FLOOD RISK ANALYSIS AND RISK MANAGEMENT in MENGWA DETENTION BASIN

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ABSTRACT

Detention basin, as one essential part of flood management measures, is usually designed to store flood temporarily in an extreme flood event for relieving the danger of embankments collapse and ensuring the safety of downstream areas. Mengwa detention basin is the study area of this thesis.
First of all, the study is setting out to make an analysis of flood risk over a typical detention basin to define under which condition Mengwa will be used and calculate how much water is to be diverted into Mengwa for different return period flood.
Secondly, four Flood Hazard Maps for 10year, 20year, 50year, 100 return year period floods are made by HEC-RAS and Arc-GIS, based on the diversion water of different return period flood calculated from the above procedure. Maps will show different inundation areas and inundation depths in the detention basin under a given scenario.
Finally, some proper suggestions like raising residents' risk awareness, making reasonable land use plan, launching flood insurance, will be provided to help reduce the damage from flood in Mengwa detention basin.

Keywords: Risk analysis, Risk management, Mengwa detention basin

INTRODUCTION

Mengwa, the first detention basin built in 1952 in Huai River Basin, lies on the north bank of middle Huai River. There are 157,800 people living inside this area with a total area of 180.4km^2. Since Mengwa being built, it has been operated 15 times in 12 years, making Mengwa Detention Basin the most frequently used detention basin among all the 97 detention area in China. To mitigate flood damage in the detention basin is the core and objective of this dissertation.

DATA

In this study, 1952-2007 records of annual highest water level and annual peak discharge of the Huai River at Gauge Station is collected for hydrological analysis and calculation. Digital Elevation Model data (DEM) data that is necessary for making Flood Hazard Map is downloaded from the U.S. Geological Survey website, http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html.

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THEORY AND METHODOLOGY

1. Hydrological Analysis and Calculation

By hydrological analysis and calculation, the following two items will be defined:

- the possibility of the operation of detention basin;
- water volume to be diverted into the basin for different return period flood.

1.1 Frequency Analysis

Frequency curve is plotted based on annual peak discharge data at Gauge Station by using K.Pearson III Distribution to find the possibility of operation of Mengwa.

1.2 Hydrograph of Sluice Gate

Water volume to be diverted into the detention basin for each return period flood is obtained from the hydrograph of sluice gate.

(1) Obtain Design Hydrograph

Design hydrographs for each return period flood is obtained by enlarging typical hydrograph in the same scale which is equal to the ratio of peak discharges of typical hydrograph and design hydrograph.

$$K_p = \frac{Q_{mp}}{Q_{mt}} \quad \ldots\ldots \quad (1)$$

where K_p is enlarging coefficient, Q_{mp} is peak discharge of certain magnitude flood, Q_{mt} is peak discharge of typical hydrograph, which is equal to 7170m^3/s.

By comparison and analysis, the hydrograph in July 11th-15th, 2005 is chosen as the typical hydrograph. The hydrograph is representative since this scenario presents a situation where water diversion was not initiated even though flood heights reached 29m, thus showing a similar case as those where water diversion work should be done. And all of the discharge data comes from actually measurements of velocity and cross section area.

(2) Calculate the hydrograph of Sluice Gate

Stage-Discharge Curve of Gauge Station

$$Q_1=\mathrm{Exp}\frac{(H-11.483)}{2.0147} \quad \ldots\ldots \quad (2)$$

where Q_1 is the discharge in the mainstream, H is the water level in the mainstream.

Stage-Discharge Curve of Sluice Gate

$$Q_2 = 0.32\times104\times19.6^{0.5}\times(H-24.46)^{1.5} \quad \ldots\ldots \quad (3)$$

where H is water level at Gauge Station. Q_2 is discharge of Sluice Gate. The maximum designed discharge of gate is 1799m3/s, and the corresponding water level H is 29.76m, i.e. even though water level H is rising after reaching 29.76m, discharge Q_2 still remains 1799m^3/s.

Considering the very close distance between Sluice Gate and Gauge Station, it is assumed that the water level at Gauge Station is the same as that at Sluice Gate during water diversion. When the detention basin is operated, discharge in the mainstream will be divided into two parts, discharge Q_1 in the mainstream and discharge Q_2 in the detention basin. Design discharge Q is obtained from the design hydrograph, so water level in the mainstream with time can be obtained by solving the equation Q=(2)+(3). Repeating the same procedure, we can get different water levels at different time until water level goes below 29m at the time when the Sluice Gate will be closed. If the water level is known, it's easy to obtain the hydrograph of Sluice Gate using the equation (3).

