Emergency Action Plans Implemented with Early Warning System (EAP-EWS) in Downstream Valley of Dams, a Real Case Study

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Abstract

Dams play a vital role in flood management and there is a close relation between effective flood management and dam safety. Therefore, the safety of dams and especially downstream valley of dams should be maintained at all phases ranging from design and construction to operation in accordance with legal aspects (guidelines, legislations and regulations), necessary measures for emergency planning and flood mitigation actions should be taken. It has been learned from past experiences that the best results in flood mitigation can be achieved by combining structural measures to non-structural measures. Emergency planning in terms of Emergency Action Plan (EAP), implemented with Early Warning Systems (EWS) where necessary, are non-structural measures to minimize flood impacts and play an important roles in emergency planning in case of dam break induced flood event. The aim of emergency planning is to save lives, minimize damages to properties located at downstream as well as environment, and real time warning to hazard zones located in downstream. In order to introduce early warning systems and the operation of crisis room, the experiences of using early flood warning system located in a dam site and downstream valley of a dam is shown. In this plan a Decision Support System (DSS) under title Citect is used to making sure decision makers and stakeholders about flood hazard. The results show that in order to mitigate the potential risks caused by both natural and technical reasons and to minimize the damages and casualties to the downstream induced dam break using EWS beside External Emergency Action Plan (EEAP) is necessary.

Key words: Dam break, Emergency Action Plan, EWS, DSS, Downstream valley of dams

1. Introduction

Dams are built for irrigation, hydropower generation, urban and industrial water supply, navigation and flood control purposes. Especially, in case of a multipurpose project, flood mitigation can be one of the main objectives to build a dam and this multi-purpose use makes dams more economically feasible when compared to other flood control and protection structures. Dams and reservoirs beyond them play an important role for flood management and mitigation in a river basin. In order for dams to be able to carry on these functions, they should be maintained in good condition at all times. Therefore, there is a close relation between flood management and dam safety (Dincergok, 2009).

It must be emphasized that the content of dam safety covers not only maintaining the good condition of the dam body and the appurtenant structures but mitigating the adverse impacts at downstream which is prone to flooding in case of a dam failure. In recent years, there is an increasing concern in terms of potential risk for the people living and for the properties and facilities located downstream of especially the large dams (Dincergok, 2009).

Contemporary dam safety regulations include risk assessment at downstream flood plains and consideration of potential damages due to dam rupture, regardless of the expected probability of occurrence of such event. The aim of these kinds of procedures is to increase the safety level along the valley against abnormal floods caused by dam accidents (Almeida, 2003).

Emergency action plans (EAP) for downstream flood plains, including zoning, warning and evacuation plans, are being developed as special risk mitigation procedures. In modern open societies these plans should include public information and training. All these valley actions will be justified in order that the global safety level be increased, not only in objective terms by increasing the survival probability, but also in subjective terms. In fact, public risk perception and EAP are very important dimensions in any risk and crisis management methodology. For dam and valley safety policy, public participation and perception becomes more and more a very important issue (Almeida, 2003).

In order to EAP for decreasing damage in valley of dams, combine this together with Early Warning Systems (EWS) is essential. Herein, emergency action plans for downstream valley of dams is introduced together with new non structural method for decreasing loss of life and property such as early flood warning systems and Decision Support Systems (DSS) which can help authorities and decision makers to make decision better.

2. Emergency Action Plan

An EAP is a formal document that identifies potential emergency conditions at a dam and specifies preplanned actions to be followed to minimize property damage and loss of life. It contains procedures and information to assist the dam owner in issuing early warning and notification messages to responsible downstream emergency management authorities of the emergency situation. It also contains inundation maps to show the emergency management authorities the critical areas for action in case of an emergency.

The necessity of EAP for downstream valley of dams can be split in 3 categories:

- To pre-plan the coordination of necessary actions by the dam owner/operator and the responsible local, state and federal emergency organizations.
- To provide timely notification of a dam emergency and evacuation in the event of potential failure of the dam.
- To minimize the risk of loss of life and reduce the risk of property damage in downstream areas resulting from a dam’s failure (Guideline…, 2009).

