

STUDYING THE FLOOD REGULATION CAPACITY OF THE RED RIVER UPSTREAM RESERVOIR TO OVERCOME INCIDENTS AT LIEN MAC DYKE

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Abstract

This article presents a study on the flood regulation capacity of the upstream reservoirs of the Red River. One and two-dimensional numerical analyses have been carried out to simulate the hydraulic flow of the upstream reservoir and the downstream river network. The effectiveness of flood mitigation in a number of reservoir capacity scenarios have been estimated. Calculation results show that, the capacity of reservoirs of 5,553 million m³ would likely reduce the the flooded downstream area by 47,528 ha in case using a part of the capacity of the construction. The time when the reservoirs completely close the floodgates without discharging water to the downstream is from 27 to 30 hours, which is adequate for the Lien Mac dyke to be completely rectified within 24 hours.

Keywords: Huge flood; upstream reservoirs in the Red River; stop dyke breaches.

1. Introduction

The Red River and Thai Binh river dyke systems include 56 dikes classified from grade III to grade I and a special grade, corresponding to the important level, i.e. Special Grade is more important than the first grade (Grade I). The total length of the dikes is approximately 2,207.75 km, which comprise 37,709 km of special grade, 553.70 km of grade I, 502.43 km of grade II and grade III. At the present, on the Red River and Thai Binh river dike systems, there are 230 dike sections, which are considered as weak with a high risk of dike failure and flooding during a period of high river water level. A number of controlled measures have been considered such as dike strengthening, upstream reservoir construction/management to reduce the risk of dike failure and flooding. Upstream reservoir is a flood mitigation measure where a dam is constructed to store water temporarily to reduce peak flood heights downstream. Flood gate and spillway are as part of the dam/reservoir and are used to control the water flow.

According to the collected data, there have been 6 - 7 storms every year that directly affect Vietnam, resulting in a high risk of flooding. This mainly focuses on the

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North and Central regions. During the period from 1990 to 2010, 74 floods were recorded in Vietnam, causing significant loss and damage to humans and infrastructure [1]. From 1998 to 2008, natural disasters in Vietnam caused huge damage such as 4863 deaths and 80,000 billion loss of property, which were mainly from the storm and floods. Almost the population concentrates in the low-lying deltas, especially in the Red River and the Mekong Delta, Vietnam is ranked 4th in the world in terms of the total population affected by flood [2].

The Red River and Thai Binh River basins have an area of 169,020 km², of which the area belongs to Vietnam's territory is 86,720 km², accounting for 51%, the area belongs to China 81,200 km², accounting for 48%, and Laos 1,100 km² accounting for 0.7%. This basin plays an important role in the Hanoi capital and the Northern Delta. The development history of the Red River Delta and Thai Binh River demonstrated that dyke failure normally occurred in the XIX and XX centuries. Van Giang dike failure occurred during the period of 18 years (1871-1897) and 20 times from 1905 to date. From 1905 to 1990, there were many severe floods, which caused extensive flooding and great loss of human and property, particularly in 1913, 1915, 1917, 1926, 1945 and 1971.

At the present, the upstream reservoir operation is implemented according to Decision No. 740/QĐ-TTg dated June 17, 2019, of the Prime Minister. However, the operation of these reservoirs in extreme heavy rain and flood conditions mainly focuses on safety. In addition, the upstream area in China plants to construct many reservoirs with a total of about 52 constructions [2], leading to remaining passive in operating the downstream reservoirs. The Red River Delta is a key economic region in the North, a political center and plays the important role in the national security and defense side. The unsafety that occurs in the downstream dyke system might result in huge economic and social losses. Therefore, studying the flood regulation capacity of the Red River upstream reservoir under the incident of the Lien Mac dyke system is a significantly meaning topic, contributing to mitigating the loss caused by floods in the Northern Delta region.

There have been many studies on the simulation aspect of flood prediction and reservoir operation upstream of the Red River. Among them, some researches relates to the application of hydraulic models MIKE 11, and MIKE FLOOD to simulate and calculate hydraulics in rivers. For instance, the studies of Nguyen Thi Bich Thuy, Ha Van Khoi, Tran Quoc Thuong, Le Van Nghi, Nguyen Dang Giap. The research results focus mainly on flood prediction and flood plains. These researches have not considered the use of reservoir capacity outside the regulation of the operation process to reduce

flood or cease flood flush in a certain time. This can support the process of solving the dike problems quickly [1-6].

2. Data and methodology

2.1. MIKE 11 HD [1, 2, 4]

MIKE 11 model is utilized to simulate and calculate the operating scenarios for the upstream reservoir systems of Son La, Hoa Binh, Tuyen Quang, and Thac Ba according to different flood patterns. It extracts the results as boundary flow and water level for the MIKE FLOOD model to simulate and calculate the flood when the Lien Mac dike incident occurs.

a) Scope of the model

In order to evaluate the effectiveness of cutting and reducing flood for downstream of upstream reservoirs when dyke incident occurs at Lien Mac, the simulation scope in the 1-D model will include all rivers in the Red River and Thai Binh river systems.

b) Boundary conditions

The upper boundary condition contains the data of stations: Yen Bai station on the Thao river; Ham Yen station on the Lo river; Tuyen Quang Lake on the Gam River; Son La Lake on the Da River; Thai Nguyen station on Cau River; Cau Son Station on the Thuong River; Tram Chu on Luc Nam River; Hung Thi station on Boi river. At other boundaries without measurement data, the rainfall-runoff model (NAM) is utilized to estimate the flow from rainfall data.

