MASTER THESIS: FINAL REPORT

Development of Climate change related Flood Risk Adaptation Strategies and Measures in Ho Chi Minh City, Vietnam

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Before taking the very first step in doing this research, I had a lot of thoughts that kept lingering in my mind and almost all of them were worries. I worried that as I will do this research in Ho Chi Minh City, Vietnam and my supervisor is in the Netherlands, whether with different time zones, I can communicate with him smoothly. Also, around one month before the deadline of my master thesis, I kept thinking that this research is too difficult for me to handle as the research topic is new to me and that time I do realize I do not have enough knowledge and experiences to answer research questions as I always want them to be. Sometimes, I think that when choosing this research topic and coming up with research questions, I was so ambitious so now I couldn't even find answers to these questions.

However, even now while I am writing these words, I do believe that with the assistance and enthusiasm of two supervisors at least, I do not give up and finally reach the goal of completing my thesis on time. Prof. Kris Lulofs always gave detailed comments to my report and I feel that he always cares about his students. I also like reading Prof. Kris' detailed reply messages to my email. Dhr. Stefan Nijwening assisted me during the very first step of doing my thesis and I really appreciate that. I would like to say thanks to my parents (my mom, my dad and my sister) for supporting me and believing in me even there were lots of hardships and challenges. I would like to say that I appreciate my boyfriend – Hieu's efforts in consoling me and telling me to keep trying whenever I wanted to give up. He was also willing to think to seek out solutions for every problem I encountered while doing the master thesis. I would love to send my 'Thank you' words to Mr. Duc Tran – a hydrological modeler in Royal HaskoningDHV, Ho Chi Minh City for helping me working on the hydrological model to answer my research questions. I was touched that even he was extremely busy, he always tried his best to engage in my thesis. Sometimes, he even worked overtime to find solutions to my own problem without hesitation. Last but not least, I say 'Thank you' to Mr. Luuk Brinkman, who was always willing to share his ideas and discuss with me about my thesis and spend time reading my report then give feedbacks.

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ABSTRACT

Ho Chi Minh City, Vietnam has suffered from in-land flooding in the last 50 years and with the occurrence of climate change, the situation will be getting worse in the future. In-land flooding hindrances Ho Chi Minh City's economic and social development as well as brings about serious damages to the natural environment. This challenges Ho Chi Minh while becoming an area of sustainable development. In this research, urban floods in Ho Chi Minh city will be mainly focused on and to be more specific, local flood risks, causes and consequences of urban floods will be figured out clearly. Based on that, solutions, especially nature-based ones, will be proposed then analyzed to fit into Ho Chi Minh city's characteristics then can be used to help solving urban-floods. These interventions will be analyzed from different stakeholders' perspectives and a wide range of disciplines. Furthermore, whether Ho Chi Minh city's capacity regarding economic, social and legal conditions to implement these interventions will be made clear in this research. Also, this research will analyze the role of community engagement in effective implementation of the nature-based solutions. Recommendations will be made based on two theories: theory on urban resilience to floods and theory on community engagement. Both primary data (from interview) and secondary data (from media, literature and documents) will be used to reach the goals of this research.

Keywords: Ho Chi Minh city, Urban floods, Nature-based solutions, Community engagement, Urban resilience to floods, In-land flooding management.

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LIST OF ABBREVIATIONS

ADB: Asian Development Bank

FDI: Foreign Direct Investment

GDP: Gross Domestic Product

HCMC: Ho Chi Minh City

ICEM: International Centre for Environmental Management

NBS: Nature-based solutions

SCFC: Steering Center for Flood Control

SRES: Special Report on Emission Scenario

UFRM: Urban Flood Risk Management

VCAPs: Vietnam Climate Adaptation Partnership

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CHAPTER 1: INTRODUCTION

1.1 Background

Ho Chi Minh City is located in the South of Vietnam and considered Vietnam's biggest City. According to the Institute of Global Environmental Strategies, HCMC is "at the crossroads of international maritime routes." Specifically, HCMC is considered an important transport hub of the southern region and has the biggest port system and airport in Vietnam. In terms of geographical characteristics, 0.6% of the total area of Vietnam is covered by HCMC. HCMC's population in 2012 was approximately 7.5 million (Vietnam Climate Adaptation Partnership, 2013) and in 2016, the figure has increased to around 8.3 million (General Statistics Office of Vietnam). In terms of economic developments, according to Colliers International Research, in 2016, HCMC's GDP was USD45.29 billion with the growth rate of 8.05% year on year. In addition, import and export values of HCMC in 2016 were 37.9 and 31.8 million respectively (Table 1). Particularly, milk and dairy products, fuel, plastics and several metals (iron and steel) contributed the most to import values and top segments of export values were agricultural products and computers, garments and electronic devices.

Table 1. Macro-economic Indicators of HCMC and Hanoi

Source: Colliers International Research, 2016

	HCMC		Hanoi	
	2016	2017	2016	2017
GDP (billion)	45.3	-	21.2	-
FDI (million)	1443.8	-	2800	-
Retail sales (billion)	30.1	-	22.3	-
Export (billion)	31.8	-	24.8	-
Import (billion)	37.9	-	14.2	-

According to Vietnam Climate Adaptation Partnership (VCAPs) in HCMC Climate Adaptation Strategy, p.30, HCMC is developed into "a modern industrial city in 2025 in which fast economic development is connected to sustainable development so that social progress and fairness are realized while protecting the environment". As a result, social-economic development in HCMC has been one of the city's priorities. It is said that social-economic development is broader and more complex than just providing house and jobs to citizens. To reach a balance between social development and economic development, a safe, healthy and pleasant environment to live and work is offered to its residents. In the case of HCMC, that healthy environment can be reached if HCMC is protected from flooding now and in the future. To be more specific, VCAPs stated that the nuisance from flooding due to heavy rainfalls in HCMC should be minimized.

To reach the goal of a healthy city, HCMC's plans are aiming at developing the City in a sustainable way. To be more specific, several spatial plans are created to harmoniously build brand new development areas, improve the quality of existing urban areas, frequently update the infrastructure system as well as the social infrastructure and protect the environment (VCAPs, 2016). For instance, green or blue infrastructures are protected as well as built. According to VCAPs, different zones along rivers in HCMC will be changed to green-blue waterfront ones to serve tourism and recreational purposes as well as to protect the environment. However, there exist several noticeable and significant constraints while developing HCMC in an environmental-friendly and healthy way and they include the population density, the increase in population, road congestion, air and water pollution and low-quality infrastructure. One of the most alarming problems is flooding due to extreme weather events and along with flooding due to high tides and high river discharges, compounding negative effects exist as a barrier to economic and social developments of HCMC. One might relate this also to low quality-infrastructure.

Intense precipitation in HCM is strongly connected to climate change. Due to climate change, according to Asian Development Bank (ADB), in the last 50 years, the annual average temperature has increased by 2^{o}C, in rainy season. The significant warming effect of climate change leads to extreme precipitation events in HCMC. As a result, local flooding will therefore become more frequent with regards to the increasing number of tropical storms. Tropical storms, along with heavy rainfalls, which used to be rarely happening in the past, now have significantly risen to approximately 20 over the last 60 years (ADB, 2010).

1.2 Problem statement

Ho Chi Minh City is considered the economic center in Vietnam and has expanded rapidly with rapid-developing economy, increasing population and a large number of new cultural and social institutions (VCAPs, 2013). However, HCMC is facing alarming environmental problems. One of them is the occurrence of flood events which bring in serious threats to human lives, infrastructures, facilities and economic, social and environment in urban areas in HCMC. The situation has gone worse also due to negative impacts of climate change (an increasing number of heavy rainfalls and extreme weather events) on Ho Chi Minh City, as a compounding effect. Because of economic development in HCMC, green spaces and areas are replaced with built-up areas and this makes HCMC more vulnerable to climate change and floods. In addition, there is a lack of effective measures of flood control and management in HCMC. As a result, current situations of urban flooding in HCMC should be analyzed to come up with solutions and measure to solve the problem as well as to prevent further damage to urban areas due to flooding.

1.3 Research objective

The objective of the research project is to develop a clear insight into local flooding in Ho Chi Minh City, Vietnam and suggest appropriate nature-based solutions to different areas in the City, in order to make recommendations on developing a framework (plans, regulations, investments and public participation) and conclude regarding the city's capacity to implement these solutions.

CHAPTER 2: LITERATURE REVIEW

3.1 Types of flooding

Figure 1. Flooding in HCMC

Source: english.vietnamnet.vn

There are mainly two ways to categorize flooding. Firstly, regarding reasons of flooding, there are two types of flooding: flooding due to high tides and heavy rainfalls. Secondly, according to International Centre for Environmental Management, flooding can be categorized by its frequency of occurrence. In this case, there are regular flooding and extreme flooding. ICEM stated that "regular floods occur throughout the year on a daily and seasonal basis and they are driven by a combination of tides and monsoon rains or by monsoon rains alone" (ICEM, 2009, p. 24) and extreme floods are expected to have a return period or frequency of occurrence of once every 30-year period. Each type of floods brings about different consequences. Extreme floods normally last shorter than regular floods. As a result, infrastructures and facilities are not under serious threats under extreme storms and flood events and buildings and households can be easily recovered after the floods. Meanwhile, regular floods normally occur on a daily basis through tidal oscillations and seasonally with heavy rainfalls, storm events and extreme tides. Many areas under regular floods can be affected for more than 100 days in a year (ICEM, 2009). For instance, it is predicted that in 2050, communes in one urban district in HCMC will be flooded up to 150 days annually due to regular floods compared to only 4 to 35 days of flooding due to extreme events.

3.2 Climate change scenario groups by SRES

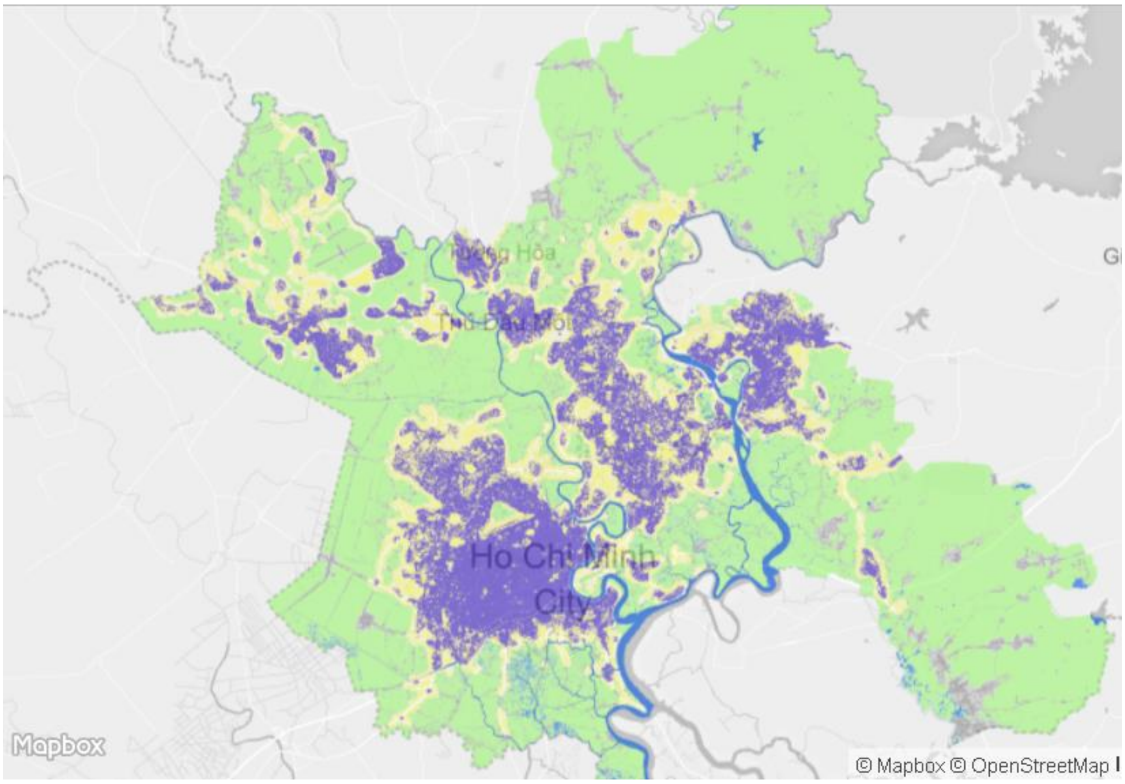
Special Report on Emission Scenario (SRES) has developed climate change storyline or family scenario to predict effects of climate change on different regions in order to come up with solutions to slow down the pace of development of climate change and “each storyline assumes a distinctly different direction for future developments” (HCMC Climate Atlas, 2013, p.1). Also, with each family and group of scenario, different predictions on global population, gross world product, and final energy are made. According to the Climate Atlas of HCMC, there are four sets of family scenario including A1, A2, B1 and B2 and six scenario groups named A2, B1, B2 and three groups within A1 scenario family: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel). A future world of rapid economic growth, introduction of new efficient technologies and global population that peaks then declines is described in A1 family scenario. Meanwhile, A2 family scenario describes a future world with increasing global population but slower economic growth and technological development. In B1 scenario, global population is in the same situation as that of A1; however, there exist rapid changes in economic structures towards a service and information economy. Another significant thing about B1 scenario is the introduction of clean and resource-efficient technology. Last but not least, local solutions on economic, social and environmental sustainability are emphasized in B2 family scenario.

3.3 Ho Chi Minh City

Urban areas

Ho Chi Minh City has 19 urban districts, namely: District 1, District 2, District 3, District 4**,** District 5**,** District 6, District 7, District 8, District 9, District 10, District 11, District 12, Tan Binh District, Tan Phu District**,** Binh Tan District, Phu Nhuan District, Go Vap District, Binh Thanh District, Thu Duc District.

Figure 2. Urban areas (blue colour) in HCMC
Source: Atlas of Urban Expansion (atlatofurbanexpansion.org)

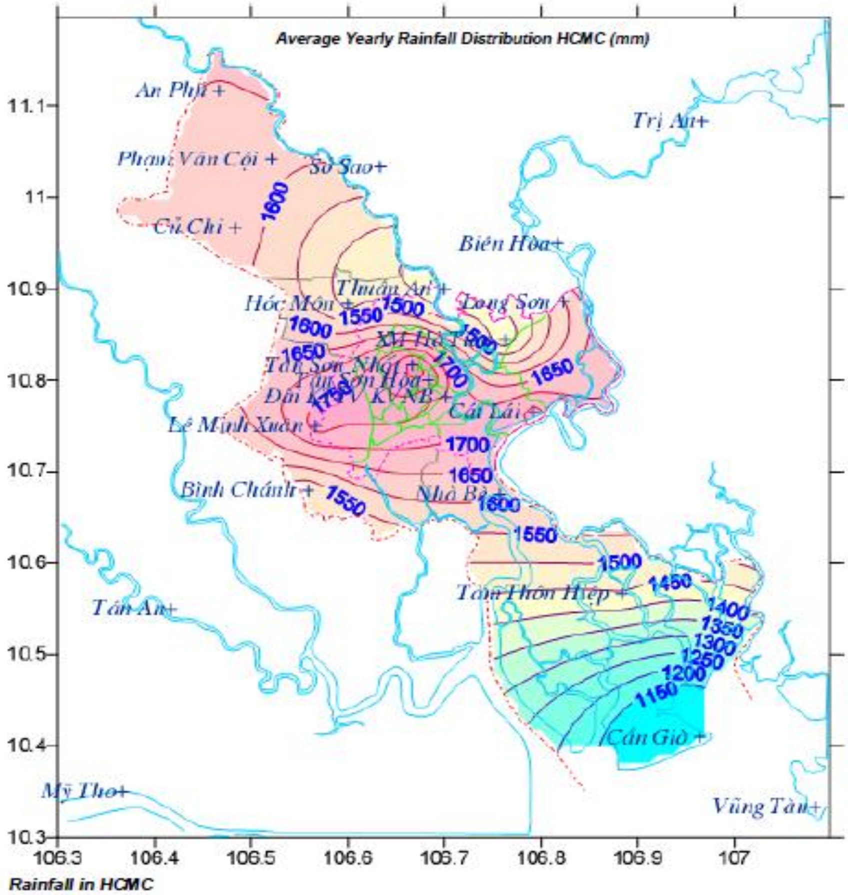


Rainfalls in Ho Chi Minh City

Ho Chi Minh City is in the list of 10 cities which are most severely affected by climate change (RoyalHaskoningDHV, n.d). One of the main reasons for flooding is extreme rainfalls, (coming with tropical storms) which are becoming more serious and alarming due to the effect of climate change.

Figure 3. Rainfalls in Ho Chi Minh City

Source: HCMC Climate Adaptation Atlas, p. 15



Because of fast-paced urbanization, there is a decrease in the amount of green space in Ho Chi Minh City. In the center of HCMC, infrastructures include paved surfaces and different kinds of buildings. These kinds of infrastructures and surfaces store heat easily and cause wind convergence in the center (with higher population). This explains the formulation of heavy rainfall in urban areas or residential areas (the center) (Map 2). According to Figure 1, in center areas of HCMC including Tan Son Hoa or Nha Be, the average amount of yearly rainfall can reach up to 1700 mm (the highest amount of rainfalls) and 1500 (the lowest amount of rainfalls). In other areas such as Can Gio, the average amount of yearly rainfall is around 1250 mm.

In terms of rainfall intensity, only rainfalls happening less than 180 minutes can bring about flooding in HCMC (Atlas: Ho Chi Minh City moving towards the sea with climate change adaptation, 2013) as beyond this period, rainfall is not significant and decentralized, which leads to less harmful effects. Also, rainfalls with longer repetition period bring about higher rainfall intensity (Figure 2).

Figure 4. Rainfall intensities in HCMC

Source: Atlas: Ho Chi Minh City moving towards the sea with climate change adaptation, HCMC Climate Adaptation Atlas, p. 15

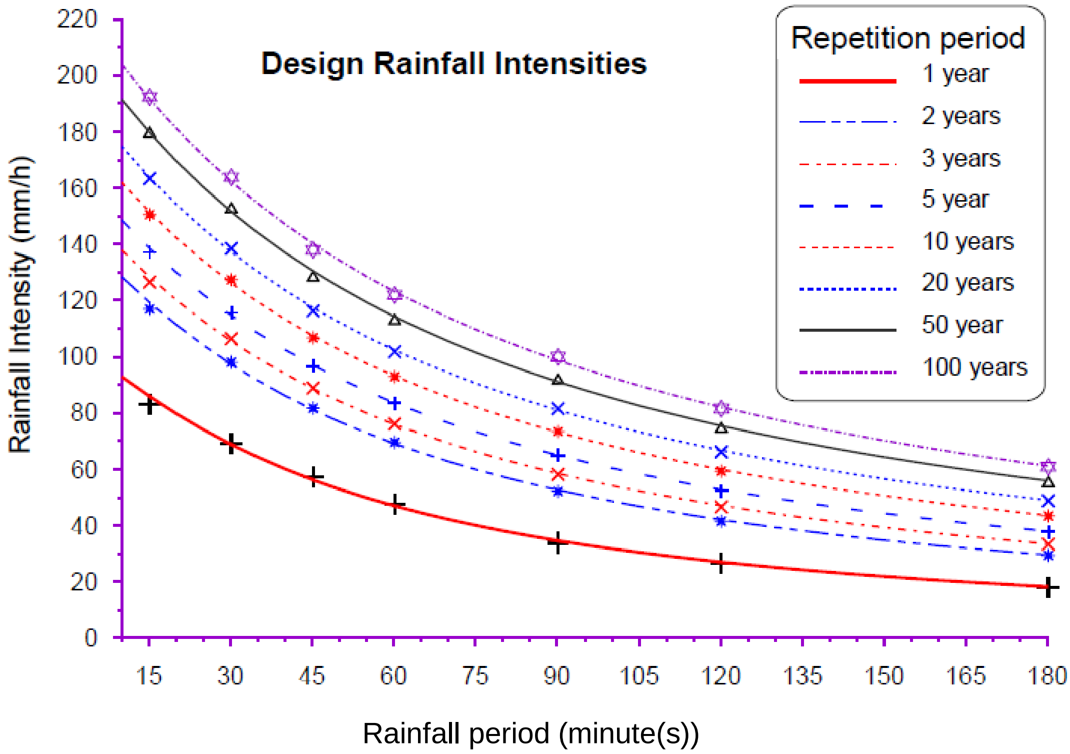


Table 2. Estimated Rainfall Change (%) based on Medium Emission Scenario (B2) for South Vietnam per decade.

Source: Atlas: Ho Chi Minh City moving towards the sea with climate change adaptation, HCMC Climate Adaptation Atlas, p. 17

Period	2020	2030	2040	2050	2060	2070	2080	2090	2100
Dec-Feb	-3,0	-4,4	-6,2	-8,1	-8,7	-11,4	-12,8	-14,2	-15,4
Mar-May	-2,8	-4,1	-5,8	-7,5	-9,1	-10,6	-12,0	-13,2	-14,3
Jun-Aug	0,3	0,5	0,6	0,9	1,1	1,2	1,4	1,5	1,6
Sep-Nov	2,6	3,8	5,3	6,8	8,3	9,6	10,9	11,9	13,0
Yearly average	**0,3**	**0,4**	**0,5**	**0,8**	**1,0**	**1,1**	**1,2**	**1,4**	**1,5**

As mentioned before, climate change, as a compounding effect, makes rainfalls in HCMC more serious (Table 2). It is predicted that the amount of yearly average rainfall will increase significantly in every 10-year period, on Medium Emission Scenario

(B2)1. B2 storyline and scenario of climate change is oriented towards local solutions in social equity, environmental protection and sustainability). It can be seen in Table 3 that average amount of rainfalls every year is expected to be higher in A2 than that of B1 (low emission scenario). In other words, rainfall intensities will be increasing more remarkably if there are no actions taken to deal with heavy rainfalls or climate change and HCMC is still oriented towards fast-paced economic development and urbanization, without paying attention to the environment. In that case, HCMC is in A1 and A2 (High Emission Scenario).

Table 3. Estimated Rainfall Change (%) based on Low Emission Scenario (B1) and High Emission Scenario (A2) for South Vietnam per Decade.

Source: Atlas: Ho Chi Minh City moving towards the sea with climate change adaptation, HCMC Climate Adaptation Atlas, p. 19.

Rainfall Scenarios MoNRE									
Estimated Rainfall Change (%) based on Low Emission Scenario (B1) for South Vietnam per Decade									
Period	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Dec-Feb	-2,7	-4,4	-6,2	-7,7	-7,7	-9,4	-9,1	-10,1	-10,1
Mar-May	-2,6	-3,6	-5,8	-7,2	-8,1	-8,7	-9,2	-9,4	-9,4
Jun-Aug	0,3	0,5	0,6	0,8	0,9	1,0	1,1	1,1	1,1
Sep-Nov	2,6	3,8	5,0	6,3	7,3	8,1	8,3	8,5	8,5
Yearly average	**0,3**	**0,4**	**0,6**	**0,7**	**0,8**	**0,9**	**1,0**	**1,0**	**1,0**
Estimated Rainfall Change (%) based on High Emission Scenario (A2) for South Vietnam per Decade									
Period	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Dec-Feb	-3,3	-4,5	-5,9	-7,4	-9,7	-12,0	-14,4	-16,9	-19,6
Mar-May	-3,0	-4,2	-5,5	-7,2	-9,0	-11,1	-13,3	-15,7	-18,2
Jun-Aug	0,4	0,5	0,6	0,8	1,0	1,3	1,5	1,8	2,1
Sep-Nov	2,8	3,8	5,0	6,5	8,2	9,3	12,1	14,3	16,5
Yearly average	**0,3**	**0,4**	**0,6**	**0,7**	**1,0**	**1,2**	**1,4**	**1,6**	**1,9**

Flooding in Ho Chi Minh City

Ho Chi Minh City is "the fifth most affected by climate change in Vietnam" and also the largest urban area with approximately 40% of the province is on the verge of permanent inundation (International Centre for Environmental Management, 2009, p.14). In addition, permanent inundation is thought to affect more than 12% of HCMC's population. It can be seen in Map 2 that urban districts are most affected by flooding due to heavy rainfalls.

