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Effect of Water Surface Elevation Study in Dam Break Modeling

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Abstract: This paper concerns the modeling of the dam break and highlights the consequences to the downstream river reaches, from the hydraulics point of view of quantitatively assessing the flow rate and the wave profile resulted along the downstream river reaches temporally and spatially, and presents an analysis of changing initial water surface elevation in dam (WSELD). The model computes the reservoir outflow hydrograph resulting from changing the initial water surface elevation, which includes effects of submergence from downstream tail water depths and corrections for approach velocities. Also, the effects of storage depletion and upstream inflows on the computed outflow hydrograph are accounted for through storage routing within the reservoir show the effect of the output discharge due to change of initial water surface elevation.
A case study is offered to illustrate the application of several changes in water surface level methods on Teton dam failure. Dam break modeling implemented the hydraulic routing (dynamic hydraulic routing in this case) through two approaches. The first approach is by developing a flood routing methodology and implemented in the FORTRAN code "MDMBRK?", compiling and running the code to produce the required results, the second involves the application of well- established and documented software "FLDWAV" developed and used by the US Army Corps of Engineers in the United State and all over the world. Both approaches have been calibrated and applied to a well-documented case study of Teton Dam failure, Idaho-USA. As conclusion the first approach requires less computational time, more flexible and simpler to be used for simulating the model. The results, for both approaches, have shown a very good agreement between the measured and simulated hydrographs. Sensitivity analysis has been demonstrated further by varying the changing of initial water surface elevation in a Dam (WSELD). The problem solving approach developed in this research is very important for dam's owners, operating authorities and emergencies and disaster management authorities.

Keywords Additives; Dam Failure; Modeling; Flood Flow Routing; Natural Disaster

1. Introduction

Dams provide society with essential benefits such as water supply, flood control, recreation, hydropower, and irrigation. However, catastrophic flooding occurs when a dam fails and the impounded water escapes through the breach into the downstream valley. Usually, the magnitude of the flow greatly exceeds all previous floods and the response time available for warning is much shorter than for precipitation-runoff floods. According to reports by the international Commission on Large Dams (ICOLD, 1973) and the United States Committee on Large Dams in cooperation with the American Society of Civil Engineers (ASCE/USCOLD, 1975), about 38% of all dam failures are caused by overtopping of the dam due to inadequate spillway capacity and by spillways being washed out during large inflows to the reservoir from heavy precipitation runoff. However, catastrophic flooding occurs when a dam fails and the impounded water escapes through the breach into the downstream valley [1].

Dam break modeling is essential to highlight the impact and consequences of any failure, which can be due to different reasons such as piping, overtopping, espionage and earthquake or any other reason [2].

Dam break flood routing models (e.g., DAMBRK, FLDWAYV) simulate the outflow from a reservoir and through the downstream valley resulting from developing initial water elevation parameter (WSELD) in a dam. These models focus their computational effort on the routing of the outflow hydrograph due to changes in initial water surface level (WSELD) [3]. FLDWAV model has been used in this

**Corresponding author: aqaiss@iukl.edu.my* research to create special modeling features including different hydrographs. This choice (dynamic wave method) is based on its ability to provide more accuracy in simulating the unsteady flow wave than that provided by the hydraulic methods as well as other less complex hydraulic methods such as the kinematic-wave and the diffusion-wave methods [4].

In this research a FORTRAN modified code and re-named as “MDMBRK” has been developed and used in this research as well as the FLDWAYV model. Both were used for the purpose of routing the flood wave of Teton dam’s failure which is the case study of this work [5].

Both models are based on an implicit finite difference solution of the complete one dimensional St. Venant equations of unsteady flow [6, 7].

Dam break problem has been considered of sufficient importance to commence a program for the development of a flood forecast procedure especially designed to cope with the unique characteristics of dam-break floods.