The lower boundary of the model is the process of water level against time $Z = f(t)$ at 9 estuaries into the sea of the Red River - Thai Binh. Nam Trieu estuary; Bach Dang - Cam estuary; Lach Tray estuary; Van Uc estuary; Thai Binh estuary; Tra Ly estuary; Red River estuary; Ninh Co estuary; Day estuary (Figure 1).

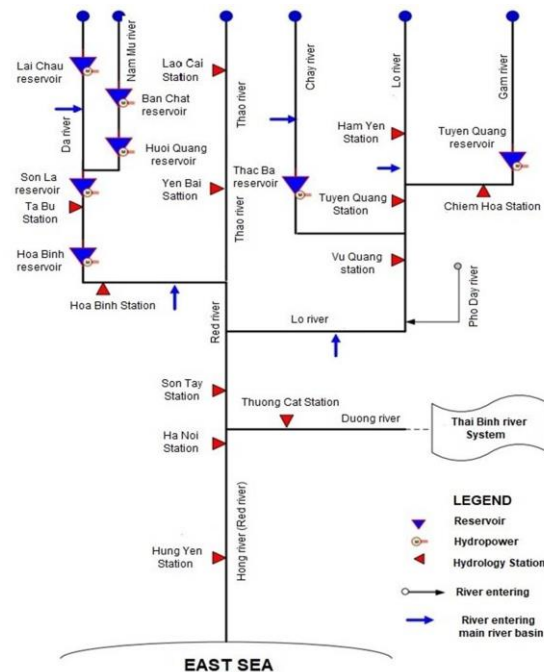


Figure 1. Network of 1D hydraulic river model.

c) Terrain data

Topographic surface data is collected from STRM (Shuttle Radar Topography Mission) with a resolution of 30 m × 30 m. Topographic data is then combined with the elevation data from maps of 1/2000, 1/5000, 1/10000, river systems, and roads issued by the Ministry of Natural Resources and Environment. Dike system data including location and elevation were updated to 2018. The river network data includes 1,427 cross-sections. Data on water level and flow at the outer stations are utilized as the boundary conditions of the model. Water level and flow at the inner stations are utilized to calibrate the model.

d) Calibration results of model

The floods in August 1996 and 2017 were selected to calibrate the model. The large flood in 1996 has a large enough amplitude to reflect the hydrological, hydraulic and roughness coefficient regimes of the river. However, the 1996 flood occurred 22 years ago and the topographical conditions of the rivers have changed significantly due to the lowering of the riverbed. Therefore, it is necessary to select 2017 flood data to calibrate the model and assess the suitability of hydraulic parameters for updated measurement data. We focus on using flood data in 1996 with a higher flood level to calibrate the roughness coefficient of the riverbank and flood data in 2017 with a lower water level to calibrate the roughness coefficient of the riverbed. The authors used a method of trial and error to calculate the roughness coefficient (hydraulic parameters of the model). The analysis water level is consistent with the real data of the locations. 28 water level stations and 6 flow stations were used to find out the appropriate set of model parameters. Calibrated results for water level and flow show good agreement in terms of peak value and period of flood.

Table 1. The error of calibrated water level for flood in 1996 at some stations

No.	Station	River	Obs. data	Simulation	ΔZ	NASH
1	Trung Ha	Da	17.55	17.83	0.28	0.78
2	Phu Tho	Thao	19.50	19.61	0.11	0.81
3	Tuyen Quang	Lo	27.98	28.08	0.10	0.91
4	Viet Tri	Lo	16.85	16.79	0.06	0.81
5	Son Tay	Red	15.09	15.37	0.28	0.75
6	Hanoi	Red	12.43	12.48	0.05	0.80
7	Hung Yen	Red	7.86	7.97	0.11	0.85
8	Thuong Cat	Duong	11.80	12.13	0.33	0.79
9	Pha Lai	Thai Binh	6.52	6.62	0.10	0.91
10	Gian Khau	Hoang Long	3.68	3.55	0.13	0.81
11	Phu Ly	Day	3.83	3.95	0.12	0.83

No.	Station	River	Obs. data	Simulation	ΔZ	NASH
12	Truc Phuong	Ninh Co	3.14	3.36	0.22	0.81
13	Quyet Chien	Tra Ly	5.27	5.57	0.30	0.76
14	Thai Binh	Tra Ly	3.75	3.85	0.10	0.81
15	Trieu Duong	Luoc	6.70	6.85	0.15	0.89

The lowest NASH of 0.75 at Son Tay hydrological station and the highest NASH achieved of 0.91 at Phu Tho hydrological station demonstrates that the results of the model calibration meet the requirements to implement the next steps.

Below figures show the water level, real data and calibration data of hydrological stations: Hanoi, Son Tay, and Thuong Cat.

