Vietnam Journal of Hydrometeorology, ISSN 2525-2208, 2019 (03): 56-61
DOI:10.36335/VNJHM.2019(3).56-61

Research Paper

ASSESSMENT OF URBAN FLOODING IN YEN HOA - HOA BANG AREA, CAU GIAY, HANOI

Tran Kim Chau[1], Tran Thi Quynh[1], Nguyen Van Minh[2], Nguyen Thanh Thuy[1]

ARTICLE HISTORY

Received: November 12, 2019 Accepted: December 20, 2019
Publish on: December 25, 2019

ABSTRACT

Hoa Bang street is known as one of flooding hot spots in Hanoi with 30 inundated times during last 4 years. In 2019, a new conduit has been set up to drain the water from Hoa Bang street to To Lich River. However, the flooding situation has not been significant improved. Therefore, it is necessary to evaluate the capacity of the drainage systems as well as effectiveness of flooding mitigation measures. In this research, the numerical model MIKE URBAN is used to simulate the rainfall-runoff, routing and surcharge processes in Yen Hoa - Hoa Bang areas. Water depth and flood durations are indicators to assess the performance of the proposed solutions. The result of this research indicates that the renovation of the drainage system, i.e. enlargement in conduits' diameter, can reduce inundation time significantly.

Keywords: *MIKE FLOOD, MIKE URBAN, urban flooding, drainage system.*

1. Introduction

In recent years, in big cities of Vietnam as well as in Hanoi, the population has been growing rapidly and the speed of urbanization have resulted in natural land's contraction and the spread of concretized land. The fact that many rivers and lakes have been filled, canals have been encroached, and high-rise buildings have been built closely to replace vacant land reduces the area of natural drainage as well as the permeability and the time of overland flow on the surface. It can be seen that, the urban drainage system of Hanoi is old and not designed to keep up with urban planning of the City. At the same time, the projects to renovate the drainage system in the inner-city area are still slow due to many reasons. Combined with heavy rains caused by climate change, Hanoi has continuously faced with large-scale floods in recent years, which greatly affected socio-economic activities, especially in the inner-city area. Historical rains occurred in late October and early November 2008 with a total rainfall common from 350 to 550 mm, causing serious inundation throughout Hanoi, many flooded spots appeared. length of 100-300 meters, depth of less than 1m, causing economic losses of up to 3,000 billion. Hoa Bang street is known as one of flooding hot spots in Hanoi. There are 9, 7, 3 11 flooding events with total flooding time of 1062, 1669, 884, 2188 minutes corresponding to year 2016, 2017, 2018 and 2019. The water depth varies from 0.1 to 0.4 m.

In recent decades, mathematical models have been increasingly applied to urban flood simulation problems. These include 1D sewer model approach, e.g. SWMM (Rossman, 2010), HydroPlaner (Fareed, 2013), or coupled with 1D sewer model with 2D surface flow models, e.g.

✉ TRAN KIM CHAU
Corresponding author: kimchau_hwru@tlu.edu.vn
[1]Thuyloi University
[2]Power Engineering Consulting Joint Stock Company 1

SOBEK 1D/2D (Deltares Delft Hydraulics, 2019), InfoWorks ICM (Innovyze 2019). According Leandro (2009), overflow is better modeled by 2D models, whereas 1D models provide a good approximation flow in pipe. Pham et al. (2015) applied MIKE URBAN to simulate the inundation in 8 inner districts of Hanoi. In their research, only main drainage routs were conducted in the networks. This means the drainage capacity of the tributaries were not considered. In this research, the coupled with 1D sewer model with 2D surface flow model has been performed for Yen Hoa - Hoa Bang area with a detailed drainage system (Fig. 1).

Yen Hoa - Hoa Bang area is located in territory of Cau Giay district. The case study covers an area of 40.47 ha. This is one of the lowest areas in Hanoi but the topography is complex with the altitude from 4.4 m to 7.8 m. The heavy rains appear frequently in the summer with maximum hourly precipitation varying from 31.9 mm to 114.9 mm. The main drainage routs are located along Hoa Bang, Yen Hoa, alley 381 of Nguyen Khang street, the Nguyen Khang street from Cot bridge to Yen Hoa bridge. The drainage systems discharge flow to To Lich river at 2 outlets.

Fig. 1. Map of the study area

2. Materials and Methods

The research was implemented in 3 main steps (Fig. 2).