In general, the forecasting of a dam-break flood consists of three parts; namely:

1. Estimation of the mode of failure, i.e., the temporal and geometrical description of the initial water elevation parameter (WSELD) (opening in the dam through which the impounded water escapes into the downstream valley)

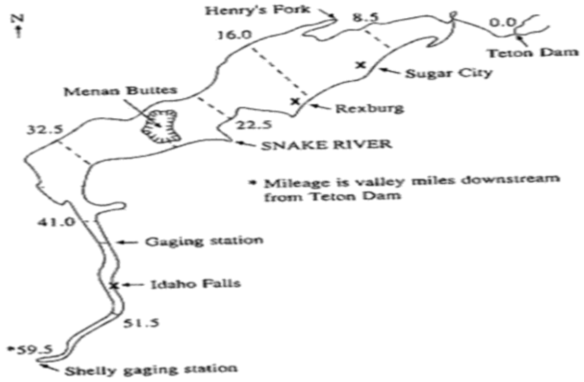
2. Computation of the outflow discharge hydrograph produced by the breach, including effects such as reservoir inflow and spillway and / or turbine outflows

3. Routing of the outflow hydrograph through the downstream valley in order to determine the hydrograph modifications, the resulting water surface elevations (stages), and the flood wave travel times.

RESULTS AND DISCUSSION

In the case study on Teton Dam failure, FLDWAYV model developed by the National Weather Service (NWS) and a modified FORTRAN computer program named as “MDMBRK” have been used to solve the dam break failure problems separately as shown in Figure 1.

All tables should be numbered with Arabic numerals. Every table should have a caption. Headings should be placed above tables, left justified. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which the authors may find useful.

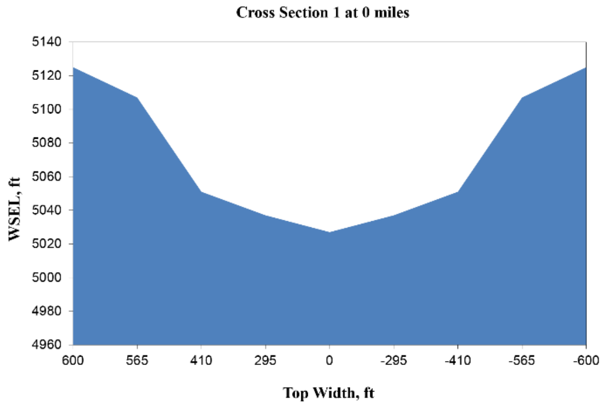


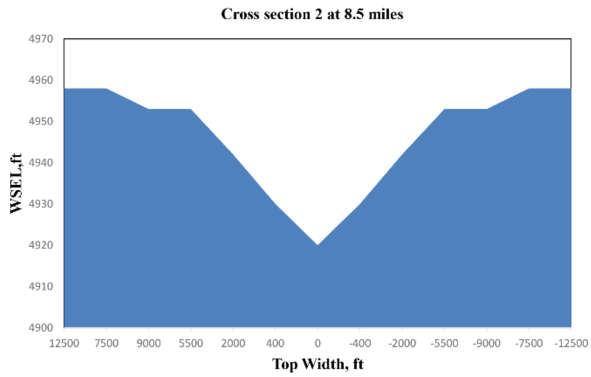
FLDWAV Model Hydrographs

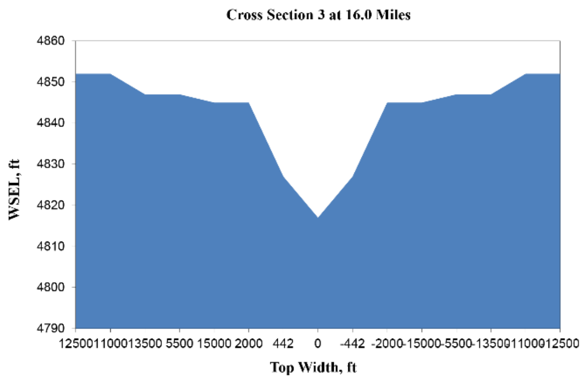
The following WSELD parameters were used in FLDWAYV to reconstitute the downstream flooding due to the failure of Teton Dam:

Due to changes in WSELD (initial water surface level in Dam) WSELD = 5200 cfs (147.25 m*/sec), 3200 cfs (90.62 m/sec), 2200 cfs (62.3 m*/sec)with side slop of breach, z = 1.04, bottom of the breach finally reaches, hy, = 0.0, the height of the dam, hy =261.5 ft. Time of failure, = 1.43 hrs, they were obtained from the WSELD model [2].

Cross-sectional properties were used at 8 locations along the 60- miles reach of the Teton - Snake River Valley below the dam as shown in Figure 1. The downstream valley consisted of a narrow canyon, approximately 1000 ft wide for the first 5 miles and thereafter a wide valley. The eight (8) locations are arbitrarily located at 0, 8.5, 16, 22.5, 32.5, 41.5, 51.5, 59.5 miles from the dam.Figure 2 shows the eight locations mentioned above [3].