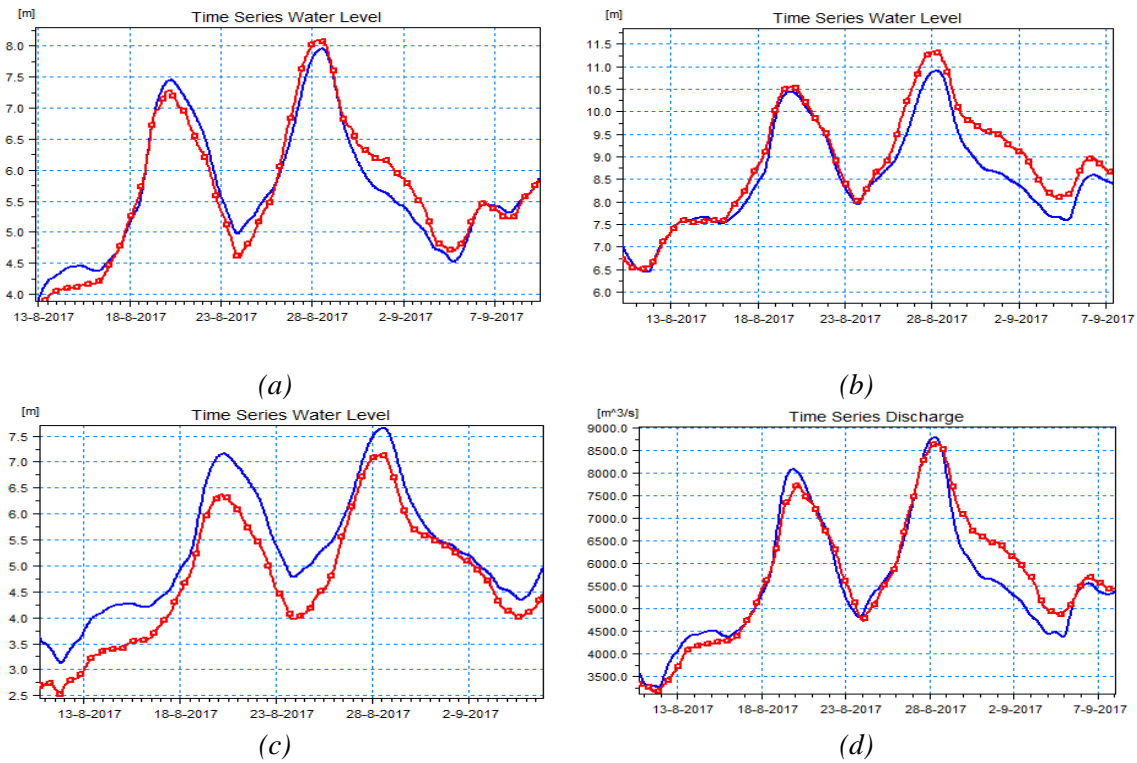


Figure 2. The water level, Obs. data (square dot) and calibration data (solid line) of hydrological stations: Hanoi (a), Son Tay (b), and Thuong Cat (c); Real data (square dot) and calibration data (solid line) of hydrological stations: Hanoi (d).

d) Validation results of model

After calibrating model, the data is verified with other floods to assess the suitability of the set of parameters with model in the overall condition of the river system. The selected data is the flood in October 2008 and August 2014. The large flood in 2008 and the small flood in 2014 including the high water (overflow) and low water (riverbed) make the appropriate characteristics for the set of parameters of the model.

Table 2. The error of verification water level at some locations in 2008

No.	Station	River	Obs. data	Simulation	ΔZ	NASH
1	Hanoi	Red	9.86	9.26	0.60	0.89
2	Son Tay	Red	12.96	12.66	0.30	0.89
3	Thuong Cat	Duong	9.35	9.10	0.25	0.93

The test results show a good agreement in water level - flow between real data and simulation at the test stations in terms of phase and peak value. Nash's coefficient reveals good results with $R > 0.8$. The model is reliable and can be used for parametric studies. The result verification of the Oct. 2008 flood model is shown in Figure 3.

