Application of GIS and SWMM model to assess urban flooding in Hung Phu 1 Residential Area of Cai Rang District

Ngan Thanh Nguyen^{1,*}, Trung Hieu Nguyen²

ABSTRACT

Cai Rang District is a fast-growing urban district in Can Tho City. In recent years, the construction land areas in this district have expanded at a rapid rate, showing that the urbanization level in this region is guite strong. Besides urbanization, Cai Rang District also faces three important environmental problems: climate change, land subsidence, sea level rise. These problems make urban flooding in this inner-city district quite serious. One of the areas often affected by urban flooding in Cai Rang District is Hung Phu 1 Residential Area. This paper introduces the preliminary results of the application of GIS and SWMM model to assess urban flooding in Hung Phu 1 Residential Area. The research has shown the main features of urban flooding in the study area, including the degree of flooding, time of flooding, flow velocity, flood volume and locations that were often flooded. Simulation results from the SWMM model indicate that when heavy rain and high tide occur at the same time, most roads in the northern area of Hung Phu 1 Residential Area were flooded. Heavily flooded roads were Ly Thai To Street, Nguyen Ngoc Bich Street, Hoang Van Thai Street, A2 Street, A6 Street, B3 Street, B18 Street, B20 Street, B23 Street. The day with the heaviest flooding in the study area was 22/10/2021. The obtained data is an important basis for developing suitable flood reduction solutions and improving the quality of life of the residents in Hung Phu 1 Residential Area. Key words: Urban flooding, GIS, SWMM model, Cai Rang District, Hung Phu 1 Residential Area

¹Ho Chi Minh City University of Natural Resources and Environment, Ho Chi Minh City, Vietnam

²Can Tho University, Can Tho City, Vietnam

Correspondence

Ngan Thanh Nguyen, Ho Chi Minh City University of Natural Resources and Environment, Ho Chi Minh City, Vietnam

Email: ntngan@hcmunre.edu.vn

History

- Received: 16-10-2023
- Revised: 30-5-2024
- Accepted: 18-12-2024
- Published Online: 31-12-2024

DOI :

https://doi.org/10.32508/stdjsee.v8i2.768

Check for updates

Copyright

© VNUHCM Press. This is an openaccess article distributed under the terms of the Creative Commons Attribution 4.0 International license.



INTRODUCTION

Cai Rang is a fast-growing urban district located in the south of Can Tho City. This district is an important socio-economic center of the city. According to statistical data for 2021, Cai Rang district has an area of 67.82 km², a population of 107,766 people with a population density of 1,589 person/km², is one of the three administrative units with the largest population concentration in Can Tho City¹. The whole district has a combined drainage system for both storm water and wastewater like most other urban areas in Vietnam². In the current period, Cai Rang District has the phenomenon of increasing construction land area at a rapid rate. This phenomenon shows that this area has a strong urbanization level. Besides urbanization, three other environmental problems that Cai Rang District is facing are climate change, land subsidence and sea level rise³. These negative environmental problems make urban flooding in this district quite serious.Hung Phu 1 Residential Area is located in the north of Cai Rang District, which is an area frequently impacted by urban flooding. This is a new residential area with modern infrastructure and convenient location for socio-economic development. In recent years, this residential area is often flooded in the rainy season, especially on days with heavy rain and high

tide. Urban flooding has made travel difficult, creating an environment for disease transmission and reducing the quality of life of residents. In order to reduce the negative impacts of flooding, this research is handled to combine GIS and SWMM model to assess urban flooding in Hung Phu 1 Residential Area. The SWMM model has been used in many countries to solve problems related to urban flooding, bringing many practical and positive results in drainage management ^{4–14}. The SWMM model is also used in many localities in Vietnam to support urban drainage and flood control ^{15–19}.

RESEARCH METHODS

Research methods

To work out the research problem, a directional approach using GIS combined with drainage model is deployed to assess urban flooding in Hung Phu 1 Residential Area. GIS is used to build data layers describing the drainage network, while drainage model is used to imitate urban flooding. The QGIS software is chosen to digitize the drainage data layers because it is open source software so it is royalty free to use. In addition, this software has a diverse and efficient library of supporting tools. The drainage model chosen to simulate urban flooding is SWMM because it

Cite this article : Nguyen N T, Nguyen T H. **Application of GIS and SWMM model to assess urban flooding in Hung Phu 1 Residential Area of Cai Rang District** . *Sci. Tech. Dev. J. - Sci. Earth Environ.* 2024 8(2):953-964.



has proven effective in solving flooding problems in many countries. In this research the flooding assessment process is divided into six main steps: (1) gathering pertinent data, (2) digitizing drainage data layers with QGIS software, (3) processing input data, (4) simulating urban flooding with SWMM model, (5) presenting the results in the form of maps and graphs, (6) analyzing the results and suggesting solutions. The general research process is shown in Figure 1.