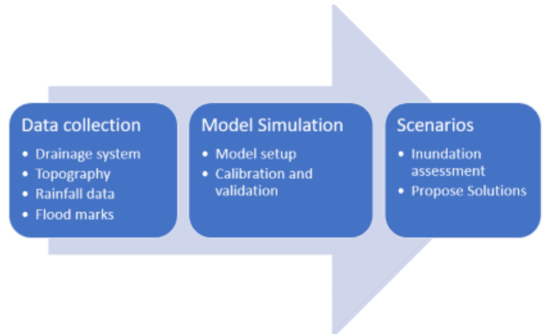

Fig. 2. The scheme of research implementation

2.1 Data collection

The collected data includes meteorological data, inundated depth and drainage system information. 10 minute rainfall data of heavy rains since June to September of 2019 at Cau Giay rain gauge were assembled. During this period, the study area were most suffered from the 2 heavy rainfall events at the end of April and early August 2019. Therefore, these 2 rainfall events were selected for calibration and validation correspondingly. Besides the meteorological data, the information on the drainage system updated to August 2019 were collected. This information includes locations of water collection stations, sewer diameter, manhole diameter, surface elevation, elevation of manhole bottom, slope slope ... Moreover, the 1/10000 scale topo data of the area has also been collected. In order to conduct validation process, flood marks corresponding to the above flood events were also studied and collected.

2.2 Description of MIKE FLOOD model

To conduct the simulations, MIKE FLOOD model was used for calculation. In this model, MIKE URBAN and MIKE 2D FM are linked together. MIKE URBAN model works based on a link of hydrological models and hydraulic models (DHI 2014c). The model structure can be described as Fig. 3.

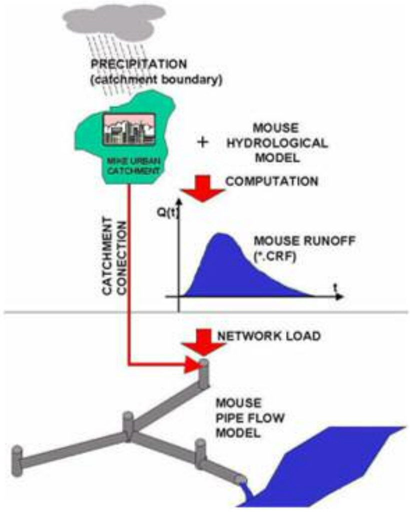

Fig. 3. The structure of MIKE URBAN

In this study, the calculated area was divided into 414 sub-basins. In each of these sub-basins, the Time-Area (T-A) method was used to convert the precipitation that falls on the sub-basin into the flow which discharges into the culverts (DHI, 2014a, 2014b). The hydraulic module routs flow in the sewer system by solving Saint Venant equations (Eq. 1, Eq. 2).

$$\frac{\partial Q}{\partial x}+\frac{\partial A}{\partial t}=q_{lat} \quad (1)$$

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{\alpha Q^2}{A}\right)+gA\left(\frac{\partial h}{\partial x}-S_o\right)+g\frac{AQ|Q|}{K^2}=0 \quad (2)$$

These two equations are applied for free surface flow. For the pressurised flow, the fictitious slot is introduced and the continuous equation Eq. 1 can be written as Eq. 3.

$$\frac{\partial Q}{\partial x}+\frac{Q}{\rho}\cdot\frac{\partial \rho}{\partial x}+\frac{\partial A}{\partial t}+\frac{A}{\rho}\cdot\frac{\partial \rho}{\partial t}=0 \quad (3)$$

2.3 Setup model

In the study area, a network of 461 sluices are simulated for the three main streets of Hoa Bang, Yen Hoa and a part of Nguyen Khang street. In addition, some main lane routes are also modeled. Roughness coefficients of sewer system are taken according to the instructions in TCVN 7957: 2008 (VIWASE, 2008). The water in the system is discharged to the To Lich river through 2 outlets. The drainage network of the area is shown in Fig. 4.

