours or paradigms can be detected: an extreme confidence on dam safety, because all aspects were considered during the project (a typical specialist-position) or because there is a blind faith in technological power (a typical position from a believer in absolute engineering efficacy), and a strong suspicion and fear by the uncertain consequences of a new technological environment or constraint.

Meanwhile, thousands of dams were built, and getting older, or are under construction, and millions of people live along the valleys often with a very dense land occupation. Valley safety, in this context, can not be just dependent on dam structural and operational reliability and should be considered as an integrated concept closely involving both the dams and reservoirs as well as the downstream valley system comprising the people, the land and the economic occupancy.

Other types of safety techniques need to be integrated: a shared risk need to be negotiated and implemented: dam risk assessment and decision-making as well as the valley risk management process need to include the human feelings and values in order to understand potential conflicts and to find equity between individual interest and public good.

The valley risk management against floods and dam hazards, as a part of an integrated dam and valley safety system, is now a topic of research and discussion in different countries.

Each dam, with its reservoir and near valley reach area, can be considered as a system. An abnormal and dangerous response of this system, in what concerns the downstream safety, can be provoked by different causes of disturbances:

- extreme inflows due to rare hydrologic events;
- geotechnical disturbances;
- structural failure;
- operation error;
- war or sabotage;

and can induce potentially severe or catastrophic accidents. In fact, any abnormal outflow will threaten the downstream system or downstream-valley system including the river, the land and the people with its social organization and infrastructures.

Economic damages or losses will be the response to abnormal and life outflows (floods). Life, economic, cultural and environmental losses are, among others, the result of the global system behaviour to an hazardous dam response to inflows or other perturbations.

In what concerns, the integrated dam and valleys safety two main objectives can be referred:

- to minimize the possibility of a hazard and failure due to an operational error or malfunction;
- to minimize human (life) losses.

2.2- Conceptual Dam-Valley Risk Framework For each potential event or hazard E_j acting on the dam system, the total mathematical risk, R_{ej} , can be considered splitted in two kinds of risk: the inner or own dam risk and the outer or downstream valley risk. In fact, the total risk can be defined as:

$$R_{ej} = P_{1ej} \times [\text{total expected consequences of the event } E_j \text{ acting on the dam}] \quad (1)$$

where P_{1ej} is the probability of the event occurrence; the outer or the valley risk R_{evj} will correspond to the expected damages along the valley downstream of the dam, including the river tributaries, or

$$R_{evj} = P_{1ej} \times [P_2 (F_v | E_j) \times P_3 (D_v | F_v) \times D_v] \quad (2)$$

where

$P_2 (F_v | E_j)$ = conditional probability of occurrence of a flood induced by the dam failure with intensity, F_v , should the event E_j occur.

$P_3 (D_v | F_v)$ = conditional probability of occurrence of the valley potential damage/losses, D_v , should the flood F_v occur.

The set of events E_j can include normal (e.g. hydrostatic action) and abnormal situations (e.g. flood and seismic actions).

The characteristics of the flood F_v , induced by the event E_j , will be a function of the dam and reservoir response, including the dam operational-hydraulic and structural type of response. This response can include an abnormal or unexpected gate operation or a dam breach due to the structural failure.

The dam-break flood intensity (peak discharge, volume and flood hydrograph) will depend on several factors, as among others dam and reservoir general characteristics and the breach dimension and opening time interval. These factors can be considered as dam or inner safety factors.

The effective valley damages will depend on the valley vulnerability to dam-induced floods. This vulnerability will be a function of several factors: flood intensity along the valley, warning system and flood time of arrival, land socio-economic occupancy on flood prone areas and people survival capability. In fact the valley risk will strongly depend on dam safety or response to hazards, so an integrated risk management or dam-valley risk management need to be considered.

By convolution procedures, it will be **theoretically** possible to obtain the probable dam total risk and the probable valley risk induced by the upstream dam(s). In practice, this is still not completely possible because we are not able to know the real response probability functions to all potential events acting on each dam of a valley.