1 A1, A2, B1 and B2 are four different climate change scenarios developed by VCAPs in HCMC Climate Atlas.

Figure 5. HCMC – frequent flood areas

Source: ICEM, 2009, p. 22

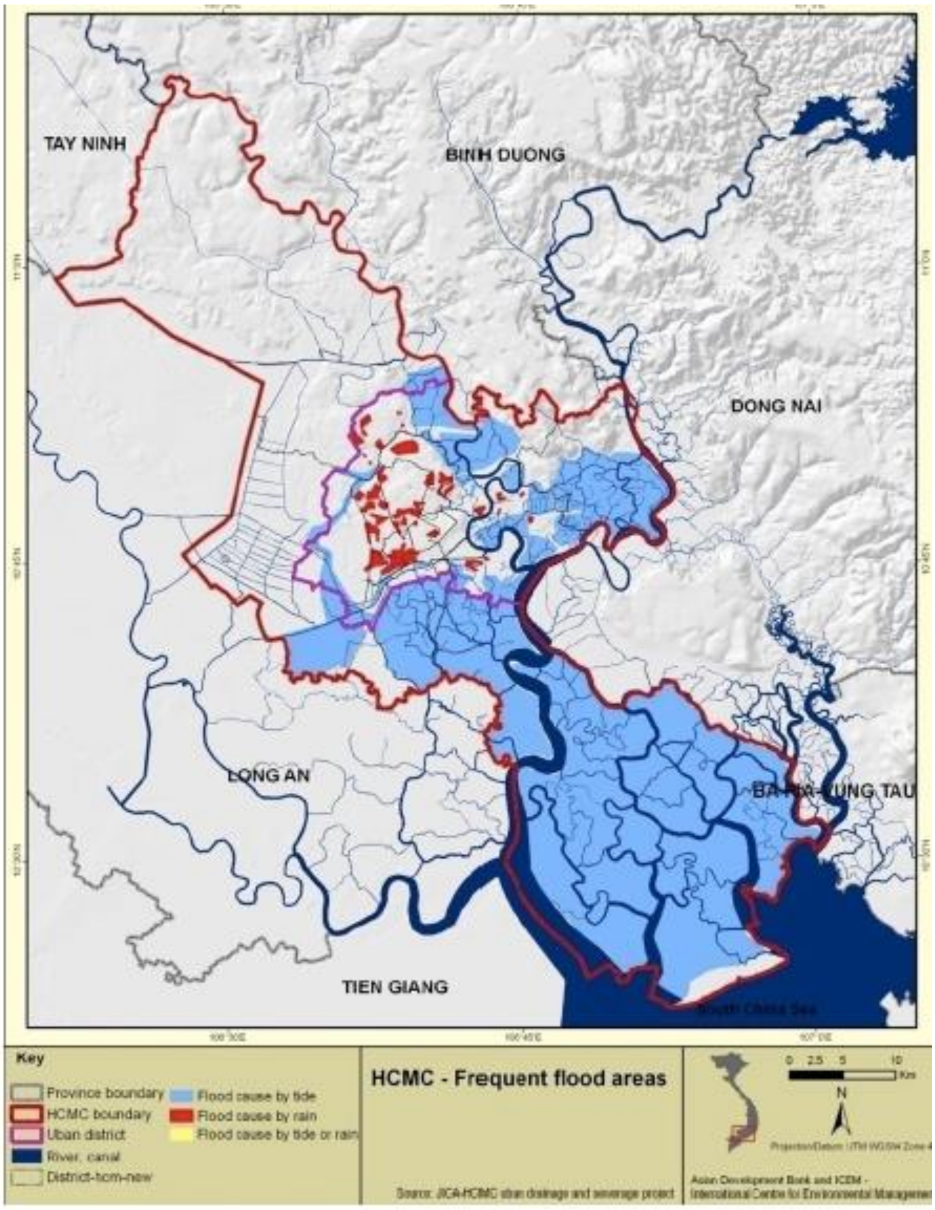
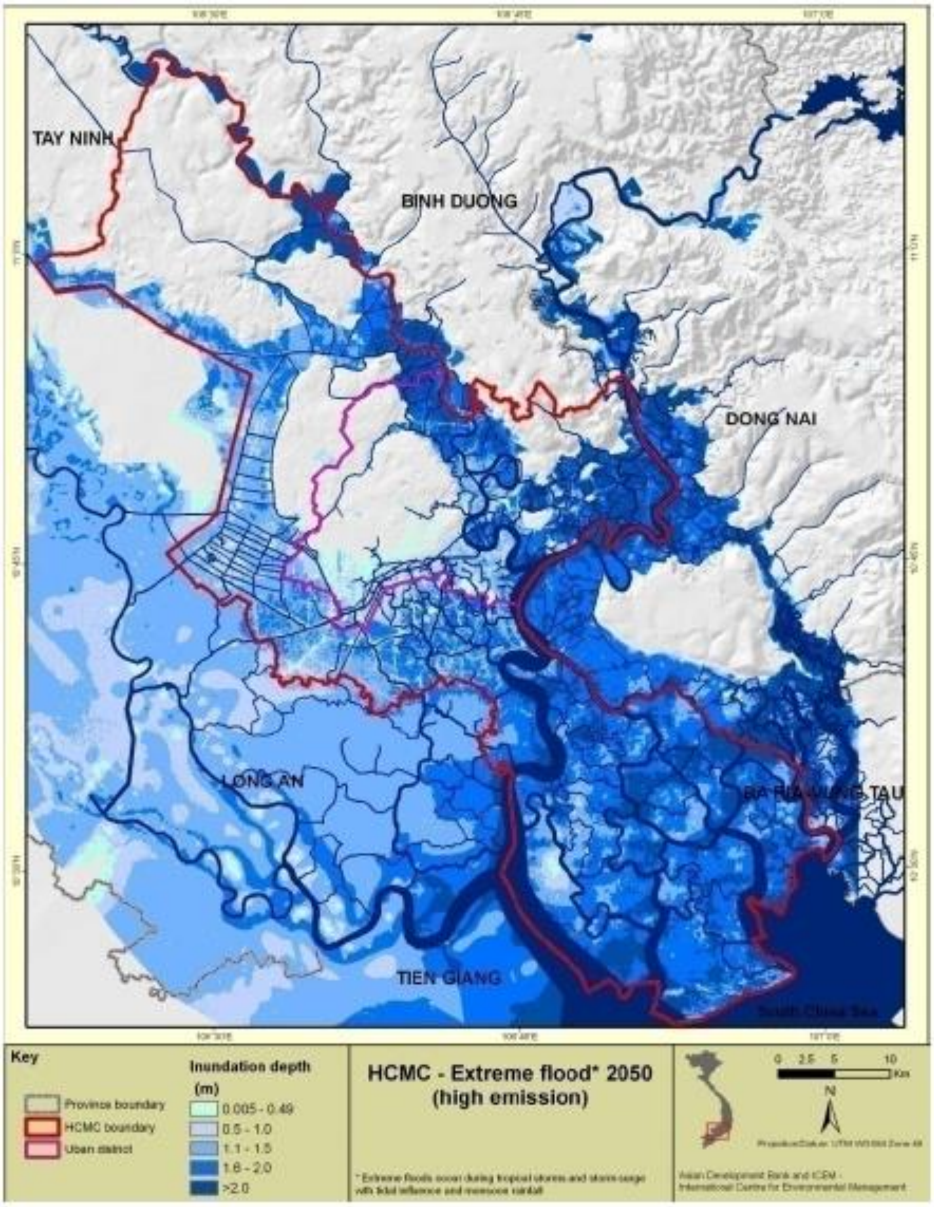


Figure 6. Predicted extent of flooding in extreme events under the high emission scenario (A1F1)

Source: ICEM, 2009, p.28



3.4 Three principles approach of urban flood risks management (UFRM)

The overall aim of this research is to come up with nature-based solutions to deal with in-land flooding in Ho Chi Minh City. The decision-making process of nature-based solutions to solve urban floods is considered complicated. To be more specific, water managers and water professionals have to take different stakeholders' points of view into consideration and different stakeholders might include urban planners, politicians, residents, architects, scientists, etc. To make the best decision of which solutions are implemented successfully regarding social and political characteristics of HCMC, three points approach (3PA) will be used as a theoretical background to analyze nature-based solutions.

According to Fratini *et al.,* 2012, the decision-making process of nature-based solutions are multidisciplinary and multifunctional. In other words, besides considering solely technological aspects, responses to climate change and inland floods require more attention to urban planning and community engagement. As a result, the 3PA is created to enhance communication skills of water managers and professionals with other stakeholders, to come up with different possible solutions which can meet different purpose (recreation, enhancement of urban resilience to floods, environmental protection). Specifically, three domains are introduced in the 3PA, including: (1) domain of technical optimization, (2) domain of urban resilience and spatial planning and (3) domain of day-to-day values (Fratini *et al.,* 2012). The first domain named technical optimization is to provide standards and guidelines for technical solutions to solve urban floods. The domain of urban resilience and spatial planning expects that water professionals or managers would communicate with urban planners or architects. The last domain is used to consider public participation and create a firm foundation for political support. This research will be based on the latter two domains – number (2) and number (3).

There are different stakeholders involved in the decision-making process and it is quite a challenge for water managers to manage the decision-making process in such a complex situation. Table 4 shows 11 aspects that stakeholders may assign to and table 5 shows characteristics of main stakeholders and what they prioritize in terms of water aspects.

Table 4. 11 aspects defining the values stakeholders involved in decisions related to UFRM may assign to water infrastructure

Source: Fratini *et al.,* 2012, p. 323

Aspect	Meaning	In relation to urban water
Biotic	Related to life processes and nature	Water is the first condition for the life of all species. Its quality and quantity have a strong influence on the quality of life of humans within the urban area. The presence of nature and a variety of species is a fundamental value for humans' health.
Sensitive	Related to perception	Water can stimulate positively or negatively all human's senses: sight, taste, hearing, smell and physical contact. When water stinks, its presence becomes unpleasant. When water is fresh and clean, people can bath in it.

Logical	In relation to the physical, chemical and mathematical functions	Urban water is part of the water cycle. It has chemical and physical characteristics that can be represented with the use of mathematics. Nowadays water behaviour can be modelled, monitored and partially controlled.
Historical	In relation to history, traditions and origins. In this sense, pedagogical to new generations	Humans have always needed water and tried to control it. Sometimes historical water structures remain within the urban environment. New generation can always learn from the past. Tourism usually appreciates the presence of historical structures.
Linguistic	In relation to symbols and communication of values	Language is a fundamental tool for communication of feelings and opinions but also rules. Communication about water can occur by road signs but can also be tacit, unwritten. Unwritten symbols are not always easy to detect. They are part of the local culture. They are maintained alive by storytelling. Communication is also an important tool to find agreement. In order to communicate, people need to share the same language or linguistic tool and have a shared understanding about them.
Social	Dealing with people and the way they meet and communicate with each other	The urban area is a place where people socialize. Water usually attracts people. Its presence can increase the opportunity of meeting the others. People usually like to walk along a river or sit in front of a lake.
Economic	In relation to costs and efficiency	The costs of water are related to space, resources and development. Thus, efficiency is important. Costs versus benefits have to be considered. On the other hand, some benefits can be: 1) not easily countable at present because their benefits relate to possible risks in the future whose level of uncertainty is very high; 2) not tangible, as the increase in quality of life and in environmental quality
Aesthetic	In relation to beauty and that which is desired.	Water can improve the aesthetics of the urban area in two directions: increasing the presence of water and nature within the urban space; enhancing the representation of art through harmonic architecture in the urban landscape.
Legal	Related to laws and official rules	Water quality and quantity in the urban area is regulated by laws and guidelines
Ethical	In relation to what is morally ‘‘good’’ and to responsibility	‘‘Good’’ water management is not the sole responsibility of the municipal management. Citizen should be aware of their responsibility for the maintenance of water structures and resources
Ideal	In relation to convictions and beliefs, the opinion of the group, religion, and to what is desirable	Water is part of the community. It is used for common rituals related to cultural habits. As a consequence, each stakeholder has inevitably his/ her own idea of what should be the desirable management of water resources within the urban area.

Table 5. Overview of the key stakeholder categories

Source: Fratini *et al.,* 2012, p. 325

Stakeholder	Responsibilities and characteristics	Prioritized water aspects
Water professionals	• Manage public or private organisations working with urban water facilities • In charge of finding solutions • Maintain service level and functionality of water infrastructures • Modellers/practitioners directly operating present water infrastructures • **Work in municipality or private company**	• Assessing solutions: Logical, Economic, Legal • Presenting options to the project sponsors: Logical, Economic • Cooperating with other professionals: Logical, Linguistic Economic, Legal • Discussing solutions with stakeholders: Logical, Linguistic, Economic, Ethical
Urban planners	• Manage municipal departments in charge of urban infrastructure not directly related with water • Organise urban space • **Responsible for new plans and visions**	• New planning: Logical, Economic, Social, Historical, Aesthetic • Communicating with stakeholders: Linguistic, Social
Architects/Landscape architects	• Design urban infrastructures and green areas • Create visions • Major driver is creativity	• Creating visions: Aesthetics, Social, Sensitive, Historical, Ideal, Ethical • Communicating with stakeholders: Linguistic
Scientists/Biologists	• Knowledgeable about natural processes in relation to environmental quality and human health • Prevent new infrastructure implementations from impacting the environment and human health negatively.	• Assessing impacts: Biotic, Legal, Logic, • Sensitive, Ethical, Ideal, Legal • Controlling and maintaining: Linguistic, Legal, Ethical, Ideal
Urban community	• Live and work in the urban area • Have diverse drivers depending on many aspects (education, knowledge, wealth, interests, etc.) • Pay to receive services • Can vote to change political goals • Use urban infrastructures daily • Major driver: improving their own quality of life	• Prioritise aspects related with their life quality: Sensitive, Historical, Social, Economic, Aesthetic • Perception depends on cultural background: Ethical, Ideal • The Linguistic aspect is very important when involving them in decision making

Politicians	• Comply with national guidelines • Work under financial constraints • Concern about citizen's happiness and safety • Seeking social support and power • Eager to maintain their prestige within the same mandate, want to be re-elected	• Setting constraints: Legal, Economic, Ethical, Ideal • Seeking social support: Sensitive, Historical, Social, Ideal, Aesthetic • The Linguistic aspect is central for them

3.5 Theory of Urban Resilience to Floods

Urban resilience

First, it is important to understand what the term "resilience" means and there are different definitions of the term. In general, resilience is "the ability to withstand an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life, and without a large amount of assistance from outside the community" (Kuei-Hsien Liao, 2012, p.3). Likewise, urban resilience is defined by Kuei-Hsien Liao, 2012, p.5 as "the capacity of the city to tolerate flooding and to reorganize should physical damage and socioeconomic disruption occur, so as to prevent deaths and injuries and maintain current socioeconomic identity." Urban resilience to floods is the capacity to accommodate flooding but not resist flooding. In other words, it is the ability of the city to adapt and adjust itself to urban floods but not suffer and then recover from floods that most of the engineers would suggest (Kuei-Hsien Liao, 2012).

Key properties of urban resilience to floods include self-organization, adaptive capacity and redundancy (Kuei-Hsien Liao, 2012). Self-organizing cities are more pro-active to urban floods than cities which are depending on central governments and thus they are considered more resilient cities by more quickly responding to in-land flooding. The adaptive capacity can be understood as the city's ability to learn from each flooding events so that it would be more well-prepared for other floods happening in the future. To be more specific, after each flood event, the city will make certain adjustments regarding physical, behavioural and institutional aspects. Lastly, redundancy means that a city has a wide range of different mitigation methods to deal with flooding events and the methods are distributed along different levels such as individuals, community and municipalities. As a result, cities with all three key properties are becoming more resilient to in-land flooding.

Flood resistance and resilience to floods

It is widely said that normally cities are flood resistant and this makes city less resilient to floods (Kuei-Hsien Liao, 2012). To further explain this, flood resistant cities are getting used to dry and stable regions thanks to flood resistance infrastructure and thus, they are extremely vulnerable to in-land floods. Furthermore, flood resistance infrastructure and facilities lower the occurrence frequency of in-land flooding so residents will have lower awareness and knowledge of floods and do not know how to tackle floods when they happen. Last but not least, flood resistance facilities are not taking full use the power of local communities to tackle floods even when community engagement is a powerful and effective tool to deal with environmental problems.

Effective resilience-based flood hazard management

As mentioned before, urban areas which are resilient are long enduring and adaptive to floods so the long-term safety of the areas will be ensured. To reach the goal of long-term safety, cities are expected to switch to resilience-based flood hazard management instead of using flood resistance infrastructures (Kuei-Hsien Liao, 2012). The first principle of this type of management is living with floods. Particularly, living with floods means that cities are aiming to be 'safety with floods' but not against them. For instance, spaces can be created for floods to get in the cities and even more than that, residents and communities can enjoy when floods come. To sum up, cities and their residents can learn how to adapt to in-land floods but not try to stay away from it. During the learning process, cities can gradually switch from flood resistance infrastructure to more diverse and flexible infrastructures to adapt to in-land flooding. For instance, blue-green measures can be created using open spaces in the cities and buildings' roofs can be altered then used to store water during flood events.

3.6 Principles of Community Engagement

"Community engagement is grounded in the principles of community organization: fairness, justice, empowerment, participation, and self-determination."

(Clinical and Translational Science Awards Program, 2011)

According to Clinical and Translational Science Awards (CTSA) Program, 2011, community could be defined from different perspectives. From the system perspective, "community is similar to a living creature, comprising different parts that represent specialized functions, activities, or interests, each operating within specific boundaries to meet community needs" (p.5). Meanwhile, from the social lens, a community is defined by "describing the social and political networks that link individuals, community organizations, and leaders” (p.5) . As a result, understanding these networks and connections are vital in planning of community engagement in every research project. From the concept of community, the definition of community engagement is developed (CSTA, 2011, p.7):

> *“The process of working collaboratively with and through groups of people affiliated by geographic proximity, special interest, or similar situations to address issues affecting the well-being of those people It is a powerful vehicle for bringing about environmental and behavioural changes that will improve the health of the community and its members It often involves partnerships and coalitions that help mobilize resources and influence systems, change relationships among partners, and serve as catalysts for changing policies, programs, and practices.”*

More importantly, there are different forms of community engagement, namely organized groups, agencies, institutions, or individuals and they can engage in research or policy making process. Furthermore, there are different levels of community engagement as community engagement can be thought as “a continuum of community involvement.” As time goes by, a collaboration can move further with greater and deeper community involvement (Figure 3).

Figure 7. Community Involvement Continuum

Source: CSTA, 2011, p.8

Increasing Level of Community Involvement, Impact, Trust, and Communication Flow

Outreach	Consult	Involve	Collaborate	Shared Leadership
Some Community Involvement *Communication flows from one to the other, to inform* Provides community with information. Entities coexist. Outcomes: Optimally, establishes communication channels and channels for outreach.	*More Community Involvement* *Communication flows to the community and then back, answer seeking* Gets information or feedback from the community. Entities share information. Outcomes: Develops connections.	*Better Community Involvement* *Communication flows both ways, participatory form of communication* Involves more participation with community on issues. Entities cooperate with each other. Outcomes: Visibility of partnership established with increased cooperation.	*Community Involvement* *Communication flow is bidirectional* Forms partnerships with community on each aspect of project from development to solution. Entities form bidirectional communication channels. Outcomes: Partnership building, trust building.	*Strong Bidirectional Relationship* Final decision making is at community level. Entities have formed strong partnership structures. Outcomes: Broader health outcomes affecting broader community. Strong bidirectional trust built.

It is widely said that the process of community engagement potentially brings about a wide range of positive impacts to different areas and fields. First of all, that the community is involved in a research project helps to enhance their skills and knowledge as well as to be recognized because of their significant distributions (CSTA, 2011). Secondly, academic researchers such as students or professionals can gain an in-depth comprehension of research objects or problems when they kindly involve community in an acceptable and ethical way. Last but not least, data collection and analysis processes in research projects can be well developed thanks to community involvement and as a result, the speed and efficiency of the research projects can be enhanced.

Effective community engagement requires to follow nine principles mentioned below: “(1) Be clear about the purposes or goals of the engagement effort and the populations and/or communities you want to engage; (2) become knowledgeable about the community’s culture, economic conditions, social networks, political and power structures, norms and values, demographic trends, history, and experience with efforts by outside groups to engage it in various programs. Learn about the community’s perceptions of those initiating the engagement activities”; (3) go to the community, establish relationships, build trust, work with the formal and informal leadership, and seek commitment from community organizations and leaders to create processes for mobilizing the community; (4) remember and accept that collective self-determination is the responsibility and right of all people in a community. No external entity should assume it can bestow on a community the power to act in its own self-interest; (5) partnering with the community is necessary to create change; (6) all aspects of community engagement must recognize and respect the diversity of the community. Awareness of the various cultures of a community and other factors affecting diversity must be paramount in planning, designing, and implementing approaches to engaging a community; (7) community engagement can only be sustained by identifying and mobilizing community assets and strengths and by developing the community’s capacity and resources to make decisions and take action; (8) organizations that wish to engage a community as well as individuals seeking to effect change must be prepared to release control of actions or interventions to the community and be flexible enough to meet its changing needs; and (9) community collaboration requires long-term commitment by the engaging organization and its partners.

Different methods can be used to make a more effective use of community involvement (CSTA, 2011). First and foremost, recognizing community’s cultural values and how they shape community’s life will help researchers to gain better understanding of the community. As a consequence, this brings about a successful collaboration with the community. Secondly, it is necessary to understand community's motivations to participate and they include their desire to have a better life, to feel a need for a sense of community or to want rewards, etc. In addition, developing a network with community and residents on mutual trust and respect helps to enhance community involvement in different projects or process. Building capacity (knowledge, resources and skills) and community empowerment are considered important to involve community in a large scale. Lastly, ethical aspects should be taken into consideration while involve community in any research or project to get any kind of purpose(s). Residents are in need of protection and not suffering from any harm to their lives during their participation.

3.7 Nature-based solutions

Figure 8. Nature-based solutions

Source: B Doherty and landezine.com

Blue-green measures are defined by Anna Cruijsen, 2015, p.48 as "an overarching term for blue and green adaptation measures highlighting the importance of combining storm water management, climate adaptation and multifunctional green space". For example, green measures could be parks, green roofs, green walls and urban forests and blue measures could be water squares, blue roofs, etc. which serve as the purpose of water storage. Green measures or nature-based solutions can be defined in a different way. Nadja Kabisch *et al.,* 2017, p.34 defines urban green infrastructure as "interconnected networks of all kinds of green spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life" and nature-bases solutions as "a way to mitigate and adapt to climate change, secure water, food and energy supplies, reduce poverty and drive economic growth". IUCN also defines nature-based solutions term: "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits".

Nature-based solutions provide multiples benefits to urban areas (Anna Cruijsen, 2015). In terms of precipitation recovery, blue and green adaptation measures can be used as appropriate methods to reach the goal of precipitation recovery or to store rainwater. As a result, rainwater's burdens on drainage system will be significantly reduced and urban flooding due to extreme weather events will be partially solved. Furthermore, water shortage and water stress are no longer serious problems because rainwater is stored using different measures. Last but not least, land and soil subsidence due to lower groundwater level can be tackled as rainwater is used to infiltrate back to the groundwater.

Nature-based solutions can be seen as an umbrella term for ecosystem-related approach (IUCN, n.d) and these approaches can be categorized into five main ones, including:

Table 6. Categories of NBS

Source: IUCN

Categorizes of NBS	**Examples**
Ecosystem restoration approaches	• Ecological restoration • Ecological Engineering • Forest landscape restoration
Issue-specific ecosystem-related approaches	• Ecosystem-based adaptation • Ecosystem-based mitigation • Climate adaptation services • Ecosystem-based disaster risk reduction

Infrastructure-related approaches	• Natural infrastructure • Green infrastructure
Ecosystem-based management approaches	• Integrated coastal zone management • Integrated water resources management
Ecosystem protection approaches	• Area-based conservation approaches, including protected area management

Anna Cruijsen, 2015 have different methods to categorized NBS. Firstly, based on NBS' characteristics, there are two main types: retention measures (having no connection to sewage system) vs. detention measures that can store water and release water gradually to the sewage system. Furthermore, nature-based solutions can be implemented in different scales, including: private, street, neighborhood or city scale.

Nature-based solutions require flexibility and strategies for long-term public support and one of the ways to enhance social acceptance of NBS is to make them multifunctional, besides making cities more resilient to urban floods (Nadja Kabisch *et al.,* 2017). To be more specific, NBS can be used in other purposes such as dealing with air pollution or recreational purpose. As a result, values of NBS will be recognized by urban communities. According to Nadja Kabisch *et al.,* 2017, public participation or community engagement in NBS can also bring about effective governance of NBS. To be more specific, a great diversity of knowledge related to NBS can be offered thanks to participation of different partners and actors in a governance linkage. Knowledge can include practice and experiences of how to manage NBS effectively. In addition, that the governance linkages or networks expand gradually can enhance effectiveness of flood adaptation and recognition of nature-based solutions in the community.

3.8 Tools to integrate nature-based solutions in urban drainage

Different terms that describe systems or tools to integrate nature-based solutions in urban drainage exist and there is no significant difference in the meaning of these terms (Anna Cruijsen, 2015). 'Green Urban Infrastructure' (GUI) is the term of blue-green networks used in Scandinavian (a cultural region in NW Europe). Another term is 'Sustainable Urban Drainage System' (SUDS) is popularly used in the United Kingdom or 'Water-Sensitive Urban Design' (WSUD) belongs to Australia, to manage flood water more efficiently and maintain recreational chances of community. North America and New Zealand describe the systems as 'Low Impact Development' (LID) or 'Best Management Practice' (BMP). One of the examples of tools used to integrate NBS in urban drainage is an initiative named 'Amsterdam Rainproof', to make the city more rainproof by creating more spaces to store, better drain or absorb water and this initiative is implemented by a network of organizations, which offers different rainproof choices to customers (Letty Reimerink, 2017).

CHAPTER 3: RESEARCH DESIGN

3.1 Research framework

According to Doorewaard and Verschuren in *Designing a research project,* research framework is created to answer the question "how to ensure that research objective will be achieved." To be more specific, below-mentioned steps are followed to achieve the research objective.

Step 1: Characterizing briefly the objective of the research project

The objective of the research project is to develop a clear insight into local flooding in Ho Chi Minh City, Vietnam and elaborate appropriate nature-based solutions to different areas in the City, in order to make recommendations on developing a framework (plans, regulations, investments and public participation) and conclude regarding the City's present situations, whether the City is capable of implementing these solutions.