3. EAP Implemented with EWS in Downstream Valley of Dams

Emergency Action Plans together with Early Warning Systems are useful non-structural tools to define the necessary procedures to be followed by certain people, both technical and civil, with pre-determined responsibilities for initiation of notification or warning of people who may be at risk at downstream in case of an emergency (Bradlow et al., 2002).

The Emergency Action Plan (EAP) is divided into two main groups, namely the Internal Emergency Action Plans (IEAP) and the External Emergency Action Plans (EEAP). The guidelines concerning monitoring and surveillance and the response actions regarding dam safety and operation in case of an emergency is managed with IEAP; whereas the necessary actions concerning the downstream valley are taken and managed by EEAP. According to this concept, EAP should include the following procedures and information (Almeida, 2002). Internal Emergency Action Plans (IEAP):

- The identification of the dangerous situations for the dam
- The definition of the safety levels for dam operation
- The methodology for hazard detection and decision making
- The notification of dam safety and local authorities
- The notification and mobilization of the civil protection services

External Emergency Action Plans (EEAP):

- The characterization of the downstream valley including population, economic activity, infrastructures
- The identification of the safety agents and their responsibilities
- The definition of the decision-making hierarchy
- The allocation of human and material resources
- The definition of shelter zones areas and the access routes
- The identification of communication systems
- The implementation of public warning and notification system

In order to reach a high security in downstream valley of Hesarsangy dam, several steps were implemented. A good characterization of the floods induced by dam breaks is a fundamental requisite for the valley risk management. For this reason, simulating the dam break and computing outflow hydrograph due to dam break by DAMBRK model are performed. Fig. 1 shows the outlet hydrograph of dam break.

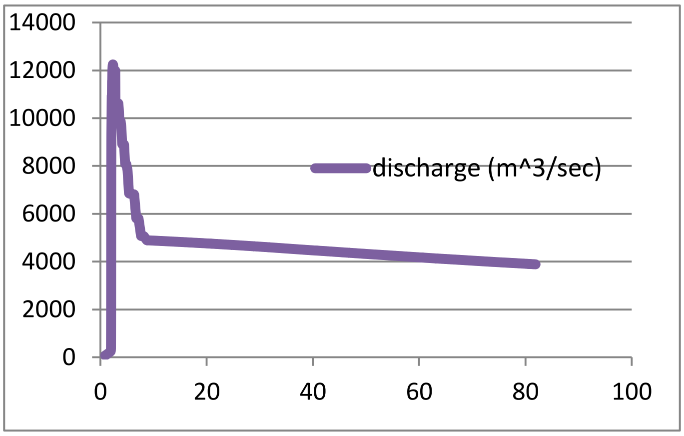

Fig. 1 The outflow hydrograph due to dam failure

After that, the computational flood plain simulation on downstream valley based on a numerical technique is calculated by HEC-RAS and CCHE2D models. Figs. 2~3 show flood plain due to dam break at the beginning of break and 2.3 hours after that. In addition, the flood plain induced the operation of spillway gates and bottom outlets of dam are calculated to produce hazard zone maps.

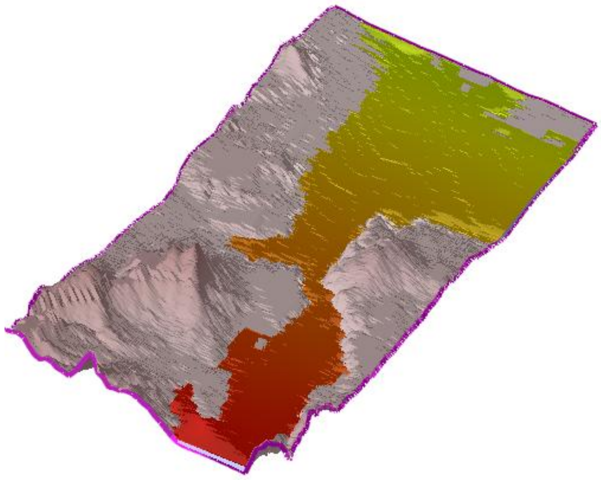

Fig. 2 Flood plain at the beginning of dam breaks.

