APPLICATION OF KRIGING INTERPOLATION METHOD ON BUILDING THE DIGITAL ELEVATION MODELS FOR NINH KIEU AND CAI RANG DISTRICTS OF CAN THO CITY

Nguyen Thanh Ngan[1,2], Nguyen Hieu Trung[3]

[1]Faculty of Environment, Ho Chi Minh City University of Natural Resources and Environment (HCMUNRE), 236B Le Van Sy Street, Ward 1, Tan Binh District, HCM City.
[2]College of Environment and Natural Resources, Can Tho University (CTU), Campus II, 3/2 Street, Xuan Khanh Ward, Ninh Kieu District, Can Tho City.
Email: ntngan@hcmunre.edu.vn
[3]DRAGON Institute - Mekong, Can Tho University (CTU), Campus II, 3/2 Street, Xuan Khanh Ward, Ninh Kieu District, Can Tho City.
Email: nhtrung@ctu.edu.vn

ABSTRACT

Ninh Kieu and Cai Rang are two urban districts established in 2004 of Can Tho City. These are thriving areas of the city and the Mekong Delta, with a long history of exploration and development. According to data from the Statistics Office of Can Tho City in 2019, Ninh Kieu District has an average population of 280,792 people and an area of 29.23 km^2, while Cai Rang District has an average population of 105,547 people and an area of 66.81 km^2. These two districts are currently facing major urban drainage challenges due to rapid urbanization. To address these challenges, it is necessary to develop a mathematical model for the urban drainage system in the study area, as a basis for providing appropriate solutions for drainage management. One of the important input data for the mathematical model building process is the digital elevation model. This paper initiates the preliminary results of building the digital elevation models based on Kriging interpolation method for Ninh Kieu and Cai Rang districts. This is also a useful data for drainage management and environmental management in the study area.

Keywords: digital elevation model, Kriging interpolation method, drainage management, Ninh Kieu District, Cai Rang District.

1. INTRODUCTION

Ninh Kieu and Cai Rang are two potential districts and also dynamic socio-economic centers of Can Tho City in the current period. These two districts were established in 2004 by the Government's Decree No. 05/2004/ND-CP (Vietnam Government, 2004). Due to the geographical position located in the right bank of the Hau River, these two districts have a system of rivers and canals that are greatly influenced by the tidal regime of this river (Can Tho City Department of Construction, 2016). Ninh Kieu and Cai Rang districts have a natural feature of low and flat terrain, so these two areas often experience heavy urban flooding (Can Tho City Department of Construction, 2016). Based on 2019 data, Ninh Kieu District has an average population of 280,792 people (133,911 men/146,881 women) and an area of 29.23 km^2, while Cai Rang District has an average population of 105,547 people (52,241 men/53,306 women) and an area of 66.81 km^2 (Can Tho City Statistics Office, 2020). The population densities of Ninh Kieu and Cai Rang districts in 2019 were 9,605 people/km^2 and 1,580 people/km^2 respectively (Can Tho City Statistics Office, 2020). Along with the socio-economic development, the urbanization process in these two urban districts has taken place at a fast pace and a complicated direction in recent years. This process has created major challenges for urban

management in these regions, among which is drainage management.

To address these challenges, managers in Ninh Kieu and Cai Rang districts need to apply new technologies to drainage management. One of the suitable solutions is to use urban stormwater modeling to solve the problems of urban drainage and flooding in these regions. This solution has been widely applied in many parts of the world and brought many practical and positive results in the field of drainage management (Montaseri *et al.*, 2015; Bisht *et al.*, 2016; Cipolla *et al.*, 2016; Chen *et al.*, 2017; Babaei *et al.*, 2018; Luan *et al.*, 2019; Macro *et al.*, 2019; Yazdi *et al.*, 2019.). To operate this mathematical model, one of the required input data types is the digital elevation model (DEM). This paper introduces the main results of building DEMs for Ninh Kieu and Cai Rang districts based on Kriging interpolation method (Goovaerts, 2019). Besides acting as an input data for the drainage mathematical model, DEMs are also a useful information for drainage management in particular and environmental management in general in the study area.