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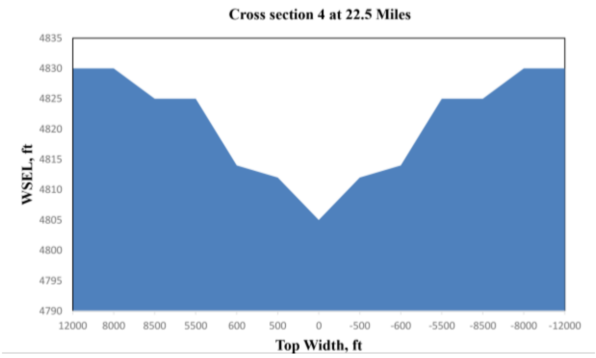

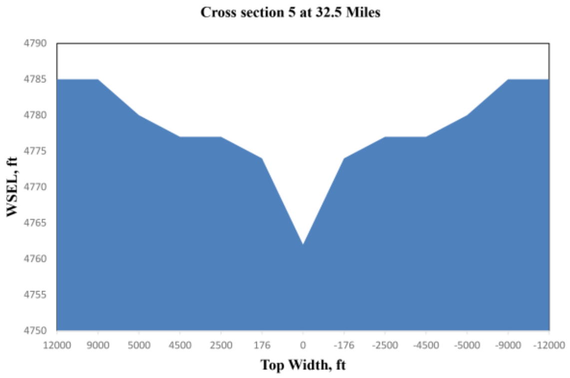

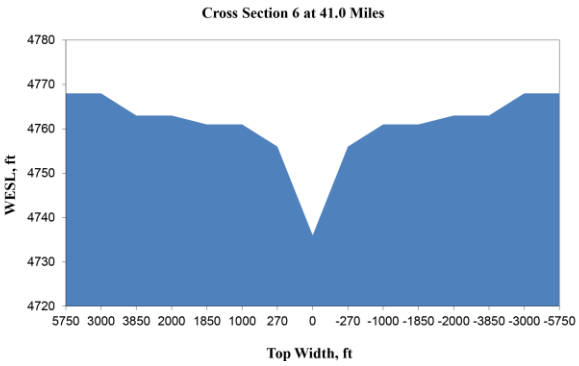

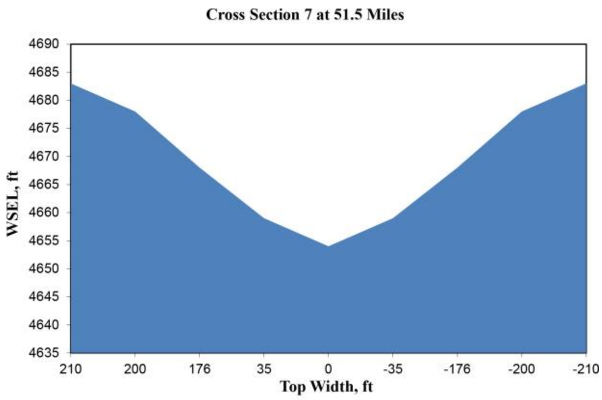

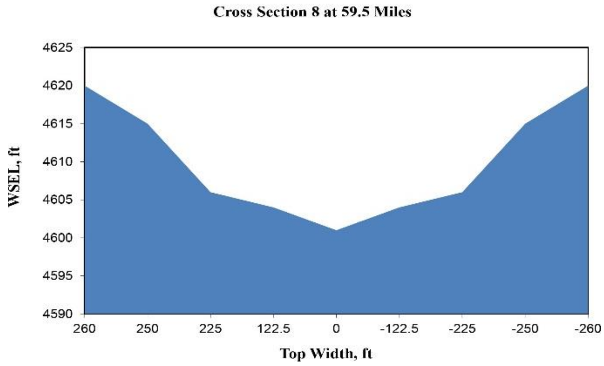

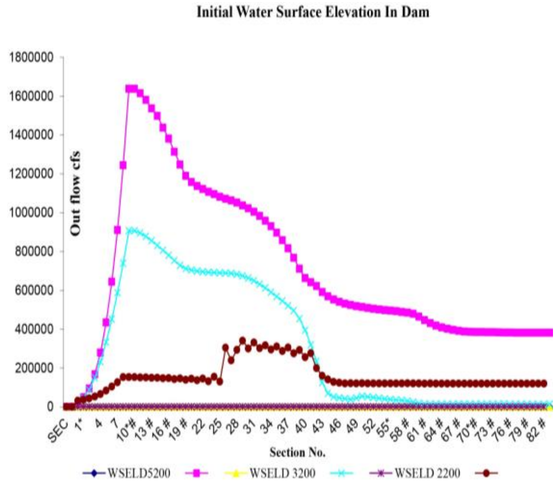

Figure 3 show the result of inflow hydrographs due to changing of WSELD values,

The peaks are5200.00 (147.25 m’/sec), 3200 (90.62 m’/sec), 2200 cfs(62.3 m'/sec) with values 1638321.0 cfs (46392.1 m'/sec), 907117.0 cfs (25686.7 m/sec), 304636 cfs(8626.3 m’/sec), which are in good agreement with that obtained by Fread[4], and with the observed values, where the differences in the peak discharges by 33%, 16.8% more and 27.9 % less respectively [4].

The sensitivity of downstream peak discharge to reasonable variation in WSELD value is shown in Figure 3. It shows large differences in the discharges (21% to 33%) near the dam (at 8.5 miles), these rapidly diminish in the downstream direction.

The Maximum Computed peak discharge values along the 60-miles (96.56 km) downstream valley are shown in Figure 4 with computed values measured at 8.5miles (13.7 km), 16miles(25.75 km),

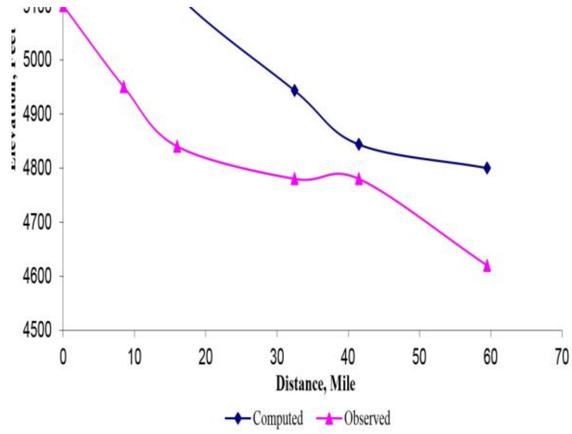

Figure. 4: Profile of peak discharge of Teton Dam