Research data

To assess urban flooding in Hung Phu 1 Residential Area, this research uses four main types of data: (1) reports on urban drainage and flooding, (2) rainfall and water level data, (3) high resolution satellite images, (4) the drainage drawings. Urban drainage and flooding reports are used to assess the overall status of drainage in Hung Phu 1 Residential Area. These reports are collected from the Can Tho City Department of Construction. Rainfall and water level data, an important input to the SWMM model, are gathered from the Can Tho City Hydrometeorological Center. High resolution satellite images are collected using Google Earth Pro software. The images showing the land covers of Hung Phu 1 Residential Area belong to the Maxar Technologies imagery. The drainage drawings depicting the main components of the drainage network is obtained from the Can Tho City Department of Construction. Figure 2 shows the study area selected to simulate urban flooding.

RESULTS AND DISCUSSION

Results of building vector drainage data layers in Hung Phu 1 Residential Area

The drainage data layers of Hung Phu 1 Residential Area are built using the Create Layer tool of QGIS software. These data layers are digitized based on high resolution satellite images and drainage drawings with the format selected as Shapefile (*.shp) to suit various GIS software. High resolution satellite images are collected using Google Earth Pro software, and then converted from the original coordinate system to UTM zone 48N WGS84 coordinate system. Drainage drawings from the Can Tho City Department of Construction are used to extract the necessary data layers and georeferenced in UTM zone 48N WGS84 coordinate system. After georeferencing process, drainage drawings are converted to Shapefile format to be used on QGIS software.Based on satellite images and drainage drawings, vector data layers representing the main components of the drainage network of Hung Phu 1 Residential Area are created. These components include roads, sidewalks, blocks, vegetation covers, sewers and manholes in the study area. The subcatchment layer is built based on blocks and vegetation covers with 129 objects. The link layer is built based on sewers with 366 objects. The node layer is built based on manholes with 361 objects. The above three data lavers (subcatchments, links, nodes) are the basic components to generate input data describing the drainage network in the SWMM model. Figure 3 depicts the thematic map showing the main components of the drainage network in the study area.



Figure 2: The map of Hung Phu 1 Residential Area.



Figure 3: The thematic map of the main components of the drainage network in Hung Phu 1 Residential Area.

Results of simulating urban flooding in Hung Phu 1 Residential Area

The input data for the SWMM model is built based on the vector drainage data layers digitized using the QGIS software. The properties of the subcatchments are updated based on information from satellite images and vector layers. The main components of the drainage network on the SWMM model are depicted in Figure 4. Hourly rainfall and water level data are also two important data types for operating the SWMM model. These types of data are collected from the Can Tho City Hydrometeorological Center with time series format. The urban flooding simulation process is carried out during the period from 20/10/2021 to 23/10/2021. This period is chosen because of heavy rain and high water levels. Figure 5 shows the graphs of hourly rainfall and water level in Can Tho City during the simulation period.

After the input data preparation step is the model calibration step, the parameters of the SWMM model are adjusted to suit the actual conditions in the study area. Adjusting the roughness coefficient of the conduits, the slope of the subcatchments, the roughness coefficient of the permeable and impermeable surfaces through the following steps:

- Simulating and comparing simulation results using the SWMM model with measurement results on 20/10/2021.

- Adjusting the parameter set by the gradual trial method for the parameters selected for the initial simulation to increase the NASH.

- Using the adjusted parameters to validate the model with data on 21/10/2021.

The validated parameters are selected as follows:

- The roughness coefficient of the conduits: 0.015.

- The slope of the subcatchments: 0.50.

- The roughness coefficient of the permeable surfaces: 0.15.

- The roughness coefficient of the impermeable surfaces: 0.013.

Validating results at outfall N151 located on Nguyen Ngoc Bich Street of Hung Phu 1 Residential Area show that the NASH coefficient is 0.94. Figure 6 is the graph comparing simulated and measured flow rate at outfall N151 during the validation period.

