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Estimation of Flood Warning Times for Flood Safety Management Downstream of Dams

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Abstract

Floods have always been a threat for people and property due to the extent of possible damages. The flooding could be catastrophic in case of possible dam failure and its impacts on downstream areas could also be very significant. Proper estimation of flood warning times plays a vital role in the flood safety management of areas downstream of the dams. This research focuses on the realistic and precise estimation of flood warning times for the downstream areas in case of possible dam failure. As Case study, the Jhelum river valley, 329 km long, downstream of Mangla dam in Pakistan has been considered. Various scenarios of an erosion based overtopping failure have been considered and one dimensional flood routing for Jhelum river valley downstream of the dam has been carried out with unsteady flow conditions by using MIKE 11. By analyzing the results of different flood routing scenarios, flood travel times for downstream areas have been computed and further the warning times have also been estimated with respect to different categories of warning initiation. This study emphasizes the importance of the estimation of flood warning times for downstream areas in case of dam failure and utilization of the estimated warning times for enhancement in warning efficiency, emergency evacuation techniques and other flood safety measures.

Keywords

Dam failure flooding, Jhelum river valley, Flood travel times, Flood warning times, Flood safety management

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Introduction

Climate change plays a very important role in the occurrence of floods. Drastic weather changes with extreme rainfall could increase reservoir water levels by large extents and could ultimately result into an overtopping failure of dams. Due to overtopping failure, there would certainly be catastrophic flooding which would pose severe risks to people and property downstream of the dam. For such situations, proper estimation of warning times for downstream areas becomes very crucial in order to minimize the possible damages. In this study, as case study Jhelum river valley downstream of Mangla dam in Pakistan has been taken into consideration. With a height of about 125 m above riverbed, Mangla dam is one of the largest earth and rock-fill dams in the world [19]. The crest length of the main dam is about 2561 m [18]. The original catchment area of the reservoir is about 33360 km^2 and the water surface area (at normal operating conditions) is about 253 km^2 [17]. The project reach has a length of about 329 km downstream of the dam with more than one million people at the risk of flooding (98-census data).The project reach downstream of Mangla dam with different hydraulic structures is shown in Fig. 1. Different cases of overtopping failure of the dam have been analyzed and subsequently the dam break flood routing for downstream river valley has been carried out by using the tool MIKE 11 (1D). The available GIS and other official data have been utilized for one dimensional modeling with unsteady flow conditions. Based on flood routing results, flood warning times have been estimated for downstream locations according to the computed flood travel times with different categories of warning initiation.

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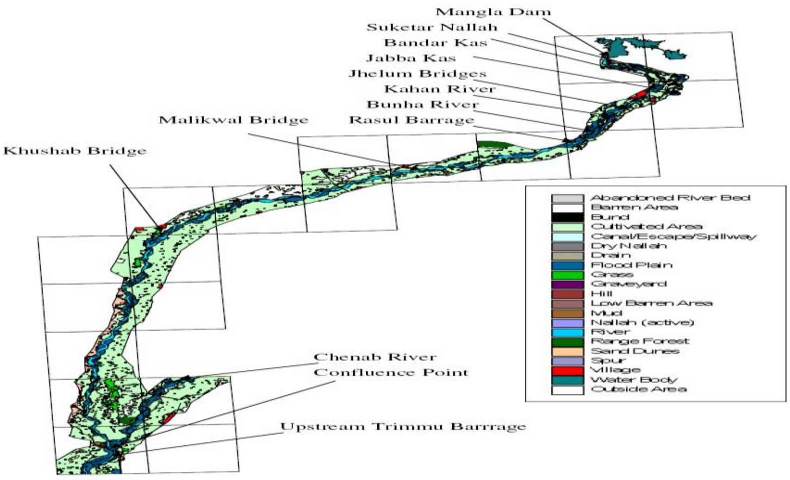

Fig. 1: Jhelum river valley downstream of Mangla dam

DAM BREAK FLOOD ROUTING IN MIKE 11

In this study, dam failure modeling has been carried out for Mangla dam by using MIKE 11. An erosion based overtopping failure has been analyzed with respect to the estimated breach geometry. Different breach cases have been considered for the dam break simulations.

