DAM-BREAK FLOOD ANALYSIS IN MID-DOWN STREAM OF HAN RIVER

DAI Minglong* **Supervisor: A.W. JAYAWARDENA****
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ABSTRACT

Dam-break flood with high velocity, huge energy, and much higher peak discharge is extremely abnormal and dangerous for the human kind. There have been around 200 notable dam and reservoir failures worldwide in the twentieth century, and caused catastrophic devastation in the valleys downstream both in terms of lives lost and widespread damage to infrastructure and property.
An analysis on dam-break flood in the Mid-down Stream of Han River, China, was performed. Among those big dams in Han River Basin, Danjiangkou Dam and Yahekou Dam may cause disastrous effect if one or both of them break. After assuming failure parameters of these two dams, peak discharges and hydrographs at dam sites are calculated by empirical methods. Then with the help of HEC-RAS hydraulic model and ARC-GIS, main work is focused on how dam-break flood propagates along the river, what is the relationship between peak discharge and distance, and what are the effects in the downstream when one or both dams break.

Keywords: Dam-break Flood, Mid-down Stream of Han River, HEC-RAS, Propagation

INTRODUCTION

The flood-resist system in mid-down stream of Han River is mainly composed of Danjiangkou Reservoir, embankments, Dujiatai Retarding Area, Dongjing River, and other small retarding areas. At present, when water level in Yangtze River is low, if flood-resist facilities in the basin are regulated properly, flood type of "1935" (100 year return period) can be resisted. After the heightening of Danjiangkou Reservoir is finished in 2009, by utilizing the integrated flood-resist system properly, 200 year return period flood can be managed safely.
It does not seem so meaningful to research on normal and natural flood hazard for the mid-down stream of Han River, so risk from an extremely abnormal and huge flood, dam-break flood, with special characteristics of high un-predictability and devastating destructivity, is mainly researched. The main objectives are to research how the dam-break flood wave propagates along the river, and what is the relationship between peak discharge and distance.
After comparing characteristics of different hydraulic softwares and their availability, since the 1-D model of HEC-RAS is free and the author has some experience in it during studying in ICHARM, it is chosen for simulation.

DAM-SITE FLOOD

There are many reservoirs in the Han River basin, but most of them are small scale or middle scale ones, only the two big dams of Danjiangkou dam with a normal storage of 29.05 billion m^3, and

* Hydrology Bureau, Yangtze Water Resource Commission, China.
** Research & Training Advisor, International Centre for Water Hazard and Risk Management (ICHARM),PWRI, Japan

Yahekou dam with a normal storage of 894 million m^3 will cause serious effect to downstream if any or both of them fail.

After analyzing the possibility of dam break, the situation of Danjiangkou reservoir and Yahekou reservoir failure by an extremely strong earthquake when their water levels are normal is considered. An illustration of breaking reservoirs, river net and important cities in the study area is shown in Fig.1.

Peak discharges at dam sites are calculated by some empirical formula.

According to the layout plan of Danjiangkou Dam, the most probable failure situation is main dam body partly collapses transversely and instantaneously. After analyzing the longitudinal sectional profile, the remaining body height is assumed as 30m holding a remaining storage of 7.672 billion m^3, and water volume escaping from the reservoir is 21.378 billion m^3. The remaining concrete dam body acts as a broad crest weir, so the peak discharge of the dam site is calculated by the weir formula