Step 2: Determining the research object

The research object in this research is urban areas in Ho Chi Minh City, Vietnam.

Step 3: Establishing the nature of research perspective

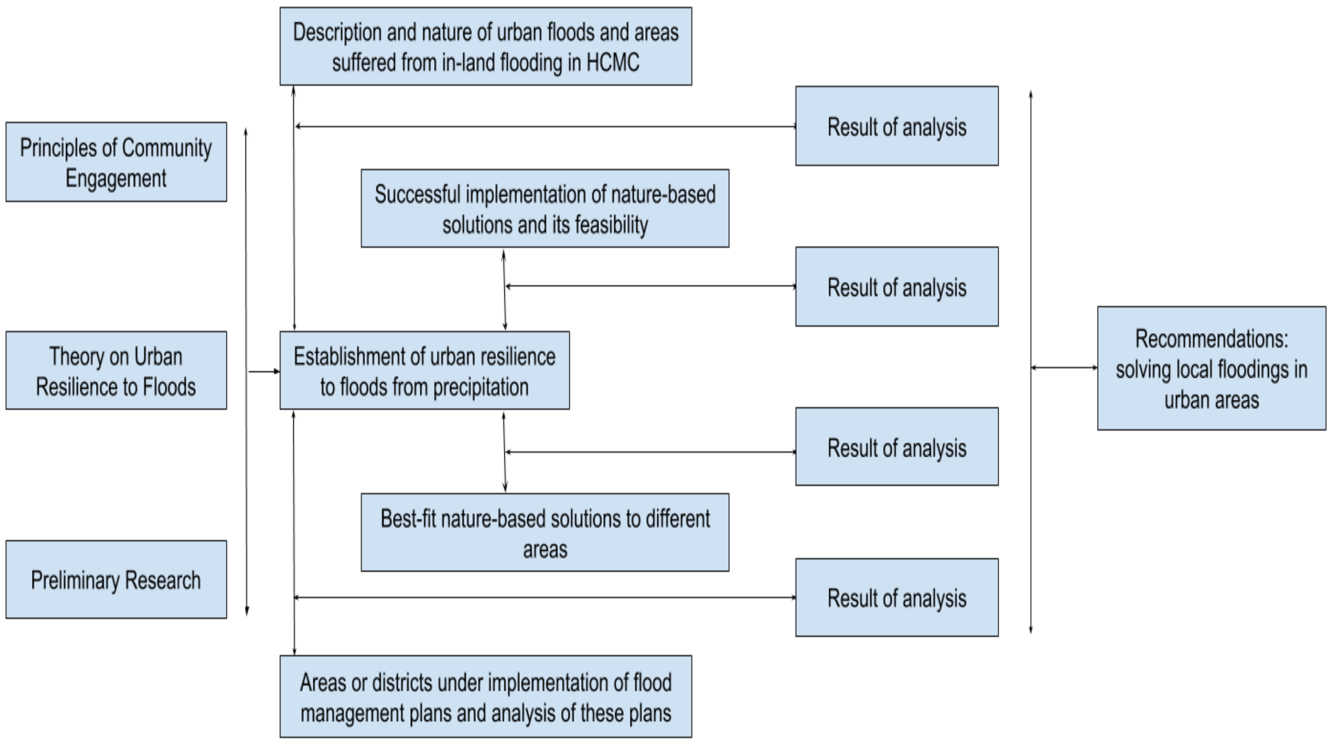
Step 4: Determining the sources of the research perspective

Table 7. Sources of research perspective

Key concepts	**Theories and documentation**
Nature-based solutions	Theory on Public Administration
Building with nature	Theory on
Urban flood management	Preliminary Research
Urban resilience	
Water sensitive city	

Step 5: Making a schematic presentation of the research framework

Figure 9. Research framework



Step 6: Formulating the research framework in the form of arguments which are elaborated

Step 7: Checking whether the model requires any change

There is no indication that any change is require.

3.2 Research question

The central question:

What are nature-based solutions to serious flooding in Ho Chi Minh city?

The sub-questions:

- What are local flood risks in urban areas in Ho Chi Minh city? What are causes of urban flooding due to heavy rainfalls in HCMC? Which areas or districts are suffering from floods due to heavy rainfalls in Ho Chi Minh city?
- Which areas or districts in HCMC that urban spatial plans or urban climate adaptation plans are focusing on? Which results do they get so far in terms of flood management in these areas? Which elements of the plans that need to be strengthened and improved to produce better results?

- What are possible and appropriate nature-based solutions to urban floods in Ho Chi Minh city? Is there any method to evaluate their effectiveness to reduce local flood risks in study sites in Ho Chi Minh City?
- What are the requirements needed from HCMC to efficiently implement above-mentioned nature-based solutions, regarding: Public Participation (community involvement); Instruments (Financial and Legal frameworks) and Governance systems; to help solving flooding? Is it feasible for HCMC to meet all these requirements?

3.3 Research strategies

Research strategy is defined by Doorewaard and Verschuren as strategic decisions that a researcher has to make for the successful operation of the research. First of all, this research focuses on depth of the problem, particularly in-depth understanding about urban floods in HCMC and then come up with appropriate nature-based solutions to solve the problem, based on characteristics of the area. This explains the second choice of using qualitative and interpreting approach to the research object. Thirdly, the researcher will be flexible about whether to try to gather primary data and then analyze them or to analyze the data gathered by others. Last but not least, two strategies will be used mainly in this method are case study and desk research, which are the most appropriate ones to gain an in-depth view of the research object and research problem. Using both case study and desk research would help the researcher to do qualitative research of the research problem and object. Especially case study strategy is characterized by depth and qualitative data and research methods (Doorewaard and Verschuren, 2010).

Research units

Because of in-depth and qualitative research, there is a small number of research units. Research units of the research include:

- Neighborhoods in urban areas in HCMC
- Urban districts
- Areas or districts under implementation of climate adaptation or urban spatial plans to deal with urban floods due to heavy rainfalls
- Non-governmental environmental organizations or governmental agencies in charge of flood management and control

Meanwhile, observation units are residents or group of residents living in urban areas in HCMC and policy officers and environmental experts who have an in-depth knowledge about urban floods and are responsible for solving the problem.

3.4 Research materials and accessing methods

As mentioned before, the two strategies that are used in this research are case study and desk research and particularly, each strategy is served as an approach to answer research questions. There are different sources of data and knowledge and methods of accessing them to answer the questions. There are mainly two sources of data and knowledge: primary data and secondary data. Primary data can be gathered by doing an interview or written poll that can be done when there is an absence of sources of secondary data. Interviewees in this research include policy officers, environmental experts in flood and water management and groups of residents in urban areas in HCMC. Written poll is used to get quantitative data from a large number of research units to acquire individuals' opinions on urban floods in the area. Furthermore, secondary data sources include literature (scientific articles and research) and documents from companies and organizations. They can be collected by making content analysis and using search method.

Table 8. Research' sources of materials and accessing methods

Research Question	Data/Information Required to Answer the Question	Sources of Data and Knowledge	Accessing Data
What are local flood risks in urban areas in Ho Chi Minh City? What are consequences of urban flooding in HCMC? Which areas or districts are suffering from floods due to heavy rainfalls in Ho Chi Minh city?	Flood events in the past 50 years in Ho Chi Minh City	Secondary data: Documents/Media	Content analysis and search method
	Consequences of urban floods in HCMC	Secondary data: Documents/Media	Narrative analysis and search method
		Primary data: People: Residents	Content analysis and search method
	List of flooded areas due to heavy rainfalls and characteristics of the areas	Primary data (knowledge): People: Environmental experts & Flood projects managers	Questioning: Face to face individual and group interview
		Secondary data: Documents/Media	Narrative analysis and search method

Which areas or districts in HCMC that urban spatial plans or urban climate adaptation plans are focusing on? What results do they get so far in terms of flood management in these areas? Which elements of the plans that need to be strengthened and improved to produce better results?	List of areas/districts that plans are focusing on	Primary data (knowledge): People: Environmental experts & Flood projects managers	Questioning: Face to face individual and group interview
		Secondary data: Documents/Media	Content analysis and search method
	Description of urban spatial plans and urban climate adaptation plans to deal with floods and their results	Primary data (knowledge): People: Environmental experts & Flood projects managers	Questioning: Face to face individual and group interview
		Secondary data: Documents/Media	Content analysis and search method
	Strengths and weak points of these plans and recommendations	Primary data (knowledge): People: Environmental experts & Flood projects managers	Questioning: Face to face individual and group interview
		Secondary data: Documents/Media	Content analysis and search method
What are HCMC's current efforts (plans and practice) in urban flood management in these areas/districts?	Current efforts to deal with urban floods in HCMC	Primary data People: Environmental experts & Flood projects managers	Questioning: Face to face individual and group interview
What are possible and appropriate nature-based solutions to urban floods in Ho Chi Minh City? Are there any local initiatives regarding nature-based solutions?	• General information about these solutions (term definition, types, benefits) • List of possible nature-based solutions	Secondary data (knowledge): Literature	Content analysis and search method
	Appropriate nature-based solutions to urban floods in HCMC	Secondary data (knowledge): Literature	Content analysis

		Primary data: People: Environmental experts & Flood projects managers	Questioning: Face to face individual interview
	Nature-based solutions combined local initiatives	Primary data (knowledge): People: Environmental experts & Flood projects managers	Questioning: Face to face individual interview
What are the requirements to efficiently implement above-mentioned nature-based solutions, regarding: Public Participation (community involvement); Instruments (Financial and Legal frameworks) and Governance systems; to help solving flooding?	Requirements to successfully implement nature-based solutions in urban areas in HCMC	Primary data: People: Environmental experts & Flood projects managers	Questioning: Face to face individual interview
Is it feasible for HCMC to meet all these requirements?	• Ho Chi Minh City's finance and legal frameworks of climate change and flood management • Willingness of community to deal with problem of urban floods	Secondary data: Documents	Content analysis and search method
		Primary data: People: Residents	Questioning: Face to face individual interview
	Feasibility level of solution implementation	Primary data: People: Environmental experts & Flood projects managers	Questioning: Face to face individual interview

Ethical concerns in data gathering process

The research will be implemented under below-mentioned ethical requirements. First of all, total respects towards research-related individuals (internal and external research supervisors, residents and communities in Ho Chi Minh City, environmental and water professionals) are always shown during the period of thesis implementation. Secondly, there will be no harm to above-mentioned individuals especially residents during interview or doing survey. Their personal information (if recorded) will be kept confidentially and only be published anonymously under their permission and respondents have total rights even after their answers are collected or recorded. Last but not least, justice will be seriously taken in consideration while doing the thesis research.

3.5 Data analysis

To achieve the research objectives and aim and to get in-depth view of urban floods, qualitative analysis method will be dominantly used in the implementation phase then to come up with possible NBS to solve the problem in HCMC.

Methods of data analysis

Table 9. Method of data analysis

Data/Information Required to Answer the Question	Method of analysis
Flood events in the past 50 years in HCMC	Qualitative: analyze the frequency of flood events in the past
Consequences of urban floods in HCMC	Qualitative: analyze reasons and the level of severity of in-land flooding in HCMC
List of flooded areas due to heavy rainfalls and characteristics of the areas	Qualitative: find similarities between areas/districts by analyzing why they suffer from inundation to heavy rainfalls
List of areas/districts that plans of climate adaptation and urban spatial planning to cope urban floods are focusing on and description of these plans and their results	Qualitative: describe plans of flood management in different areas in HCMC and analyze their effectiveness based on their results
Strengths and weak points of the plans of flood management and recommendations	Qualitative: analyze plans and come up with recommendations
• General information about nature-based solutions (term definition, types, benefits) • List of possible nature-based solutions	Qualitative: analyze possible flood management solutions
Appropriate nature-based solutions to urban floods in HCMC	Qualitative: analyze the level of appropriation of different NBS applied to HCMC

Nature-based solutions combined local initiatives	Qualitative: analyze community engagement in applying NBS
Requirements to successfully implement nature-based solutions in urban areas in HCMC	Qualitative: analyze conditions and feasibility of applying NBS in HCMC
• Ho Chi Minh City's finance and legal frameworks of climate change and flood management • Willingness of community to deal with problem of urban floods	Qualitative: analyze HCMC characteristics
Feasibility level of solution implementation	Qualitative: analyze the level of success in applying and implementing NBS
Similarities between HCMC and New York City with Rotterdam	Qualitative: analyze characteristics of these three cities

Data analysis will be conducted in the following sequences:

- The first step of data analysis is to analyze characteristics of urban floods (risks, causes and consequences) and past and current flood management efforts in HCMC. These can be shown through how effective flood management solutions are in terms of reducing severity of urban floods in the past 50 years (by taking an in-depth view in the consequences of in-land flooding to HCMC).
- Next, list of areas or districts suffered from inundation due to excess rainfalls will be established. Based on that, areas' characteristics making them vulnerable to floods from heavy rainfalls will be gathered then analyzed.
- Thirdly, list of areas or districts that plans of flood management are focusing on will be created and these plans will be clearly described (general description and results). The plans will be analyzed to get their strong and weak points (the quality of the plans) in reaching the goal of flood management.
- Then, nature-based solutions are listed to enhance HCMC's resilience to in-land flooding and then these solutions will be analyzed from different disciplines and perspectives of different stakeholders (water professionals, urban planners, scientists, urban community, architects).
- Lastly, based on HCMC's legal framework, economic and other conditions, these NBS will be analyzed from economic, legal, aesthetic and social perspective

(community engagement) to find appropriate solutions that can be feasibly implemented in HCMC.

Validation of data analysis

Triangulation method will be used to test validation of data analysis to avoid research bias. Triangulation method is a combination of interview, participant observation and content analysis and results of each data gathering method will be compared. Another triangulation method is to compare results of research to the perspective from theories.

CHAPTER 4: FLOODING IN HO CHI MINH CITY

Research sub-question: *What are local flood risks in urban areas in Ho Chi Minh City? What are causes of urban flooding due to heavy rainfalls in HCMC? Which areas or districts are suffering from floods due to heavy rainfalls in Ho Chi Minh City?*

Chapter 4 provides information about flooding in several districts in Ho Chi Minh City. Part 4.1 elaborates on reasons for selection of districts to develop strategies of local flood risk reduction and climate change adaptation. In this part, statistics on yearly rainfalls such as the amount of rainfalls, inundation depth and predicted duration of regular flooding are shown via maps. Several causes of flooding in District 2 and District 7 is shown in part 4.2. Data of flooding due to heavy rainfalls in several areas in District 2 and District 7 in the past several years provided by Steering Center for Flood Control are illustrated in the part 4.3.

4.1 Selection of districts to develop strategies of local flood risk reduction and climate change adaptation

It is said that each city district requires a specific plan of adaptation measures and this type of local planning "should start with the districts that are most vulnerable" (C*limate Adaptation Strategy Ho Chi Minh City,* VCAPS, p. 72). We follow this advice and apply it in this research and we reach a conclusion that district 2 and district 7 are chosen in this research as these districts are more vulnerable to flooding due to heavy precipitation especially under the effects of climate change. First of all, district 2 and district 7 have the highest amount of annual rainfall, which are recorded 1,650 mm/year and 1700 mm/year respectively (Figure 10). Secondly, under different scenario of climate change and flood protection the duration of regular flooding in a year in district 2 and district 7 is expected to be longer than that in any other districts. It can be seen in Figure 11, under the scenario of "2050 High Scenario – A2 (High emission scenario)" with flood control system, there are from 121 to 180 days of regular flood in district 2 and from 91 to 120 days of regular floods in district 7 and the situation could go worse (more days of regular flooding) without flood control system. Furthermore, according to Figure 13, district 2 and district 7 are low-lying areas. To be more specific, these two districts are only from 0.5 to 2 meters above mean sea level, compared to other districts and this makes district 2 and 7 more vulnerable to regular floods due to heavy rainfall as water often goes to lower regions. Also, it is suitable to develop a flood-management strategy using nature-based solutions in district 2 and 7 because these two districts are not fully urbanized, there are lots of open spaces for them to implement nature-based strategies to deal with local flooding due to heavy rainfalls (Nijwening, S., Personal Interview, April 13th, 2018).

Figure 10. Average yearly rainfall distribution in HCMC (in mm)

Source: HCMC Climate Atlas, 2013, p.23

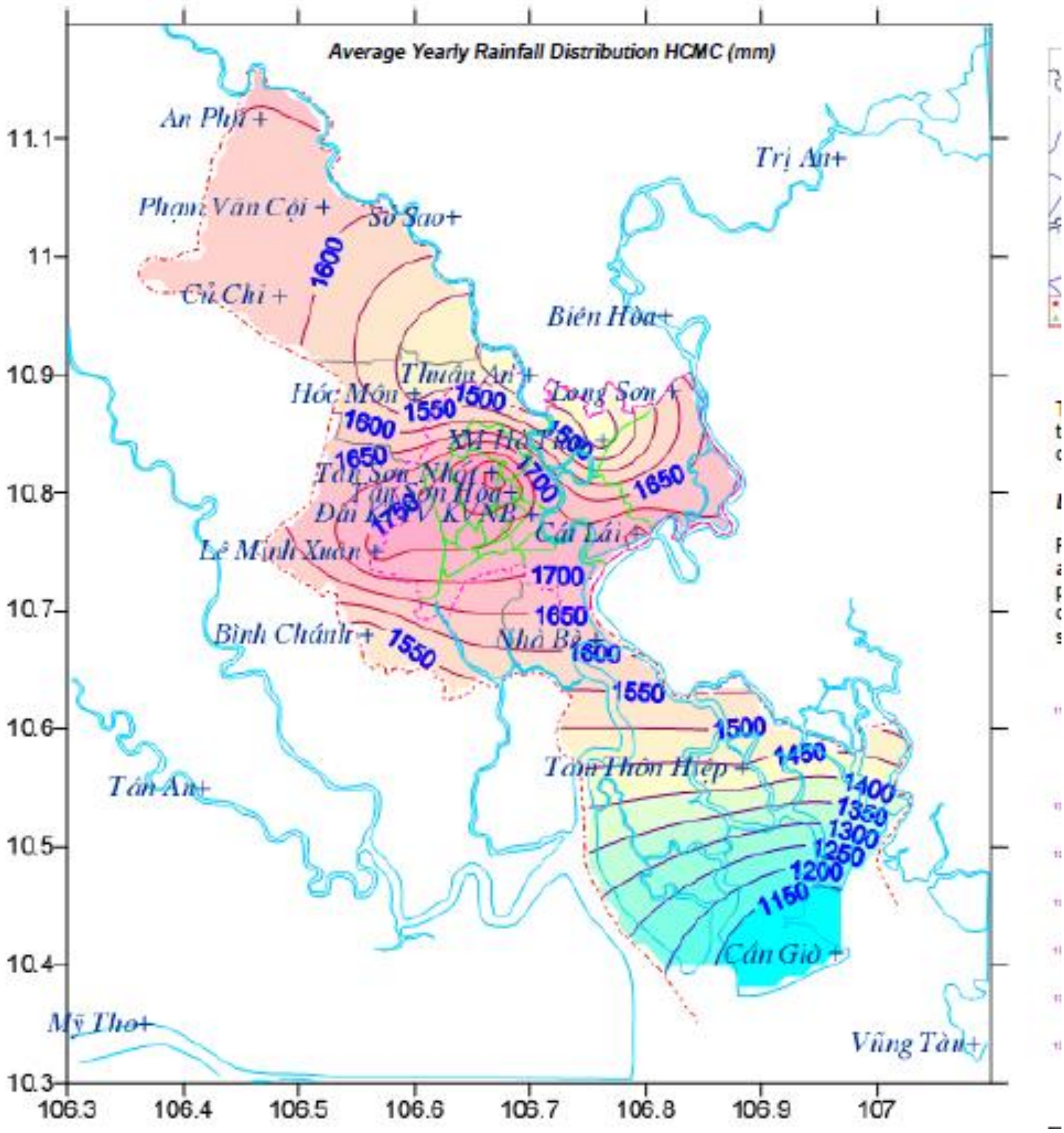


Figure 11. Predicted duration of regular flooding in Ho Chi Minh City in 2050

Source: Climate Atlas in Ho Chi Minh City, VCAPS, p.23

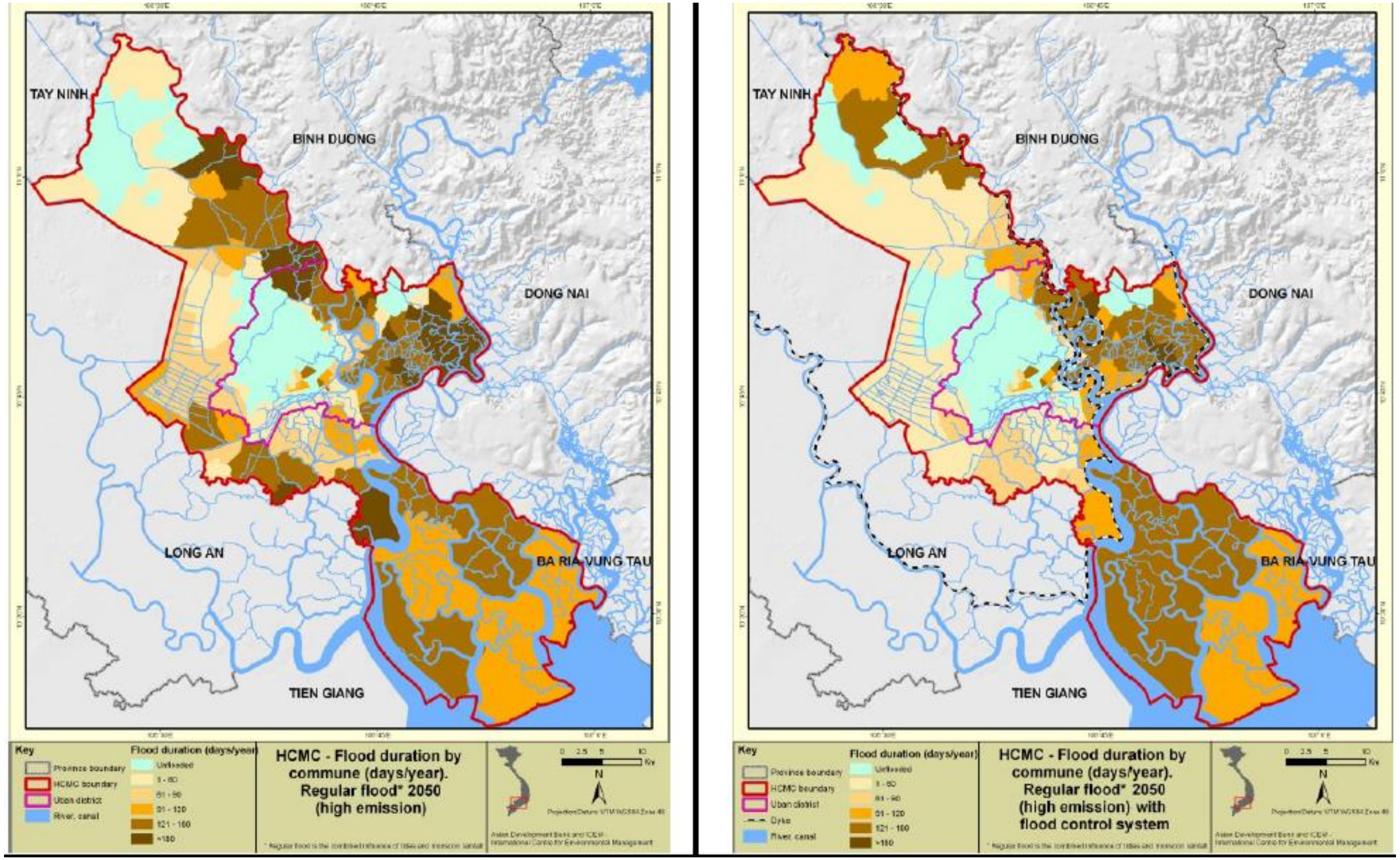


Figure 12. Predicted inundation depth of regular flooding in Ho Chi Minh City in 2050