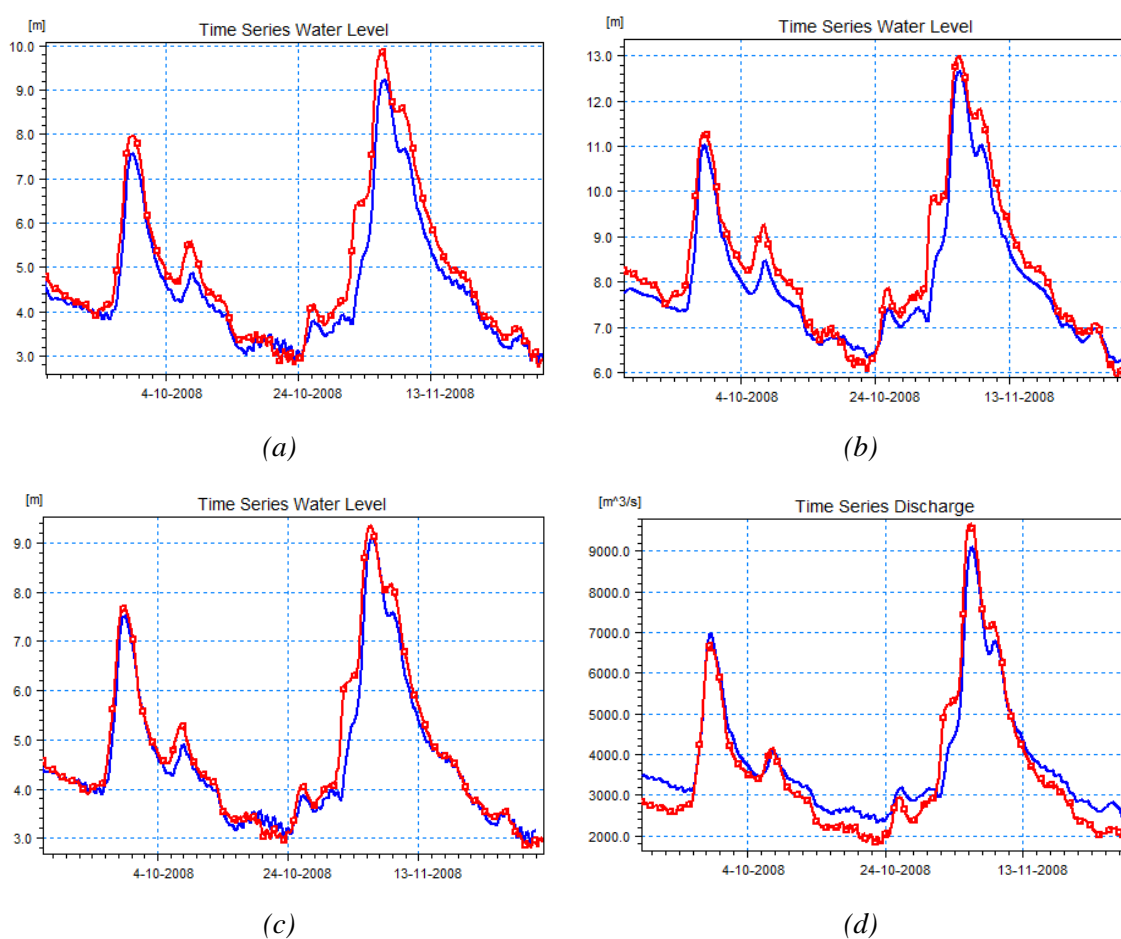


Figure 3. Calibration line (solid line) and real data (square dot) of water level at Hanoi (a), Son Tay (b), Thuong Cat stations (c); Calibration - real data of flow at Hanoi station (d) with the flood in 2008.

2.2. MIKE FLOOD [1, 2, 4]

MIKE FLOOD is a hydraulic model combined between 1D MIKE 11 and 2D

MIKE 21 with rectangular mesh or MIKE 21FM unstructured mesh. The MIKE FLOOD model is utilized to evaluate the change of flooded areas in the model using a reservoir located in upstream of Red River for cutting and reducing flood as the incident of Lien Mac dyke occurs. The MIKE FLOOD model is calibrated with the Aug. 1971 flood and verified with the Oct. 2008 flood. The verified results are reliable and can be used in the simulation. The results of the MIKE FLOOD model calibration are presented in Table 3. The model calibration results show the error in terms of water level and flow at hydrological stations to meet the requirements of the problem.

Table 3. Results of the MIKE FLOOD calibration model in the Aug. 1971 flood

No.	Station	Location	H _{max} (m)		ΔZ	Q _{max} (m ³ /s)		ΔZ
			Obs. data	Sim. data		Obs. data	Sim. data	
1	Yen Bai	Thao	32.59	32.7	0.11	10100	10104	4
2	Phu Tho	Thao	20.66	20.66	0.00	9710	9557	47
3	Na Hang	Gam	59.5	59.57	0.07	5868	5868	0
4	Thac Ba	Chay	29.15	29.15	0.00	3590	3590	0
5	TV Ham Yen	Lo	38.82	38.79	-0.03	5170	5170	0
8	Vu Quang	Lo	21.83	21.98	0.15	14000	14297	-297
9	TV Viet Tri	Lo	18.10	17.86	-0.24			
11	Ba Tha	Day	7.34	7.21	-0.13	760	925	165
12	Hung Thi	Hoang Long	10.4	10.49	0.09	275	274	-1
13	TTV Hoa Binh	Da	23.61	23.59	-0.02	16200	16188	-12
14	TTV Son Tay	Hong	16.19	16.39	0.14	34200	33570	-630
15	TTV Hanoi	Hong	13.97	13.86	-0.11	22200	21444	-756
16	TTV Thuong Cat	Duong	13.39	13.40	0.01	9000	9362	362
17	TTV. Duong Trieu	Luoc	7.71	7.70	-0.01	2460	2271	-188
18	TTV. Nam Dinh	Dao Nam Dinh	5.37	5.31	-0.07	6630	5844	-785
19	Cau Son	Thuong	13.64	13.45	-0.03	625	623	-2
20	Thac Bui	Cau	36.3	36.23	-0.07	2010	2008	-2

Based on the set of model parameters determined in the simulation which was calibrated by the Aug. 1971 flood, the model is calculated with the real flood in August 2008. The results of the model verification are shown in Table 4.

Table 4. Results of the MIKE FLOOD verification model in the Aug. 2008 flood

No.	Station	River	H _{max} (m)		ΔZ	Q _{max} (m ³ /s)		ΔZ
			Obs. data	Sim. data		Obs. data	Sim. data	
1	Yen Bai	Thao	34.26	34.31	0.05	10800	10797	-2.91
2	Phu Tho	Thao	19.14	19.23	0.09			

No.	Station	River	H _{max} (m)		ΔZ	Q _{max} (m ³ /s)		ΔZ
			Obs. data	Sim. data		Obs. data	Sim. data	
3	Na Hang	Gam	55.45	55.47	0.02	2472	2471	-1
4	Vu Quang	Lo	17.39	17.48	0.09	5550	5225	-25
5	TV Viet Tri	Lo	15.33	15.27	-0.06			
6	Ham Yen	Lo	33.56	33.59	0.03	3260	3260	0
7	TV Thac Ba	Chay	22.74	22.75	0.01	540	537	-3
8	TTV. Hoa Binh	Da	19.14	19.21	0.07	7320	7321	-1
9	TTV. Son Tay	Hong	13.50	13.64	0.14	17500	18380	880
10	TTV. Hanoi	Hong	10.42	10.43	0.01	10700	11135	435
11	TTV. Thuong Cat	Duong	9.84	9.95	0.11	6090	6294	204
12	Hung Thi	Hoang Long	10.02	9.95	-0.07	218	217	-1
13	Thac Buoi	Cau	32.25	32.26	0.01	948	947	-1
14	Thai Nguyen	Cau	25.27	25.33	0.06	1080	1086	6
15	Chu	Luc Nam	8.62	8.59	-0.03	1390	1387	-3

The results of model verification show that the error between the calculation and the real data of the water level is $0.00 \div 0.23$ m. Thus, the set of MIKE FLOOD model parameters ensures reliability for simulating scenarios.