After being calibrated and verified, the SWMM model is used to simulate urban flooding in the study area at selected time period (4 days). Preliminary flood simulation results at Hung Phu 1 Residential Area are shown in Figure 7 to Figure 14 respectively.

The modeling results show that 348 out of 361 nodes (about 96% of the total) are flooded due to the influence of rain and tide during the simulation period.

The simulation results also express that maximum rate varies from 2.37 l/s to 19,022.46 l/s, total flood volume varies from 1,000 l to 14,230,000 l, flooding time varies from 0.01 hours to 2.81 hours. The day with the highest number of flooded nodes during the simulation period in the study area is 22/10/2021. The node with the longest flooding time is N188 (2.81 hours) on Nguyen Ngoc Bich Street. The simulation results also show that most of the roads in Hung Phu 1 Residential Area are flooded during the study period due to the impact of rain and high tide. Table 1 introduces some typical parameters of the nodes with the longest flooding time in the simulation area.

CONCLUSION

The simulation results have reflected the current status of urban flooding in the study area through characteristic parameters such as flow rate, flow velocity, flood volume, inundation times and hours of flooding. The data from the simulation show the level of flooding and frequently flooded locations in Hung Phu 1 Residential Area. Simulation results from the SWMM model indicate that when heavy rain and high tide occur at the same time, most roads in the northern area of Hung Phu 1 Residential Area were flooded. Heavily flooded roads were Ly Thai To Street, Nguyen Ngoc Bich Street, Hoang Van Thai Street, A2 Street, A6 Street, B3 Street, B18 Street, B20 Street, B23 Street. The areas with the longest flooding time were on Nguyen Ngoc Bich Street. The day with the highest number of flooded points during the simulation period was 22/10/2021. The information obtained from the simulation is the initial basis for building appropriate solutions for each flooded location, thereby minimizing the harmful effects of urban flooding and improving the quality of life of the residents in the study area. This research also proved that the SWMM model is a useful tool for scientists and managers in urban flood assessment. The research has built a process using QGIS software in combination with SWMM model to assess urban flooding, reducing time and labor in building input data for drainage model, creating an effective method in studying urban flooding. The research results and methods used are a useful reference for similar studies on urban flooding in Can Tho City in particular and the Mekong Delta in general.

ACKNOWLEDGMENT

The authors would like to thank the DRAGON-Mekong Institute at Can Tho University, the Can Tho City Department of Construction and the Can Tho City Hydrometeorological Center for providing data support for this research.



Figure 4: The diagram of drainage network at Hung Phu 1 Residential Area on SWMM model.

Table 1: The parameters of the nodes with the longest flooding time.

ID	Node	Flooding Time (hours)	Maximum Rate (l/s)	Time of Max Occurrence	
				Day	Time
1	N188	2.81	77.08	22/10/2021	18:09
2	N195	2.78	39.32	22/10/2021	18:23
3	N265	2.52	14.09	22/10/2021	18:15
4	N192	2.41	156.58	22/10/2021	17:54
5	N118	2.31	158.51	22/10/2021	18:15
6	N190	2.16	80.26	22/10/2021	17:54
7	N194	2.09	22.35	22/10/2021	18:15
8	N189	1.98	37.2	22/10/2021	18:15
9	N207	1.95	34.45	22/10/2021	18:02
10	N193	1.92	70.87	22/10/2021	17:54



Figure 5: The graphs show the hourly rainfall and water level in the period from 20/10/2021 to 23/10/2021.







Figure 7: The diagrams show Max Lat Flow (m³/s) at nodes in Hung Phu 1 Residential Area.







Figure 9: The diagrams show Total Flooding (megaliter) at nodes in Hung Phu 1 Residential Area.





Science & Technology Development Journal - Science of The Earth & Environment 2025, 8(2):953-964



Figure 11: The diagrams Max Flow (m³/s) at links in Hung Phu 1 Residential Area.





Science & Technology Development Journal - Science of The Earth & Environment 2025, 8(2):953-964



Figure 13: The diagrams Hours Full (hour) at links in Hung Phu 1 Residential Area.





ABBREVIATIONS

SWMM: Storm Water Management Model

CONFLICTS OF INTEREST

The authors would like to confirm that there is no conflicts of interest in publishing the article.