$$Q_m = 1.30 \cdot B \cdot H^{3/2} \qquad (1)$$

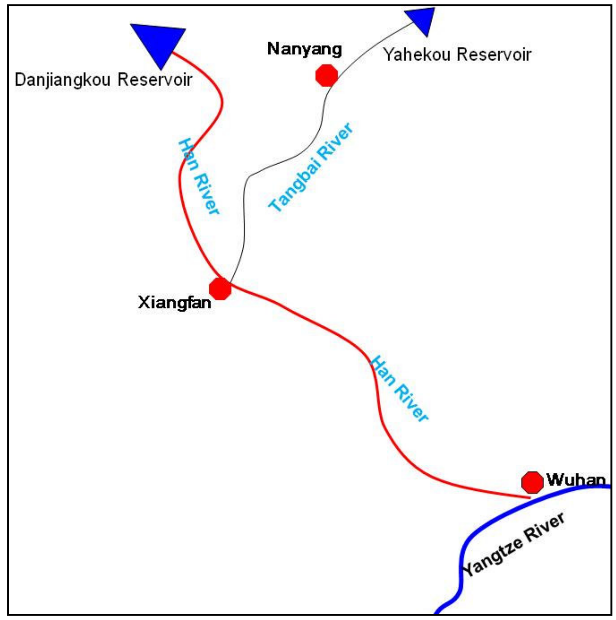

Fig.1 Illustration of Study Area

Where H is water head above the weir, Q_m is peak discharge at the dam site, B is width of breach, and the calculated peak discharge at Danjiangkou Dam site is 127,000m^3/s.

For Yahekou Dam, the most dangerous situation is the whole main dam body breaches instantaneously. The calculation of peak discharge is calculated by the formula

$$Q_m = \lambda B \sqrt{g} H_0^{1.5} \qquad (2)$$

Where g is acceleration of gravity, H_0 is initial depth, λ is discharge coefficient, and the calculated peak discharge at Yahekou Dam site is 95,600m^3/s.

Hydrology Bureau, Yangtze Water Resources Commission used a dimensionless curve to calculate hydrographs at dam sites. Their results were used as input condition for flow routing in downstream.

HYDRAULIC MODEL

The physical laws which govern the flow of water in a stream are: (1) the principle of conservation of mass (continuity), and (2) the principle of conservation of momentum. The most successful and accepted procedure for solving the one-dimensional unsteady flow equations is the four-point implicit scheme, also known as the box scheme, which is shown in Fig.2.

Under this scheme, space derivatives and function values are evaluated at an interior point, $(n+\theta)\Delta t$. Thus values at (n+1) Δt enter into all terms in the equations. For a reach of river, there is a system of simultaneous equations. The simultaneous solution is an important aspect of this scheme because it allows information from the entire reach to influence the solution at any one point. Consequently, the time step can be significantly larger than with explicit numerical schemes.

Continuity Equation

The continuity equation describes conservation of mass for the one-dimensional system, and it can be written as:

$$\Delta Q + \frac{\Delta A_f}{\Delta t}\Delta x_f + \frac{\Delta A_c}{\Delta t}\Delta x_c + \frac{\Delta S}{\Delta t}\Delta x_f = \overline{Q}_l \quad (3)$$

Where Q is flow, A is cross-sectional area, S is storage from non conveying portions of cross section, and the subscripts c and f refer to the channel and floodplain respectively, $\overline{Q}_l$ is the average lateral inflow.

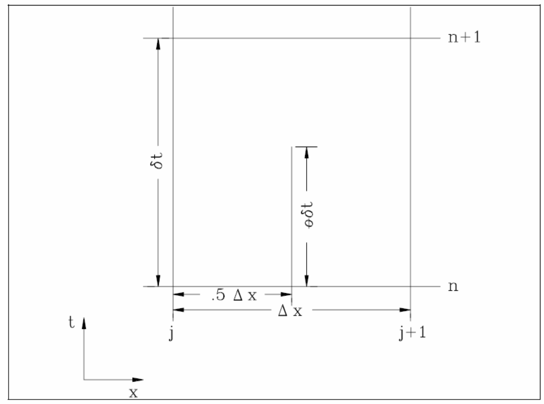

Fig.2 Typical finite difference cell

Momentum Equation

The momentum equation states that the rate of change in momentum is equal to the external forces acting on the system, and it can be written as:

$$\frac{\Delta(Q_c\Delta x_c + Q_f\Delta x_f)}{\Delta t\Delta x_e} + \frac{\Delta(\beta VQ)}{\Delta x_e} + g\overline{A}(\frac{\Delta z}{\Delta x_e}\overline{S}_f) = 0 \quad (4)$$

Where: x is distance along the channel, and the subscripts c and f refer to the channel and floodplain respectively, Δx_e is equivalent flow path.

HYDRAULIC SIMULATION

Geometric data in DEM type is downloaded from HydroSHEDS, with a cell grid of 90×90m. Though this data is still not precise enough, it's the only geometric data available by now.