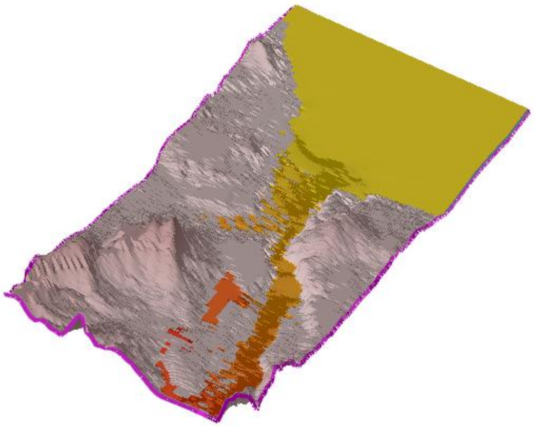

Fig.3 Flood plain after 2.3 hours.

3.1. Impact of dam break risk

This project made the inquiries about dam risk social perception along the valley. In downstream valley both structures and roads located along valley which are indicates in table 1 (KPM, 2009).

Infrastructural structure		Roads	
Investment Value	Structure's name	Length (Kilometer)	Rod's name
- - - -	- Intake structure - Hydrometric station - Diversion dam and its structures - Water diversion channels	39 75	Tributary Road Mani Road

Table 2. Infrastructural roads and structures under hazard.

Also, there are approximately 8 villages with different populations in downstream of dam which are under flooding hazard induced dam break or incorrect operation of gates and outlets. The information on flooding conditions at downstream locations might include distance downstream, arrival time of leading edge of flood wave, water surface elevation and peak velocity (Rodrigues et al., 2002). Table 2 shows village distance from dam and hydraulic condition due to dam break in location of each village.

Velocity (M/S)	Width of water surface (M)	Water level (M)	Wave height (M)	Distance from dam (KM)	village	Row
1.12	2252	398	11	1	Village I	1
1.72	3263	367.80	8	22	Village II	2
1.68	2288	343.34	4.5	36.51	Village III	3
1.6	2682	334.35	4.35	43.85	Village IV	4
1.63	2797	326.84	2.9	48	Village V	5
1.72	1482	314.64	5.7	62.91	Village VI	6
0.92	6542	299.18	2.2	73.76	Village VII	7

0.88	8892	277.58	1.5	86.27	Village VIII	8

Table 2. The characterization of hydraulic parameters in location of each village.

3.2. Early warning systems

The warning system is used for issuing flood warnings after analyzing the model forecasts. It is based on the results of the hydrological/hydraulic simulations resulting from the array of meteorological models, or can also include other forecast systems such as radar technology. It allows visualization of flood warnings as a GIS map layer with descriptive station and marks.

The process of complicated data transfer within system is automated by the developed telemetry system consist a main station on dam, a repeater station located on elevation, alarm stations located along downstream valley, and crisis room. These stations link together base on radio waves (VHF and/or UHF).

As flood alarm stations location in downstream valley play an important role in flood emergency management due to dam break or incorrectly operation of dam, choosing flood alarm stations depend on the following objects is necessary:

1. Flood plains caused by dam break or incorrectly operation of dam in downstream valley which is illustrated in Fig. 3.
2. The topography condition of downstream valley
3. The residential regions located along the valley

Upper objects were considered in Hesarsangy dam Project.

Herein, the analyzed data in main station are transferred as a frequency to receiver located in main station and repeater station. Repeater station transfers the frequency to alarm station and crisis room. Deciding and warning is base on critical data which are determined by model base subsystem; also, Users can control all stations and subsystems; and, they can discover any problem in system by using Decision Support System.

4. Decision Support System

A decision support system allows decision-makers to combine personal judgment with computer output, in a user-machine interface, to produce meaningful information for support in a decision making process. Such systems are capable of assisting in solution of all problems (structured, semi structured, and unstructured) using all information available on request. They are an integral part of the decision-makers approach to problem identification and solution (Simonovic, 1996). There are three fundamental components of DSSs (Andrew, 1991).