AUTHORS' CONTRIBUTIONS

The manuscript was prepared by Ngan Thanh Nguyen; Comments and edits of the manuscript made by Trung Hieu Nguyen.

REFERENCES

- Can Tho City Statistics Office . Can Tho City Statistical Yearbook 2021. Statistical Publishing House Publishing registration confirmation number: 1907-2022/CXBIPH/09-15/TK. 2022;67-75;.
- Can Tho City Department of Construction. Thuyết minh tổng hợp Quy hoạch thoát nước thành phố Cần Thơ đến năm 2030, tẩm nhìn đến năm 2050: Chương 3 Hiện trạng thoát nước. General explanation Can Tho City. 2016; III-2-III-53;.
- World Bank Group. Can Tho, Vietnam: Enhancing Urban Resilience. Global Practice on Social, Urban, Rural and Resilience, The World Bank Group, 1818 H Street NW, Washington D.C 20433, USA, 8-79, Access date 29/08/2022.
 2014;Available from: https://openknowledge.worldbank.org/ handle/10986/20743.
- Badiezadeh S, Bahremand A, Dehghani AA. Urban flood management by simulation of surface runoff using SWMM model in Gorgan city, Golestan Province-Iran. J Water Soil Conserv. 2015;22(4):155-70;.
- Jiang L, Chen Y, Wang H. Urban flood simulation based on the SWMM model. Proc Int Assoc Hydrol Sci. 2015;368:186-91;Available from: https://doi.org/10.5194/piahs-368-186-2015.
- Babaei S, Ghazavi R, Erfanian M. Urban flood simulation and prioritization of critical urban sub-catchments using SWMM model and PROMETHEE II approach. Phys Chem Earth A/B/C. 2018;105:3-11;.
- Wu X, Wang Z, Guo S, Lai C, Chen X. A simplified approach for flood modeling in urban environments. Hydrol Res. 2018;49(6):1804-16;.
- 8. Bai Y, Zhao N, Zhang R, Zeng X. Storm water management of low impact development in urban areas based on SWMM.

Water. 2019;11(1):33;Available from: https://doi.org/10.3390/w11010033.

- Ahamed SMF, Agarwal S. Urban flood modeling and management using SWMM for New R.R. Pet region, Vijayawada, India. Int J Recent Technol Eng (JJRTE). 2019;7(6C2):317-22;.
- Agarwal S, Kumar S. Urban flood modeling using SWMM for historical and future extreme rainfall events under climate change scenario. Indian J Ecol. 2020;47(11):48-53;.
- Sañudo E, Cea L, Puertas J. Modelling pluvial flooding in urban areas coupling the models iber and SWMM. Water. 2020;12(9):2647;Available from: https://doi.org/10.3390/ w12092647.
- Brendel CE, Dymond RL, Aguilar MF. Modeling storm sewer networks and urban flooding in Roanoke, Virginia, with SWMM and GSSHA. J Hydrol Eng. 2021;26(1):05020044;Available from: https://doi.org/10.1061/(ASCE)HE.1943-5584. 0002021.
- Ma B, Wu Z, Hu C, Wang H, Xu H, Yan D. Process-oriented SWMM real-time correction and urban flood dynamic simulation. J Hydrol. 2022;605:127269;Available from: https://doi. org/10.1016/j.jhydrol.2021.127269.
- Wang H, Hu Y, Guo Y, Wu Z, Yan D. Urban flood forecasting based on the coupling of numerical weather model and stormwater model: A case study of Zhengzhou city. J Hydrol Reg Stud. 2022;39:100985;Available from: https://doi.org/10. 1016/j.ejrh.2021.100985.
- Huong HTL, Pathirana A. Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam. Hydrol Earth Syst Sci. 2013;17(1):379-94;.
- Hai DM. Ảnh hưởng của các đặc trưng mưa thiết kế tới hiệu quả kiểm soát dòng chảy của các công trình thoát nước bền vững. J Water Resour Environ Eng. 2020;68:98-106;.
- Len NT. Ứng dụng mô hình thủy văn EPA SWMM, sóng động lực Hydrodynamic wave phân tích mạng lưới thoát nước cho khu đô thị mới Lê Minh Xuân, quận Bình Chánh, TP. Hồ Chí Minh. Univ Danang - J Sci Technol. 2020;18(7):90-5;.
- Nu HTT, Vu DT, Phung LV, Van CT. Mô phỏng mức độ ngập và để xuất giải pháp thoát nước chống ngập cho khu vực Văn Thánh - Thành phố Hồ Chí Minh. Vietnam J Hydrometeorol. 2020;716:12-25;Available from: https://doi.org/10.36335/ VNJHM.2020(716).12-25.
- Ngan NVC, Nam NDG, Toan NN. Ứng dụng mô hình SWMM đề xuất giải pháp giảm ngập cho quận Bình Thủy, thành phố Cần Thơ. In: International Conference on Sustainable Construction Development in the Context of Climate Change in the Mekong Delta (SCD2021). 2021. p. 199-207. ISBN 978-604-82-5956-3;.