As shown in Fig.3, between every reach, at the upstream, initial hydrograph is put into the HEC-RAS hydraulic model as input condition, the hydraulic equations of continuity and momentum are solved by HEC-RAS model, and the downstream hydrograph is obtained.

For simplicity and more precise results, the whole study area is divided into two parts, one is Tangbai River, the tributary, and the other is Han River, the main stream. The two rivers join at the point of Xiangfan city.

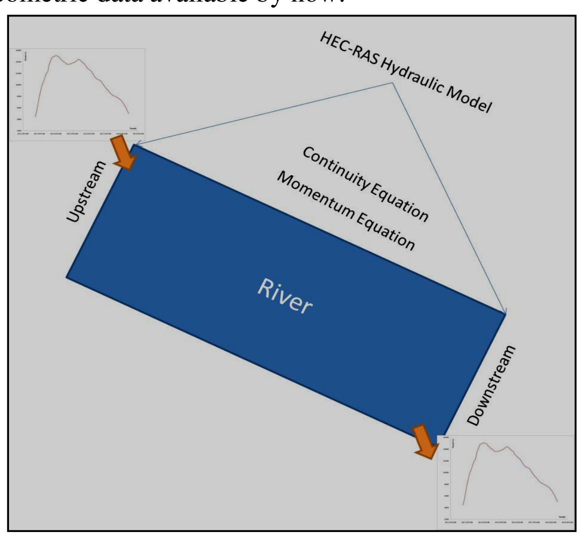

Fig.3 Illustration of Simulation Method

Simulation process for the whole study area is:

- Suppose only Danjiangkou Dam breaks, simulate dam-break flood from its dam site along the Han River main stream to the river confluence;
- Suppose only Yahekou Dam breaks, simulate dam-break flood from its dam site along

Tangbai River to its river confluence at Xiangfan city, then judge whether there is a need for flow routing further along main stream of Han River or not;

- Suppose both Danjiangkou Dam and Yahekou Dam break, flow routing their dam-break flood individually to the confluence point of Xiangfan, and merge hydrographs of Danjiangkou and Yahekou at Xiangfan together, then judge whether to simulate downward to Han River confluence or not.

For get a stable result, the main stream of Han River and the tributary of Tangbai River are both divided into seven reaches. At the first reach, hydrograph at Dam site is put into the model as upstream boundary condition, calculation is conducted by HEC-RAS model, and hydrograph of down stream is obtained. For next reach, the hydrograph of the previous down stream is treated as new upstream boundary condition, and the hydrograph of the new down stream is obtained. Repeating this process, hydrographs of other downstream reaches can be obtained.

CONCLUSIONS

Hydrographs of the seven downstream reaches along the Han River main stream are shown in Fig.4, and hydrographs of down streams along Tangbai River are shown in Fig.5.