2. Make Flood Hazard Map

ArcGIS9.1 and HEC-RAS3.1.3 are chosen for caculating and viewing the inundation depth and area in Mengwa.

RESULTS AND DISCUSSIONS

Frequency curve

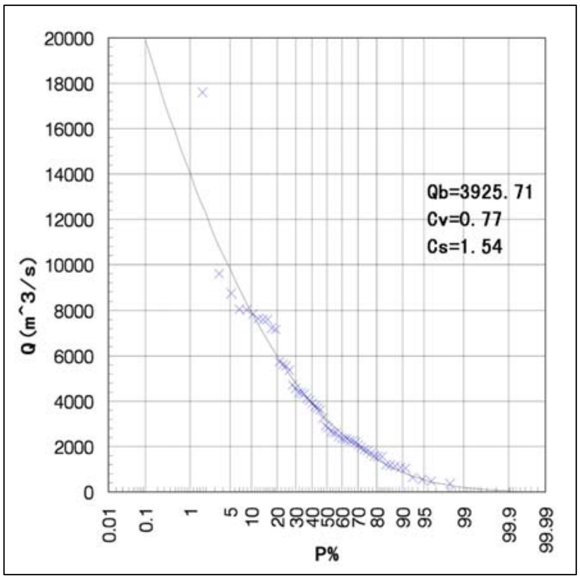


Fig. 1 Frequency curve

The line in Fig.1 is the frequency curve.

According to the utilization scheme of Mengwa, the water level of 29m in the mainstream is a crucial point to decide whether or not to use Mengwa. From Equation (1), we know the discharge is about 5970m^3/s when water level reaches 29m. From Fig.1, we know the probability is 20.20% when the discharge is 5970 m^3/s. That means Mengwa will leave open the possibility that it will be used when more than 5-year return period flood comes. Table 1 is obtained from Fig.1, showing the relationship of flood probability, return period, peak discharge and highest water level.

Table 1 The relationship of Probability, return period, discharge and water level

Probability	1%	2%	5%	10%	20%
Return Period	100year	50year	20year	10year	5year
Peak discharge(m^3/s)	14063	12262	9837	7951	5995
Highest water level(m)	31	30	30	30	29

Enlarging coefficient K_p and water volume to be diverted

Table 2 The relationship of return period, K_P and water volume

Return Period	10year	20year	50year	100year
Enlarging coeffecient K_p	1.1089	1.3719	1.7102	1.9614
Water volume	0.211	0.372	0.557	0.638

to be diverted(billion m^3)				

Design hydrograph and hydrograph of Sluice Gate for different return period flood

In Table 3 Q is the design discharge, Q_2 is the discharge at the sluice gate under the condition of the operation of the detention basin. The time interval is 2 hours.