Source: Climate Atlas in Ho Chi Minh City, VCAPS, p.31

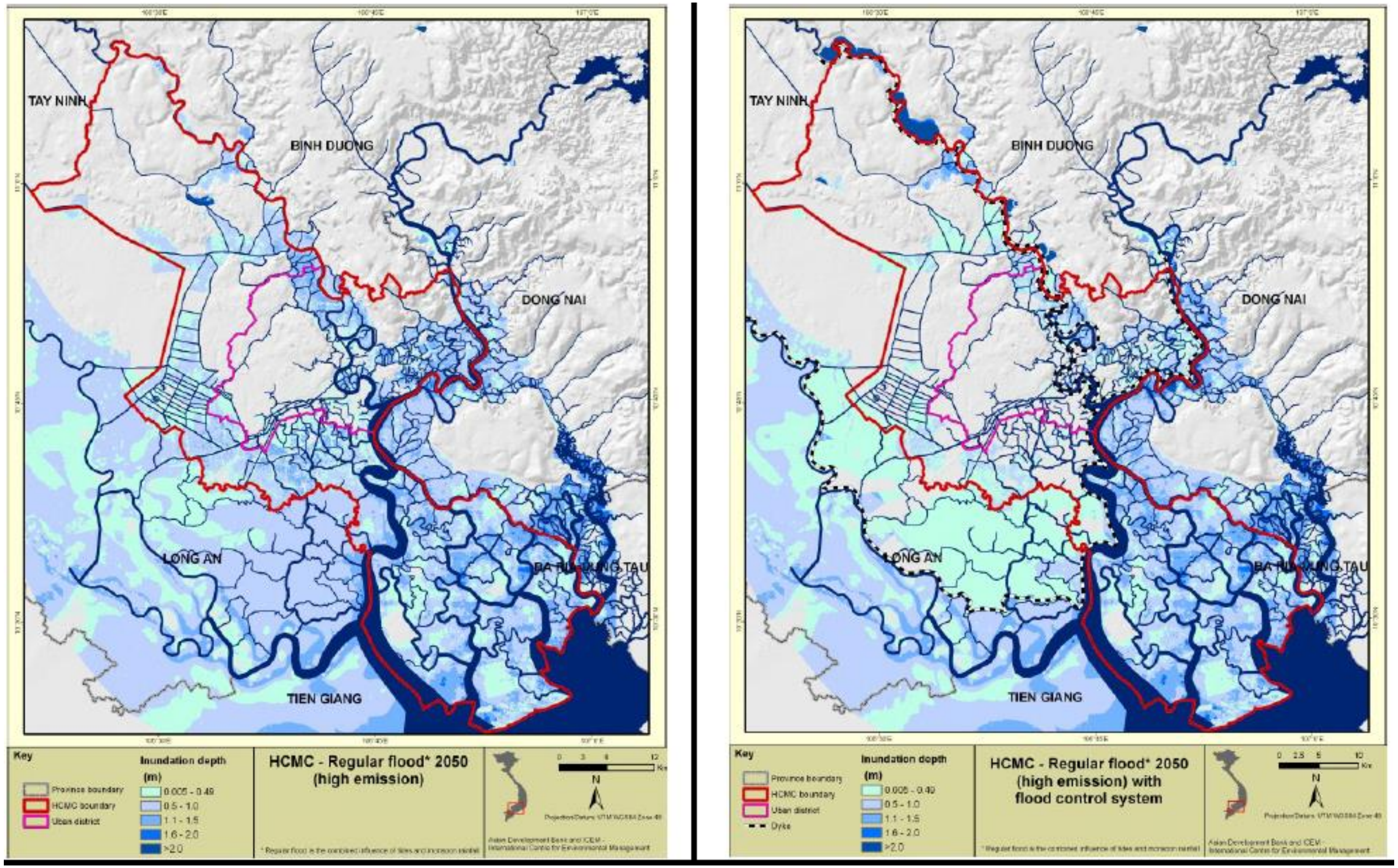
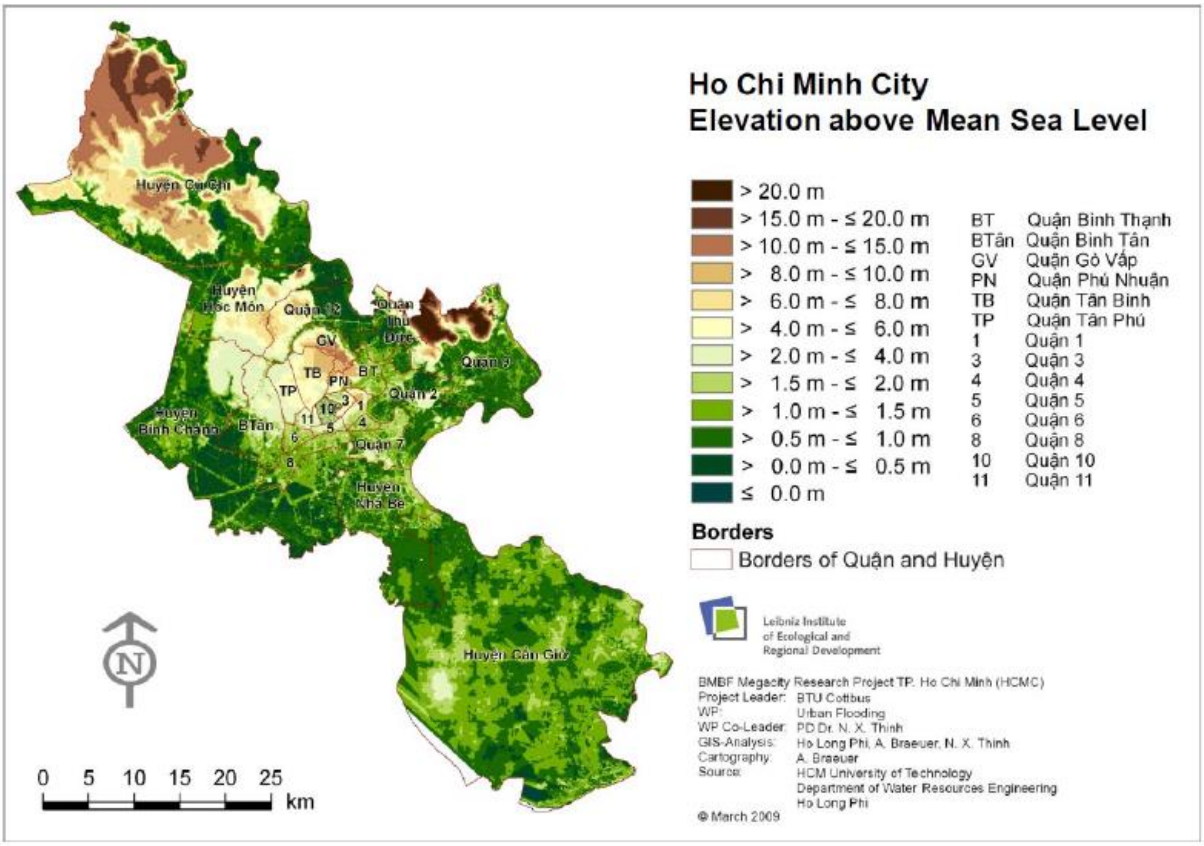


Figure 13. Elevation map of Ho Chi Minh City

Source: Climate Atlas in Ho Chi Minh City, VCAPS, p.9



4.2 Causes of urban flooding in District 2 and District 7 in Ho Chi Minh City

As mentioned before, this research aims at seeking solutions to reduce local flood risks due to heavy rainfalls in District 2 and District 7 in Ho Chi Minh City. However, in reality, the situation is more complicated as 'extreme precipitation' is not the only reason that brings about local inundation in these two districts. As far as we have known, precipitation in Ho Chi Minh City is a serious problem, especially in low-lying districts, because of urbanization and fast-paced development in Ho Chi Minh City (Royal Haskoning DHV, 2011), green and blue open spaces have been constantly replaced with houses, buildings, roads, etc., which cannot naturally absorb water runoffs. In other words, lands and spaces are not wisely used to absorb rainwater and reduce runoffs' pressure on sewage and drainage systems in Ho Chi Minh City. Furthermore, increased intensity of rainfalls due to climate change bring about more and more flooding events. Last but not least, drainage sysem is ineffective and not properly functioning to serve the purpose of catching excess amount of rainwater (Royal Haskoning DHV, 2011). For instance, Nguyen Huu Canh street (both situated in District 2 and Binh Thanh District), Ho

Chi Minh City is a typical example of areas in Ho Chi Minh City which is extremely vulnerable to flooding because it is situated in the most low-lying area. With the appearance of high-rise buildings in Nguyen Huu Canh street, soil subsidence and flooding have become more severe with time (Tran, D., Personal Interview, May 29th, 2018). In addition, the appearance of high-rise buildings has decreased storage capacity of rainwater in, which increases the frequency of flooding.

4.3 Flooding data due to heavy rainfalls in District 2 and District 7, Ho Chi Minh City from from 2016 to 2018

The Steering Center for Flood Control reported on flooding sites in District 2 and District 7. The statistical information in the synthetical report includes depth (m), length (m), area of flooding (m^2), the amount of time for water to go down (minutes), times of flooding (times) and period of time (days) of flood events. This information is synthesized in the following figures. There are several days of flooding in each month; however, the below figures only provide rainfall data on one or two days of flooding in each month to demonstrate rainfall amount in District 2 and District 7 in each year. Years of 2016, 2017 and 2018 are chosen to describe rainfall patterns in the two districts to provide the most reliable and updated data.

Because of differences in terms of the amount of rainfalls between different areas in District 2 and District 7, the rainfall data will be described separately. Also, as Ho Chi Minh City as well as Vietnam is located in tropical regions, the amount of rainfall reaches its peak value in months from May to November (Asian Development Bank, 2010), so rainfall data in these months is mainly provided.

Rainfall data in District 2 in 2016 and 2017

As described in Figure 14, Quoc Huong road (covered by red lines) is located in the middle of Thao Dien area, District 2 and Thao Dien area, which is located next to Sai Gon River, belongs to the north-western part of District 2. The figures will be shown about flooding due to heavy rainfalls in each area based on time order.

Figure 14. Quoc Huong road, District 2

Source: Google Maps

Figure 15 shows the area of Road 65 to House no. 79 in Quoc Huong road, Thao Dien, District 2 and Figure 16 shows the rainfall data of the small area in 2016. In 2016, rainfall data was recorded on May 18th, June 20th, July 27th and August 11th. The area of flooding (in m^2) reached its highest number of 800 m^2 on August 11th; meanwhile, on May 18th, the time of flooding was up to 210 minutes (more than 3 hours). The depth of flooding in all 4 days was approximately 0.15 meters.

Figure 15. The area of Road 65 to SN 79 (House no.79) in Quoc Huong, Thao Dien, District 2

Source: Google Maps

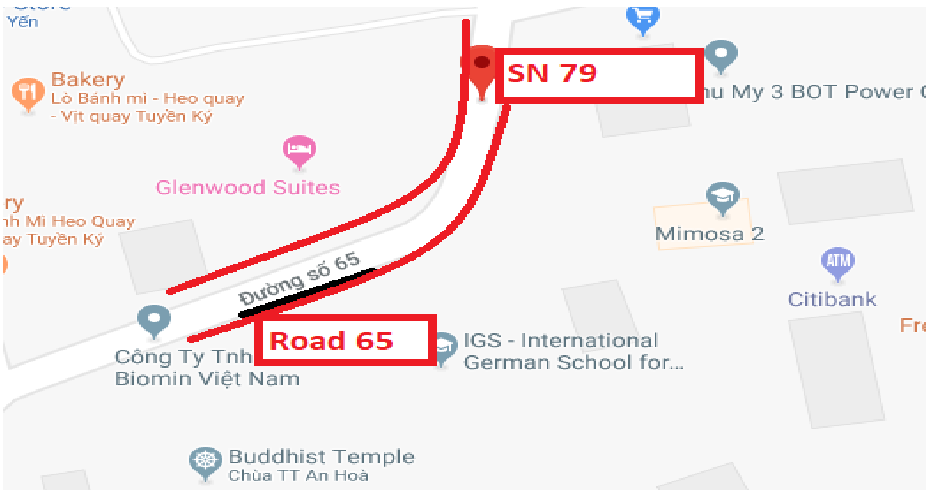
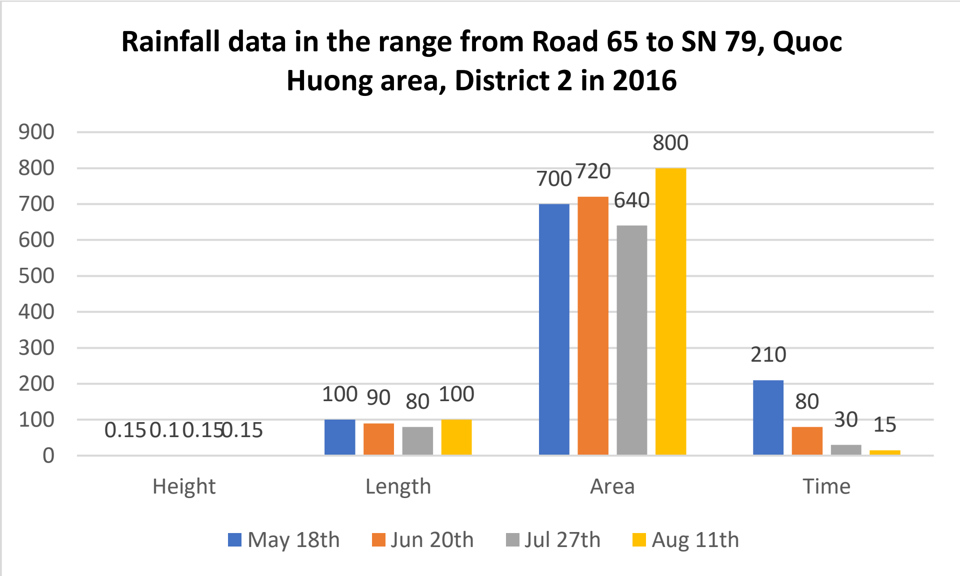


Figure 16. Rainfall data in the area from Road 65 to SN79, Quoc Huong, District 2 in 2016

(Height: meters; Length: meters; Area: m^2; Time: minutes)

Source: Steering Center for Flood Control



*(Height: meters; Length: meters; Area: m^2; Time: minutes)

Figure 17 describes another part of Quoc Huong area, which is from Road 47 to Xuan Thuy Road and its rainfall data is shown in Figure 18. There are two days of heavy rainfalls bringing about flooding in this area, which are August 26th and October 23rd, 2016. The area of flooding went up to 1600 m^2 on August 26th and the time for water to draw down took up to 363 minutes. The inundation depth was 0.35 meters on average.

Figure 17. The area of Road 47 to Xuan Thuy Road, Quoc Huong, District 2

Source: Google Maps

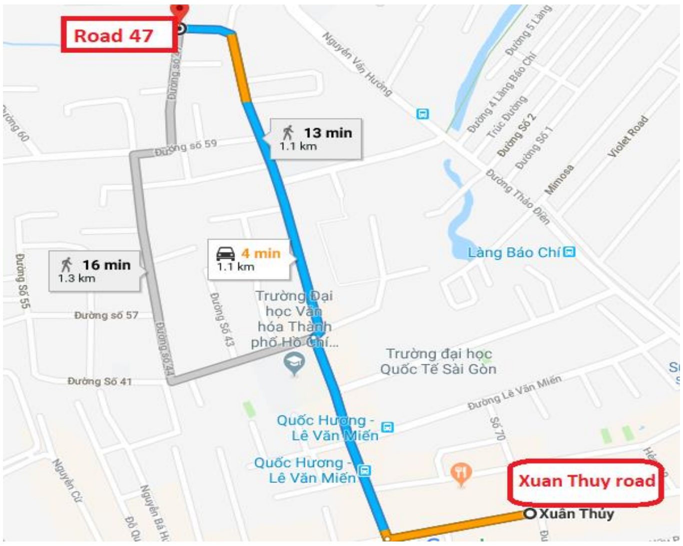
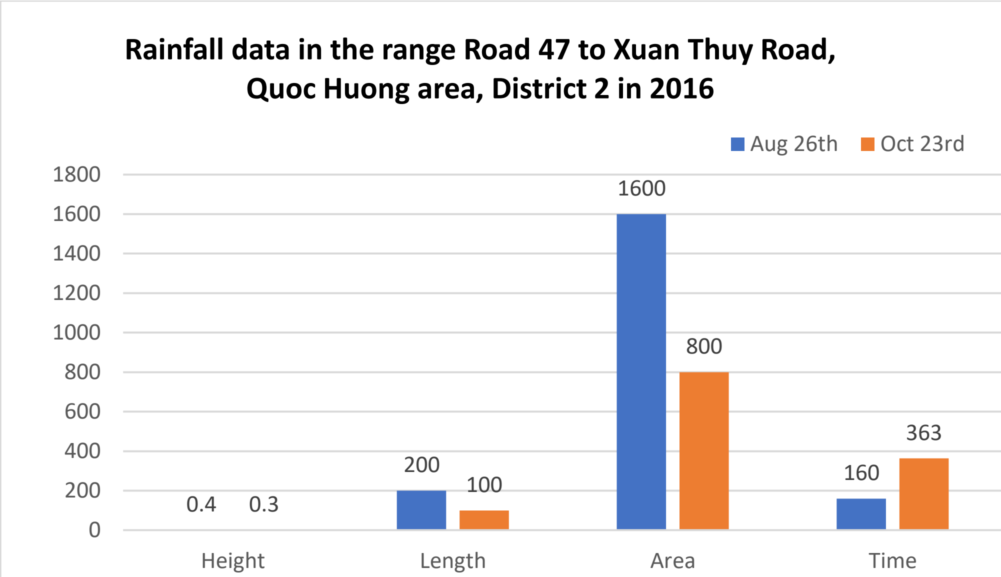


Figure 18. Rainfall data in the area from Road 47 to Xuan Thuy Road, Quoc Huong, District 2 in 2016

Source: Steering Center for Flood Control



*(Height: meters; Length: meters; Area: m^2; Time: minutes)

Figure 19 and Figure 20 below provide data on the area from Van Hoa University of SN 85, Quoc Huong, District 2. Rainfall that causes flooding happened on October 29th and November 5th, 2016. The recorded flooding depth was approximately 20 cm and the time for water to draw down was nearly 1 hour and a half. The area of flooding in two days was quite remarkable, ranging from 1000 to 1800 m^2.

Figure 19. The area of Van Hoa University to SN 85, Quoc Huong

Source: Google Maps

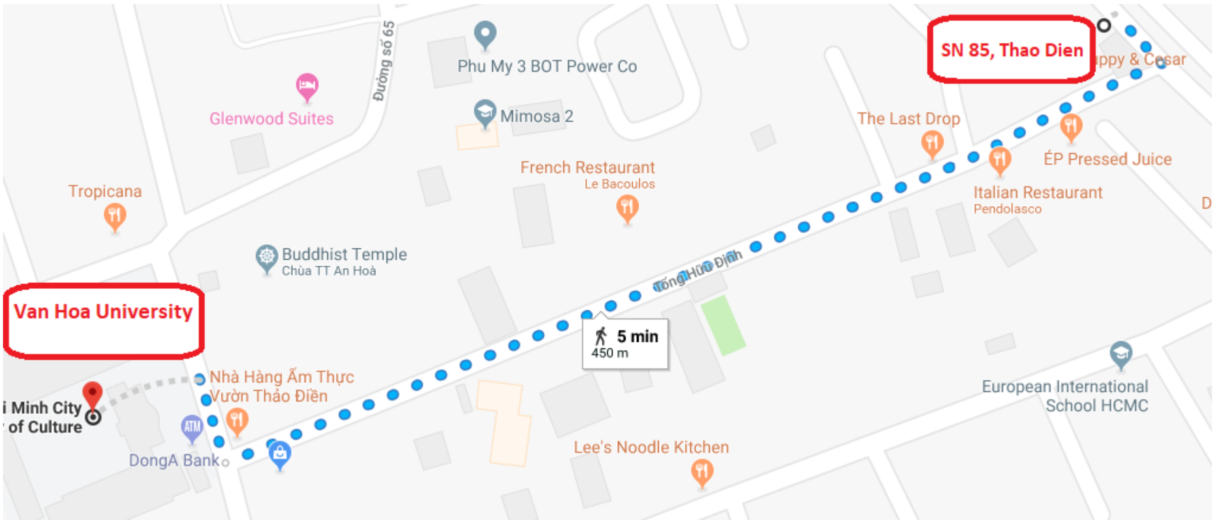
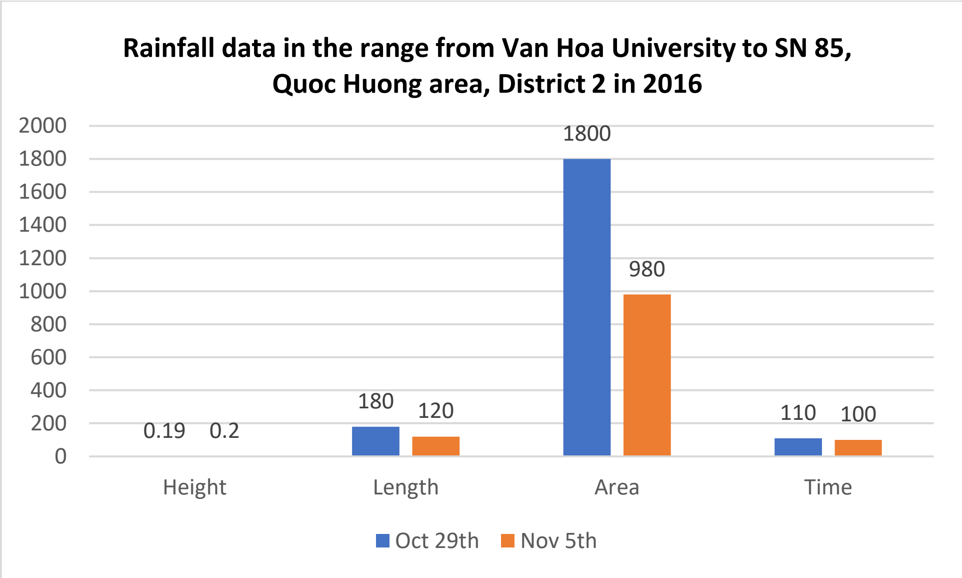


Figure 20. Rainfall data in the area from Van Hoa University to SN 85, Quoc Huong, District 2 in 2016

Source: Steering Center for Flood Control

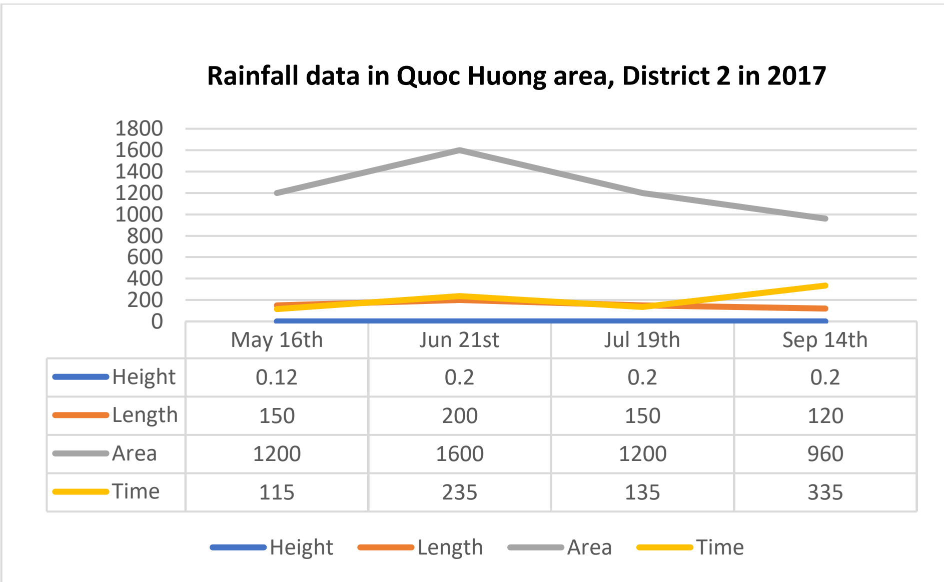


*(Height: meters; Length: meters; Area: m^2; Time: minutes)

Figure 21 shows rainfall data in Quoc Huong area, District 2 in 2017. It was following the same trend in 2016, the area of flooding in 4 days were significant and its reached its peak on June 21st, 2017 with the value of 1600 m^2. On average, it took more than 2 hours for water to go down and the inundation depth was approximately 0.15 meters.

Figure 21. Rainfall data in Quoc Huong area, District 2 in 2017

Source: Steering Center for Flood Control



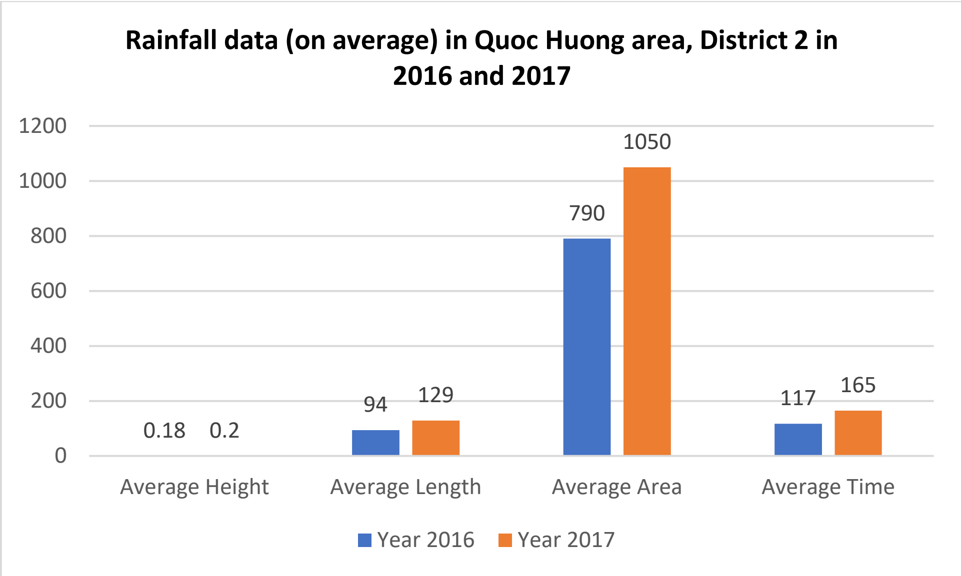
	May 16th	Jun 21st	Jul 19th	Sep 14th
Height	0.12	0.2	0.2	0.2
Length	150	200	150	120
Area	1200	1600	1200	960
Time	115	235	135	335

*(Height: meters; Length: meters; Area: m^2; Time: minutes

Furthermore, comparison of rainfalls in Quoc Huong area in District 2 between 2016 and 2017 is clearly illustrated in Figure 22. To be more specific, from 2016 to 2017, it is an increasing trend in all aspects (inundation depth, length of flooding, area of flooding and time of flooding).