Advances in structural safety control, including probabilistic methods and reliability theories, have been presented at several conferences, including the International Conference on Safety of Dams held in Coimbra, 1984 (SERAFIM, 1984). However, the dam failure probability as a quantitative safety appraisal is still very questionable from the scientific point of view. Fanelli (1991) argues that "if probabilities are to be somehow related to physical frequencies of occurrence, the existence of a large homogeneous population is a prerequisite; but this is not the case for dams, which are always unique". According to Fanelli "the concept of probability has actually been introduced mainly to cover the important aspects of inevitable uncertainty and incompleteness of knowledge on which design is based".

2.3-Dam-Valley Risk Management Based on the theoretically risk framework, an integrated dam-valley Risk Management System¹ can be conceptually composed by two parts:

- **The risk assessment process**, in which an approximate quantitative basis or level is laid (risk estimation and evaluation) for the actions that have to be taken. It includes the hazard characterization or identification and the dam risk analysis.

- **The risk mitigation process**, in which actions to reduce the risk will be identified and implemented, as well as appropriate techniques and management

¹ The concept is explained in ALMEIDA and VISEU, 1997.

principles to reduce other likelihood of an occurrence or this consequence or both. It includes the risk control and reduction and risk response.

According to this classification the risk management system comprises four types of actions grouped as follows:

1. Hazard determination and evaluation including the identification of potential events (and probabilities) that may cause a disaster induced by the dam response.

2. Risk analysis as an applied methodology of combining the probability (or frequency) of occurrence of the identified hazards and the magnitude of the consequences (damages) of the occurrence in order to obtain a safety level estimation based on the mathematical expectation of the consequences induced by an adverse event. Risk analysis is concerned with the methods by means of which hazard or a set of hazards are linked to the identified consequences which might occur in different situations as well as with the comparison of the total calculated risk value with accepted levels of risks.

3. Risk control and reduction including decision methodologies to choice actions to be taken should the risk level obtained by the risk analysis exceeds the acceptable risk level. This includes actions to reduce the response probabilities functions P_2 and P_3 using structural or/and non-structural techniques or actions. The first actions are related to the structural and operational safety of each dam including the monitoring and inspection procedures. The second ones will include all alternative actions to face a potential hazard: early warning systems, emergency action plans, preparedness training and land use or occupation management and control techniques (zoning). For finding, among the available alternatives, the one that yields the most protection for the available resources, operational risk decision methodologies need to be developed and applied.

4. Risk response or the actions to be taken in order to develop the response planning should a disaster struck induced by a dam incident or failure, including short term assistance, evacuation and survival planning for emergency end post-emergency phases.

The first action comprises a better knowledge of all potential environmental (natural or man-induced) events E_j that can struck each dam and its reservoir, including bad design or construction practices; this better knowledge, based on past experience or on natural event characterization (e.g. local flood and risk characterization), set of probabilities P_{1ej} .

The second action will try to select and quantify the dam response and consequences to each event scenario fundamentally, based on fault tree analysis and on branch probabilities. Typically this analysis focuses the dam structural and operational behaviour and the probabilities $P_2(F_v | E_j)$ and the approximate evaluation of potential damages D_v .

The third action (risk control and reduction) is one of the most important within the integrated dam-valley risk management. This action will include all measures to be taken during all phases of dam live in order to diminish both the

probabilities $P_2 (F_v | E_j)$, including dam safety design and operational guidelines and the enforcement of safety regulations, and $P_3 (D_v | F_v)$, by implementing monitoring and failure prediction systems, a valley warning system, emergency and evacuation plans, including training and exercises, as well as to reduce the potential damages D_v by land-use control (risk zoning) and public information.

The last action will include the valley civil protection system that should guarantee the adequate implementation and response should a real emergency or crisis situation occur induced by a dam accident.

The integrated dam-valley risk management has a definitive complementary role to the restricted dam safety concept only based on procedures related to dam works and operation. This concept pretends to embrace both the control of the main risk focus as well as the control of social-economic consequences external to dam and its near valley reach. Two main benefits can be identified from this concept:

- a more **rational safety and risk analysis and evaluation** including a real damage reduction that can be considered by the society (e.g. improving the expected damage estimations made by insurance companies, including a more realistic framework for price evaluation).