2. METHODS AND DATA

2.1 Research methods

Spatial interpolation method is used to generate DEMs for Ninh Kieu and Cai Rang districts. The interpolation algorithm used in this research is Kriging, also known as Gaussian process regression. Kriging is a type of spatial interpolation that estimates values at unsampled locations using a linear combination of measured values at nearby sampled locations (Goovaerts, 2019). The estimated result from the Kriging algorithm depends on three main factors: (1) the distance to the unsampled location, (2) the spatial arrangement of all sampled points, (3) the spatial correlation characteristics of the dataset (Goovaerts, 2019). The process of building DEMs for the study area is divided into five main stages: (1) collecting relevant data, (2) preprocessing digital map data, (3) interpolating point dataset to build DEMs, (4) correcting DEMs error with administrative boundary and hydrological network data, (5) evaluating results and drawing conclusions. The detailed implementation process of this research is shown in Figure 1.

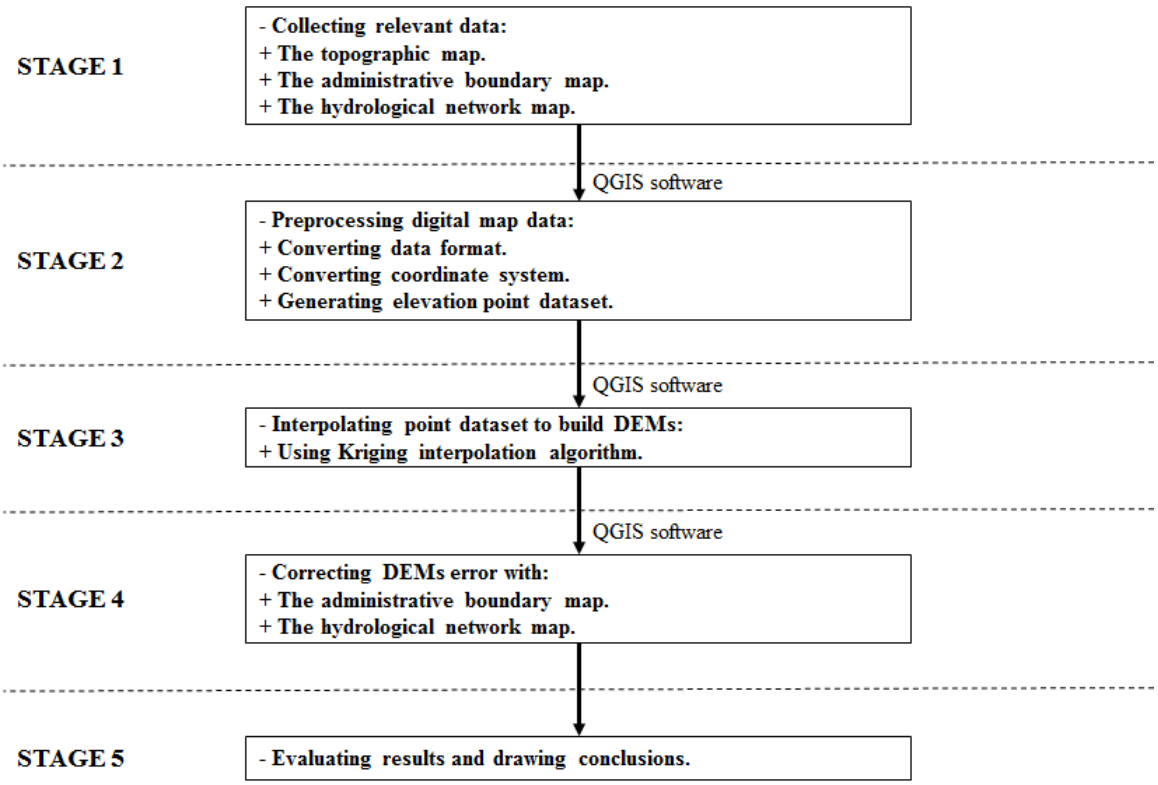

Figure 1. The detailed implementation process of the research.