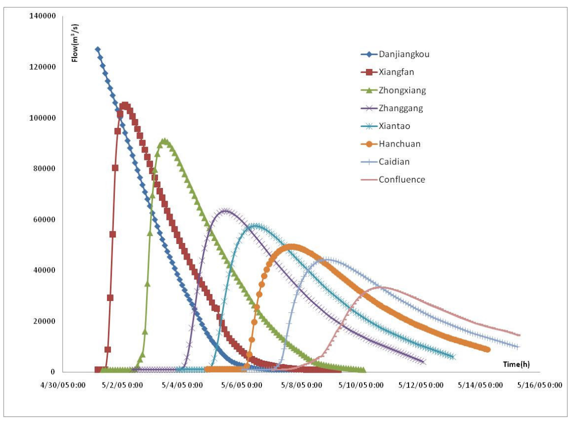

Fig.4 Hydrographs of different points along Han River

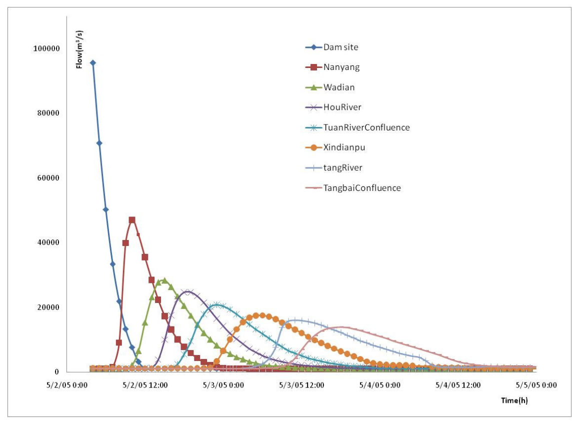

Fig.5 Hydrographs of different points along Tangbai River

The main conclusions of this study are following

- If only Yahekou Dam breaks with normal water level, the effect of Yahekou failure only exists in Tangbai River. It will not affect greatly to main stream of Han River. Peak discharge at Nanyang is 47,000m^3/s, with a return period of 10,000 years. The whole city is terribly inundated, and inundation depth is about 3-4 meters, but in lower parts, the depth will be about 5 meters. But when the dam-break flood wave reaches Tangbai River confluence, peak discharge is 13,900m^3/s, and the return period is only about 2 years.
- If only Danjiangkou Dam breaks with normal water level, the affected area is almost the whole Mid-down Stream of Han River, and it will not cause serious effect to Yangtze River. Peak discharge at Xiangfan is 105,000m^3/s, return period is 10,000 years. Almost whole Xiangfan City is inundated with the water depth of about 3 meters. And in some lower area, the water depth will be 6 meters. Peak discharge at Zhongxiang is 91,000m^3/s, return period is more than 20,000 years. Almost whole Zhongxiang City is inundated with the water depth of about 4 meters. And in some lower area, the water depth will be 6 meters. At last when dam-break flood wave reaches Yangtze River main stream, the peak discharge at Han River confluence is 33,300m^3/s, it will not cause huge disaster for downstream of Yangtze River.

- If both Yahekou and Danjiangkou break at the same time, the total effect to the downstream is somewhat same as that from Danjiangkou only. The two flood waves do not reach Xiangfan at the same time. When flood wave from Danjiangkou Dam propagates to Xiangfan City, the wave from Yahekou Dam has not reached. The aggregated peak discharge is 106,000m^3/s. When the peak discharge in Tangbai River reaches Xiangfan, peak discharge in Han River has already passed, the aggregated discharge is 101,000m^3/s. Even if the two individual peak discharges are added directly, the merged peak discharge is119, 000m^3/s, only is about 10% more than Danjiangkou's.

It will cause huge hardships for rescue efforts and evacuation after strong earthquake. How to evacuate the large population on time under such abnormal condition is a hard challenge for disaster management center.

DISCUSSIONS

- This research is based on dam-break flood from one or both of Danjiangkou Dam and Yahekou Dam failing with normal water level because of strong earthquake. But if these dams fail with higher water level when heavy rain and strong earthquake occur at the same time, the effect in the downstream is more serious than the above conclusions.
- Geometric data used in this research is downloaded from HydroSHEDS, the accuracy is not very high. It is certain it caused deficiency in the results. A more precise result can be obtained with a more accurate DEM data.
- In HEC-RAS, better results can be obtained by more cross sections along the river. But because of some unknown reasons, if the number of cross sections is more than a certain number in ARC-GIS, it exports only blank data without any information. It is certain that the less cross section also affected the result.
- Because of inconvenience of collecting data, and some parameters are assumed in this research, so it may contribute deficiency to the result.

SUGGESTIONS

- In most cases, dam failure could have been prevented if the structure had been properly maintained. So safety management of these two reservoirs is of great importance. New regulations should be made based on existing ones and safety education should be strengthened, any break from man wrong doings should be avoided.
- Because the results are got from 1-D hydraulic model and the geometric data is not precise enough, the results is certain to be relatively rough. To get a more accurate result, further researches applying 2-D or 3-D models with a more precise geometric data should be implemented if possible in the future.
- Warning systems should be strengthened in the study area. In case of dam breaks, timely dissemination of evacuation order on time is of great importance for disaster mitigation. Especially in the situation of breaking from strong earthquake, information should be successfully disseminated even if normal communication system be destroyed.
- Emergency plan should be made. Other researches should be made on how to rescue affected people, and how to evacuate a big population on time before dam-break flood reaches.

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