A) Dam Break Flood Routing

An erosion based overtopping failure has been analyzed by using MIKE 11 dam break module. The time to failure is related to the full development of the breach with respect to erosion after the initiation of dam failure. The breach parameters for different breach cases have been estimated by using various available relations based on case studies [1], [5], [6], [7], [9], [11], [12], [13], [14]. The estimated breach heights for breach cases are about; 41 m, 62 m and 84 m [2], [3], [4].

In MIKE 11, an erosion based breach development is modeled only by using the energy equation. The initial and the final breach shape must be specified. During the development of the breach the trapezoid increases in size and changes the shape to a linear way.

In large reservoirs, the peak discharge occurs when the breach reaches its maximum depth and width [15], [16], [20].

B) Failure Outflow Hydrographs

Depending on the estimated breach parameters and dam break setup in MIKE 11, dam break simulations were run for three failure cases in order to determine the outflow hydrographs after failure (Fig. 2). For all failure cases, the side erosion index (*SE*) of 0.75 was considered. Generally, the side erosion index (*SE*) is in the range of 0.5-1.0 [10]. The failure outflow for the worst case is more than 300,000 m^3/s which could be the highest possible discharge after the failure of Mangla dam [2], [3], [4].

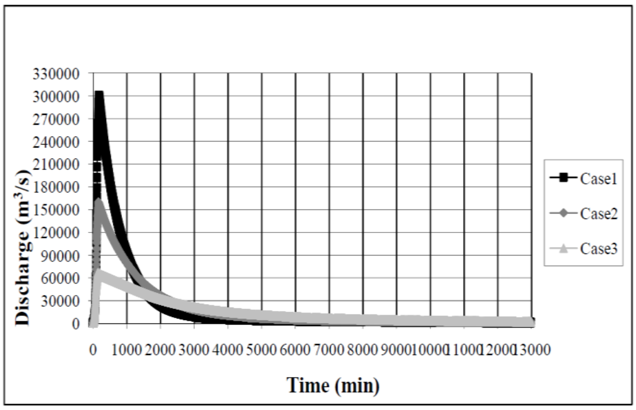

Fig. 2: Failure Outflow hydrographs

C) 1D-Hydrodynamic Modeling with MIKE 11

Using the failure outflow hydrographs, one dimensional hydrodynamic modeling for Jhelum river valley downstream of Mangla dam has been carried out with MIKE 11 for unsteady flow conditions. Different hydraulic structures as shown in Fig. 1 have also been considered for the modeling of the investigated 329 km. The results of maximum discharge after dam break flood routing are shown in Fig. 3. [3], [4]

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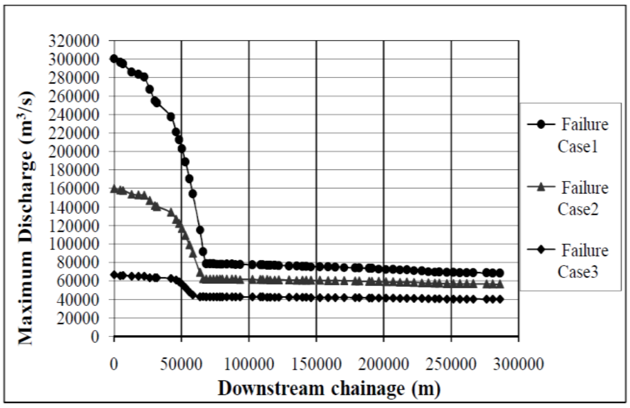

Fig. 3: Maximum discharges after dam break flood routing

In all scenarios the maximum discharge decreases along the reach due to retention of upstream hydrograph with respect to the shape of cross-sections. The random increase in the discharge in the upstream part of the reach is due to the contribution of the tributaries at different locations.

Computation of Flood Travel Times

Flood travel time (FTT) has been computed at downstream locations for different failure cases according to the results of flood routing as mentioned below.