2.2 Research data

The main data source used in this study is the digital maps of the two districts of Ninh Kieu and Cai Rang. The first type of digital map used is the topographic maps of the study area, which was collected from two main sources, the Mekong Delta Geographic Information Systems Project and the Can Tho City Department of Construction, in various formats. These topographic maps are reprocessed and converted into a uniform elevation point dataset in shapefile format. This elevation point dataset is the input data for spatial interpolation by Kriging algorithm to form DEMs using Quantum GIS (QGIS) software (Goovaerts, 2019). The second type of digital map used is the administrative boundary maps of the study area. These administrative boundary maps are used to define the spatial extent of the DEMs. The third type of digital map used is the hydrological network maps of the study area. These hydrological network maps are used to correct DEMs error by removing elevation values at water surface locations. Figure 2 depicts the administrative scope of the study area including Ninh Kieu and Cai Rang districts.

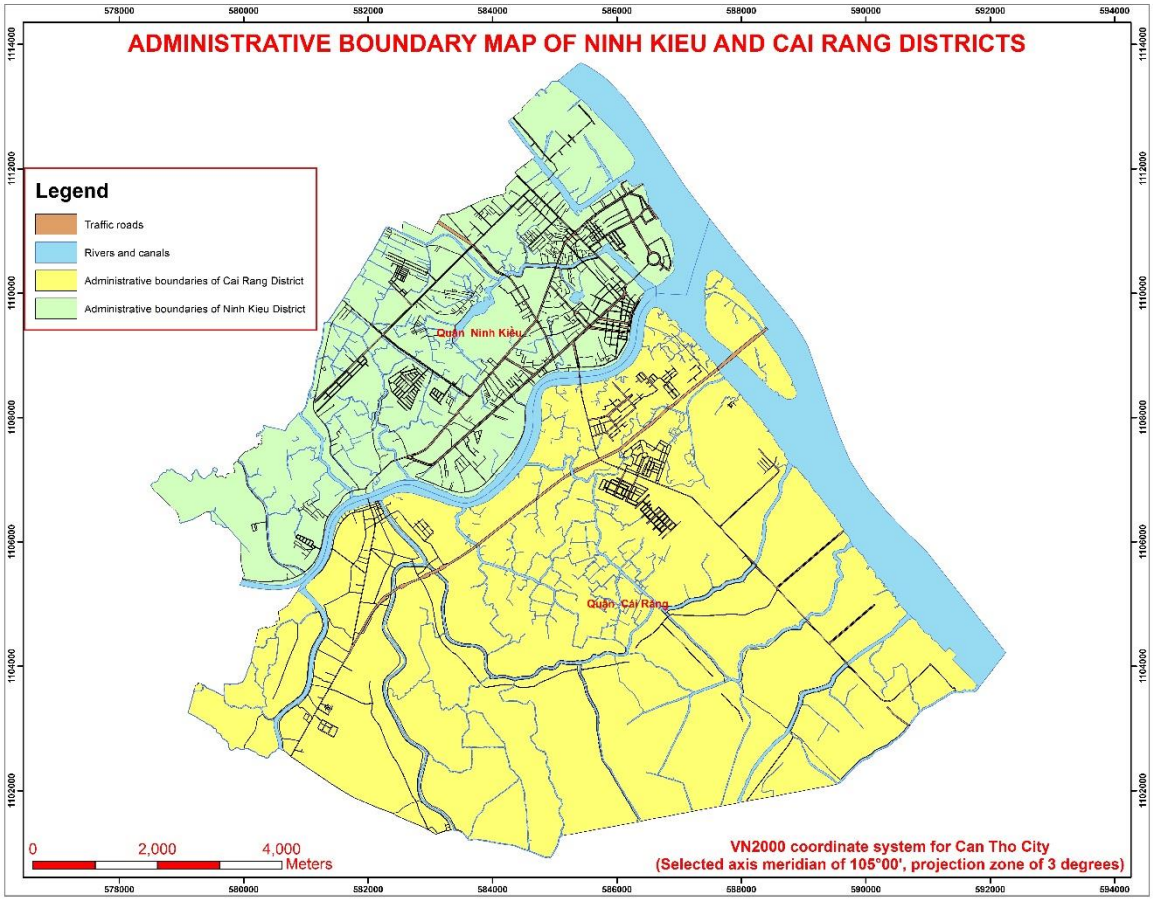

Figure 2. The administrative scope of the study area.