2.3. Simulation and calculation scenario

With the assumption that dyke failure in the downstream area occurs when the reservoirs are still operated normally. In order to minimize damage under downstream dyke failure, accumulating the water level in reservoirs is higher than the permitted value can be considered. In Article 8, the process of multi-reservoir operation in the Red River upstream according to 740/QĐ-TTg stipulates the maximum water level of the reservoirs as shown in Table 5.

Table 5. Design parameters of reservoirs according to Decision 740/QĐ-TTg [5]

No.	Reservoirs	Normal water level (m)	Dead water level (m)	Water level design (m)	Highest water level (m)	Total Capacity (10 ⁶ m ³)	Useful Capacity (10 ⁶ m ³)
1	Son La	215	175	217.83	228.07	9,260	6,504
2	Hoa Binh	117	80		122	9,862	6,062
3	Thac Ba	58	46		61	2,940	2,160
4	Tuyen Quang	120	90	122.55		2,260	1,699

According to Article 12 of process 740, as a serious incident occurs to the downstream dyke system, the head of the Central Committee for Flood and Storm Control proposes a handling plan and reports it to the Prime Minister. The Prime

Minister considers, decides or performs the responsibilities according to the provisions of the law.

At the present, the dyke system in the Northern Delta and Hanoi capital has 230 and 16 weak locations, respectively. In particular, the key location of Lien Mac in Bac Tu Liem district includes the Lien Mac sluice and the Huu Hong dyke system. This is particularly important because it directly impacts the central area of the Hanoi capital. Based on the above comments, the article presents the results of calculation for scenarios using reservoir capacity to regulate flood under the dyke incident at Lien Mac. The simulation model of the flood is followed by Decision No. 257/QĐ-TTg Feb. 18, 2016 of the Prime Minister: Approving plan on flood prevention and planning on dikes of the Red River, Thai Binh River system [6]. According to these principles, a flood with a 300-year cycle in Son Tay, 1969 flood and the main flood season was selected for simulation. The dimension of the fracture was assumed with a maximum length of 200 m and a maximum height of 5 m. The step time for the formation and propagation of the fracture is 60 minutes. Scenarios using the capacity of the upstream reservoir of the Red River as follows:

- Scenario 1: Using the capacity of Hoa Binh reservoir to the design flood level.
- Scenario 2: Using the capacity of the reservoir: Hoa Binh, Thac Ba and Tuyen Quang to the design flood level.
- Scenario 3: Using the capacity of the reservoir: Son La, Hoa Binh, Thac Ba and Tuyen Quang to the design flood level.
- Scenario 4: Son La reservoir uses up to 30% of the flood control capacity. Hoa Binh, Thac Ba and Tuyen Quang reservoir use capacity to the design flood level.
- Scenario 5: Son La Lake uses up to 50% of the flood control capacity. Hoa Binh, Thac Ba and Tuyen Quang reservoir use capacity to the design flood level.

3. Results and discussion

3.1. Effectiveness of flood reduction at downstream

In order to evaluate the effectiveness of cutting flood and reducing flood for downstream when the upstream reservoirs of the Red River use the flood control capacity. The article compares the results of the calculation of the respective scenarios when operating the reservoirs according to the process and proposed scenario. The calculation results are presented in Tables 6, 7.

Table 6. Highest water level after regulation of upstream reservoirs

Scenario	Z_{Max} - Son La		Z_{Max} - Hoa Binh		Z_{Max} - Tuyen Quang		Z_{Max} - Thac Ba	
	Process	Capacity	Process	Capacity	Process	Capacity	Process	Capacity
KB1	217.83		117.00	122.00	120.00		58.00	
KB2	217.83		117.00	122.00	120.00	122.55	58.00	61.00
KB3	217.83		117.00	122.00	120.00	122.55	58.00	61.00
KB4	217.83	221.47	117.00	122.00	120.00	122.55	58.00	61.00
KB5	217.83	223.00	117.00	122.00	120.00	122.55	58.00	61.00

(KB: Scenario)

Table 7. Effectiveness of cutting floods, reducing floods at downstream by utilizing flood control capacity

Scenario	W- Son La Storage Capacity		W - Hoa Binh Storage Capacity		W- Tuyen Quang Storage Capacity		W - Thac Ba Storage Capacity		ΣW Total Storage Capacity
	Process	Capacity	Process	Capacity	Process	Capacity	Process	Capacity	
KB1	633.92	633.92	964.42	2,000.82	97.02	97.02	138.56	138.56	1,036.40
KB2	633.92	633.92	964.42	2,000.82	97.02	317.85	138.56	793.56	1,912.23
KB3	633.92	2,999.20	964.42	2,000.82	97.02	317.85	138.56	793.56	4,277.51
KB4	633.92	3,764.55	964.42	2,000.82	97.02	317.85	138.56	793.56	5,042.86
KB5	633.92	4,274.80	964.42	2,000.82	97.02	317.85	138.56	793.56	5,553.11

Results show that the effectiveness of flood cutting and flood reduction of upstream reservoirs to support the Lien Mac dike incident is very large:

- The capacity of upstream reservoirs for flood control and flood reduction reaches the minimum value of 1,036 million m^3 by utilizing.