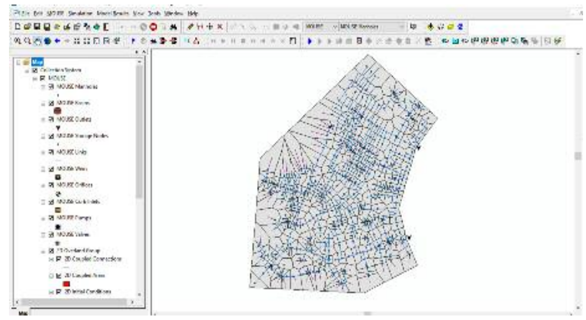

Fig. 4. MIKE URBAN model for research area

MIKE URBAN is combined with MIKE 2D FM to account for flooding when the drainage capacity of the system does not meet the runoff from in the catchments. The mesh of this 2D model was constructed from detailed grid cells with an area of 1 to 5 m2. MIKE URBAN and MIKE 2D FM are connected at the manholes. The water level at the manholes is calculated at each time and compared with the water level in the 2D grid at that location. If there is a water level difference, the water exchange between the two models will be performed.

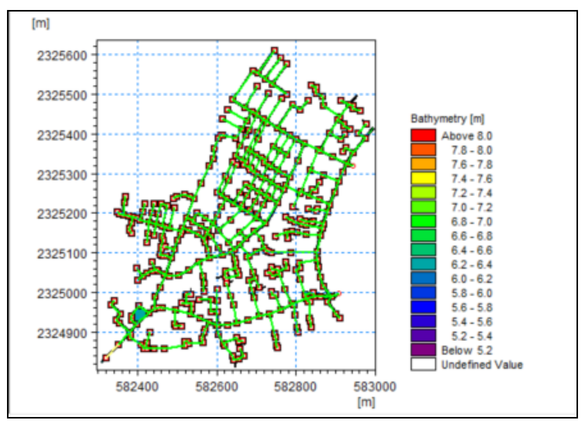

Fig. 5. MIKE FLOOD model for research area

The data collected for the rain since April 29th, 2019 to April 30th, 2019 was used for calibration and the data since August 1st, 2019 to August 4th, 2019 was used for validation. The simulation results were compared with observed inundated depths to ensure the accuracy of the model.

After calibration and validation, the model will be used to simulate the design rains. Besides, a flood mitigation measure was proposed. The calculation scenarios are shown in detail as Table 1.

Table 1. The scenarios

ID	Description
KB 01	Simulate the rain of April 29th, 2019 to April 30th, 2019 to adjust the model
KB 02	Simulate the rain of August 1st, 2019 to August 4th, 2019 to test the model
KB 03	Simulation of design storm with current condition
KB 04	Simulation of design storm with expanded conduits' diameter in Hoa Bang street

3. Results and discussions

Tables 2 and 3 shows that the calculation results are quite consistent with the reality at some typical flooding points in both calibration and validation.

It was found that the flooding in the study area is still severe with the current drainage system condition. Especially, the storm event since August 1st, 2019 to August 4th, 2019 affected by typhoon No. 3 with heavy rain on August 3rd and August 4th, 2019 made Hoa Bang area was inundated for a long time. Especially the water depth at alley 90, Hoa Bang street was 0.35m, Lane 35 was 0.23m. Some specific points such as 90 Hoa Bang flooded 0.35m and 35 Hoa Bang flooded 0.29m. there is no flooding in some areas such as Nguyen Khang and Yen Hoa streets because the sewers in these areas have sluices' diameter from 0.8m to 1m. Additionally, these areas are closed to To Lich River so the amount rainwater quickly drains into the river. The cause of inundation at Hoa Bang street can be caused by two main reasons. First, heavy rains occurred, the drainage capacity of the existing sewer system could not address. Especially Hoa Bang street, when the drain diameter of the main line is only 0.6m. The second, the concave terrain of this area is also a major factor causing flooding in the area. Figure 8 describes the longitude profile along the Hoa Bang route. Looking at the figure, it is noticed that the topography of Hoa Bang Street in the middle creates favorable conditions for forming local flooding spots. Overflow is unable to drain into the river but stays and waits for flow through the public system. Therefore, reducing the depth of flooding in this area is very difficult to overcome. However, it is possible to reduce the flooding time by increasing the likelihood of drainage through the sewer system.