Figure 22. Average yearly rainfall in District 2 in 2016 and 2017

Source: Steering Center for Flood Control

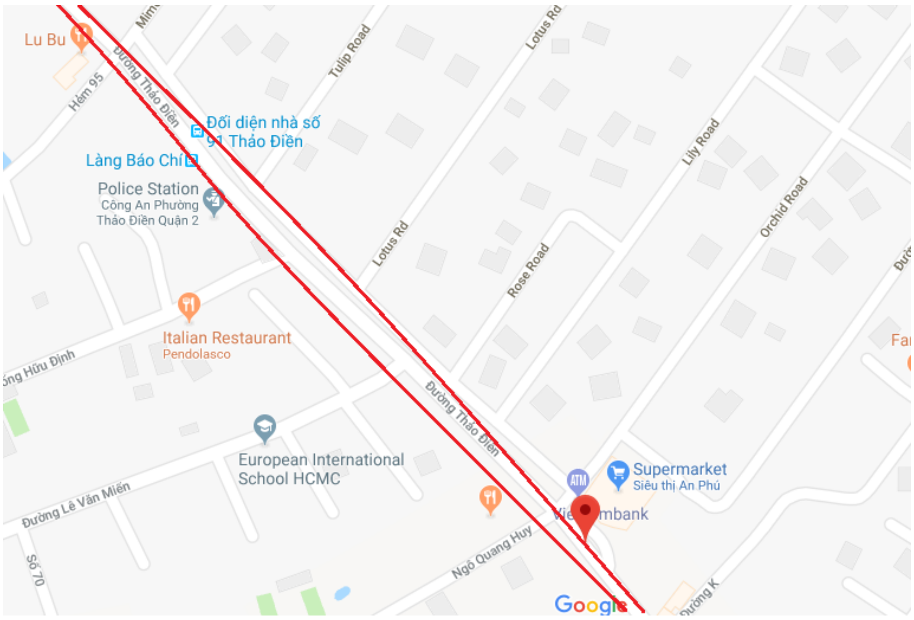


*(Height: meters; Length: meters; Area: m^2; Time: minutes)

Figure 23 shows Thao Dien road in the map of District 2 and Figure 24 and 25 shows the rainfall data of Thao Dien road in 2016 and 2017.

Figure 23. Thao Dien road, District 2

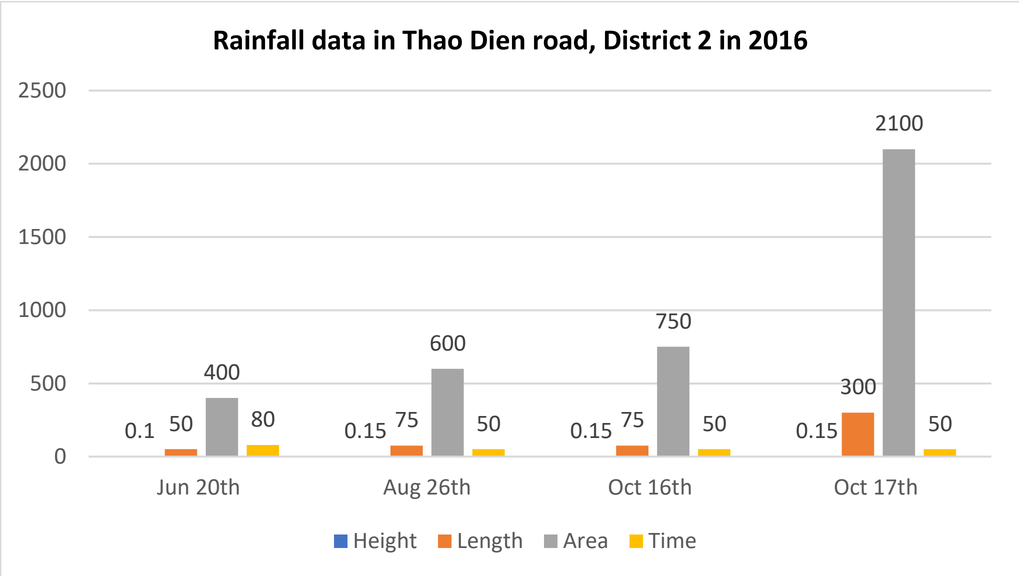
Source: Google Maps



In Thao Dien road, District 2, there are 4 days of flooding in 2016: June 20th, August 26th, October 16th and October 17th. Area of flooding increased over months in 2016 and it reached its highest value (2100 m^2) in October 17th. Rainfall event on October 17th also had the highest length of 300 m. Average inundation depth in four days of flooding was approximately 0.13 m (Figure 24).

Figure 24. Rainfall data in Thao Dien road, District 2 in 2016

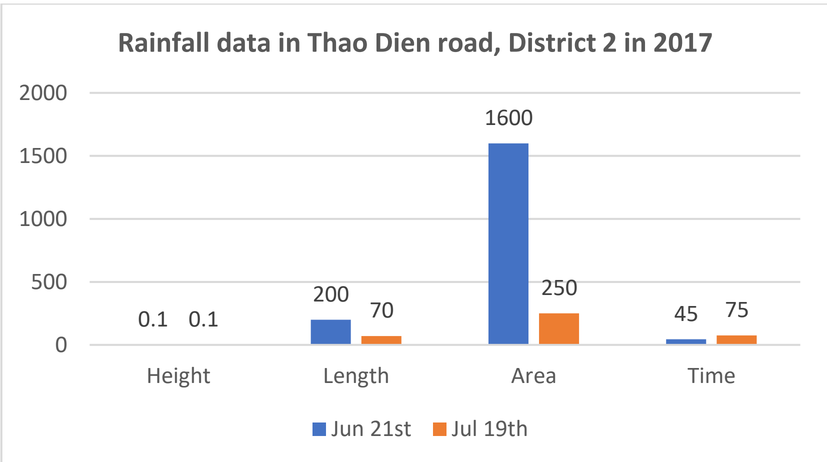
Source: Steering Center for Flood Control



*(Height: meters; Length: meters; Area: m^2; Time: minutes)

Figure 25. Rainfall data in Thao Dien road, District 2 in 2017

Source: Steering Center for Flood Control



*(Height: meters; Length: meters; Area: m^2; Time: minutes)

In 2017, in Thao Dien road both inundation depth and area of flooding reduced quite significant compared to these values in 2016 (Figure 25). To be more specific, the maximum area of flooding was 1600 m^2 compared to 2100 m^2 in 2016. Also, time for water to draw down reached its maximum at 75 minutes, which is 5 minutes sooner than that of rainfalls in Thao Dien road in 2016.

Figure 26 and Figure 27 below provide information on location of Nguyen Van Huong Road on the map and its rainfall statistics in 2016.

Figure 26. Nguyen Van Huong road, District 2

Source: Google Maps

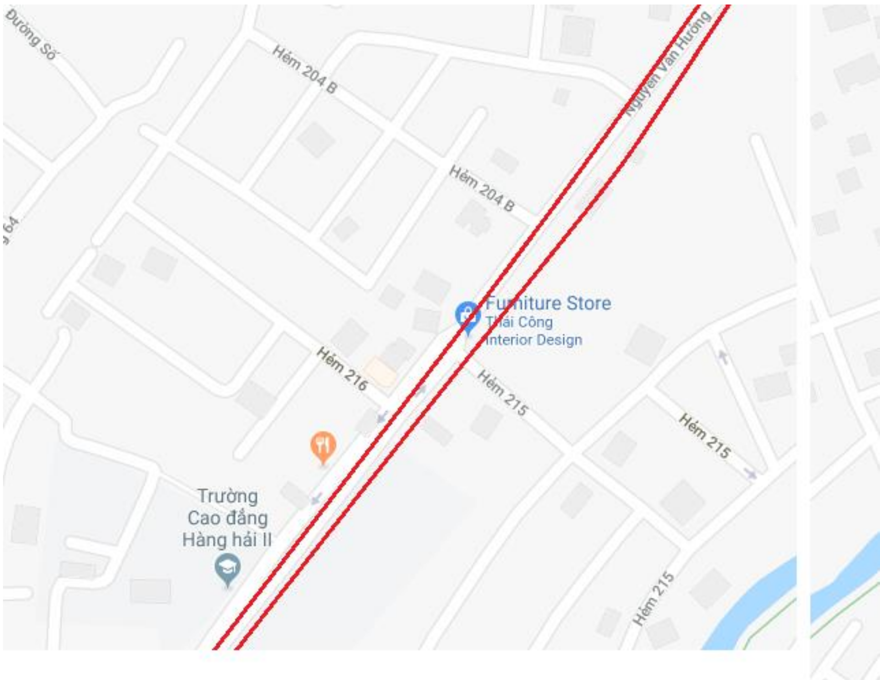
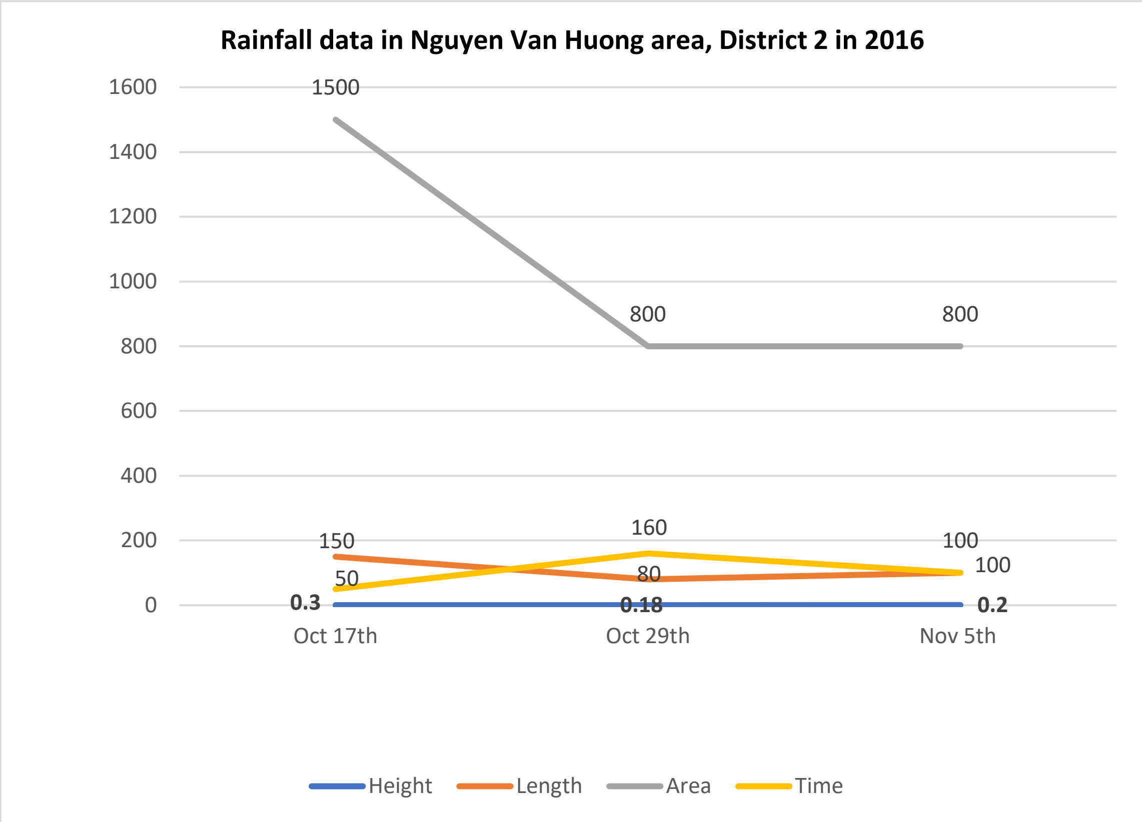


Figure 27. Rainfall data in Nguyen Van Huong Road, District 2 in 2016

Source: Steering Center for Flood Control



*(Height: meters; Length: meters; Area: m^2; Time: minutes)

It can be seen clearly in Figure 27 that the greatest amount of time of water to draw down was on October 29th, 2016, the highest level of flooding (0.3 meters) was on October 17th, 2016 and 1500 m^2 was the biggest area of flooding, which happened also on October 17th.

Rainfall data in District 7

The below figure shows Huynh Tan Phat road on the map and average rainfall data in Huynh Tan Phat road in 2016, 2017 and the first half of 2018 is illustrated in Figure 28.

Figure 28. Huynh Tan Phat road, District 7

Source: Google Maps

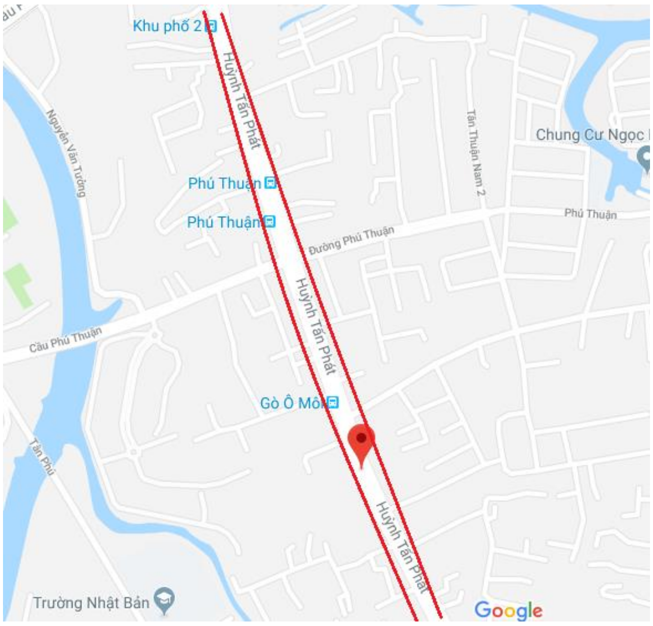
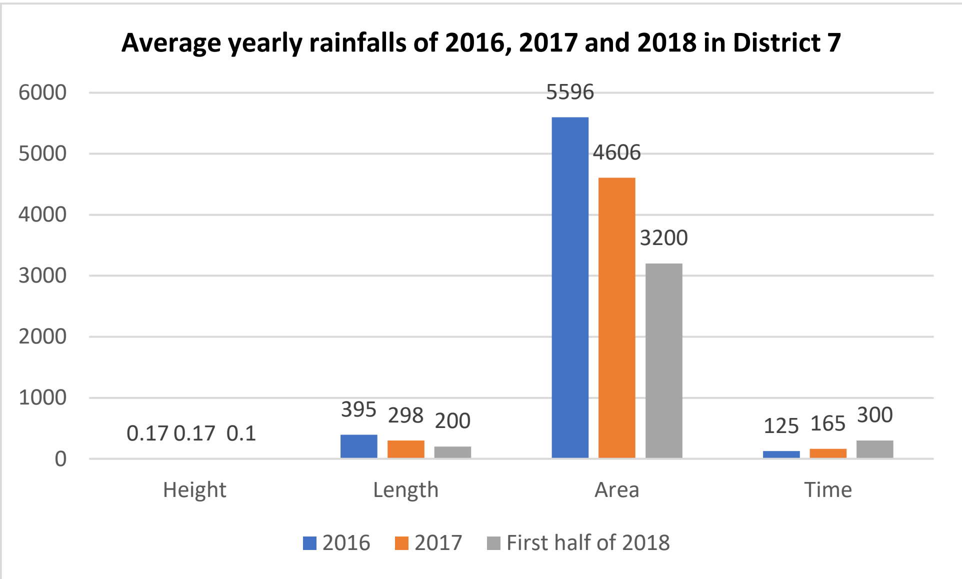


Figure 29. Comparison of average yearly rainfall in Huynh Tan Phat, District between 2016, 2017 and 2018

Source: Steering Center for Flood Control



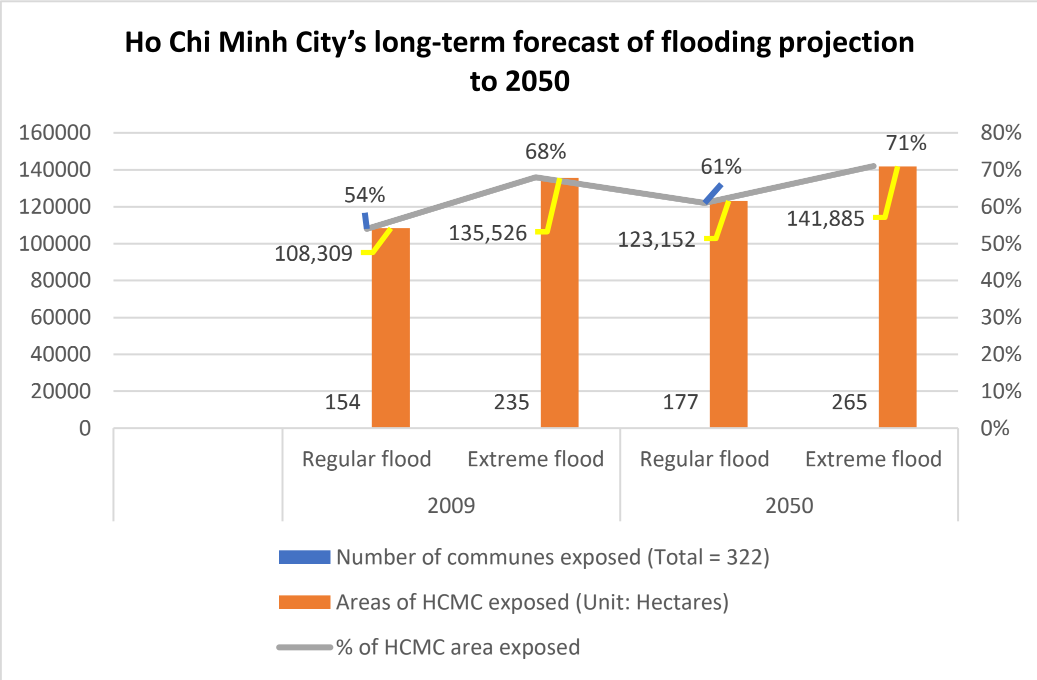
*(Height: meters; Length: meters; Area: m^2; Time: minutes)

From 2016 to 2018, height of flooding, length of flooding and area of flooding all showed a decreasing trend; however, time of flooding was on the rise, from 125 minutes in 2016 to 165 minutes in 2017 and 300 minutes in 2018.

Long-term forecast on flooding due to rainfalls in Ho Chi Minh City

Figure 30. Ho Chi Minh City's long-term forecast of flooding, projection to 2050

Source: Asian Development Bank, 2010



Asian Development Bank, 2010 predicted rainfall and flooding patterns in Ho Chi Minh City, projection to 2050 (Figure 30). Of HCMC's 322 communes, in 2050, 177 will suffer from regular flooding and 265 will suffer from extreme flooding, compared to 154 and 235 in 2009. In 2009, regular flooding covered 108,308 ha and extreme flooding covered 135,526 ha. It is expected that in 2050, these numbers will be increasing to 123,152 ha (for regular flood) and 141,885 ha (for extreme flood) and this will account for 61% and 71% of HCMC area. One of the reasons that trigger this in the future is urban development. According to Asian Development Bank, 2010, flooding due to heavy rainfalls under the impacts of climate change will be intensified owing to urbanization as it reduces the capacity of the city to infiltrate rainwater, which causes localized flooding in Ho Chi Minh City.

CHAPTER 5: AMBITIONS, GOALS AND PLANS AND MEASURES OF FLOOD MANAGEMENT IN HO CHI MINH CITY

Research sub-question: *Which areas or districts in HCMC that urban spatial plans or urban climate adaptation plans are focusing on? Which results do they get so far in terms of flood management in these areas? Which elements of the plans that need to be strengthened and improved to produce better results?*

Chapter 5 describes Ho Chi Minh City's goals and measures of flood management in the city, especially in District 2 and District 7. The part 5.1 elaborates on ambitions and goals of HCMC in flood risk control by HCMC People Committee, Steering Center for Flood Control, etc. Furthermore, from these goals and ambitions, plans and measures are implemented in several regions in HCMC, which are clearly illustrated in part 5.2. In this part, effectiveness of these current plans and measures are also analysed. On top of that, recommendations on improvements of these plans and measures to increase Ho Chi Minh City's capacity in reduce local flood risks are developed in the text.

5.1 Ambitions and goals

According to VCAPS' report: Climate Adaptation Strategy in Ho Chi Minh City, 2013, Ho Chi Minh City's general ambition in the Master Plan 2015 is to turn Ho Chi Minh City into "a modern industrial city in 2025 in which fast economic development is connected with sustainable development so that social progress and fairness are realised whilst protecting the environment" (VCAPs, 2013, p.10). Particularly, Ho Chi Minh City's citizens will be offered a safe, healthy and pleasant environment to live and work. In this meaning, Ho Chi Minh City is expected to be less vulnerable to climate change and its impacts such as heavy precipitation, changes in river runoff and flooding. It is also reported in the report that if Ho Chi Minh City would like to achieve above-mentioned ambitions, a climate adaptive approach will soon be needed and the important issues that need looking at include: reducing the effects of flooding, maintaining better living conditions (parks, open spaces, open water, etc. and lastly, enhance housing and infrastructures' ability to adapt to climate change such as using green roofs and developing heat adapted buildings.

Flood control goals by HCMC People Committee

Under the program of flood and inundation controls in the period 2016 – 2020 in Ho Chi Minh City, HCMC People Committee has come up with a plan with aims, goals, missions and actions for flood control in central urban areas and other areas in Ho Chi

Minh City. The aim of the People Committee is to solve inundation central districts and other areas, with the total area of 550 km^2 and a population of 6.5 million people; to enhance water storage capacity within the city and to improve living conditions of residents. In addition to projects and plans to enhance the capacity of drainage systems and to construct waste water treatment plants, several non-structural measures will be implemented under the program, in which they are:

- Quality improvement in the process of spatial planning and spatial planning management;
- Research in finding flooding sites due to heavy rainfalls;
- Enhancement of effective collaboration and communication between different regions in terms of flood management;
- Development and planning of back-up plans to reduce flood risks due to extreme precipitation;
- Improvement in management skills of governmental and state agencies towards drainage systems and waste water treatment plants;
- Focus on seeking financial investments and international collaboration and consultation in flood and inundation controls;

5.2 Current measures

It is mentioned by a representative from SCFC that primarily there are two kinds of measures to reduce local flood risks in Ho Chi Minh City, including structural and non-structural measures. SCFC representative stated that non-structural measures include public communication towards environmental protection such as littering in proper places to prevent trash stuck in mouths or drains and proper spatial planning of drainage systems in Ho Chi Minh City. Meanwhile, the representative reported that structural measures are divided into short-term, mid-term and long-term measures. Short-term measures include the construction of pumping stations and implementation of dredging canals to enhance the capacity of water storage; mid- and long-term measures are improvement of drainage and sewerage systems, construction of tidal sluice gates and investment on building waste water treatment plants.

Effectiveness of flood and inundation control activities by SCFC

Programs and efforts in flood control of SCFC finally showed several positive results. According to a representative from SCFC, in 2008, there were 126 flooding sites in Ho Chi Minh City. In 2011, the number of flooding sites reduced to 58 (around 54% reduced compared to 2008). In general, flooding is no longer a serious problem in several roads such as 3/2, Xo Viet Nghe Tinh, No Trang Long, etc. In 2015, there were 40 flooding sites left (in total) and 17 out of them were flooded due to heavy rainfalls. Up to now, in total, there have been only 25 flooding sites left.

Other adaption measures in reducing local flood risks in Ho Chi Minh City

Scussolini, P. *et al.,* 2014 have synthesized primary adaption measures to control flooding in Ho Chi Minh City. They include, firstly, Business-as-Usual or in other words, traditional urban drainage systems with (underground) pipes, dykes and levees. This urban drainage system is currently being upgraded but ineffectively maintained in general. Another adaptation measure is Ring Dike encircling the inner part of Ho Chi Minh City and along with a peripheral ring road, known as primary measures in flood control in MARD Plan of Ministry of Agricultural and Rural Development. Furthermore, buildings in Ho Chi Minh City are being constructed at higher elevation by raising ground level with sand.

Each measure of flooding control has its own effectiveness and impacts, said by Scussolini, P. *et al*., 2014. For example, ring dike is considered effective within dike-enclosed areas, even when large floods with the probability of one every 1000 years happens. To be more specific, ring dike could lower the damage by 80 to 90% (Scussolini, P. *et al*., 2014, p.10850). However, ring dike might cause flooding problems outside the dike-enclosed areas by diverting waters outside and then increase flood depth in the eastern part of Sai Gon river.

Ho Chi Minh City's governments used to make a decision in using the most modern pumping technology with the capacity of 96,000 m^3 to solve flooding due to heavy rainfalls in Nguyen Huu Canh street (Figure 31 and 32) and this project was implemented by Quang Trung Mechanical Engineering Group (Nguyen, D., *et al,* 2017). However, according to an expert from Ho Chi Minh City University of Technology – Luong Van Thanh, that technology itself is not effective in reducing flood risks. First of all, old and insufficient drainage systems (manholes) cannot deal with great amount of water from high-powered pumping machines. Furthermore, as Vietnamese people often litters so trash and solid wastes following runoffs went into the pumping machines, which reduce their capacity in pumping rainwater and bring about damages to the machines.