- a **shared risk responsibility** (Figura 1) can be developed between dam owners, safety authorities and public, due to a better consideration and as open analysis and characterization of the dam benefits and risks as well as the mitigation or control action to protect the valley according to an accepted societal risk level (e.g. the integrated and shared risk management can be a positive way to consider during public discussions related to a new dam construction or safety reinforcement).

FIGURA

2.4- New Dam-Valley Safety and Risk Paradigms Due to historical dam failures in the sixties and seventies that had a very dramatic effects on dam engineering practice, dam failure scenarios, inundation maps due to dam-break floods, warning systems and emergency plans and other valley risk assessment techniques began to be included in safety regulations. On the other hand dam risk economic analysis based on the expected probability of dam failure and damage was introduced as an approach to find optimum dam design decisions (e.g. the spillway capacity).

The new safety and risk paradigm considers an integrated approach at all levels of decision and operation based on a shared and accepted level of dam-valley risk. The integrated approach is based on three safety vectors that need to be developed according to very high technical levels:

- dam design, construction and operation;
- dam surveillance monitoring and hazard prediction;
- emergency management including damage mitigation or control.

Dam-valley decision criteria need to be based on public information and special methodologies in order to consider the subjective feelings and risk public

perception. The **societal risk criteria** followed in some countries (Mac Donald 1995) is one of these methodologies and try to reflect the society's a version to potential disasters or catastrophes. However it has no regard to particular persons (individual risk) but give the "acceptable" frequencies of events that would induce a certain level of damages (e.g. to kill more than a certain number of people).

The quantitative evaluation of the probabilities involved the in dam-valley risk calculation as well as how to communicate this quantitative risk assessment (typically based on very low probabilities) to lay people.

(C-1)

To assess the failure probabilities of each scenario and failure mode is very difficult indeed and in most cases is simply based in subjective proposals coming from a panel of experts.

An analysis of historical worldwide dam accidents and incidents based on a well structured and consistent data base developed by ICOLD would be a strong contribution to risk analysis. Much more difficult is to evaluate the people survival probabilities against floods induced by dam failure, taking in consideration the valley vulnerability and civil protection and mitigation schemes.

The integrated approach can now be supported by advanced simulation models of flood propagation and inundation mapping, as well as powerful new information and decision support systems. A new phase of valley safety can now be implemented based on advanced dam monitoring and hazard prediction and valley warning systems.

2.5- Operational Risk Management Difficulties Rare events and very low yearly failure probabilities are difficult to feel and to control. In fact, risk perception involves people's beliefs, attitudes, judgements and feelings, as well as the wider social or cultural values and dispositions people adopt toward dam hazards and benefits.

Engineers are well trained to work with the physical truth or objective safety evaluation based on a quantitative analysis and on, as much as possible, "neutral" and rational decisions. However, the media in an open society are now part of the decision process on what concerns a large dam impact. Typically, the individual doesn't easily accept a new uncertain risk or threat imposed to him and family by others. However, each individual may react in an opposite way should the risk decisions be from its own responsibility and for its own benefit. So, the benefits of the project and the threat real dimensions of it need to be clearly presented and discussed in order to obtain public trust and acceptance to share future risks and to accept land-use restrictions for protection in flood-prone areas.

Engineers are very pragmatic and it is not easy to develop an integrated operational methodology, including the quantitative physical or **objective** approach and the **subjective** domain of human feelings and values, with guaranteed pre-fixed results, the new approach must conciliate the individuals and the group of people under potential threat as a whole. Social psychology and sociology are two social sciences that will be introduced in the interdisciplinary set of specialists involved in dam safety and valley risk

assessment and management. They will try, among other methods, the quantification of the social characteristics or profile of the people under potential threat along the valley.

Difficulties can arise from the fact that the consideration of social values in the design and decision-making process will impose, to all specialists, a better understanding of their role (including new ethical attitudes) and a strong confidence on the benefits of their work for the community. The control of the nature need now to be considered a challenge that must have the support of the public, which means that the knowledge and acceptance of the not ultimate benefits of a dam is not only a specialized technical problem but also an open issue for very different actors, including laymen.