Table 2. The observation and calculation depth in calibration process (m)

Location	D obs.	D cal.
No 35 Hoa Bang	0.4	0.31
No 90 Hoa Bằng	0.4	0.38
Alley 35 Hoa Bang	0.3	0.22
Alley 90 Hoa Bang	0.5	0.41

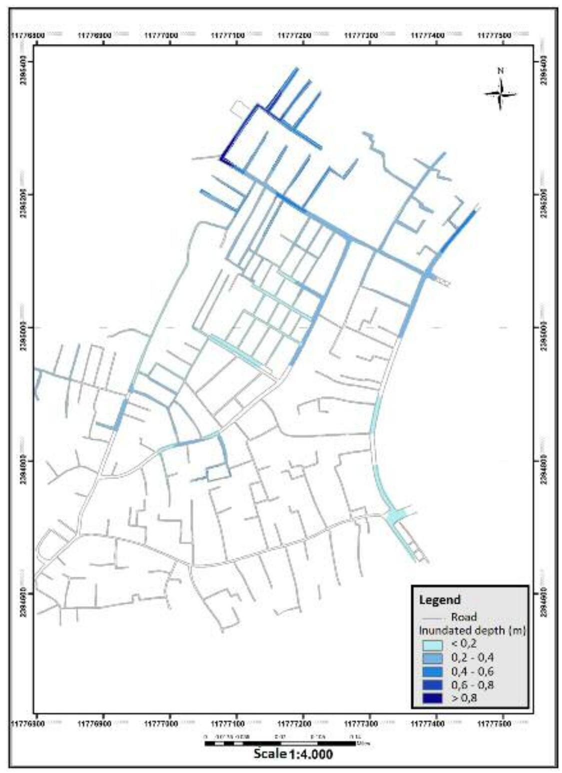

Fig. 6. Flood area for storm event in 29/04-30/04

Table 3. The observation and calculation depth in validation process (m)

Location	D obs.	D cal.
No 35 Hoa Bang	0.4	0.31
No 90 Hoa Bang	0.4	0.38
Alley 35 Hoa Bang	0.3	0.22
Alley 90 Hoa Bang	0.5	0.41

Based on the analysis, the study proposes mitigated solution. According to decision 725/QĐ-TTg (Prime Minister 2014), Hanoi urban area must respond to design rain with a frequency of

10%. In this study, two scenarios were simulated. In the first scenario (KB03), the inundation situation was calculated based on the current condition of the area. In the second scenario (KB04), the size of some sewers in the flooded area was expanded to increase their drainage capacity. Specifically, the drainage routes at Hoa Bang street were increased from 0.6m to 0.8m. This value is selected so that the diameter of the conduits in the Hoa Bang area is homogeneous with surrounding system. The simulated results are shown in the Tables 4 and 5.

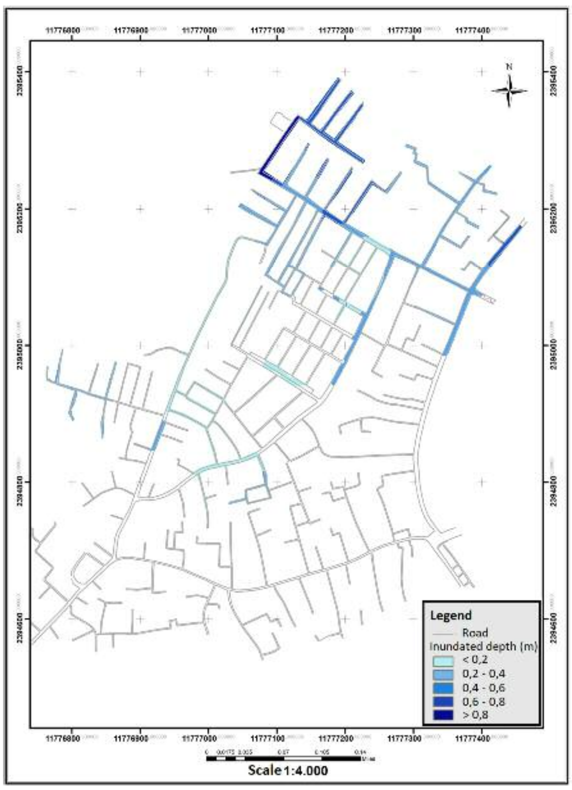

Fig. 7. Flood area for storm event in 01/08-04/08

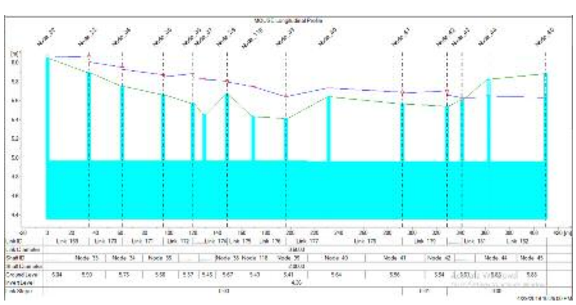

Fig. 8. Longitude profile of Hoa Bang street

Table 4. The flooding duration in scenarios (h)