Figure 31. Super drainage pump in Nguyen Huu Canh street, HCMC

Source: Nguyen, D., *et al,* 2017

Figure 32. Operating super drainage pump in Nguyen Huu Canh street, HCMC

Source: Nguyen, D., *et al,* 2017

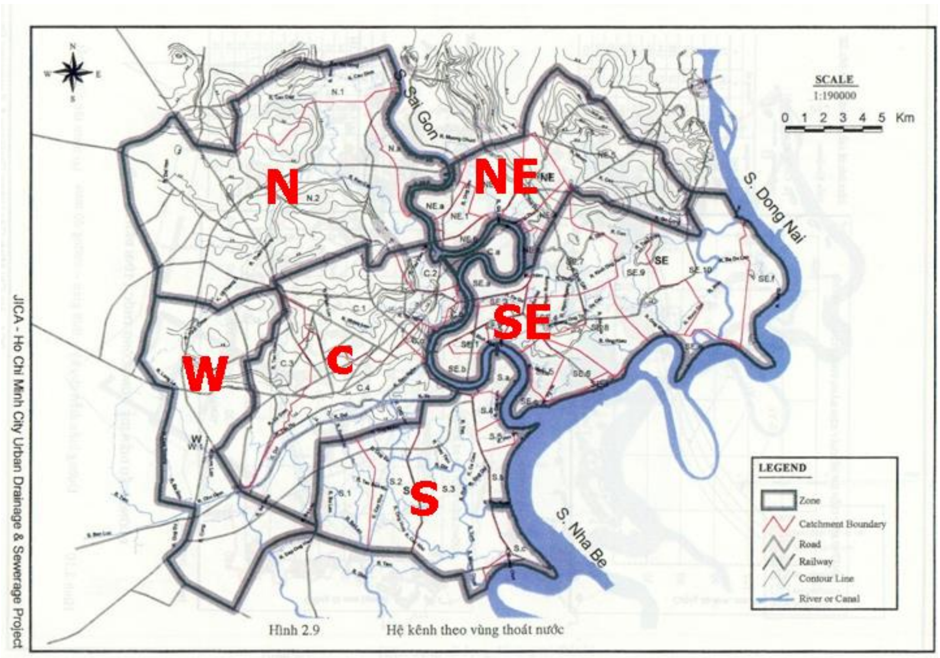
5.3 Plans of flood and inundation management

JICA Master Plan

It is clearly indicated in the Inception report: Ho Chi Minh City Flood and Inundation Management by Royal HaskoningDHV, 2011 that HCMC Urban Drainage and Sewerage System Master Plan by JICA Study Team or JICA Master Plan, approved by the Prime Minister dated June 19th, 2001, mainly concentrated on improving drainage conditions in approximately 650 km^2 of urban areas in Ho Chi Minh City. A certain number of drainage enhancement projects for 9 sub-basins in Ho Chi Minh City have been identified by the JICA Master Plan. To name a few, there are several projects: HCMC Water Environment Improvement Project (Tau Hu – Ben Nghe – Doi – Te Canals sub-basin), HCMC Environmental Sanitation Project (Nhieu Loc – Thi Nghe Sub-basin), Tham Luong – Ben Cat – Nuoc Len Canal Drainage and Pollution Improvement Project (Tham Luong, Ben Cat, Nuoc Len), HCMC Urban Upgrading and Sanitation Project (Tan Hoa – Lo Gom Sub-basin), etc.

Figure 33. Zoning in JICA Master Plan

Source: Desk Review Report, Royal Haskoning DHV and Deltares



To be more specific, according to the Inception Report of Flood and Inundation Management by Royal Haskoning DHV, the plan is implemented in different drainage zones (Table 13) and District 2 is located in the zone SE and District 7 is in Zone S. Table 13 provides several main activities that applied to different zones in the plan.

Table 10. Activities in Zone SE (including District 2) and Zone S (including District 7) in JICA Master Plan

Source: Inception Report of Flood and Inundation Management, Royal Haskoning DHV

Zone	Characteristics	Activities
S	Southern part of Doi- Te Canal Population of 110,000 people	Structural measures: construction of drainage channel, drains and pipes in the existing built-up area and drainage facilities in newly developed areas; partial improvement of main canals. Non-structural measures: land use regulations.
SE	Population of 120,000 people	Structural measures: rehabilitation of secondary/tertiary drainage facilities in the existing urbanized areas; canal improvement in adjustment with urbanization; construction of secondary/tertiary drainage facilities in newly developed areas. Non-structural measures: land use regulation for low-lying paddy field and preservation for future land requirement along the existing canals.

Review and analysis of JICA Master Plan

The JICA Master Plan on improvements of drainage systems in different zones in Ho Chi Minh City was reviewed in Desk Review Report 2014 of Royal HaskoningDHV and Deltares, as summary below:

- Heavy storms, sea level rise under the impacts of Climate Change and soil subsidence are not taken into consideration.
- Existing urban drainage system in Zone C was performing as expected in the plan.

Other ongoing projects

Other ongoing projects of flood controls in Ho Chi Minh City were implemented, as reported by Royal Haskoning DHV, 2011.

Table 11. Other ongoing projects of flood controls in Ho Chi Minh City

Source: Interim Report of Flood and Inundation Management, Royal HaskoningDHV

Number	Project	Main activities
1	Urban Drainage System Upgrading Project (Hang Bang subprojects)	Construction of 7 drainage systems in District 5, 6 and 11 in Hang Bang sub-basin.
2	Suoi Nhum Drainage System Project	Improvement of storm and rainwater drainage for about 4,080 ha of HCMC and 1,400 ha of Binh Duong Province.
3	Ba Bo Canal Rehabilitation Project	Rehabilitation of Ba Bo Canal (including dredging), construction of stabilization pond and canal system.

5.4 Review and analysis of these plans and measures

- It is easily noticed in projects and plans of flood and inundation controls in Ho Chi Minh City that they mostly depend on hard infrastructures to deal with flooding problems. These kinds of measures have high level of effectiveness in a large scale as well as to deal with big problems such as tidal flooding. However, using hard infrastructures somehow are considered not flexible and adaptive enough under the context of fast-changing climatic conditions as construction of hard infrastructures often need a great amount of time and sometimes, financial investments to complete.
- It is stated by World Bank that “in HCMC, most of the efforts to date have focused on structural measures” (World Bank, 2016, p.3). For instance, the JICA PLAN mainly deals with flooding due to heavy rainfalls by improving the efficiency of urban drainage systems within HCMC. Furthermore, World Bank also states that spatial planning in Ho Chi Minh City do not integrate flood risks management.
- Currently, there is high possibility or potential for Ho Chi Minh City to integrate Building with Nature principles into flood risk reduction, especially with the international support from different countries and multinational enterprises. As a result, it is recommended by the researcher of this research that to adapt to climate change and heavy rainfalls with greater intensity, it is necessary for Ho Chi Minh City

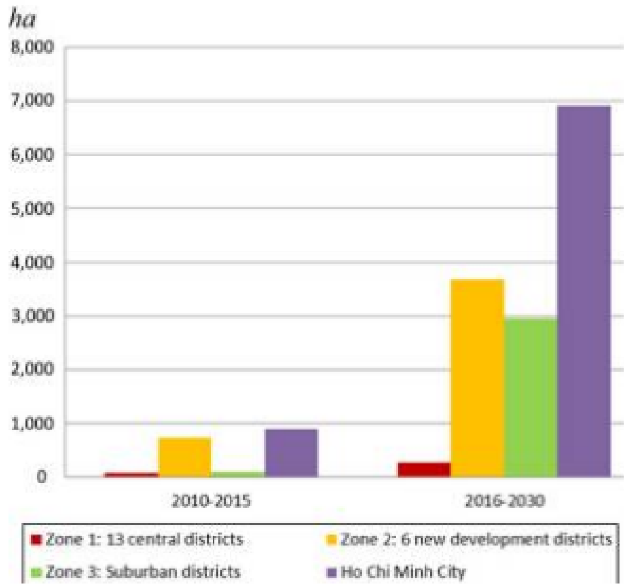
to use sustainable measures of flood management or apply Building with Nature principles into the process of flood management.

Recommendation on improvements of these measures and plans of flood control

It is stated by Phan, N., D., *et al.,* 2017 that District 2 and District 7 are new development districts, which have fast pace of urbanization. Owing to fast-paced urban development, Phan, N., D. *et al.,* 2017 also mentioned that several sub-areas such as District 2 and District 7 have high risks of flooding. Two newly developed areas as illustration are Thu Thiem (675 ha, District 2) and Phu My Hung (409 ha, District 7). Figure 17 shows prediction of land-use amount of housing of Zone 2 (newly developed areas, including District 2 and District 7) in the period of 2016 – 2030. From only nearly 1000 ha in the period 2010 – 2015, it is predicted that the area of land-use for housing will be increasing to approximately 3800 ha in the next 15 years (2016 – 2030). Also, Phan. N., D. *et al.,* 2017 triggered a concern that "these newly developed areas negatively affect indigenous hydrological systems, including green spaces and water bodies" (p.201). If there are fewer green areas to absorb rainwater and water storage spaces, flooding will become more alarming in these areas. In other words, with the rise of impermeable spaces in District 2 and District 7 and a significant loss of water bodies and green spaces, it can be seen that there is a tight interconnection between urbanization, urban planning and increasing frequency of flooding due to heavy rainfalls.

Figure 34. Predicted land-use for housing in different zones in HCMC

Source: Phan, N., D., *et al.,* 2017



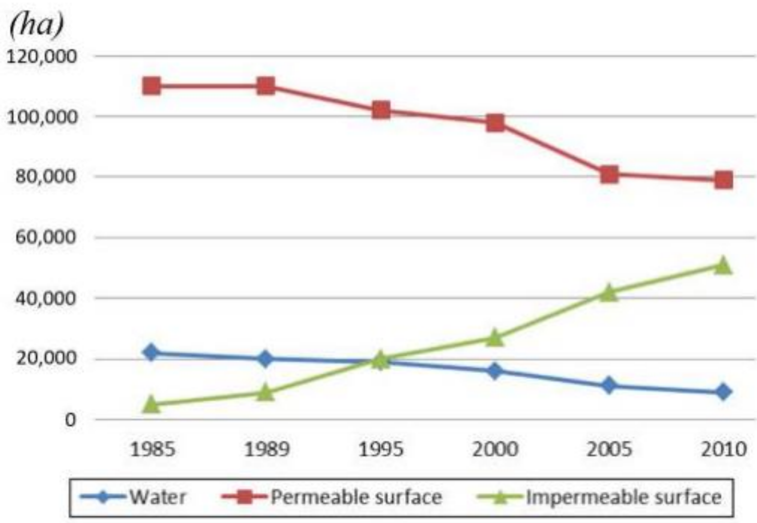
Meanwhile, using technical solutions (or structural measures) such as dikes, dams, etc., as Ho Chi Minh City is currently doing, is no longer adequate to reduce flood risks and not an adapting solution to climate change and more extreme rainfall patterns (van de Wouw, R., no year). Ran, J., and Nedovic-Budic, Z., 2014 mentioned that "flood-risk management strategies no longer primarily rely on structural measures" (p.69).

Instead of only using structural measures to control flooding, for newly developed areas such as District 2 and District 7 in Ho Chi Minh City, spatial planning plays an important role in flood protection and Ran, J., and Nedovic-Budic, Z., 2014 gave several following reasons for this statement. First of all, spatial planning or urban planning is potential for flood risk mitigation because by focusing on spatial distribution of types of land use and designs of physical infrastructures, spatial planning directly influences the incidence of flooding and its damages. Furthermore, in most cases, as planning agencies or urban planners have more power regarding land-use planning in different scale more than flood-risk agencies, urban planning potentially affects more crucial factors.

In Ho Chi Minh City, it can be figured out in Figure 35 that there is a lack of integration between spatial planning and flood risk management as urban development has made the amount of permeable surface decrease and the amount of impermeable surface increase, up to 2010. Also, the area for water in Ho Chi Minh City has also decreased slightly from 1985 to 2010, under the impacts of urban development along with population growth.

Figure 35. Changes in area of water, permeable surface and impermeable surface

Source: Phan, N., D., *et al.,* 2017



Under this circumstance, assume that urban development is inevitable, it is recommended that making effective use of urban planning and management is a potential solution to enhance Ho Chi Minh City's capacity to 'live with floods'. In other words, spatial planning should be integrated into the process of water or flood management. This new approach could be more appropriate for new development areas such as District 2 and District 7 because they are not fully urbanized; as a result, there are still opportunities and spaces to change.

Rotterdam, the Netherlands is an important example of 'Urban design for a waterproof city' (Moraci, F., *et al.,* 2018). Protection of the city from flooding is the main priority in its climatic strategy. Rotterdam is also making full use of urban or spatial planning to make the city less vulnerable and more adaptive to climate change. Urban retrofitting actions are widely applied through new technologies to improve the capacity of current infrastructures to help Rotterdam more resilient to fast-developed climatic situations. Moraci, F., *et al.,* 2018 stated that green roofs and enhanced water collection systems are two of five initiatives which are being promoted widely in Rotterdam. Furthermore, blue and green spaces are constructed in Rotterdam to increase city's permeable surface. It is important to note that both Rotterdam and Ho Chi Minh City are low-lying cities which are vulnerable to floods and climate change so it is a wise choice for Ho Chi Minh City to get to learn from what Rotterdam is currently doing.

Different international organizations have suggested a method for HCMC to reduce vulnerability to flooding, which is "increasing compactness in terms of spatial planning and management" (Phan, N., D., *et al.,* 2017, p.208). It is suggested that urban flood risks will soon be reduced if taking full advantage of urban planning at different management levels. To be more specific, turning open public space into 'water absorbable surface' such as green and blue areas to store and infiltrate runoffs can help control and reduce runoffs in heavy precipitation events. This approach of increasing water absorbable space is potentially appropriate for new development areas such as District 2 and District 7.

CHAPTER 6: NATURE-BASED SOLUTIONS FOR FLOOD CONTROL IN STUDY SITES IN HO CHI MINH CITY

Research sub-question: *What are possible and appropriate nature-based solutions to urban floods in Ho Chi Minh city? Is there any method to evaluate their effectiveness to reduce local flood risks in study sites in Ho Chi Minh City?*

Chapter 6 takes an in-depth view of nature-based solutions for flood risk management in District 2 and District 7 in Ho Chi Minh City. Roles of nature-based solutions in reducing local flood risks and helping Ho Chi Minh City to become less vulnerable and more resilient to flooding. Current studies, research and application of nature-based solutions in Ho Chi Minh City are described in Part 6.2. Part 6.3 and 6.4 elaborates on potentially appropriate nature-based solutions for sub-areas in District 2 and District 7. Also, Stormwater Management Model by the U.S Environmental Protection Agency is used to test the effectiveness of nature-based solutions in controlling runoffs and reduce flooding in Thao Dien area, District 2 and the results are illustrated in Part 6.5.

6.1 Importance of nature-based solutions in reducing local flood risks in Ho Chi Minh City

According to Royal Haskoning DHV, 2011, Ho Chi Minh City will be continuing to expand, even fast, in the nearest future and without careful and proper spatial planning, soon the city will be packed with high-rise buildings, industries and houses and that increases local flood risks due to heavy rainfalls. Official integration of nature-based solutions as water management potentially increases the chance to reduce local flood risks of urban spatial planning projects in District 2 and District 7. First of all, nature-based solutions, such as green and blue measures, can efficiently store or absorb rainwater so that reduces pressure on sewage and drainage systems of the studied areas. Secondly, via these measures, rainwater could be infiltrated back to the ground to slow down the rate of land subsidence. In addition, plants and trees used as nature-based solutions can absorb green-house gases to slow down global warming/climate change. Lastly, nature-based solutions with the involvement of different stakeholders (local community, companies and industries) can raise people’s awareness of flooding and flood management.

6.2 Current status of research, study and application of nature-based solutions in flood control in Ho Chi Minh City

According to Phong, N., V., 2014, the definition of sustainable flood management has been gained more attention because of the increasing frequency of flooding events in Ho Chi Minh City. There were several projects and research of different professors to analyse probability and feasibility of sustainable solutions to control flooding. Among them, there are two studies and applications that need to be mentioned. First of all, Professor Viet Anh Nguyen gave a presentation about the topic "sustainable methods of solving flooding due to heavy rainfalls in urban areas" in a workshop "Sustainable Urban Drainage" in National University of Civil Engineering along with a university in Loughborough, England in 2003 (Phong, N., V., 2004). Approximately 10 years later, he published a research to promote a new method and model of urban drainage in urban areas in Vietnam. These below-mentioned aspects were developed in the research:

- Sustainable urban drainage and wastewater treatment for different urban areas
- Sustainable urban drainage of surface water and runoffs
- Official proposal in urban drainage improvement for Vietnam
- Rainwater harvesting and reuse

There was also a research of Professor Canh Doan and his colleagues about the application of ecological engineering into construction of sustainable urban drainage systems to control flooding in Ho Chi Minh City. Besides, he also proposed an urban drainage system using the principle of ecological engineering for Hoang Van Thu park (Phong, N., V., 2014).

According to Nguyen, D., *et al,* 2017 in Australian Water Association, Ho Chi Minh City's authorities also invested in building retention ponds in District 2 (Figure 36) and in Tan Son Nhat airport (Figure 37). Furthermore, nature-based solutions in Ho Chi Minh City also gain attention from international firms. Sekisui Chemical Co. from Japan, to battle flooding due to precipitation, proposed a solution of using underground reservoir and it is said by a representative from the company that the very first capacity is about 100,000 cubic meters (Figure 38) (Nguyen, D., *et al,* 2017). The whole project of around 10 underground reservoirs in Ho Chi Minh City is expected to reduce flooding by one third.

Figure 36. Retention ponds (under construction) in District 2, Ho Chi Minh City

Source: Nguyen, D., *et al,* 2017

Figure 37. Retention ponds (under construction) near Tan Son Nhat Airport, HCMC

Source: Nguyen, D., *et al,* 2017

Figure 38. Underground reservoir by Sekisui Chemical Co., Japan

Source: Nguyen, D., *et al,* 2017

It is important to mention Green Real Estate in Vietnam. In the past 10 years, developers, investors and real estate agencies have played an important role in promoting green residential buildings in Vietnam. One of the purposes of green buildings is to reduce the amount of runoff after heavy rainfalls by keeping natural environmental as much as possible in upcoming real estate projects. As mentioned by a representative from GreenViet – a consulting company based in Ho Chi Minh City, in 2017, there were approximately 120 green buildings registered in Vietnam. In Ho Chi Minh City, Palm City, The Estella and Estella Heights in District 2 are some examples of Green Buildings.

Furthermore, several conferences about green buildings/green real estate were organized in Ho Chi Minh City, to promote green buildings, educate people about their benefits to the environment as well as to create a network in the field. In July, 2018, a bilingual conference of Green and Sustainable Real Estate in Ho Chi Minh City was organized by GreenViet, with the official participation of different experts, governors and firms from different countries to promote Green Real Estate in Vietnam (Figure 39). This conference was a platform for different stakeholders to bring about connection among real estate officers, customers and investors as well as to discuss about pros and cons of these sustainable projects in real estate in terms of water management, flood reduction and environmental protection within the city. Investors and developers were also important stakeholders in the conference as for them to have an opportunity to gain an in-depth understanding about sustainable real estate. The event can be seen as an effort by Vietnamese enterprises, governors and investors in integrating environmental aspects (flood management) into urban infrastructures to make Ho Chi Minh City more adaptive and less vulnerable to climate change.

Figure 39. Green Estate Conference in a hotel in District 1, Ho Chi Minh City

Source: Taken by master student (as the researcher of this thesis)

6.3 Potentially appropriate nature-based solutions for District 2 in Ho Chi Minh City

Nature-based solutions are chosen after considering one criterium in the area: current state of spatial planning in District 2 (as clearly explained suggestion for newly developed areas in part 5.3 of Chapter 5). In other words, the percentage of wide open spaces in different regions in District 2. First of all, in this context, decision-makers are primarily urban planners and landscapes architects to choose appropriate nature-based solutions based on current states of spatial planning in these areas.

Nature-based solutions fitting with current state of spatial planning in different parts of District 2

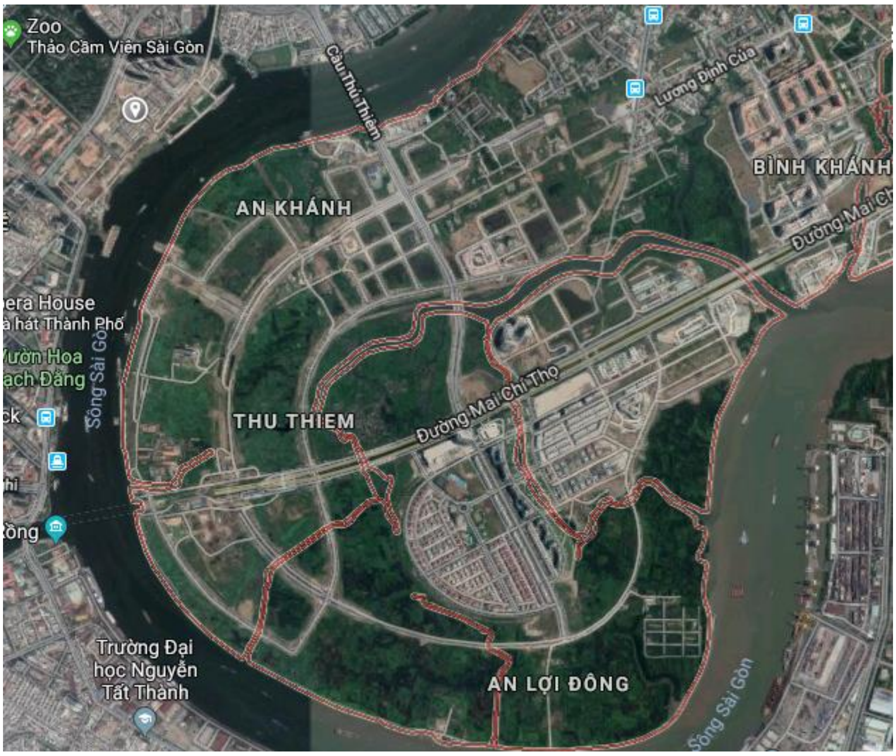
District 2 has the population of 147,168 and the area of 49.74 square km^2, which include 11 wards, said by the website named Modoho. As District 2 is relatively big, it is divided into several sub-areas to analyse to selection potentially appropriate nature-based solutions.

South-western area

South-western areas of Ho Chi Minh City have a wide range of open green spaces (Figure 40). There are also commercial buildings, different kinds of shops and stores, residential areas such as Sai Gon – Sala apartment and public spaces such as Sala stadium and supermarkets. Sai Gon River flows in the western part of the area. Based on above-mentioned characteristics in south-western area and soil characteristics in District 2, appropriate nature-based solutions for south-western part of Ho Chi Minh City include big-size rain gardens and big underground storage as they require a great deal of open spaces. Also, green roofs can be constructed in different residential buildings in the area such as Sala residential areas and Sadora apartments.

Figure 40. Satellite image of South-western region in District 2, Ho Chi Minh City

Source: Google Maps

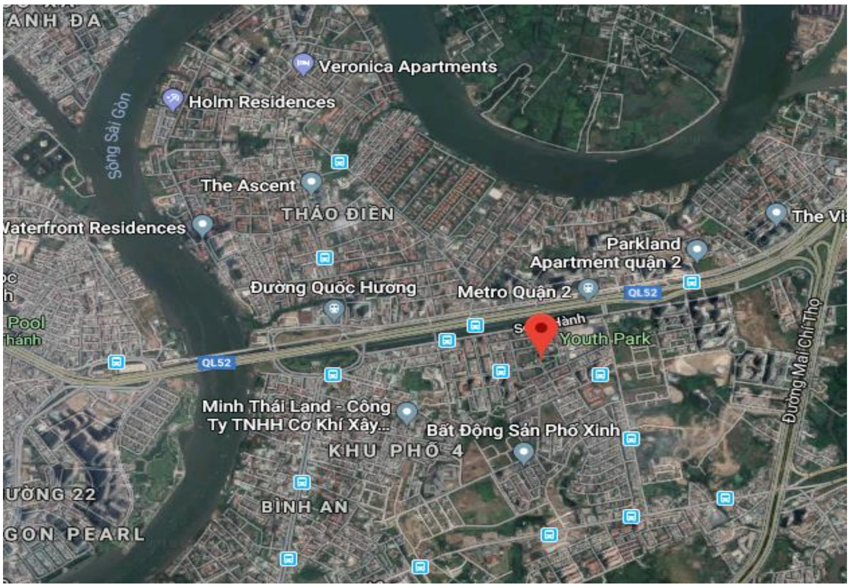


North-western area

North-western areas include Thao Dien sub-area, An Phu – An Khanh sub-area, etc. In this north-western part of the city, there are a wide range of high-rise residential buildings, several commercial buildings, parks, big supermarkets and shopping malls (Figure 41). There is less open space for the development of nature-based solutions compared to south-western part of District 2. However, in this north-western region, there is a canal along Xa Lo Ha Noi road to store rainwater. Because of limited open space, appropriate nature-based solutions for this region include stormwater street trees, green roofs, stormwater tree pits, and subsurface storage, which could be used and applied gradually in households in different residential places such as Holm Residences, Veronica Apartments, Parkland apartment, etc.