3. RESULTS AND DISCUSSION

In the first phase of the study, the topographic maps of Ninh Kieu and Cai Rang districts were collected from the Mekong Delta Geographic Information Systems Project and the Can Tho City Department of Construction in various formats. These topographic maps are reprocessed to the same format and geographic coordinate system, and then converted into an elevation point dataset. This elevation point dataset is the input data for the spatial interpolation process to create the DEMs on QGIS software. The SAGA toolkit operating on QGIS software is used to generate raster interpolated surfaces from the point dataset. The interpolation algorithm used in this process is Kriging. Location of elevation points in the study area is shown in Figure 3.

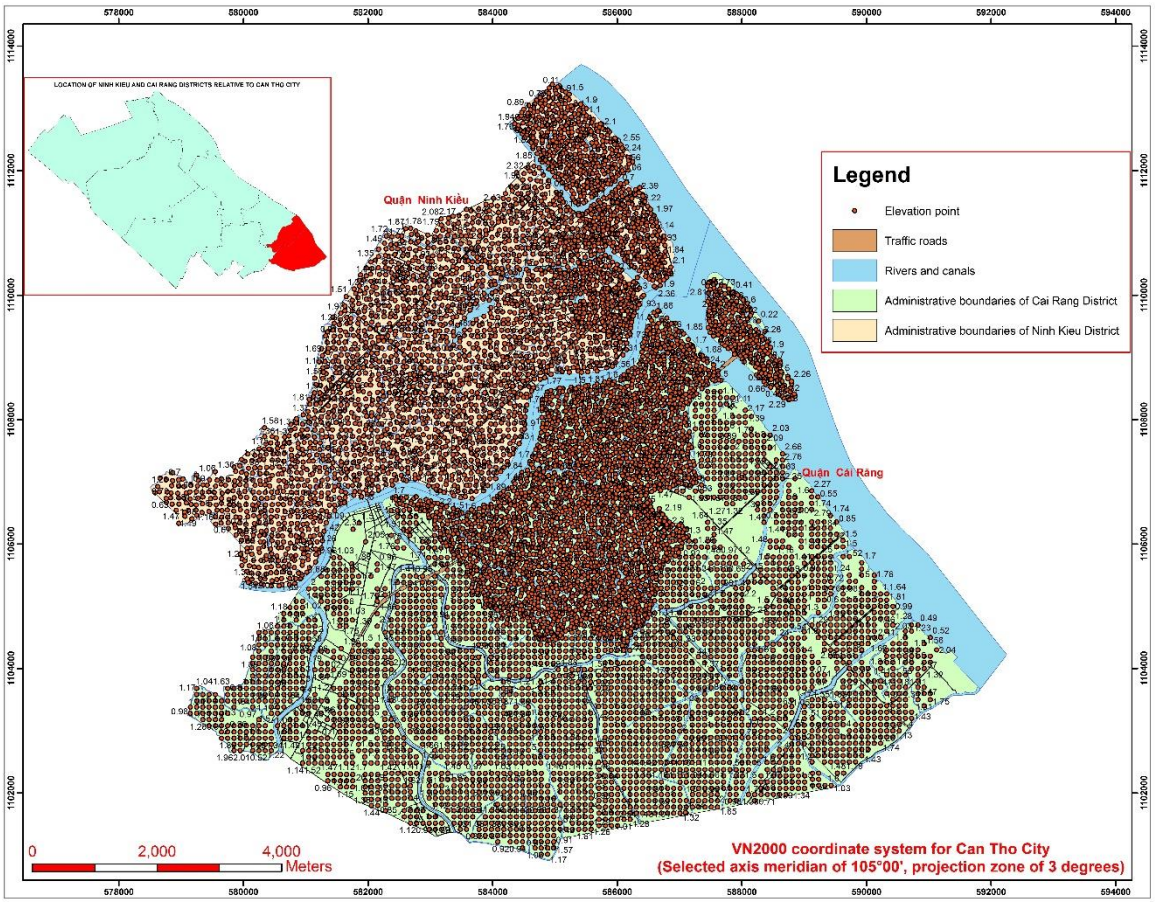

Figure 3. Elevation point locations in the study area.