Among other characteristics, the following difference between the two approaches can be easily identified:

- engineering and physical sciences have methods that can be universally applied (with the same initial conditions the some results can be expected);
- social sciences are strongly dependent on local, or regional, cultural characteristics, including abnormal human behaviours (each valley will be a new case within a new social or cultural context).

This can lead to a severe methodological shift between the two types of approaches: the subjective one introducing potential uncertainties into the process and unpredictable results in the decision-making planning. This is a true practical problem but in the present (and much more in the future) society, based on free information and participation, this uncertainty will be much more dramatic and harmful should the subjective human behaviour and feelings and other social values be out of the decision and management processes of environmental and safety issues.

Safety and risk management will be possible if people believes or trust the engineers and scientists that generate the dam risk assessment.

The systematic practice of new integrated methodologies can give the confidence and the basis for a comprehensive and successful framework with new guidelines. Meanwhile the following general principles should be taken in consideration:

- Quantitative or objective risk assessments are not easily understood or felt by laymen. Perceptions are the result of complex subjective and objective factors including emotional feeling and values. So, public perception of rare events can be very different from what scientists or specialists feel.
- Public information, as an instrument for a better or unbiased judgment of risk management, need to be carefully prepared and to recognise public values and feelings in order that the message don't be distorted.
- Public participation within a framework of respect of both objective information and subjective beliefs can be a critical more towards an accepted shared risk and an efficient non-structural valley risk management against floods and dam incidents or accidents.

- Ethical principles can not be neglected in this process. These principles will apply to both short and long time decisions and consequences as, respectively, the following two examples: the new approach for dam risk decision should not be transformed in just a trick for more easily to impose a decision to the public; the uncertainty about values and choices of future generations should not be completely neglected nor be a source of block to our decisions (Catron *et al.*, 1996).

- A moral dimension should also be considered in the accepted shared risk: a freely accepted risk by the people living along the valley may be not enough to make that process morally acceptable.

For large floods and potential rare events, including dam accidents, a set of emergency procedures need to be prepared as it is now required by the safety regulations and is the role of the civil protection systems. The consideration of both subjective (human response) and objective factors (inundation maps and evacuation plans), can improve the emergency response and also the real survival capability under limit or critical conditions.

The integrated valley safety management should include abnormal floods and dam outflows.

3- NATO PO-FLOODRISK Project

3.1- Project Structure and Objectives Funded by the NATO Science for Stability Programme, the Dam Break Flood Risk Management in Portugal, code NATO PO-FLOODRISK Project², began in 1994 and will end in the fall of 1999 (Almeida *et al.*, 1997).

At a national level the project pretend to improve the Portuguese operational implemented of the dam safety regulation published in 1990. At a scientific and technical level the aim is to develop new concepts and methodologies for an integrated dam and valley risk management.

The following four general objectives of the project were chosen in order to inspire the research work:

- To improve the engineering capability for dam-break flow analysis and prediction on real complex situations, as well as, to improve the use of social sciences in dam risk management.

- To develop methodologies and guidelines for dam-break flood risk management in Portugal, as a first step towards a new integrated flood safety system based on structural and non-structural measures, including public participation, and on advanced information support.

- To implement new advanced information technologies applied to hydraulic engineering analysis and land-use and safety management techniques.

² Preliminary results and products of NATO Project are included in ALMEIDA and VISEU, 1997.

- To create a new concept for operational crisis control and integrated dam safety management and also to contribute to the improvement of the Portuguese dam safety regulation and land-use management in risk prone areas.

The NATO Project develops in the context of an integrated methodology for dam-break flood risk and safety management at downstream valleys is supposed to include:

- Computational modeling and simulation systems;
- On-line multimedia databases;
- A Geographical Information System (GIS);
- Applied social sciences techniques, strongly dependent on local and regional cultural characteristics and human behaviour.

The NATO PO-FLOODRISK Project (1994-1999) encompasses the following five sub-projects (Figure 2):

1. Hydraulic Analysis and Computational Simulations.
2. Dam and Reservoir Safety Analysis.
3. Land-use, Safety Management and Civil Protection.
4. Computer Aided Decision Support System.
5. Experimental Integrated Emergency System and Training.