- Database management system (DBMS). A DBMS serves as a data bank for the DSS. It stores large quantities of data that are relevant to the class of problems for which the DSS has been designed and provides logical data structures (as opposed to the physical data structures) with which the users interact.
- Model base management system (MBMS). The role of MBMS is analogous to that of a DBMS. Its primary function is providing independence between specific models that are used in a DSS from the applications that use them.
- Dialog generation and management system (DGMS). The main product of an interaction with a DSS is insight. As their users are often managers who are not computer-trained, DSSs need to be equipped with intuitive and easy to use interfaces. The primary responsibility of a DGMS is to enhance the ability of the system user to utilize and benefit from the DSS.

While a variety of DSSs exists, the above three components can be found in many DSS architectures and play a prominent role in their structure. Interaction among them is illustrated in Fig. 1.

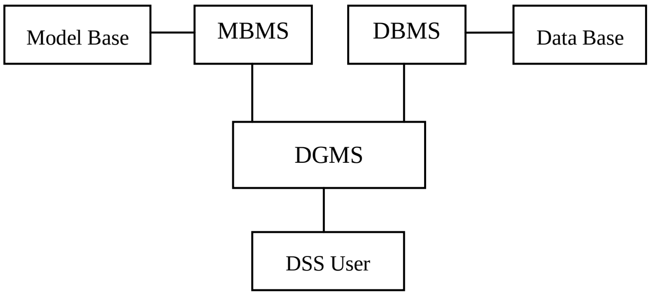

Fig. 4 The architecture of a DSS (Andrew, 1991).

In this context, the flood warning system is based on local forecasting. This system is consisting of telemetry and decision support system. DSS is defined to collecting information from different stations and their analyzing, monitoring and finally decision making to warn to authorities and decision making. Telemetry based system consist instruments, control equipments, telecommunication and linkage equipments, electronic equipments, software package, central and local crisis room. The data used by the modeling system include correct and useful data streams. Within this project, the existing data collection system had to be expanded to provide sufficient and good quality data to support the forecasting system, which could be polled at regular and specific intervals. The instruments needed are rain gauges and water level gauges.

Control and monitoring room is the most important part in telemetry and decision support system. And; main actions have been done in this part. Herein, in order to monitoring and surveying the equipments work in telecommunication bed, a comprehensive program that covers early flood warning process is developed and described. This system has capability as follow:

1. Warning time regulation in implementation situation
2. Existing security in implementation situation
3. Capability link with information banks such as ORACLE, ACCESS, etc.
4. Capability defining different scenarios about flood warning
5. Capability into saving data and giving report

Telecommunication link between monitoring center and stations is shown in Fig. 9.