Hoa Binh reservoir and 5,553 million m^3 as utilizing 50% of the flood control capacity of Son La reservoir. It is combined with the reservoirs of Hoa Binh, Thac Ba, and Tuyen Quang to the design water level.

- With scenario 3, Son La reservoir can close all floodgates within 27 h, Hoa Binh reservoir within 29 h, Tuyen Quang reservoir within 30 h, and Thac Ba reservoir can close all floodgates during the remaining time of the flood to support the process of solving the Lien Mac dike.

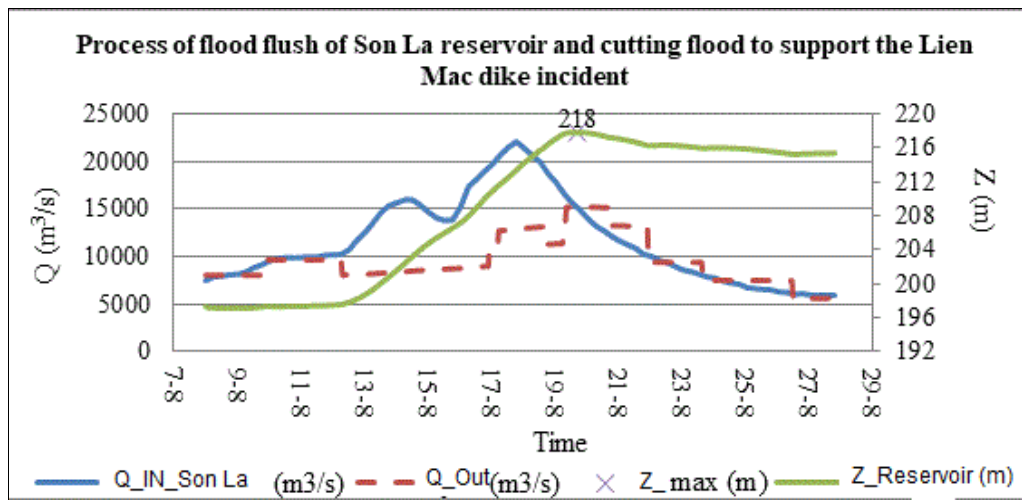
3.2. Effectiveness of reducing downstream flood as occurring Lien Mac dyke incident

3.2.1. Calculating the process of flood flush for reservoirs

In order to evaluate the effectiveness of flood reduction in case of dyke failure at Lien Mac, the article will show the result of the calculation for scenario 3 (KB3). This scenario utilizes the capacity of reservoirs up to the design water level: Son La, Hoa Binh, Tuyen Quang and Thac Ba in storing and reducing flood for downstream under dyke incident at Lien Mac. After the incident of dyke failure at Lien Mac, the floodgates of Son La, Hoa Binh, Tuyen Quang and Thac Ba have to be closed to reduce the water level in downstream. Analysis results of reservoir regulation are shown in Table 8 and Fig. 4.

Table 8. The largest capacity that can be stored according to the water level of the reservoirs

Detail	Son La	Hoa Binh	Tuyen Quang	Thac Ba
Water level at the moment of dyke failure (m)	215.81	112.21	118.74	57.36
Remaining capacity to water level according to procedure (10^6 m^3)	311.36	964.42	97.02	138.56
Remaining capacity to design water level (10^6 m^3)	633.92	2,000.82	317.85	793.56
Time to completely close the floodgates (h)	27	29	30	Total timing