After the spatial interpolation step, the generated DEMs are clipped based on administrative boundary vector data to remove the redundant parts that are outside the scope of the study area. The hydrological network data is converted from vector to raster using the Rasterize tool and then used to correct the clipped DEMs. This correction process removes the elevation values at the water surface grid cells on the clipped DEMs. The DEMs representing the topographical surface of the study area after correction are shown in Figure 4 and 5.

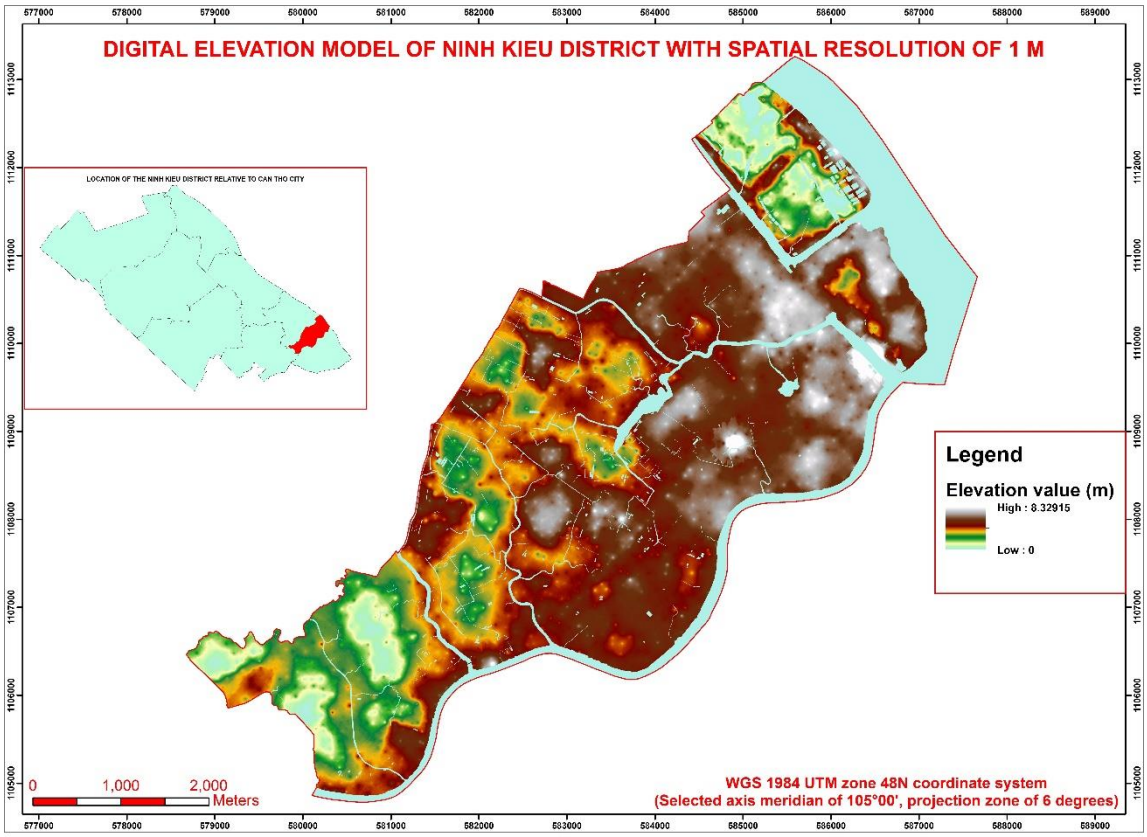

Figure 4. The digital elevation model of Ninh Kieu District.