FTT = computed arrival time of peak Q at a downstream location – time of peak failure outflow

The computed flood travel times after dam failure are shown for the upper part of the reach downstream of the Mangla Dam in Fig. 4. For the worst case of failure, flood travel times at downstream locations are the shortest. It is obvious from the results that the flood travel time at all downstream locations increases with the decrease in flood intensity and vice versa.

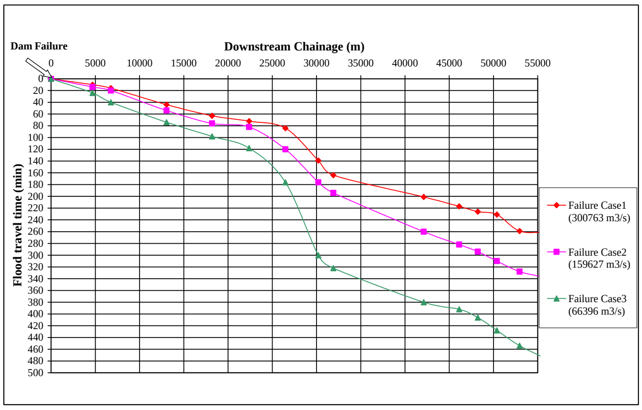

Fig. 4: Computed Flood travel times for different failure cases

Estimation of Warning Times

Warning time (WT) depends on the initiation of warning and the flood travel time. Warning times for downstream locations have been estimated according to the computed flood travel times for different categories of warning initiation as mentioned below. [8]

- 2hrs before Failure
- 1hr before Failure
- At Failure
- 15min after Failure
- 30min after Failure (Worst Case)

Fig. 5 illustrates the flood warning with respect to the warning initiation and arrival of flooding at a location based on flood travel time.

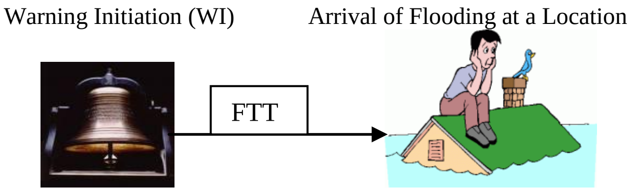

Fig. 5: Schematic Illustration of Flood Warning

For different cases of dam failure flooding, the warning times have been estimated with respect to various categories of warning initiation (Figs. 6, 7 & 8). It is very clear from the results that for all considered categories of warning initiation, the flood warning times for downstream locations decrease with the increase in the intensity and magnitude of flooding. So for the worst case of dam failure flooding (300,763 m^3/s) in Fig. 6, the warning times for downstream areas are shortest due to the fastest rate of flooding. Further the results also reveal that the estimated warning times for all downstream locations decrease with the delay in warning initiation (WI) with respect to the dam failure and vice versa.

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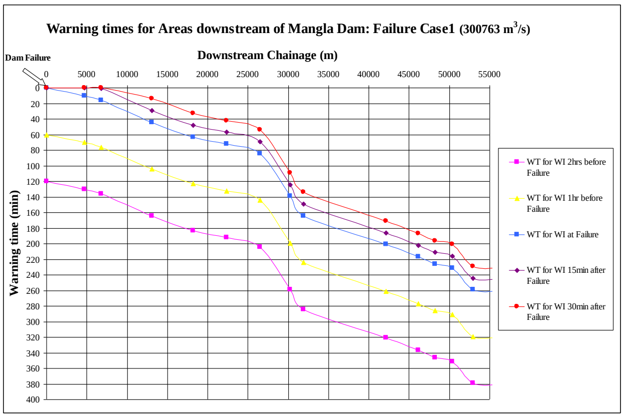

Fig. 6: Estimated Warning times for Failure Case1 (worst case)