These five sub-projects are coordinated in order to reach the following general objectives:

- to improve the engineering capability for dam-break flow analysis and assessment on real situations, as well as the applied social sciences capability in the design and implementation of civil protection systems;

- to develop experimental methodologies and guidelines for dam-break flood risk management in Portugal, including public perception and participation, flood vulnerability, valley risk assessment and land-use management;

- to implement new advanced information technologies applied to hydraulic analysis, safety management and training;

- to develop and operational crisis control and integrated dam safety management system.

Each sub-project is composed of several tasks with precise objectives:

- **Sub-project 1** develops new computational models for a better dam-break flood prediction and zoning and will contribute for a better understanding of hydrodynamic problems related to transcritical flows with abrupt waves (bores) – (Almeida, 1994).

- **Sub-project 2** prepares design criteria for practical dam-break analysis, dam rupture scenarios, including initial hydrologic conditions, to satisfy dam safety legislation.

- **Sub-project 3** develops research studies related to the social impact of dam failure risk and downstream land-use and risk management (Lima *et al.*, 1997; Silva, D., 1997).

- **Sub-project 4** implements an advanced decision support system (DSS) to be used in dam-break flood safety management (Gamboa and Santos, 1997 and Fernandes and Andrade, 1997).

- **Sub-project 5** will prepare the final specific products on the project including final fields exercises and tests, the implementation, of a crisis management system and the actions for training and dissemination of knowledge.

FIGURA

3.2- Case Study A field study took place in a valley located in the south of Portugal – Silves with two dams built in cascade (Almeida *et al.*, 1997). The data was collected in three different areas in order to operationalize three different levels of risk exposure. The first area was a high risk area near the river (Area 1), the second was a lower risk area (Area 2) and the third was a none risk area, near the train station located on the other side of the river (Area 3).

In the questionnaire topics on demographic data, flood experience data, awareness of dam failure risk, perceived risk of dam failure and positive illusions related to this risk were included.

Dam risk awareness included: worry (1- not at all to 5- very much), frequency of thoughts (1- never to 5- frequently); city and house affected (1- not at all to 5- very much). Dam failure perceived risk included: dam failure probability in 2 and 10 years (1- not at all probable to 5- very much probable). Positive self illusions included: self-efficacy (1- I am certain that I could not do it to 5- I am certain that I could do it). Positive control illusions: control over life and over risk (1- strongly disagree to 5- strongly agree). Unrealistic optimism: evaluations of house safety (1- more unsafe than other houses to 5- much more safe than other houses); and of house damage (1- less drainage than other houses, 5- much more damage than other houses).

This questionnaire was applied by an experienced interviewer. Our sample included 91 persons of both genders (56% female), all with flood experience. On the first area people were younger than on the other areas. Due to this result the age was controlled in further analysis.

Analyses of variance were performed on each of the dependent variables with age being a covariant. A post hoc test was also conducted (Tukey Honestly Significant Difference) whenever necessary.

Threat awareness

Results show that inhabitants in area 1 have a greater threat awareness than subjects in the other two areas. They thought more often about the dam

failure possibility and they were more worried about this possibility. They thought that the city would be more affected and also their house.

Dam failure risk perception

Results for the variable dam failure risk perception showed that people on area 1 and 2 minimise the possibility of dam failure occurrence as compared to area 3. They consider this probability as very low or even inexistent for the next two years and also for the next ten years. Results show different cognitive beliefs in the samples studied, which are congruent with our predictions. The existence of unrealistic optimism were analysed in two steps. First the estimation of people from area 1 and 2 on the perception of safety and eventual damages in their houses in case of dam break were compared. Afterwards we compared those self reported events with the evaluation of safety and damages made by Area 3 residents.

The results for the self evaluation for house safety shown that people on the first area considered their house less safe than people of Area 2. But when we compared their self evaluation with the evaluation of people on Area 3 we saw that they overestimate their house security. Area 2 and 3 subjects do not differ in their safety evaluations concerning Area 2 houses.

The results show that people on Area 1 estimate greater damage for their house than Area 2. Once again when we compared their results with evaluation done by the persons of Area 3 we found that they underestimate their probability of damage. For this variable we didn't, also, observed differences between Area 2 and Area 3 evaluations concerning the damages in Area 2 houses.