Smiles (36.21 km), 32.5miles (52.3 km), 41.5miles (66.78 km), 51.5miles (82.88 km), and 5 miles (95.75 km). The peak discharge of 1,638321 cfs(46392.1m*/sec) at 8.5 miles (13.7) from the dam is well compared with that reported in the literature of ~1090910 cfs (30891.1 sec)[4] with 33% more than the observed measured mean that 33% increased the failure sibility, in 27.9%, which is less than the peak discharges mean that decrease the failure sibility by 27.9%

Computer Program (MDMBRK) Hydrographs

On-Dam data obtained by the National Weather Service (NWS) was used to the FORTRAN gram. A computed outflow hydrograph along with an inflow hydrograph areshown in Figure Routing hydrograph below.

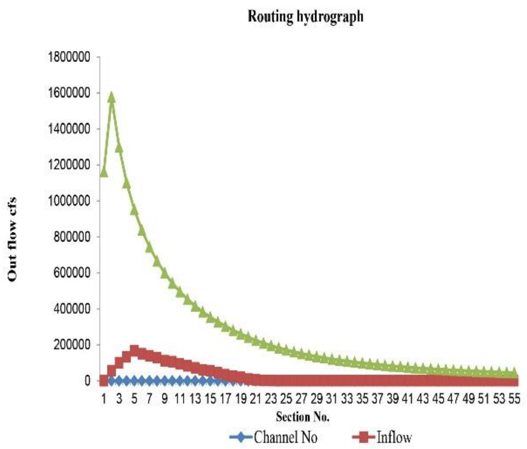

Figure 5: Routing hydrograph of Teton Dam, using MDMBRK program

The computed hydrograph has a peak value of 1,588592.5 cfs (44983.9 m'/sec), a time to peak of 2.0 hours and a total duration of significant outflow of about 30-40 hours. The extreme attenuation and rapid damping is obvious in the peak discharge which is well compared with that of the FLDWAYV model hydrograph.

However inflow hydrograph has a peak value of 1588592.5 cfs (44983.9 m'/sec), at time to peak of 2 hours, and a total duration of significant inflow of about 30-40 hours.