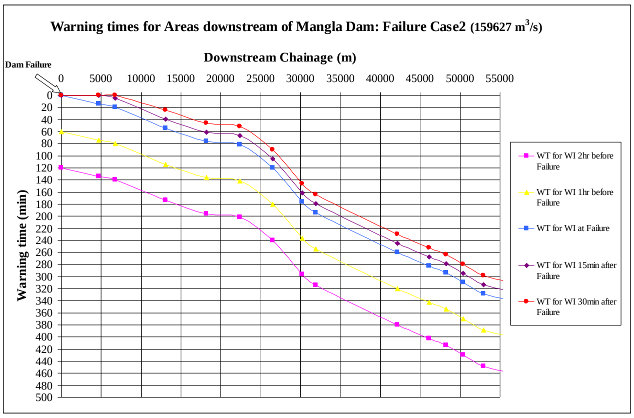

Fig. 7: Estimated Warning times for Failure Case2

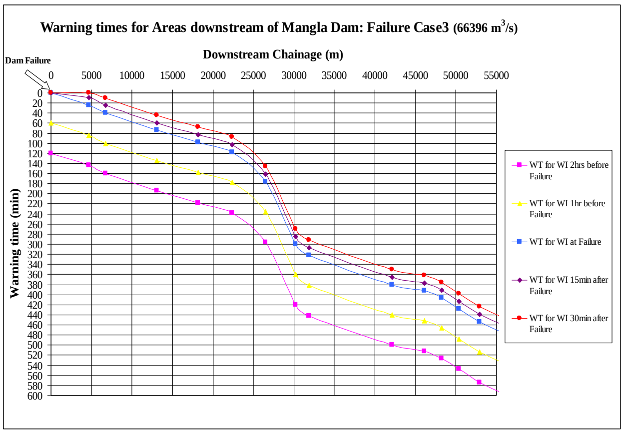

Fig. 8: Estimated Warning times for Failure Case3

In literature [8], different warning categories are also available to categorize the estimated flood warning times.

No Warning: no official warning, only possible sound or sight of flooding serves as a warning
Some Warning: official warning of 15-60 min before the arrival of flooding
Adequate Warning: official warning of more than 60 min before the arrival of flooding

Fig. 9 highlights the downstream distance covered in different warning categories for the worst case of dam failure flooding. For the worst case of WI (30 min after failure), the category "No Warning" covers the first 13 km downstream of the dam. Then, the category "Some Warning" (WT: 15-60 min) starts after 13 km and extends to about 27 km downstream. From 27 km onwards, the downstream reach comes into the category "Adequate Warning" (WT: >60 min).

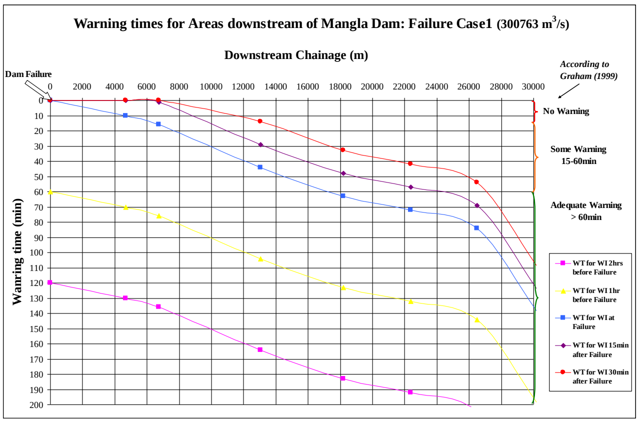

Fig. 9: Distance covered in different warning categories for the worst case

Conclusions and Recommendations

Due to extreme changes in weather with intense rainfall, catastrophic flooding can occur downstream of a dam as a result of dam failure. Flood travel time and warning initiation are necessary for the estimation of warning times. Flood travel time decreases with the increase in flooding force and vice versa. The delay in warning initiation with respect to dam failure reduces the warning time and poses severe risks to the people living downstream of a dam. A reliable estimation of flood warning time helps in enhancing warning efficiency, emergency evacuation planning and other flood mitigation measures. This innovative study provides useful guidelines for the reliable estimation of warning times for areas downstream of Mangla dam in case of catastrophic flooding. The approach adopted in this study should also be utilized for estimating flood warning times downstream of others dams in Pakistan as well as in others parts of the world to enhance the flood safety management downstream of dams.