Table 3 Discharge at different time during the usage of Mengwa

10-year return period flood								
Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$
1	5600.19	0.00	9	7124.99	1387.76	17	7744.89	1472.14
2	5994.97	1218.70	10	7152.71	1391.49	18	7829.17	1483.57
3	6157.99	1244.71	11	7180.44	1395.23	19	7951.16	1499.35
4	6387.54	1279.99	12	7215.92	1400.38	20	7934.52	1497.44
5	6587.15	1309.63	13	7493.16	1438.47	21	7779.27	1476.90
6	6698.05	1326.15	14	7626.24	1456.46	22	7640.65	1458.35
7	6853.30	1147.01	15	7642.87	1458.83	23	7274.70	1408.81
8	6997.46	1369.59	16	7627.34	1456.46	24	7075.09	0.00
20-year return period flood								
Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$
1	5838.95	0.00	13	8814.68	1607.41	25	9624.12	1701.93
2	6105.11	1236.17	14	8848.97	1611.82	26	9452.63	1682.49
3	6393.21	1280.90	15	8883.27	1615.75	27	8999.89	1630.01
4	6667.60	1321.55	16	8927.17	1621.15	28	8752.94	1600.06
5	6928.27	1359.85	17	9270.16	1661.63	29	8493.64	1568.36
6	7416.68	1428.09	18	9434.79	1680.50	30	8364.68	1552.34
7	7618.35	1455.51	19	9455.37	1682.98	31	8234.35	1535.90
8	7902.34	1493.13	20	9436.16	1680.50	32	8112.25	1520.47
9	8149.29	1524.81	21	9581.59	1697.44	33	8014.84	1507.98
10	8286.48	1542.18	22	9685.85	1708.93	34	7916.06	1495.04
11	8478.55	1566.41	23	9836.77	1725.97	35	7381.00	1423.38
12	8656.90	1588.33	24	9816.19	1723.46	36	7298.69	0.00
50-year return period flood								
Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$
1	5746.37	0.00	18	11073.73	1799.00	35	10112.58	1755.67
2	6020.01	1222.72	19	11128.46	1799.00	36	9991.16	1742.56
3	6635.69	1316.96	20	11556.02	1799.00	37	9868.02	1728.98
4	7278.73	1408.81	21	11761.24	1799.00	38	9201.03	1653.21
5	7610.52	1454.08	22	11786.90	1799.00	39	9098.42	1641.35
6	7969.67	1501.27	23	11762.96	1799.00	40	9081.32	1639.38
7	8311.71	1545.56	24	11944.24	1799.00	41	8841.88	1610.84
8	8636.66	1585.89	25	12074.22	1799.00	42	8653.76	1587.84
9	9245.50	1658.66	26	12262.34	1799.00	43	8380.12	1553.79
10	9496.90	1686.97	27	12236.69	1799.00	44	8072.28	1515.18
11	9850.92	1726.97	28	11997.26	1799.00	45	7880.74	1490.26
12	10158.76	1760.72	29	11783.48	1799.00	46	7690.90	1465.00
13	10329.78	1778.94	30	11219.10	1799.00	47	7501.06	1439.41
14	10569.22	1799.00	31	10911.26	1799.00	48	7179.54	1395.70
15	10791.54	1799.00	32	10588.03	1799.00	49	6858.02	0.00

16	10988.22	1799.00	33	10427.27	1789.60			
17	11030.98	1799.00	34	10264.79	1772.35			
100-year return period flood								
Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$	Time	Q	$Q_{2(ti)}$
1	5589.99	0.00	20	12651.03	1799.00	39	11458.50	1799.00
2	6001.88	1220.04	21	12700.07	1799.00	40	11317.28	1799.00
3	6296.09	1265.93	22	12762.83	1799.00	41	10552.33	1799.00
4	6590.30	1310.09	23	13253.18	1799.00	42	10434.65	1790.61
5	6904.13	1356.14	24	13488.55	1799.00	43	10415.03	1788.58
6	7610.23	1454.56	25	13517.97	1799.00	44	10140.44	1758.70
7	8347.72	1549.92	26	13490.51	1799.00	45	9924.68	1735.52
8	8728.23	1597.13	27	13698.42	1799.00	46	9610.86	1700.44
9	9140.12	1646.29	28	13847.48	1799.00	47	9257.81	1660.14
10	9532.40	1691.45	29	14063.24	1799.00	48	9038.13	1633.95
11	9905.07	1733.00	30	14033.82	1799.00	49	8820.42	1608.39
12	10603.33	1799.00	31	13759.22	1799.00	50	8602.70	1581.50
13	10891.65	1799.00	32	13514.05	1799.00	51	8233.96	1535.90
14	11297.66	1799.00	33	12866.78	1799.00	52	7865.21	1488.35
15	11650.72	1799.00	34	12513.73	1799.00	53	7584.73	1450.77
16	11846.86	1799.00	35	12143.03	1799.00	54	6845.29	1347.81
17	12121.45	1799.00	36	11958.66	1799.00	55	6507.93	0.00
18	12376.43	1799.00	37	11772.32	1799.00			
19	12602.00	1799.00	38	11597.76	1799.00			