Location	KB03	KB04	Δt
No 35 Hoa Bang	4.5	3.75	0.75
No 90 Hoa Bang	4.83	4	0.83
Alley 35 Hoa Bang	3.75	3.25	0.5
Alley 90 Hoa Bang	4.83	4	0.83

Table 5. The flooded depth in scenarios (m)

Location	KB03	KB04	Δh
No 35 Hoa Bang	0.82	0.77	0.05
No 90 Hoa Bang	0.89	0.8	0.09
Alley 35 Hoa Bang	0.7	0.6	0.1
Alley 90 Hoa Bang	0.9	0.8	0.1

The Tables 4 and 5 shows the flooding duration and flooded depth in scenarios and their differences. In this tables, we can see that, when the sewer size increases, the inundation depth is not reduced significantly (0.05 - 0.1m), but the flooding time is significantly decreased. This is also reasonable with the original judgment of the authors.

4. Conclusions

The research has developed a MIKE FLOOD model that simulates urban flooding for the study area. The model was calibrated and validated to ensure the reliability of the calculated results.

According to the research results, the current statement of the drainage system of the Hoa Bang route is not able to escape the heavy rainfall corresponding with frequency P = 10%. The solution introduced in the direction of increasing the size of the work shows that the time of inundation is reduced significantly. The inundation duration at heavy flooding points can be reduced from 30 to 50 minutes.

The study proposes only one traditional measure to indicate the application of the numerical model in urban drainage planning. In the coming time, more green solutions should be considered.

Acknowledgement

This research was supported by "Assessment of urban flood hazard in Hanoi under current and future climate conditions" project funded by VLIR-UOS (VN2019SIN267A101). We would also like to show our gratitude to the Ha Noi Sewage and Drainage limited company for sharing the data during this research.

References

1. Deltares Delft Hydraulics 2019. SOBEK Hydrodynamics, Rainfall Runoff and Real Time Control User Manual, The Netherlands.

2. Denmark Hydraulic Institute 2014a. MIKE URBAN Collection System.

3. Denmark Hydraulic Institute 2014b. MIKE URBAN User Guide, Denmark.

4. Denmark Hydraulic Institute 2014c. MIKE FLOOD Modelling of urban flood, Denmark.

5. Fareed, M., Shiroma, M., Stephanie, A., Luis, N., Daniel, K., Esther, C., 2013. HydroPlanner: A Prototype Modelling Tool to Aid Development of Integrated Urban Water Management Strategies, Australia.

6. Innovyze, 2019. InfoWorks ICM User Manual, United Kingdom.

7. Leandro, J., Chen, A.S., Djordjević, S., Savić, D.A., 2009. Comparison of 1D/1D and 1D/2D Coupled (Sewer/Surface) Hydraulic Models for Urban Flood Simulation. Journal of Hydraulic Engineering, 135 (6): 495-504. Doi:10.1061/(asce)hy.1943-7900.0000037.

8. Fletcher, T.D., Andrieu, H., Hamel, P., 2013. Understanding, management and modelling of urban hydrology and its consequences for receiving waters: A state of the art. Advances in Water Resources, 51: 261-279.

9. Nguyen, Q.B., Tran, L.P., Nguyen, T.H., 2016. Applying MIKE URBAN Model to Evaluate Stormwater Drainage System. A Case Study in Cam Le District, Da Nang City, ATCESD 2016.

10. Rossman, L.A., 2010. Storm water management model user's manual. USEPA Software.

11. Prime Minister 2013. Decision No. 725/QD-TTg of May 10, 2013, approving the master plan on Hanoi capital's drainage through 2030 with a vision toward 2050.

12. Pham, M.C., Tran, N.A., Dang, D.K., Dang, D.D., Nguyen, M.K., Pham, Q.H., 2015. Inundation Solution for Hanoi Inner City by Studying of Unbalanced Nodes, Technical Solutions for Local Flooding Cases. VNU Journal of Science Natural Sciences and Technology, 31 (3S): 44-55.

13. VIWASE 2008. TCVN 7975:2008. Drainage and sewerage - External Networks and Facilities - Design Standard.