Open Access Full Text Article

Ứng dụng GIS và mô hình SWMM đánh giá hiện tượng ngập đô thị tại Khu dân cư Hưng Phú 1 Quận Cái Răng

Nguyễn Thanh Ngân^{1,*}, Nguyễn Hiếu Trung²

TÓM TẮT

Quân Cái Răng là một quân nội độ có tốc độ phát triển nhanh ở Thành phố Cần Thơ. Trong những năm gần đây, diện tích đất xây dựng trên địa bàn quận mở rộng với tốc độ nhanh cho thấy mức độ đô thị hóa tại khu vực này khá mạnh. Bên cạnh đô thị hóa, Quận Cái Răng còn phải đối mặt với ba vấn đề môi trường quan trọng: biến đổi khí hậu, sụt lún đất, nước biển dâng. Những vấn đề này khiến tình trạng ngập đô thị tại vùng này khá nghiêm trọng. Một trong những khu vực thường xuyên bị ảnh hưởng bởi ngập đô thị ở quận Cái Răng là Khu dân cư Hưng Phú 1. Bài báo giới thiệu kết quả ứng dụng công nghệ GIS và mô hình SWMM để đánh giá hiện tượng ngập đô thị tại Khu dân cư Hưng Phú 1. Nghiên cứu đã chỉ ra những đặc điểm chính của hiện tượng ngập đô thị tại khu vực nghiên cứu bao gồm mức độ ngập, thời gian ngập, lượng lũ, vận tốc dòng chảy và các vị trí thường bị ngập. Kết quả mô phỏng từ mô hình SWMM cho thấy khi mưa lớn và triều cường xảy ra cùng lúc, hầu hết các tuyến đường ở khu vực phía Bắc Khu dân cự Hưng Phú 1 đều bị ngập. Các tuyến đường bị ngập nặng là đường Lý Thái Tổ, đường Nguyễn Ngọc Bích, đường Hoàng Văn Thái, đường A2, đường A6, đường B3, đường B18, đường B20, đường B23. Ngày xảy ra tình trạng ngập lụt nặng nhất tại khu vực nghiên cứu là ngày 22/10/2021. Các số liệu thu được là cơ sở quan trọng để xây dựng các giải pháp giảm ngập phù hợp và nâng cao chất lượng cuộc sống của người dân Khu dân cư Hưng Phú 1

Từ khoá: Ngập đô thị, GIS, mô hình SWMM, Quận Cái Răng, Khu dân cư Hưng Phú 1

¹Trường Đại học Tài nguyên và Môi trường Thành phố Hồ Chí Minh, Thành phố Hồ Chí Minh, Việt Nam

²Đại học Cần Thơ, Thành phố Cần Thơ, Việt Nam

Liên hệ

Nguyễn Thanh Ngân, Trường Đại học Tài nguyên và Môi trường Thành phố Hồ Chí Minh, Thành phố Hồ Chí Minh, Việt Nam

Email: ntngan@hcmunre.edu.vn

Lịch sử

- Ngày nhận: 16-10-2023
- Ngày sửa đổi: 30-5-2024
- Ngày chấp nhận: 18-12-2024
- Ngày đăng: 31-12-2024

DOI: https://doi.org/10.32508/stdjsee.v8i2.768



Bản quyền

© ĐHQG Tp.HCM. Đây là bài báo công bố mở được phát hành theo các điều khoản của the Creative Commons Attribution 4.0 International license.



Trích dẫn bài báo này: Ngân N T, Trung N H. Ứng dụng GIS và mô hình SWMM đánh giá hiện tượng ngập đô thị tại Khu dân cư Hưng Phú 1 Quận Cái Răng . Sci. Tech. Dev. J. - Sci. Earth Environ. 2024, 8(2):953-964.