Inundation area and depth

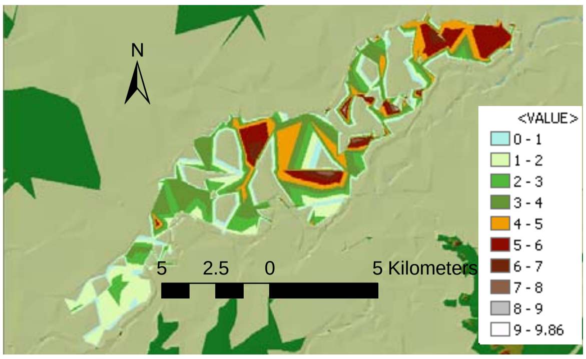


Fig.2 10-year return period flood

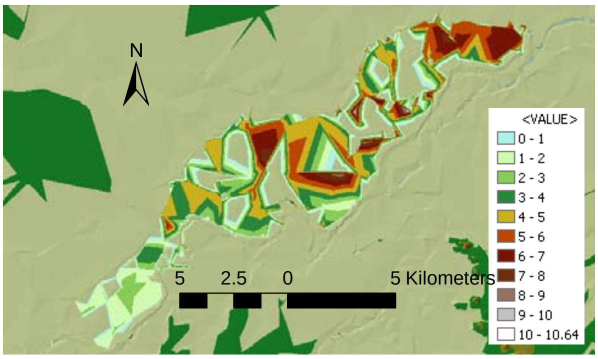
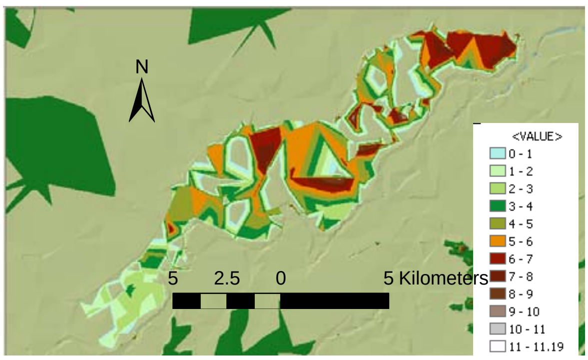


Fig.3 20-year return period flood



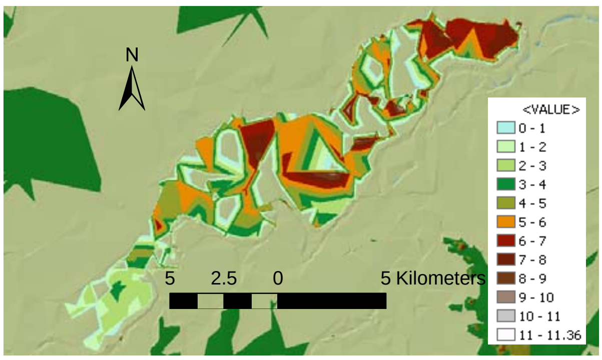


Fig.4 50-year return period flood Fig.5 100-year return period flood

Application of Flood Hazard Map

Raise Awareness

- Involve residents' participation in the preparation of flood hazard map.
- Distribute flood hazard map to each household and train them how to understand these information on the map.
- Launch some drills which will guide them how to reach safe places as soon as possible by using these information on the hazard map.
- Start with the flood risk education from the elementary school.

Reasonable Land Use Plan

- Land use plan should consider the good protection of people's property and life from flood as the top priority since Mengwa is a detention basin.
- Mengwa area is supposed to be defined as that with different flood risk levels.
- Guide and encourage farmers to plant crops which are not vulnerable to inundation condition.
- Encourage people to build their houses on the places with low flood.
- A participatory approach is recommended in decision-making and implementation of activities because these activities are very closely related with people's benefits.

Flood Insurance Plan

- FHM is the important foundation of the application of flood insurace.
- Flood insurance should be compulsory.
- Flood risk will be shared by Government, society and individuals including especially those who benefit from the utilization of detention basin.

CONCLUSIONS

- The results on FHM is confirmed to live up to actual inundation situation by calibrating the historical data recorded at some sites inside.
- The information about inundation area and depth is very crucial and indispensable for the the implementation of these suggestions in the detention basin.
- Out of the suggestions, the role of land use plan is projected in flood damage mitigation work.
- A down-top approach is proved to be effective in flood damage mitigation by giving stakeholders the chance to participate in the process of decision-making and implementation of activities.

RECOMMENDATION

- Field survey in Mengwa Detention Basin is recommended.
- The vertical resolution of the DEM data is recommended.
- Due to the limited data, only a rough evaluation and general suggestions are given.

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REFERENCES

BWR (2005), Bureau of Water Resources.
Ben, Wisner (2003). ISBN0-415-252164.
Chen, XT (1998). Compiled and printed by Policy Research vol.5.
David R.M. (2002). ISBN 7-03-010449-8.

HRC (2005), Huai River Commission.
Zhan, D.J. & Ye, S.Z. (2000). ISBN 7-5084-0281-2.