To summarise the results, we can say that the sample people in Area 1 showed greater awareness of the threat and at the same time greater minimisation of the risk. This group also revelled greater positive evaluation of their capacities to cope with threat and higher levels of control over the risk. We didn't find the expected differences between Area 1 and Area 2 for the variables house safety and damage probability. However, when we compared the evaluations results of the first group with the evaluations of the third group we observed the expected optimistic effect. These results suggest that people with higher levels of threat awareness minimise the risk of dam failure using positive illusions.

The Methodologies developed are being applied to this particular case study (computational models, digital terrain model, GIS, and vulnerability analysis). A physical model (scale 1/15) was built and is now under operation at LNEC.

3.3- Land-use and Risk Management Support System Within NATO project Dam Break Flood Risk Management In Portugal is also under development a study concerned with:

a. The interface between risk management and land use planning techniques in the specific case of dam break floods risks;

b. Developing methods and tools to be used by local, regional and national authorities, that integrate flood risk in planning and management of valleys downstream of dams;

c. Developing of risk management techniques among land use planners and authorities that are responsible for location of infrastructure and public services and improve the application of these techniques.

One of the tools being considered is a decision support system, based on GIS technology, and containing relevant data for land use management in face of dam break flood risk, subsequently called land use management decision support system. This system, subsequently called the land use management module, is part of a larger information system, being developed within the NATO research project, including the support to dam and valley safety as well as to crisis and emergency management.

Land use planning mediates a struggle between a dynamic reality and a mainly static organizational framework. Land use planning methods must be perfected to make the organizational framework more dynamic. This way of reasoning finds its full application in the subject of this research project. As a starting point, there is a valley, downstream of an existing or projected dam. This valley has a current occupation. Facing the risk that is brought about by the dam, land use management decisions in the valley should immediately be oriented by three major considerations:

a. To avoid increased exposure to risk of existing occupations;

b. To create alternatives for the more exposed existing occupations, particularly strategic infrastructure and service facilities;

c. To assist civil protection authorities in drawing emergency plans.

The rationale behind the study is that adequate safety in the valley can only be achieved through the permanent consideration of risk in the current land use decisions. This requires appropriate information and an adequate decision support system, allowing for good co-ordination and timely communication of the different agents concerned. In case of an accident there will be little or no time to produce new information.

Thus, the development study was oriented by two main objectives:

a. To support current land use management decisions and current dam operational decisions that may affect land use or people and property in the downstream valley;

b. To prepare and support emergency dam operational decisions and civil protection operations in case of dam failure or severe accident.

4- Conclusions

A new multidisciplinary integrated research project funded by NATO Science for Stability Program is under development in Portugal concerning dam-break flood risk and safety management at downstream valleys.

The impact of dams on environment and downstream safety is a very complex topic. Dam safety regulations impose nowadays an emergency action plan based on a flood mapping or zoning. The NATO PO-FLOODRISK Project intends to develop new integrated methodologies for dam-break flood risk management in Portugal based on a cross-fertilization between different engineering and social sciences techniques. The dam design practice and safety legislation can be improved as a result of innovative proposals related to the accuracy of computational models and to an integrated land-use management, dam risk public perception and flood zoning.

Several factors lead us to the conclusion that dam failure can be perceived as a potential threat to the populations living downstream. Even in normal circumstances the exposure to the potential threat of a dam accident converts the event into an ambient stressor. There are two main strategies to cope with this stress: problem solving and emotional regulation. These two strategies are not incompatible, and in many cases they are simultaneously used to manage the same stressor.

Social psychology advances can be married with other engineering procedures in order to improve the civil protection operational systems, specially the warning systems. New information technology system for decision support is nowadays a tremendous step forward in order to improve the dam safety requirements in what concerns the downstream safety.

The integrated dam-valley risk management actions will try to control and diminish the risk level, both in what concerns dam safety and valley safety, through monitoring, monitoring and civil protection systems against the potential floods induced by dam accidents.

The consideration of emergency actions, including warning systems, evacuation planning and risk zoning as well as public information training and exercises will low the loss probability and should be considered as important as other dam safety procedures.

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