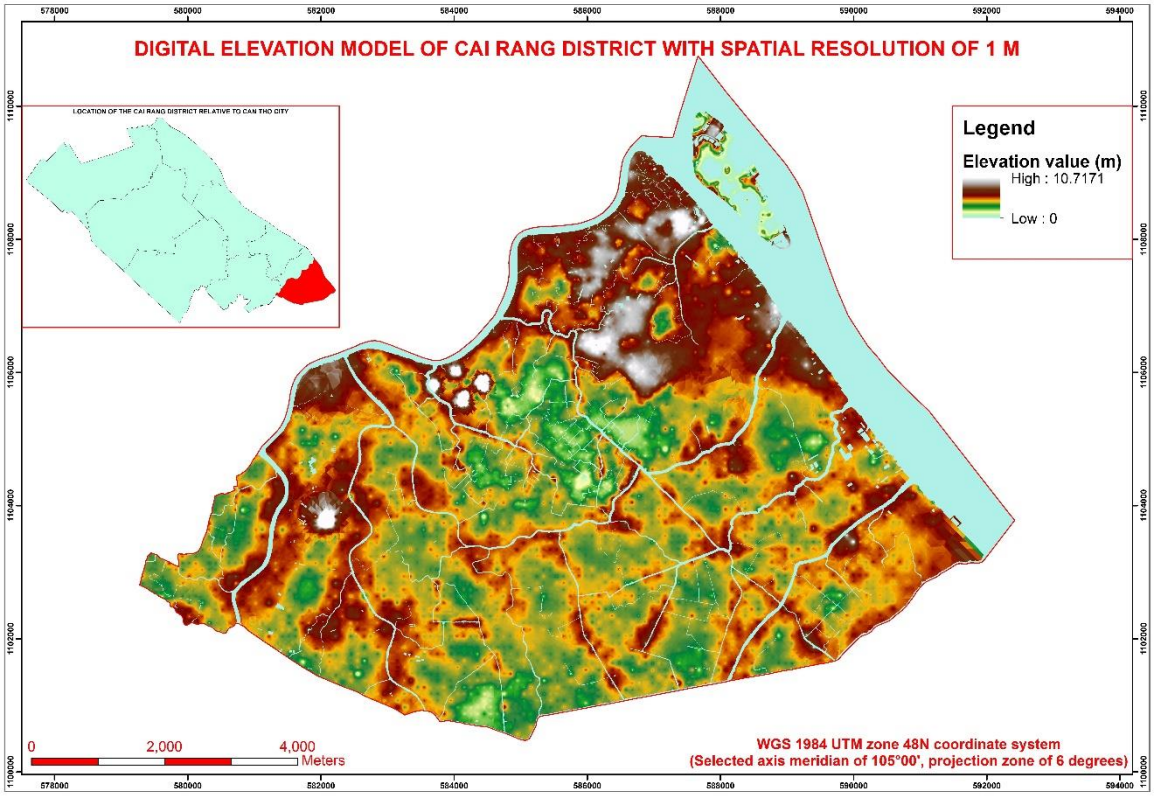

Figure 5. The digital elevation model of Cai Rang District.

The DEM created to represent the topographical surface of Ninh Kieu District has a total area of 29.06 km^2 with spatial resolution of 1.00 m, average elevation of 1.36 m, maximum elevation of 8.33 m and minimum elevation of 0.00 m. Meanwhile, the DEM created for Cai Rang District has a total area of 67.56 km^2 with spatial resolution of 1.00 m, average elevation of 1.15 m, maximum elevation of 10.72 m and minimum elevation of 0.00 m. Table 1 shows the basic statistics of the DEMs generated for the two districts of Ninh Kieu and Cai Rang.

Table 1. The basic statistics of the DEMs for Ninh Kieu and Cai Rang districts.