To study the effect of changing the WSELD parameters on the computed outflow peak discharge, efforts have been done to measure and analysis the safety elevation suitable for any specific dam

All hydrographs for new parameters of the WSELD are plotted vs. time showed some effects on the peak discharge as compared with the peak discharge of observed outflow hydrographs of standard parameters; see Figure 6.

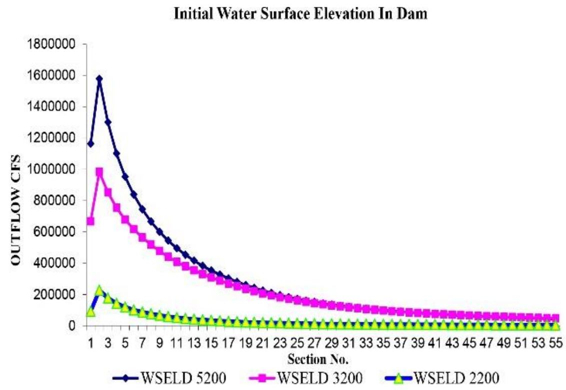

Figure 6: Sensitivity of outflow peak discharge of various WSELD

However, changing WSELD, significantly affecting the flood peak discharge in which the peak is 1588592.5 cfs (44983.9 m'/sec) (WSELD 5200, 147.25 m'/sec) with 0.45% more different from the observed discharge. The peak is 983230.88 cfs (27816.5 m/sec) (WSELD 3200, 90.614 m'/sec) for with 9.8% less different from the observed discharge. And On the other hand the peak is 226827.84 cfs (6423.05 m'/sec) (WSELD 2200, 62.3m'/sec) with 79.2% less different from the observed discharge. To compare between FLDWAYV and MDMBRK programs, Table 1 shows, the peak discharge at different WSELD values. With this result can easily measure the suitable or the Maximum water elevation storage in the dam.

Table 1, shows the peak discharge at different values, for FLDWAV and MDMBRK programs.

WSELD Variable in m^3/sec	Peak Discharge m^3/sec In FLDWAV Model	Peak Discharge in m^3/sec MDMBRK Model	Error percentage % than the observed values
147.25 (5200.0cfs)	46392.1	44983.9	3.03%
90.61 (3200.0 cfs)	25686.7	27816.5	7.74%
62.3 (2200 cfs)	8626.3	6423.05	25.5%

TABLE 1: PEAK DISCHARGE

CONCLUSION

This paper is concerned with the analysis of an embankment dam rupture (failure). Such a failure, based on recorded case histories, has caused a horrific catastrophes leading to loss of lives and resources. Modeling of dam break is important in increasing or reducing any potential losses.

And guide the planning for an emergency action plan that involves evacuation. The research has based on the application of the dynamic hydraulic routing methodologies only. Several concluding points can be drawn from this research summarized as below:

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1. The research presented a numerical investigation of the important problem of “Dam Breaking”

2. The research has adopted a parametric comparative study through the use of a standard software “FLDWAV” and modified, compile and run a FORTRAN program named as “MDMBRK?”

3. A comprehensive modeling of a well-documented dam failure case of Teton Dam in Idaho-USA has shown agreed results of this research with other observed and simulated results for the same case.

4. A hydrograph of discharge vs. distance form Teton Dam failure showing the sensitivity of downstream peak discharge to reasonable variations in WSELD obtained from the FLDWAY software showed large differences in the discharge near the Dam, (16.8% to 33%) this rapidly diminish in the downstream direction at shelly, the difference diminished to <2%, Which is diminishes the risk assessments evaluation.

5. A hydrograph of discharge vs. time form Teton Dam failure showing the sensitivity of downstream peak discharge to reasonable variations in WSELD (Dam failure) obtainedfrom the MDMBRK computer program in which the peak is 1588592.5 cfs (44983.9 m/sec) (for WSELD = 5200 cfs, 147.25 m’/sec) with 3.03% error. On the other hand the peak is 983230.88 cfs (27816.5 m’/sec) with 9.8% error.

6. One of the highlight conclusion is to measure and analysis the safety water elevation suitable for any specific Dam

7. The program MDMBRK coded specifically for this study can be used for a real case study and confidently can produce a reliable results.

8. The “MDMBRK” model that employed in this study requires less computational time, more flexible and simpler to be used for simulating the problem as compared to FLDWAYV model.

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