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http://www.scijour.com/jre
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REFERENCES

[1] ***Dewey RL, Gillette DR.*** *Prediction of embankment dam breaching for hazard assessment, Proceedings, ASCE Specialty Conference on Geotechnical Practice in Dam Rehabilitation; Raleigh, North Carolina. 1993.*

[2] ***Ehsan S.*** *Evaluation of Life Safety Risks Related to Severe Flooding; Institute of Hydraulic Engineering, Universität Stuttgart, Germany: 2009, Vol. 180, ISBN: 978-3-933761-84-2.*

[3] ***Ehsan S, Wieprecht S.*** *Estimation of possible flooding risks for enhancement in flood resilience in river valleys, Journal of River Engineering, Scientific Journals Publisher (SCIJOUR), 2013, Vol. 1, Issue 1, ISSN: 2345-4199 (Online Edition).*

[4] ***Ehsan S, Marx W***. *Dam break modeling for large dams- A Case Study of Mangla Dam in Pakistan, Proceedings of International Conference on Water Resources Engineering & Management (ICWREM); Lahore. 7-8 March 2011. pp. 133-139. ISBN: 978-969546020-7.*

[5] ***Froehlich DC.*** *Embankment-Dam breach parameters, Hydraulic Engineering, Proceedings of the 1987 ASCE National Conference on Hydraulic Engineering; Williamsburg, Virginia, 1987. pp. 570-575.*

[6] ***Froehlich DC.*** *Peak outflow from breached embankment dam, Water Resources Engineering, Proceedings of the 1995 ASCE Conference on Water Resources Engineering; San Antonio, Texas, 1995a. pp. 887-891.*

[7] ***Froehlich DC.*** *Embankment Dam Breach Parameters Revisited, Journal of Water Resources Planning and Management; 121: 90-97. 1995b.*

[8] ***Graham WJ.*** *A procedure for estimating loss of life caused by dam failure (DSO-99-06); U.S. Department of the Interior, Bureau of Reclamation, Denver Colorado: 1999.*

[9] ***Johnson FA, Illes P.*** *A classification of dam failures, International Water Power and Dam Construction; 28: 43-45. 1976.*

[10] ***Reference Manual MIKE 11***. *A modeling system for rivers and channels; 2004.*

[11] ***Singh KP.*** *Snorrason A. Sensitivity of outflow peaks and flood stages to the selection of dam breach parameters and simulation models, SWS Contract Report 288, Illinois Department of Energy and Natural Resources, State Water Survey Division, Surface Water Section at the University of Illinois; 1982.*

[12] ***Singh KP.*** *Snorrason A. Sensitivity of outflow peaks and flood stages to the selection of dam breach parameters and simulation models, Journal of Hydrology; 68: 295-310. 1984.*

[13] ***Singh VP, Scarlatos PD.*** *Analysis of gradual earth-dam failure, Journal of Hydraulic Engineering; 114: 21-42. 1988.*

[14] ***Von Thun JL, Gillette DR.*** *Guidance on breach parameters, internal document; U.S. Bureau of Reclamation, Denver, Colorado: 1990.*

[15] ***Wahl TL.*** *Prediction of embankment dam breach parameters, A Literature review and needs assessment (DSO-98-004), Dam safety report; U.S. Department of the Interior, Bureau of Reclamation, Denver: 1998.*

[16] ***Wahl TL.*** *Uncertainty of predictions of embankment dam breach parameters, Journal of Hydraulic Engineering; 130: 389-397. 2004.*

[17] ***WAPDA*** *Mangla Dam Raising Project, Feasibility Study Report Volume I: Main Report; Pakistan: 2001.*

[18] ***WAPDA*** *Mangla Dam Raising Project, Tender design Report Volume I: Section 3, Embankment Dams; Pakistan: 2004.*

[19] ***WAPDA*** *Mangla Dam Raising Project; Pakistan: 2007. (http://www.wapda.gov.pk/htmls/ongoing-index.html)*

[20] ***Wurbs RA.*** *Dam-Breach Flood Wave Models, Journal of Hydraulic Engineering; 113: 29-46. 1987.*