Statistics of the DEMs	Ninh Kieu District	Cai Rang District
Columns	**8,986**	**13,147**
Rows	**8,476**	**10,285**
Cells	**29,063,042**	**67,557,805**
Area Value	**29.06 km^2**	**67.56 km^2**
Spatial Resolution	**1.00 m**	**1.00 m**
Spatial Reference	**WGS 1984 UTM zone 48N**	**WGS 1984 UTM zone 48N**
Maximum Elevation Value	**8.33 m**	**10.72 m**
Minimum Elevation Value	**0.00 m**	**0.00 m**
Average Elevation Value	**1.36 m**	**1.15 m**
Standard Deviation	**0.69 m**	**0.57 m**

4. CONCLUSIONS AND RECOMMENDATIONS

The research has built DEMs for two districts of Ninh Kieu and Cai Rang from a dataset of elevation points in Shapefile format. These DEMs have a spatial resolution of 1.00 m, with a geographic coordinate system of WGS 1984 UTM zone 48N, built on the *.GIF raster format. The generated DEMs are input data for mathematical models used to simulate urban drainage systems in two districts of Ninh Kieu and Cai Rang. In addition, these DEMs are also a valuable reference source for environmental resource management in the study area. The future direction of the research is to use more elevation points to increase the accuracy of the DEMs.

5. ACKNOWLEDGMENTS

The authors would like to thank the ValBGI Project for sharing as well as supporting and introducing to collect data from the authorities of the Mekong Delta, the Mekong Delta Geographic Information Systems Project (MGIS) of Assoc. Prof. Dr. Le Van Trung for providing data support for this research.

6. REFERENCES

Babaei, S., Ghazavi, R., Erfanian, M., 2018. Urban flood simulation and prioritization of critical urban sub-catchments using SWMM model and PROMETHEE II approach. *Physics and Chemistry of the Earth, Parts A/B/C, 105,* 3-11.

Bisht, D. S., Chatterjee, C., Kalakoti, S., Upadhyay, P., Sahoo, M., Panda, A., 2016. Modeling urban floods and drainage using SWMM and MIKE URBAN: a case study. *Natural Hazards 84(2),* 749-776.

Can Tho City Department of Construction, 2016. *Thuyết minh tổng hợp Quy hoạch thoát nước thành phố Cần Thơ đến năm 2030, tầm nhìn đến năm 2050: Chương 3 Hiện trạng thoát nước*. General explanation Can Tho City, III-2-III-53.

Can Tho City Statistics Office, 2020. *Can Tho City Statistical Yearbook 2019*. Statistical Publishing House Publishing, Registration confirmation number: 2075-2020/CXBIPH/05-14/TK, 21-85.

Chen, W., Huang, G., Zhang, H., 2017. Urban stormwater inundation simulation based on SWMM and diffusive overland-flow model. *Water science and technology, 76(12), 3392-3403.*

Cipolla, S. S., Maglionico, M., Stojkov, I., 2016. A long-term hydrological modelling of an extensive green roof by means of SWMM. *Ecological Engineering 95, 876-887.*

Goovaerts, P., 2019. *Kriging Interpolation*. The Geographic Information Science and Technology Body of Knowledge (4th Quarter 2019 Edition), John P. Wilson (ed.), DOI: 10.22224/gistbok/2019.4.4.

Luan, B., Yin, R., Xu, P., Wang, X., Yang, X., Zhang, L., Tang, X., 2019. Evaluating Green Stormwater Infrastructure strategies efficiencies in a rapidly urbanizing catchment using SWMM-based TOPSIS. *Journal of Cleaner Production 223,* 680-691.

Macro, K., Matott, L. S., Rabideau, A., Ghodsi, S. H., Zhu, Z., 2019. OSTRICH-SWMM: A new multi-objective optimization tool for green infrastructure planning with SWMM. *Environmental Modelling and Software 113*, 42-47.

Montaseri, M., Afshar, M. H., Bozorg-Haddad, O., 2015. Development of simulation-optimization model (MUSIC-GA) for urban stormwater management. *Water resources management 29(13),* 4649-4665.

Vietnam Government, 2004. *Decree on establishing Ninh Kieu, Binh Thuy, Cai Rang, O Mon, Phong Dien, Co Do, Vinh Thanh, Thot Not districts and communes, wards, towns of Can Tho City under the Central Government*. Number: 05/2004/ND-CP, 1-6.

Yazdi, M. N., Ketabchy, M., Sample, D. J., Scott, D., Liao, H., 2019. An evaluation of HSPF and SWMM for simulating streamflow regimes in an urban watershed. *Environmental Modelling and Software 118,* 211-225.