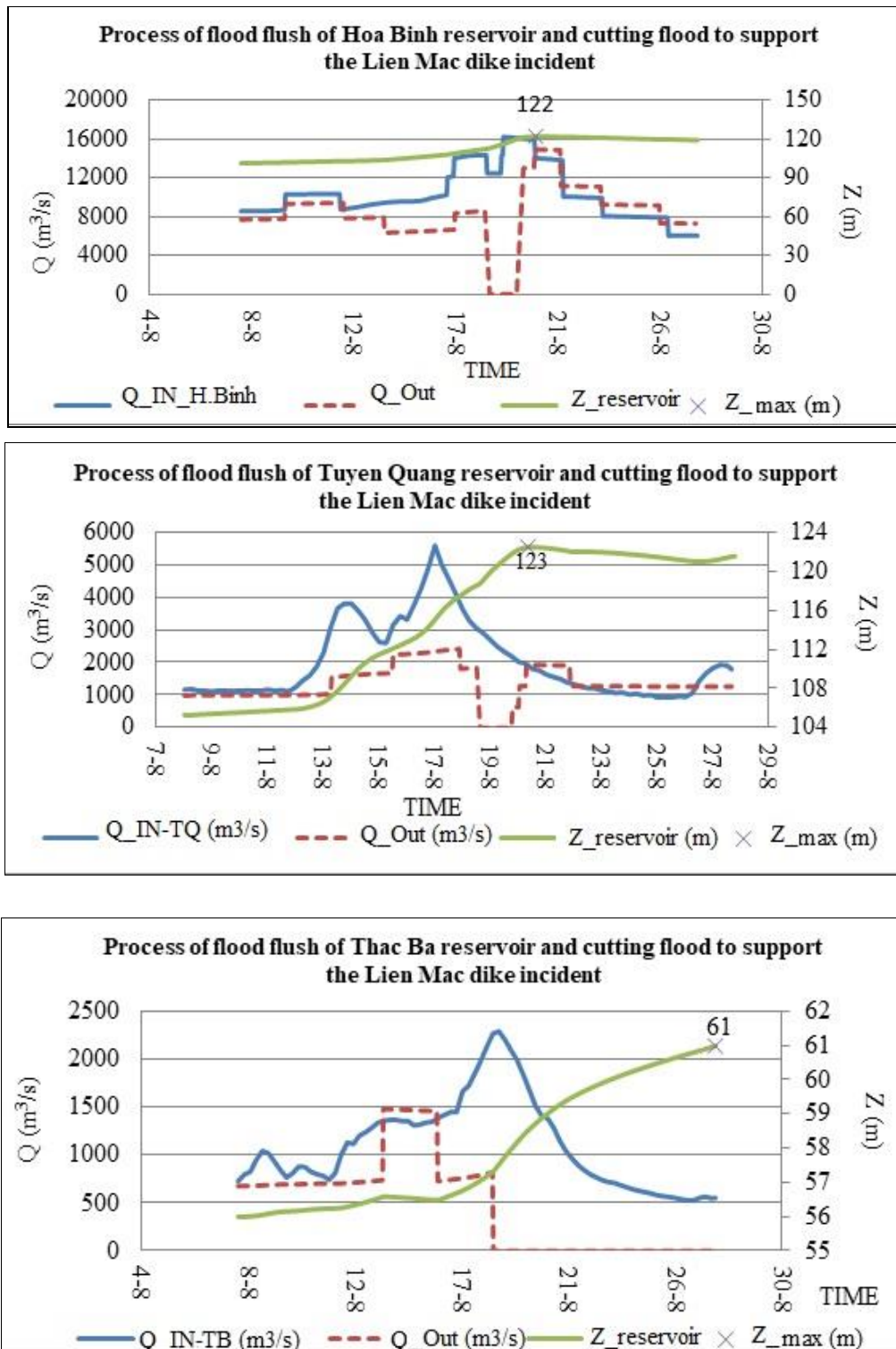


Figure 4. Process of flood flush of upstream reservoirs participates in cutting and reducing downstream floods.

3.2.2. Evaluation of the effectiveness of flood reduction in the downstream area

Within the scope of the article, authors present the simulation result of flood for 2 cases:

i) Utilizing the capacity to the design flood water level of the Son La, Hoa Binh, Thac Ba, Tuyen Quang reservoirs and Lien Mac dike has not stopped dyke breaches.

ii) Utilizing the capacity to the design flood water level of Son La, Hoa Binh, Thac Ba, Tuyen Quang and Lien Mac dike Lien Mac has stopped dyke breaches within 24 hours. Results are shown in Table 9 and Figures 5-6.

Table 9. The greatest effectiveness of flood reduction effect as using the flood control capacity of the upstream reservoirs

No.	The case of calculation and simulation	The largest flooded area (ha)		Effectiveness of reducing flooding in the downstream areas (ha)
		According to the procedure	Utilization of control capacity flood of reservoirs	
1	Lien Mac dike has not stopped dyke breaches	199,303	151,775	47,528
2	Lien Mac dike has stopped dyke breaches within 24 hours	199,303	59,502	140,101

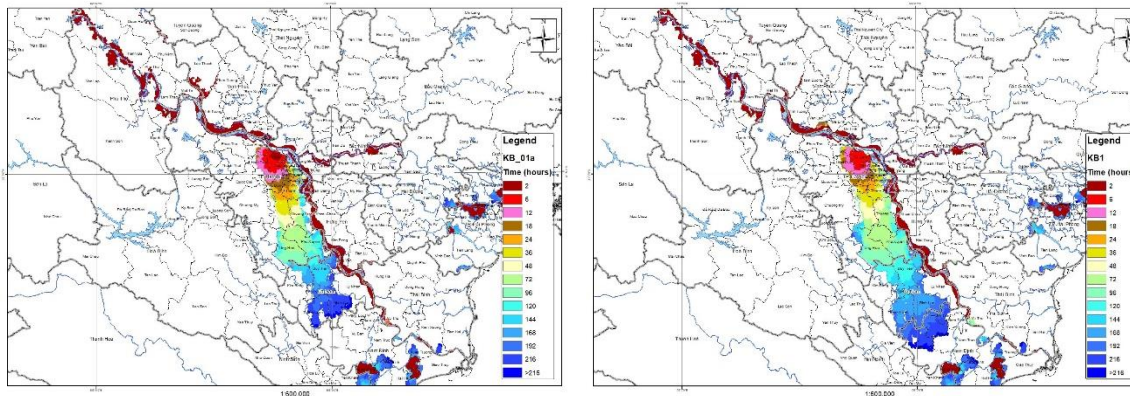


Figure 5. Flooding evolution over time in case of using the capacity of reservoirs upstream of the Red River for cutting and reducing flood in the downstream area.

The simulation results from Table 9 show that:

- The largest flooded area according to the procedure is 199,303 ha when the capacity of upstream reservoirs is utilized to design a flood water level of 151,775 ha.
- In case the Lien Mac dike has not stopped dyke breaches, the downstream

flooded area reduces by 47,528 ha compared to the case where the capacity of upstream reservoirs is not utilized at the design flood water level.