Station Station Station Station

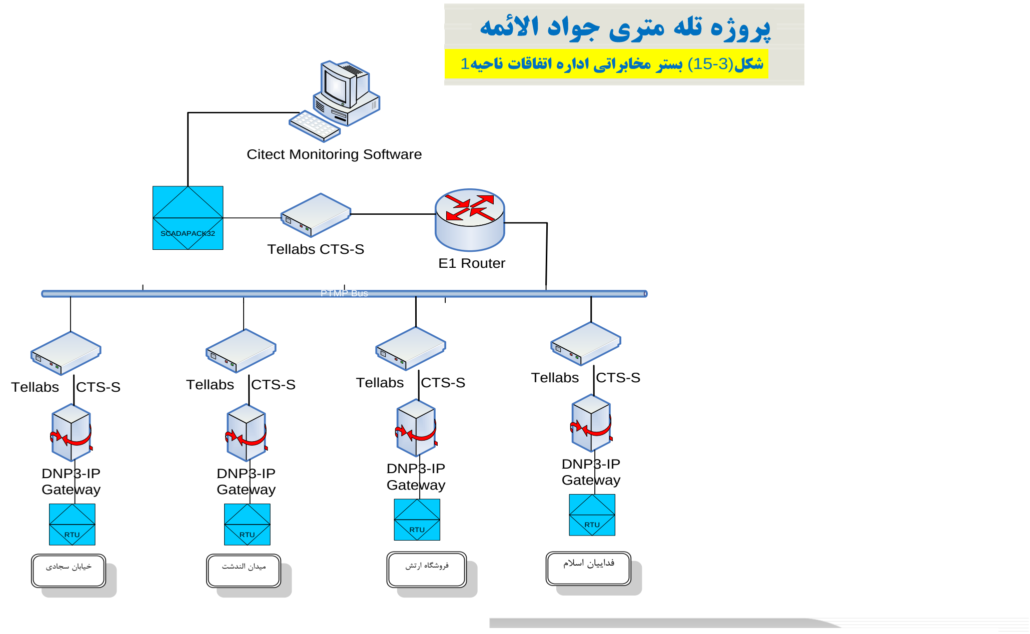

Fig. 5 Telecommunication bed between monitoring center and stations

Moreover, The DSS simulates a number of scenarios for various degree of hazard. It also provides the associated probabilities of occurrence of these degrees. The probabilities help as means of making a choice among the possible degrees of flooding. Associated with each degree of flooding there will be a list of actions to be taken by authorities or the public. Herein, each degree of hazard and the appropriate response for each degree, as given (Table 3) is determined. Table 3 shows critical conditions, warning levels and appropriate responses to each condition.

Appropriate Response	Critical Condition	Warning Level
-Evaluating problem - Performing early and appropriate actions - Informing to managers	473.8 (m) <water level<474.8 (m)	SMS
-Evaluating problem - Performing accurate action - Evaluating emergency condition - Informing to managers and decision makers - Performing reduction actions	If x hours after onset necessary action, water level don't	SMS
- Evaluating problem - Performing early and appropriate actions - Increasing reservoir water release - Informing to managers - Warning to downstream - Opening more percentage of dates	If simultaneous with performing reduction actions suddenly water level reach 474.8 meter	SMS Local Alarm
- Performing reduction action - Increasing flow release - Gathering relief group in downstream - People lived in high dangerous region should	If water level increase so that managers are forced to opening more	Manual Alarm to Downstream

be prepared for evacuation - Informing to managers and decision makers - Informing to residential regions along valley by manual alarm	percentage of spillway gates	
- Performing reduction action - Opening all outlines - Preparing and gathering relief groups in dam state and downstream -Evacuating hazard zone in downstream - Informing to residential regions by automatic alarm - Informing to relief groups - Informing to decision makers in urban areas to perform appropriate actions	Water level reach 476.8 meter	Automatic Alarm to Downstream

Table 3. Critical levels and appropriate responses in EAP.

5. Conclusions

According to the statistics, a majority of fatalities from natural disasters are caused by flooding. Although not very often when compared to the others, dam break induced floods may happen in case of a dam failure. When dams fail property damage is certain, but loss of life can vary dramatically with the extent of the inundation area, the size of population at risk, and the amount of warning time available. Consequently, this explains that dam safety procedures are necessary and play a vital role in terms of "Emergency Planning" in case of a dam-break or incorrect operation of gates and outlets induced flood event.
Civil protection authorities or valley safety authorities faces a responsibility to diminish the probability of human and economic losses should a dam-break event occur. To mitigate the risk along the valley, non-structural procedures should be implemented according to flood risk zoning and emergency planning.
Emergency action plans and effective warning systems are now mandatory by the Portuguese dam safety regulation and all modern dam safety regulations. However, these procedures need to be implemented with the support of local authorities and with an adequate public information and participation according to the risk perception level of the population at risk.
The outcomes of results show that using Emergency Action Plans implemented with Early Warning System to aim gathering the accurate and real data, analyzing data, making decision and warning the flood event to authorities and people decrease the loss of life and property in downstream valleys of dam. However, it is most useful than the structural methods to reach this aim.
It is noticeably recommended that together with all action plans, given public education to people about the operation of flood warning systems and their responsibility when they are warned from flood, providing good coordination between dam owners, dam safety authorities and civil protection authorities in order to be sure that emergency and evacuation planning's are effective, and given good public information in order to guarantee a good response to flood crisis is necessary.

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