Figure 41. Satellite image of North-western region in District 2, Ho Chi Minh City

Source: Google Maps



The middle area

Figure 42. Satellite image of north-middle region of District 2, HCMC

Source: Google Maps

As seen in Figure 42, there is a big difference between the northern part and the southern part in this region in District 2: there is a lot more open space in the northern part than in the southern part. Suitable nature-based solutions for this area could be basins, ponds, subsurface storage devices, and permeable pavements.

Figure 43. Satellite image of south-middle region of District 2, HCMC

Source: Google Maps

On the other hand, in the southern parts (Figure 43), there are mainly Local Government Office, hospitals, houses, residential buildings, companies and churches. As a result, the southern part in the middle area, District 2 is already fully packed with urban infrastructures so it is a challenge to develop Building with Nature solutions requiring large open spaces. The applicable nature-based solutions mainly are green roofs, rain gardens, stormwater tree pits and stormwater street trees.

North-eastern area

In this area, there are mainly villas, An Khang – Phu Huu residential areas, apartments, companies, corporations, supermarkets, shopping malls, stores (Figure 44). Appropriate nature-based solutions could be green roofs, permeable paving, stormwater street trees, basins and ponds and rain gardens, which are fit to the area without much open spaces.

Figure 44. North-eastern part of District 2, Ho Chi Minh City

Source: Google Maps

Figure 45. Villas in north-eastern region in District 2, Ho Chi Minh City

Source: Google Maps

South-eastern area

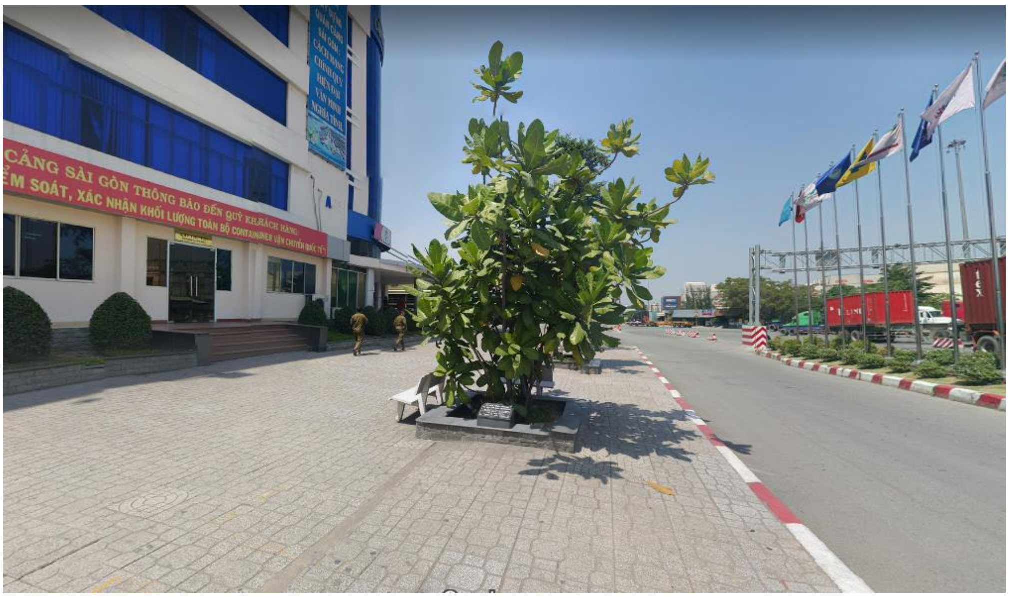
It can be seen clearly in Figure 45, the area is located next to Soai Rap River and it includes Cat Lai 2 Industrial Areas, Cat Lai Port, Citihomes apartments, schools, companies, and factories. The list of potential nature-based solutions for the region contains green roofs, street trees to store stormwater, rain gardens and subsurface storage.

Figure 46. Satellite image of South-eastern region in District 2, HCMC

Source: Google Maps

Figure 47. Tan Cang Sai Gon Company in District 2, HCMC

Source: Google Map



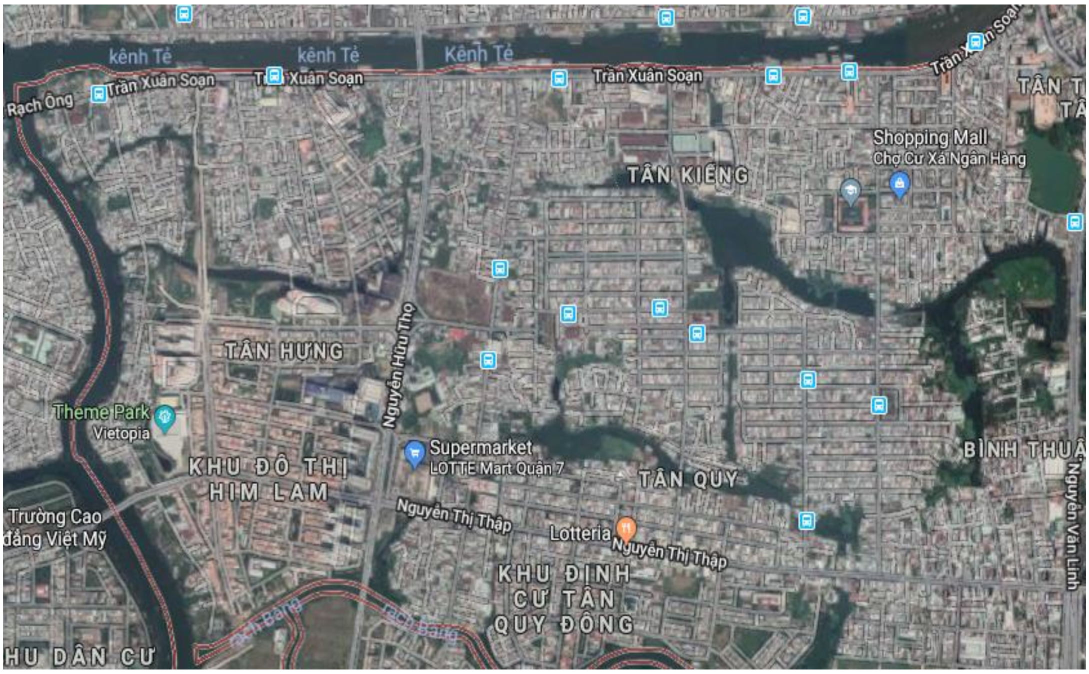
6.4 Appropriate nature-based solutions for District 7 in Ho Chi Minh City

Nature-based solutions for District 7 are also chosen based on current spatial planning (how urbanized the area is and how many percent of the sub-area is wide open space). According to Modoho, District 7 has 310,178 people living in the area of 35.69 square km^2. As being seen in Google Map in the following figures, there is less open space in District 7 compared to District 2.

North-western area

Figure 48. Satellite image of North-western region in District 7, HCMC

Source: Google Maps



As being seen in Figure 48, the north-western area in District 7 is quite packed with residential areas such as Him Lam urban area and An Phu Hung residential areas, supermarkets, schools, hospitals, convenience stores, etc. There are also several creeks and canals in the area. As there is limited open space, appropriate nature-based solutions for the area are green roofs, stormwater tree pits, rain gardens, and subsurface storage which can be applied at a household level.

South-western area

In District 7, the south-western area is less densely-populated than the north-western area. Several infrastructures include Ton Duc Thang University, Golf Course in Phu My Hung urban area, RMIT University, Sky Garden 3 residential buildings, Vietnam

– France Hospital, etc. (Figure 49) As it has a certain amount of open space, suitable nature-based solutions are permeable pavements, green roofs, stormwater tree pits, and basins and ponds.

Figure 49. Satellite image of South-western region in District 7, HCMC

Source: Google Maps

North-eastern area

In this area, besides residential areas, there are also industrial zones including Tan Thuan export processing zone, firms such as Pungkook Sai Gon, waste water treatment plants and several ports such as Ben Nghe port, Tan Thuan port and Tan Thuan 2 port (Figure 50). Appropriate nature-based solutions could be subsurface storage, green roofs, stormwater street trees and rain gardens because of limited open space.

Figure 50. Satellite image of North-eastern region in District 7, HCMC

Source: Google Maps

South-eastern area

Figure 51. Satellite image of South-eastern region in District 7, HCMC

Source: Google Maps

The region is a combination of residential areas (for example, Jamona City on Dao Tri road), companies such as Sinovitrans Logistics, Preferred Freezer Services Vietnam and ports (for example, Lotus Port on Nguyen Van Quy road) (Figure 51). Appropriate nature-based solutions could be subsurface storage, green roofs, stormwater street trees and rain gardens.

To sum up, the below table summarizes potential nature-based solutions which could be applied to different sub-regions in District 2 and District 7, in which the decisions are made depend on current state of of spatial planning or the level of urbanization that each district has. The table also provides general understanding about potentially appropriate nature-based solutions in District 2 and District 7.

Table 12. Basic information about potentially appropriate nature-based solutions to Ho Chi Minh City

Source: greenroofs.org; gsa.gov; epa.gov; groundwater.org; lakesuperiorstreams.org; crwa.org; susdrain.org*

*Full citation is in reference part

Nature-based solutions	**Characteristics**
Green roofs	• Green roof is defined as green space on top of human-made infrastructures such as buildings and houses. • Green roofs can slow down the flow velocity of runoffs up to 65% then delay the flow rate by (up to) 3 hours. • Green roofs can also temporarily store rain water.
Rain gardens	• Rain garden is defined by United States Environmental Protection Agency as “a depressed area in the landscape that collects rain water from a roof, driveway or street and allows it to soak into the ground”. • Rain gardens consist of natural shrubs, perennials and flower plants. • Rain gardens have multifunctional roles: provision of natural habitats; recharging water into ground and educational purposes of environmental protection.
Sub-surface storage devices	• Underground storage or sub-surface storage devices are often used to store runoffs in which there is an availability of land. • These infrastructures play an important role in slow down runoffs and are suitable for high-density urban areas with limited open spaces.

Storm-water tree pits	• There are two main structures in stormwater tree pits: (1) above-ground plantings and (2) an underground structure. • They collect and treat stormwater through layers of soil and tree roots. • Water could be infiltrated into the groundwater system.
Retention ponds	• Retention pond could be used as a solution of rainwater storage and attenuation. • It has aquatic vegetations along its shorelines so it can be used to treat rainwater as well. • Retention pond could be built in residential areas and industrial areas.
Permeable pavements	• According to United States Environmental Protection Agency states that permeable pavements are made of concretes and asphats and have a wide range of voids and spaces permitting rainwater to go through. • Permeable pavements have these following benefits: ❖ Infiltration. ❖ Reduction of runoffs.

6.5 Evaluation of effectiveness of NbS in flood controls using Stormwater Management Model

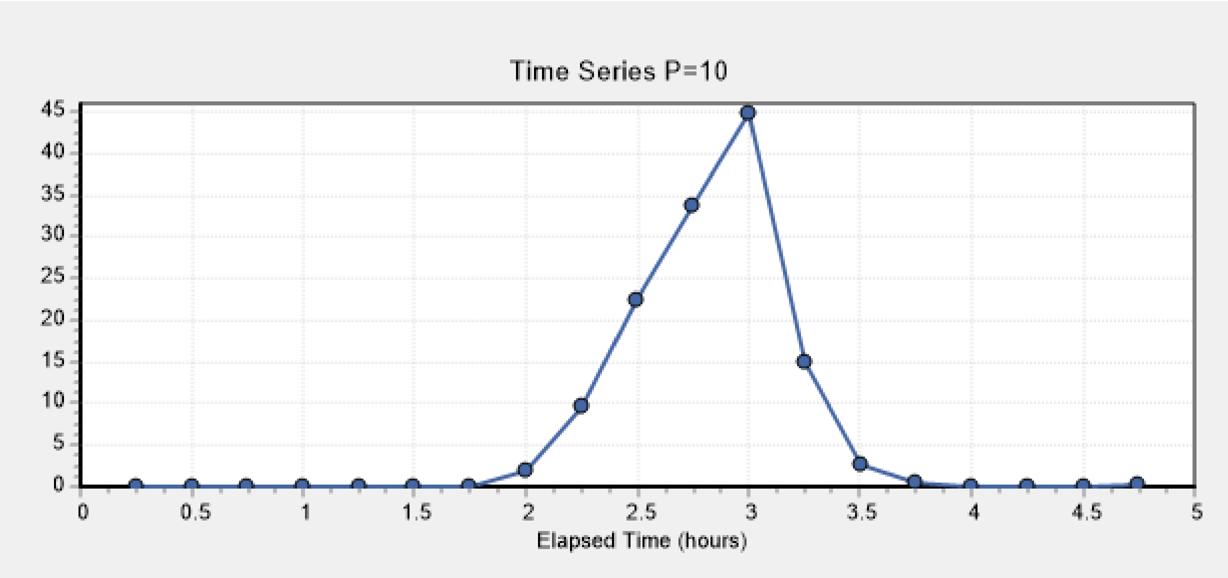
On the establishment of appropriate nature-based solutions to District 2 and District 7 in Ho Chi Minh City, the effectiveness of these solutions in flood management will be tested using Stormwater Management Model. All the statistical data to run the model provided by Royal HaskoningDHV in Ho Chi Minh City, Vietnam.

Data as inputs

Rainfall data with P = 10% (happening once every 10 years) is used as simulation data to test the effectiveness of nature-based solutions in Thao Dien region, District 2, Ho Chi Minh City. The amount of the rain event can be seen clearly in the figure below. After approximately 3 hours, it reached the maximum amount at 45 mm (Figure 52).

Figure 52. Rainfalls with P = 10% (happening once every 10 years)

Source: SWMM data provided by Royal HaskoningDHV Vietnam



Results

Stormwater management model (SWMM) is used to analyse the effectiveness of appropriate nature-based solutions in District 2, Ho Chi Minh City. It is important to note down that the model is run by me (the researcher) and the input values are provided by a staff in Royal HaskoningDHV, HCMC. The model is applied in different sub-catchments in Thao Dien area (North-western part) of District 2. The data used in the model, including rain gage, sub-catchments, conduits, junctions, etc. about Thao Dien area were provided by Royal HaskoningDHV in Ho Chi Minh City. The rain applied to this area is the one that happens once every 10 years in Ho Chi Minh City (Tran, D., Personal Interview, 2018). Figure 53, 54 and 55 below shows drainage systems and sub-catchments in Thao Dien area in District 2.

Figure 53. Image of Thao Dien area in Stormwater Management Model

Source: Royal HaskoningDHV Vietnam

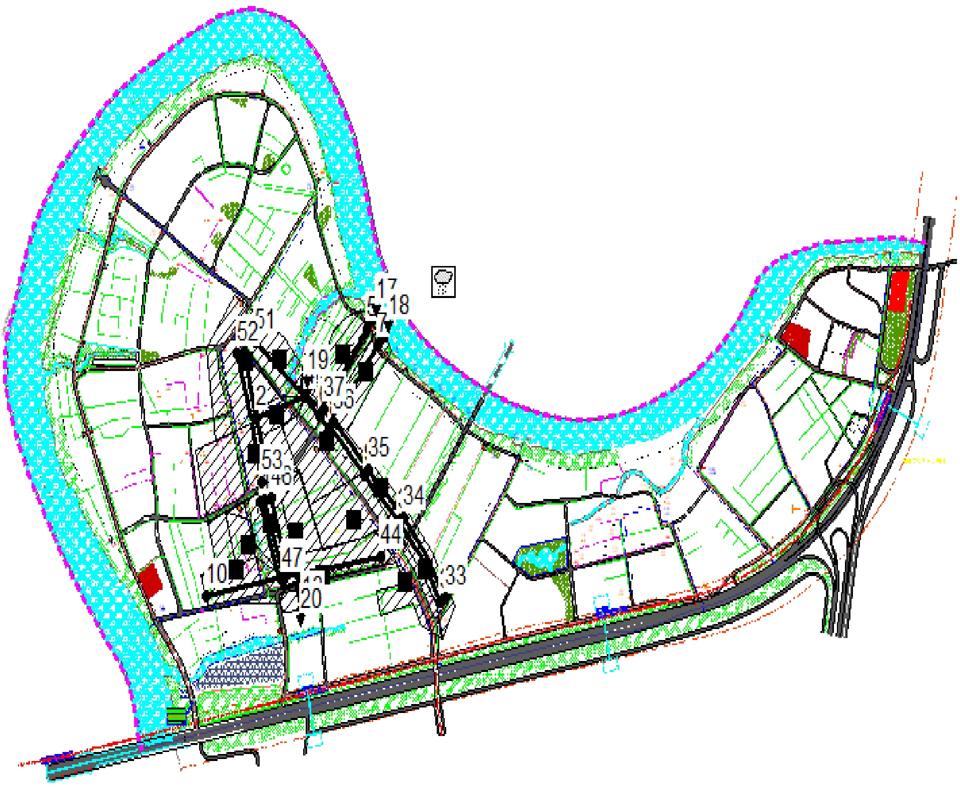


Figure 54. Subcatchment 39, 41 and 43 in the model

Source: SWMM

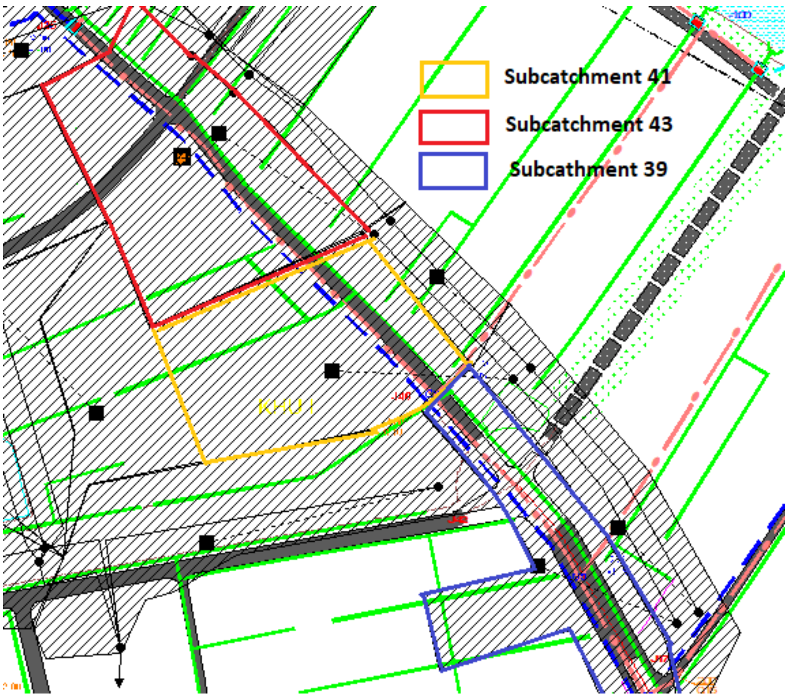
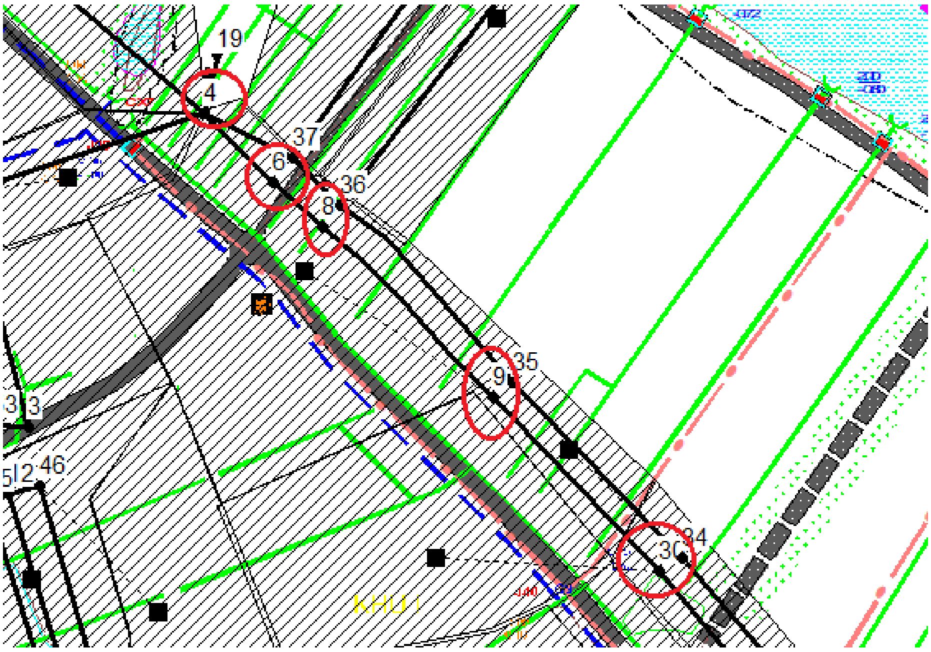


Figure 55. Junction 4, 6, 8, 9 and 30 in the main drainage system in Thao Dien area, District 2

Source: SWMM

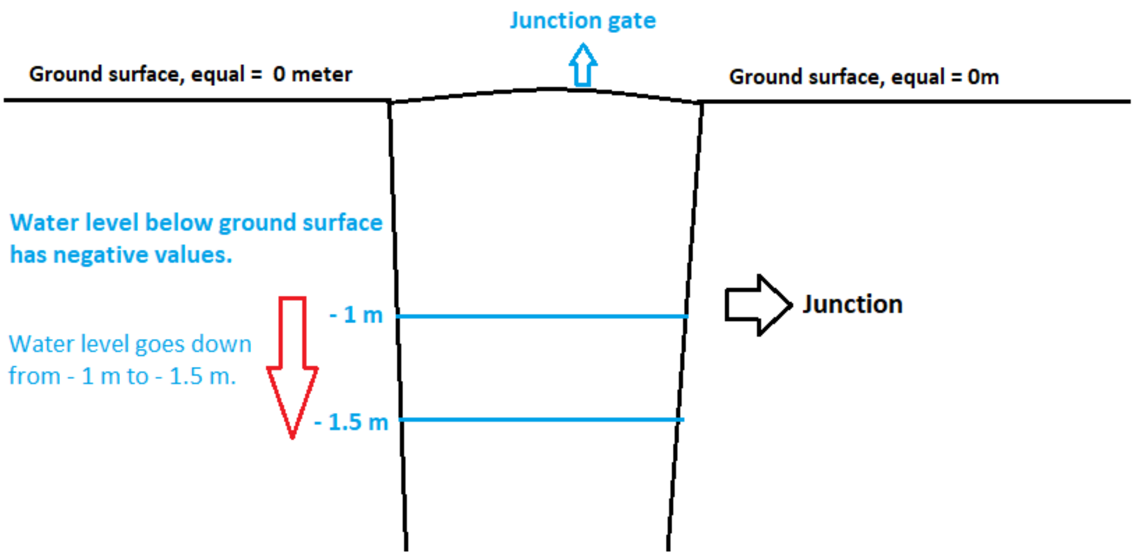


In each sub-catchment, there are different statistics, including Width, Area, Slope, Percentage of impervious cover, etc. Sub-catchments 39, 41 and 43 (Figure 54), which are close to main drainage systems (including Junction 4, 6, 8, 9, and 30) (Figure 55) in Thao Dien area, will be taken an in-depth look to test the effectiveness of nature-based solutions in slowing down the velocity of rainwater runoffs. The drainage system is located in Nguyen Van Huong road and Thao Dien road in Thao Dien area, District 2.

Only 3 sub-catchments (39, 41, and 43) is analysed because they are situated close to main drainage system (the number of junctions in Figure 54 in Thao Dien road, District 2); as a result, if nature-based solutions are applied, we can see directly changes in water levels in near-by junctions. In other words, if we choose to analyse this in other junctions (that is far from main drainage systems), it is a challenge to see the differences between different assumptions and scenarios.

Figure 56. Water level inside junction (below ground surface) has negative values

Source: developed by the researcher of this thesis



It can be seen from Google Maps that Thao Dien area is packed with houses and residential buildings and there is no longer open space left. As a result, green roofs and sub-storage units in each household are suitable solutions for this area and they are used to develop different scenario to test the effectiveness of nature-based solutions. When each solution is applied to Thao Dien area, water level in front of each junction or manhole will be analysed. The below table provides the water level in front of each manhole under normal situation (without nature-based solutions). For instance, water level inside Junction 6 is -1.33 meters (minus value represents the water level below the ground surface as explained in Figure 56).

Table 13. Original water depth measured in different junctions in the main part of drainage system

Source: Royal HaskoningDHV Vietnam

Node	Type	Maximum HGL*	Time of Max Occurrence
		Meters	Days – hr: min
4	JUNCTION	-2.14*	0
6	JUNCTION	-1.33	0 – 03:13
8	JUNCTION	-1.18	0 – 03:11

9	JUNCTION	-0.94	0 – 03:10
30	JUNCTION	-0.37	0 – 03:08
*water level inside the junction (below ground surface) has negative values			

All the assumptions to test the efficiency of different nature-based solutions are the results of the discussion between the researcher of this thesis (MEEM'19 student) and a hydrological modeler in Royal HaskoningDHV in Ho Chi Minh City. It is said by the hydrological modeller that all the assumptions cannot cover all aspects and do not include real-life conditions while applying nature-based solutions in local flood risks; however, this is the down side to acknowledge under limited time conditions. It would be better if real experiments were implemented such as construction of green roofs on top of any building in Ho Chi Minh City.