- In case the Lien Mac dike has stopped dyke breaches within 24 hours, the downstream flooded area will be reduced by 140,101 ha compared to the case where the capacity of upstream reservoirs is not utilized at the design flood water level.

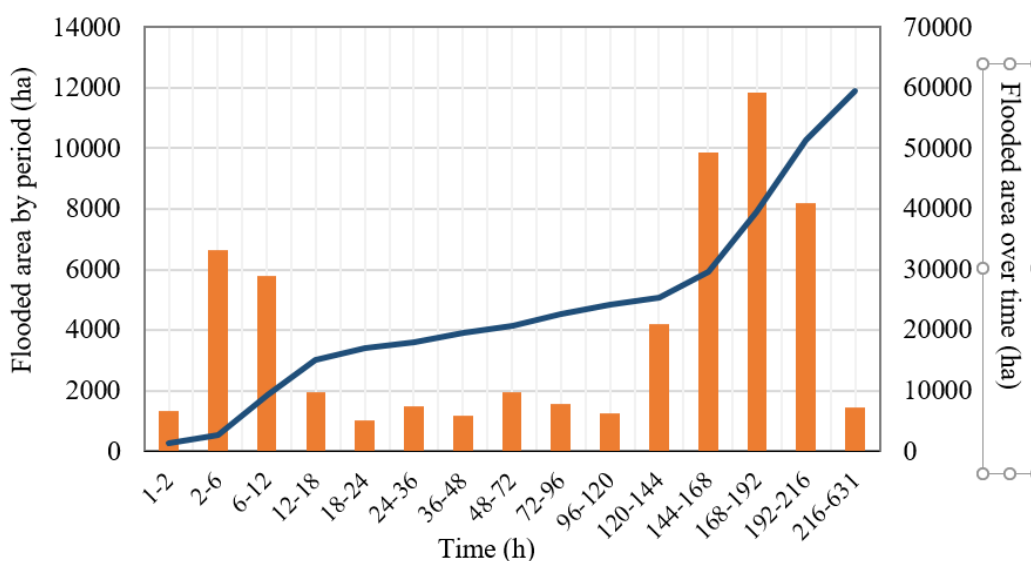


Figure 6. Flooding evolution in the downstream area during the stopping dyke breaches of the Lien Mac dike.

4. Conclusions

Within the scope of the article, the authors assumed that the downstream dyke system has an incident at the Lien Mac key location, thereby studying solutions to operate the upstream reservoir for reducing floods in the downstream area. This is to support the response and stop dyke breaches more quickly, which also reduces the level of flooding area in downstream.

The results of the calculation to regulate the Red River upstream reservoirs for the flood with a 300 years period in Son Tay, the 1969 flood model demonstrates that the Red River upstream reservoirs possess the significant capacity in regulating flow and mitigating flood. According to the scenario 5 calculation results, the maximum total capacity of reservoirs that can be utilized to participate in flood control and flood reduction is up to 5,553 million m^3 and the flooded area is reduced by 47,528 ha in case of utilizing the flood control capacity of the upstream reservoirs. On the other hand,

when using the flood control capacity of the reservoirs to cut floods and reduce floods for downstream, Son La reservoir can completely close flood it's gates in 27 h, Hoa Binh reservoir in 29 h, Tuyen Quang reservoir in 30 h, and Thac Ba reservoir during the remaining time of the flood. This can support the process of stopping dyke breaches at the Lien Mac location.

In the case of utilizing the capacity Son La, Hoa Binh, Tuyen Quang, Thac Ba reservoirs up to the designed flood water level for cutting and reducing floods and at the same time, the incident at the Lien Mac location can be solved within 24 h. A reduction in a flooded area of 140.101 ha shows the effectiveness of the solution which can reduce damage to infrastructure, economy, society and environment.

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KHẢ NĂNG ĐIỀU TIẾT LŨ CỦA HỒ CHỨA THƯỢNG NGUỒN SÔNG HỒNG KHI XUẤT HIỆN SỰ CỐ ĐÊ ĐIỀU TẠI LIÊN MẠC

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Tóm tắt: Bài báo trình bày việc nghiên cứu khả năng điều tiết lũ cho hạ du của hệ thống hồ chứa thượng nguồn sông Hồng và hỗ trợ công tác ứng phó, hàn khẩu đê khi trên lưu vực xuất hiện lũ đặc biệt lớn, đồng thời xảy ra sự cố đê điều tại Liên Mạc. Trong phạm vi bài báo này, chúng tôi sử dụng phương pháp mô hình toán thủy lực 1 chiều, 2 chiều tính toán, mô phỏng các kịch bản điều tiết hồ chứa thượng nguồn sông Hồng và diễn toán thủy lực mạng sông hạ du, từ đó xác định hiệu quả cắt lũ, giảm lũ của từng kịch bản. Kết quả tính toán, mô phỏng cho thấy, tùy theo các kịch bản tính toán, dung tích các hồ chứa có thể huy động được 5.553 triệu m³ để cắt lũ, giảm lũ cho hạ du và diện tích ngập lụt sẽ giảm 47.528 ha nếu sử dụng một phần dung tích chống lũ của công trình. Thời gian các hồ chứa đóng hoàn toàn các cửa xả lũ, không xả lũ xuống hạ du từ 27 - 30 giờ, đây là thời gian quan trọng đê Liên Mạc có thể được hàn khẩu hoàn toàn trong vòng 24 giờ.

Từ khóa: Lũ đặc biệt lớn; hồ chứa thượng nguồn sông Hồng; hàn khẩu đê.

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