6.5.1 The first solution: Green roofs

Green roofs could be built upon roofs of each household buildings or houses. Green roofs can be used to temporarily store rainwater during rainfall events then rainwater will be gradually released into drainage systems (Tran, D., Personal Interview, 2018). Then, green roofs will play an important role in reducing pressures on drainage systems in the area.

In the SWMM, it is hypothesized in this research that the application of green roofs can (1) increase the depth of depression storage (as the first hypothesis) on impervious cover and (2) increase the ability to store water of impervious cover (as the second hypothesis).

The first hypothesis: the application of green roofs (impervious cover) can increase the depth of depression storage of rainwater

In SWMM, Dstore-Imperv is the depth of temporary depression storage of rainwater of impervious cover. By increasing the depth of temporary depression storage of rainwater, green roofs (parts of impervious cover) will be effective in reducing the pressure of runoffs on drainage systems. In the SWMM, the data of Dstore-Imperv is only 0.05 (mm), which means that only 0.05 mm of rainwater is stored because Thao Dien area is mostly urbanized and covered with concretes, which reduces the capacity to store rainwater. This test can be done in two steps:

Step 1: Changing Dstore-Imperv to different values and then running the model.

Step 2: Seeing changes in water level in different manholes in different Dstore-Imperv and giving conclusion by comparing water level in hypothesized scenario to that of current situation (Dstore-Imperv = 0.05 mm).

According to Shafique, M. *et al.,* 2018, the level of water retained in green roofs could be up to 0.027 meters (27 mm). As a result, it is hypothesized that Dstore-Imperv could be 2 mm, 5 mm, 8 mm and 10 mm to run the SWMM and the results will be shown in Table 14 and Figure 57.

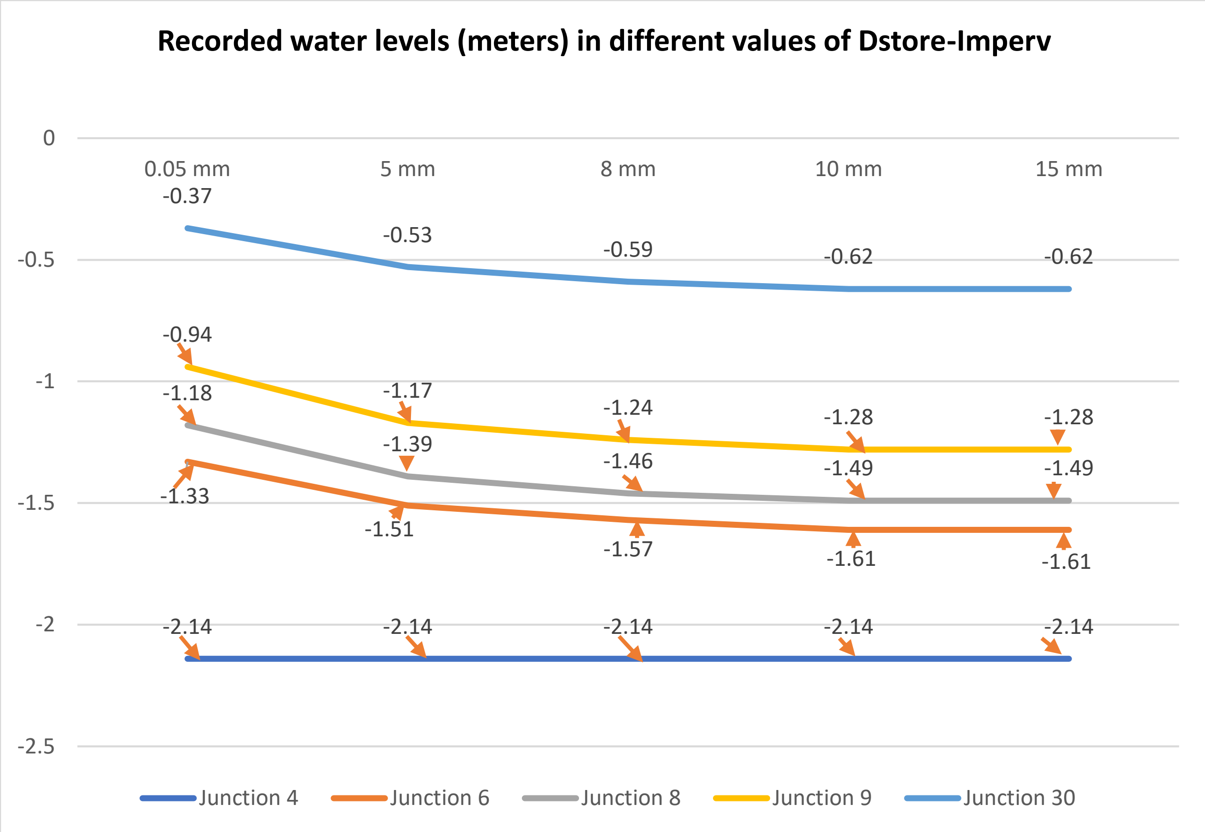
Table 14. Hypothesized statistics on Dstore-Imperv in 3 subcatchments and the resulted water level in different manholes

Hypothesized Dstore-Imperv	0.05 mm	5 mm	8 mm	10 mm	15 mm
Water level in different manholes/junctions					
Junction 4	-2.14	-2.14	-2.14	-2.14	-2.14*
Junction 6	-1.33	-1.51	-1.57	-1.61	-1.61
Junction 8	-1.18	-1.39	-1.46	-1.49	-1.49
Junction 9	-0.94	-1.17	-1.24	-1.28	-1.28
Junction 30	-0.37	-0.53	-0.59	-0.62	-0.62

***The data in Junction 4 remains unchanged because junction 4 is in the lowest elevation compared to other junctions**

Figure 57. Water levels of different junctions in different values of Dstore-Imperv

Source: creation by researcher using data from Table 17



It can be seen clearly in Figure 57 that with increasing Dstore-Imperv (green roofs could store greater amount of rainwater), the water level in almost all junctions will be decreasing. For instance, in Junction 9, when Dstore-Imperv increases to 5 mm, the water level decreases to -1.17 meters from -0,94 meters of 0.05 mm. In Junction 6, when Dstore-Imperv reaches 10 mm, the water level decreases nearly 30 centimeters. The water level in Junction 4 remains unchanged because junction 4 is in the lowest elevation compared to other junctions.

6.5.2 The second solution: Subsurface storage/Rain gardens

In densely populated areas such as Thao Dien ward, District 2, nature-based solutions that infiltrates water to the ground and do not consume too much space are considered appropriate to the area and for instance, they could be subsurface storage units, rain gardens or stormwater tree pits. These measures do not only help reduce impervious cover but they also play an important role in bringing more pervious cover which can absorb rainwater.

SWMM can be used to test the effectiveness of these solutions in reducing flood risks in subcatchments by deducing the percentage of impervious cover. In Thao Dien area, because of urbanization, the percentage of impervious cover in almost all the subcatchments is 80%). Under different scenario, that percentage will be reduced to 70%, 60% and 50% and the result is shown in Table 18.

The table below provides statistics on water depth after changing the percentage of impervious surface to 70%, 60% and 50% in 3 sub-catchments.

Table 15. Water depth in different manholes with 70%, 60% and 50% of impervious cover

Source: SWMM Model

Node	Type	Original maximum HGL	Maximum HGL with 70% of impervious cover	Maximum HGL with 60% of impervious cover	Maximum HGL with 50% of impervious cover
		Meters	Meters	Meters	Meters
4	JUNCTION	-2.14	-2.14*	-2.14**	-2.14
6	JUNCTION	-1.33	-1.35	-1.37	-1.39
8	JUNCTION	-1.18	-1.20	-1.22	-1.25
9	JUNCTION	-0.94	-0.97	-0.99	-1.02
30	JUNCTION	-0.37	-0.38	-0.40	-0.43
*minus number showing the water level below the ground has negative values					

Figure 58. Water levels of different junctions in different percent of impervious cover

Source: creation by researcher using data from Table 18

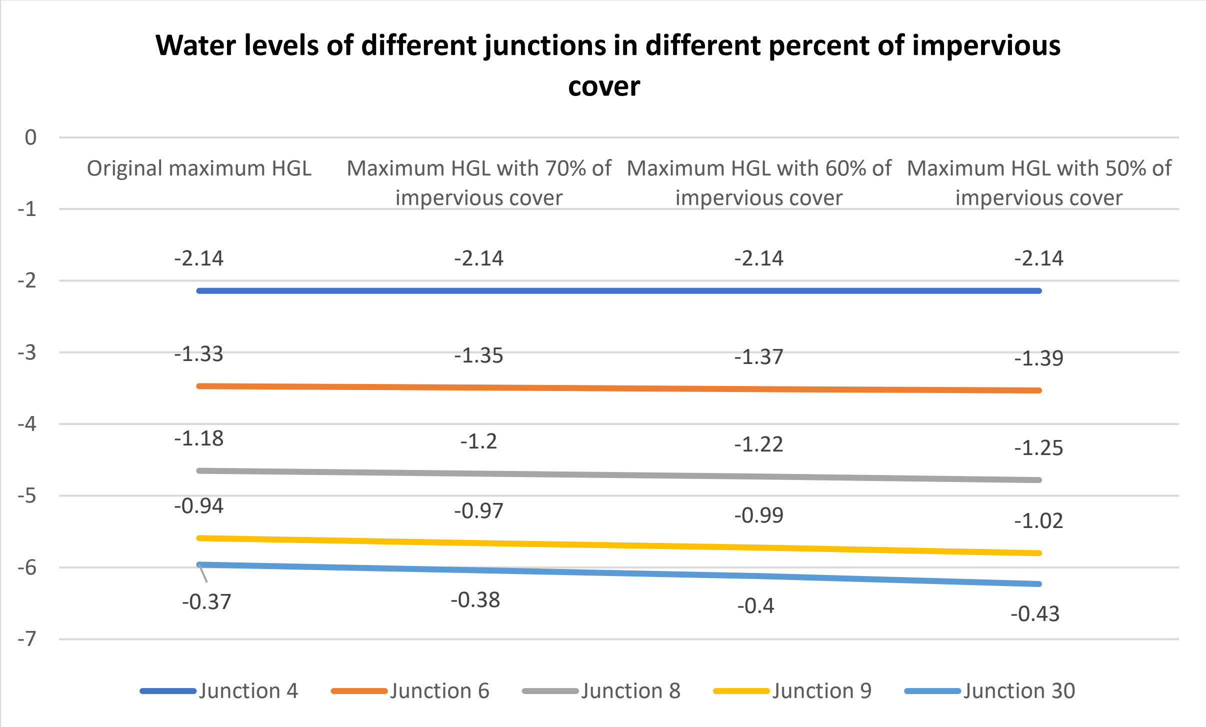


Figure 578is the line graph showing the differences in water levels in 3 different scenarios (70%, 60% and 50% of impervious cover). It can be seen in Figure 57 that there is a slight decrease of water levels when reducing impervious cover from 70% to 50%. The most noticeable change in water level is shown in Junction 9 with water level decreasing by 9 cm (from -0.94 m to -1.02 m). According to Table 18 and Figure 35, this is to conclude that even the positive impact of nature-based solutions in increasing impervious cover and reducing water level is not significant in the short period of time, impacts of flooding due to heavy rainfalls will be partially and effectively minimized if more than one nature-based solutions are constantly and increasingly put in application in Thao Dien area or even in the whole District 2 and District 7.

6.6 Reflection on using SWMM to test the efficiency of nature-based solutions in Thao Dien area

General information about SWMM

Stormwater Management Model (SWMM) is developed by the U.S Environmental Protection Agency and it is used to plan, analyse, and design related to stormwater runoffs and other drainage systems. To be more specific, the model was created to help to reduce runoff through infiltration and retention and help to reduce discharges that cause nuisance negatively affecting people's live, especially in urban areas (Gironas, J., *et al.,* 2009).

According to the U.S Environmental Protection Agency, one of the most important roles of SWMM is to help engineers and urban planners in representing green infrastructure or nature-based solution practices to make conclusion of the effectiveness of these solutions. SWMM tests the effectiveness by modelling the reduction of runoff mass load, from the reduction in runoff flow volume in different rainfall events. SWMM can model several green infrastructures such as rain gardens, green roofs, bioretention cells, vegetative swales, permeable pavement systems, etc.

Reflection on using SWWM in the research

In this research, tasks of running the model, gathering and then analysing data to give conclusion are done by the researcher, under the guidance of a hydrological modeller in Royal HaskoningDHV, HCMC. The researcher of this research also had a discussion with the modeller about how to give reasonable explanation for the results after running the model as well as to make reasonable assumptions.

All the hypothesized assumptions in the research are created after a thorough discussion between the researcher of this master thesis and the hydrological modeler, who has experience in using SWMM. Also, those assumptions in this research are scientific-based after looking at scientific papers and articles. For example, how much water (in mm) that green roofs could store is gathered from a scientific paper from Korea.

Using SWMM in testing the effectiveness of nature-based solutions in reducing local flood risks has its pros and cons. In terms of positives, SWMM by the U.S Environmental Protection Agency has different variables such as Dstore-Imperv or Percentage of Impervious Cover to demonstrate different scenario of sustainable flood control or nature-based solutions. Also, SWMM has many applications and one of them is to control site runoffs using nature-based solutions then to evaluate their effectiveness. However, SWMM only produce data to do qualitative analysis as it does not include map of land-use planning as well as other real-life conditions such as slope of roofs of houses and buildings, elevation of different sub-catchments or the case that rain water comes from other sub-catchment into the study site, etc. to get the most exact data.

CHAPTER 7: CONCLUSIONS AND DISCUSSIONS

7.1 Conclusions

This research provides an in-depth view of a problem of flooding due to heavy rainfalls in District 2 and District 7 in Ho Chi Minh City. Also, efforts of authorities and other stakeholders in HCMC in flood control are widely explained. Based on an in-depth understanding of flooding in these two districts, integrated flood management approach using nature-based solutions are suggested to reduce local flood risks.

Chapter 4

Sub-question: What are local flood risks in urban areas in Ho Chi Minh City?

The local flood risk in Ho Chi Minh City (mainly District 2 and District 7) is shown in sub-part 4.3**.** This part provides rainfall data in different sub-areas in District 2 and District 7 in the past 2 years 2016, 2017 and the first half of 2018. The data is provided by Steering Center for Flood Control in Ho Chi Minh City. What can be shown in the data are time of flooding (minutes), length of flooding (meters), area of flooding (m^2) and inundation depth (meters). As Ho Chi Minh City (Vietnam) is situated in a tropical region, precipitation events occur in months from May to November (Asian Development Bank, 2010). In different sub-areas of District 2 and District 7, it can be described that rainfalls were putting more serious impacts on the areas between 2016 and 2017. For instance, in Quoc Huong area in District 2, it can be seen that there was an increasing trend in all aspects (inundation depth, length of flooding, area of flooding and time of flooding). However, on average, from 2016 to the first half of 2018, in Huynh Tan Phat area in District 7, the amount of rainfalls was significantly decreasing.

Furthermore, Asian Development Bank also predicted patterns of rainfall in Ho Chi Minh City, projection to 2050. It is expected that due to urban developments, flooding due to heavy rainfalls under the impacts of climate change will be intensified owing to urbanization as it reduces the capacity of the city to infiltrate rainwater, which causes localized flooding in Ho Chi Minh City. The number of communes in Ho Chi Minh City and area of flooding (in hectares) are predicted to be increasing significantly until 2050.

Sub-question: What are causes of urban flooding due to heavy rainfalls in HCMC?

Causes of urban flooding in Ho Chi Minh City are clarified in part 4.2. The most important reason is that urban development in Ho Chi Minh City, especially in District 2 and District 2 has reduced a great amount of green and blue spaces, which have the function of absorb rainwater. They are replaced with houses, buildings and pavements which have almost no capacity to store or infiltrate runoffs. Another reason is that precipitation events are intensified under the impact of climate change. Last but not least, drainage systems are not properly operated so they lack capacity to catch the excess amount of rainwater.

Sub-question: Which areas or districts are suffering from floods due to heavy rainfalls in Ho Chi Minh City?

District 2 and District 7 are chosen to develop strategies of local flood risk reduction and climate change adaptation as these two districts are the most vulnerable under the effects of climate change and heavy precipitation. This can be shown by their higher amount of rainfalls and longer duration of flooding compared to that of other districts. Also, it is suitable to develop strategies of flood risk reduction in these two districts because they are not fully urbanized so it will become less challenging to integrate flood risk management strategies using nature-based solutions into spatial planning.

Chapter 5

Sub-question: Which areas or districts in HCMC that urban spatial plans or urban climate adaptation plans are focusing on? Which results do they get so far in terms of flood management in these areas?

Main ambition of Ho Chi Minh City's authorities is to turn Ho Chi Minh City into a city of modern industrial city, which is a combination of economic development and sustainable development in 2025, according to VCAPS, 2013. Ho Chi Minh City will be a city with safe, healthy and pleasant environment to live and work. To be more specific, Ho Chi Minh City is aiming at becoming less vulnerable to climate change's effects and one of them is heavy precipitation along with flooding. The primary goa is set by Steering Center for Flood Control to fulfill the ambition. The aim of the SCFC is to solve inundation central districts and other areas, with the total area of 550 km^2 and a population of 6.5 million people; to enhance water storage capacity within the city and to improve living conditions of residents.

On what Ho Chi Minh City was doing and is currently doing to control flooding due to heavy rainfalls, first of all, what SCFC (Steering Center for Flood Control) is mainly doing include: structural measures (construction of pumping stations, implementation of dredging canals to enhance the capacity of water storage, improvement of drainage and sewerage systems, construction of tidal sluice gates and investment on building waste water treatment plants) and non-structural measures (public communication towards environmental protection and proper spatial planning of drainage systems in Ho Chi Minh City). These efforts of SCFC have shown several positive results: in 2011, the number of flooding sites reduced to 58 (around 54% reduced compared to 2008). In general, flooding is no longer a serious problem in several roads such as 3/2, Xo Viet Nghe Tinh, No Trang Long, etc. In 2015, there were 40 flooding sites left (in total) (17 out of them were flooded due to heavy rainfalls). Up to now, in total, there have been only 25 flooding sites left.

Other stakeholders also made efforts in controlling local flood risks. One adaptation measure, Ring Dike, is implemented in the MARD Plan by Ministry of Agricultural and Rural Development. Ring Dike is reported to lower flooding damage's by approximately 80% to 90%, which is considered effective within dike-enclosed areas (Scussolini, P. *et al*., 2014, p.10850). Also, buildings and houses are constructed at higher elevation to assist residents to deal with flooding. Another flood control action is the construction of modern pumping technology with the capacity of 96,000 m^3 in Nguyen Huu Canh street. However, this solution does not receive positive feedbacks from environmental experts and related stakeholders because old and insufficient drainage systems (manholes) cannot deal with great amount of water from high-powered pumping machines. Furthermore, as Vietnamese people often litters so trash and solid wastes following runoffs went into the pumping machines, which reduce their capacity in pumping rainwater and bring about damages to the machines.

A significant plan of flood management is JICA Master Plan, approved by the Prime Minister dated June 19th, 2001, mainly concentrated on improving drainage conditions in approximately 650 km^2 of urban areas in Ho Chi Minh City. A certain number of drainage enhancement projects for 9 sub-basins in Ho Chi Minh City have been identified by the JICA Master Plan. To name a few, there are several projects: HCMC Water Environment Improvement Project (Tau Hu – Ben Nghe – Doi – Te Canals sub-basin), HCMC Environmental Sanitation Project (Nhieu Loc – Thi Nghe Sub-basin), Tham Luong – Ben Cat – Nuoc Len Canal Drainage and Pollution Improvement Project (Tham Luong, Ben Cat, Nuoc Len), HCMC Urban Upgrading and Sanitation Project (Tan Hoa – Lo Gom Sub-basin), etc. JICA Master Plan is conducted in District 2 and District 7 with the following activities: construction of drainage channel, drains and pipes in the existing built-up area and drainage facilities in newly developed areas; partial improvement of main canals; rehabilitation of secondary/tertiary drainage facilities in the existing urbanized areas; and canal improvement in adjustment with urbanization.

Sub-question: Which elements of the plans that need to be strengthened and improved to produce better results?

Phan, N., D. *et al.,* 2017 stated that District 2 and District 7 are newly developed areas with a high pace of urban development. It is predicted that the amount of open spaces used for housing and urban infrastructures will be increasing two-fold in the period of 2016 – 2030. There is a concern that "these newly developed areas negatively affect indigenous hydrological systems, including green spaces and water bodies" (Phan, N., D. *et al.,* 2017, p.201). Other scientists such as van de Wouw, R., no year and Ran, J., and Nedovic-Budic, Z., 2015 shared the same opinion that flood risk management solutions no longer fully depend on technical solutions or structural measures. Under this circumstance, assume that urban development is inevitable, it is recommended that making effective use of urban planning and management is a potential solution to enhance Ho Chi Minh City's capacity to 'live with floods'. In other words, spatial planning should be integrated into the process of water or flood management. This new approach could be more appropriate for new development areas such as District 2 and District 7 because they are not fully urbanized; as a result, there are still opportunities and spaces to change. To sum up, as a recommendation, integrated flood risks management using spatial planning in combination with nature-based solutions is considered potential for District 2 and District 7 in Ho Chi Minh City to control flooding more efficiently.

Chapter 6

Sub-question: What are possible and appropriate nature-based solutions to urban floods in Ho Chi Minh city?

First of all, importance of nature-based solutions in reducing local flood risks in Ho Chi Minh City are explained in Part 6.1. Nature-based solutions could be served as storage units of runoffs to reduce pressures on drainage systems. Also, rainfalls, via nature-based solutions, could be infiltrated back into the ground water level. Besides reducing impacts of climate change, nature-based solutions with the participation of different stakeholders could help raise awareness of people in terms of flooding and flood management.

Ho Chi Minh City's authorities and stakeholders pay certain attention in using nature-based solutions to reduce local flood risks in the city. Firstly, several researchers and scientists have done lots of research regarding using a more sustainable approach in flood management. For example, Professor Viet Anh Nguyen gave a presentation about the topic “sustainable methods of solving flooding due to heavy rainfalls in urban areas” in a workshop “Sustainable Urban Drainage” in National University of Civil Engineering along with a university in Loughborough, England in 2003 (Phong, N., V., 2004). There was also a research of Professor Canh Doan and his colleagues about the application of ecological engineering into construction of sustainable urban drainage systems to control flooding in the city.

Beside doing research, different stakeholders actually apply nature-based solutions in reducing flood risks. According to Nguyen, D., *et al,* 2017 in Australian Water Association, Ho Chi Minh City’s authorities also invested in building retention ponds in District 2 and in Tan Son Nhat airport. Furthermore, nature-based solutions in Ho Chi Minh City also gain attention from international firms. Sekisui Chemical Co. from Japan, to battle flooding due to precipitation, proposed a solution of using underground reservoir and it is said by a representative from the company that the very first capacity is about 100,000 cubic meters (Nguyen, D., *et al,* 2017). It is important to note the efforts of real estate companies such as GreenViet in organizing a conference of green real estate as a method to integrate urban development with environmental protection as well as flood management.

Part 6.3 elaborates on potentially appropriate nature-based solutions for District 2, Ho Chi Minh City. As District 2 is relatively big, nature-based solutions are under selection in different sub-areas. District 2 is divided into 6 sub-areas: North-western, East-western, South-middle and North-middle part, North-eastern and South-eastern and each sub-area has different urban infrastructures as well as ways of spatial planning. As almost all sub-areas in District 2 have less open space and are packed with urban infrastructures, several potentially appropriate nature-based solutions for District 2 are green roofs, permeable paving, stormwater street trees, basins and ponds and rain gardens. To the area with greater amount of open space such as North-middle region, subsurface storage devices, and big-size retention ponds could be constructed.

Part 6.4 elaborates on potentially appropriate nature-based solutions for District 7, Ho Chi Minh City. As District 7 is relatively big, nature-based solutions are under selection in different sub-areas: North-eastern, South-eastern, North-western and South-western. Compared to District 2, District 7 has less open space so nature-based solutions are only retrofitted in current housing and urban infrastructures. Appropriate nature-based solutions could be subsurface storage, green roofs, stormwater street trees and rain gardens.

Sub-question: Is there any method to evaluate their effectiveness to reduce local flood risks in study sites in Ho Chi Minh City?

Stormwater Management Model developed by the U.S Environmental Protection Agency is used to test the effectiveness of nature-based solutions in flood control. Once any nature-based solution is applied to different subcatchments, changes in water level in different junctions will be recorded. If water level in any junction decreases in any assumption, this shows that nature-based solutions are considered effective in reducing flood risks in Ho Chi Minh City. The SWMM is run in Thao Dien area in District 2 and nature-based solutions will be applied in 3 subcatchments: 39, 41, 43, which are close to the main drainage systems. The main drainage system is located in Thao Dien road, which includes five main junctions 4, 6, 8, 9 and 30. It is shown in tables and figures in this part that under several assumptions, green roofs are considered highly effective in reducing flood risks by storing a great deal of runoffs. Applying this solution, water level in any junction could decrease up to 30 cm, which will reduce the severity of localized flooding in the area. On the other hand, there is a slight decrease of water level in junctions with the application of subsurface storage or rain gardens to reduce impervious cover. Overall, the water level could be reduced up to 9 cm.

7.2 Discussions

For the whole process of doing research, gathering data is a challenge while doing research in Ho Chi Minh City. First of all, nature-based solution is quite a new topic in Ho Chi Minh City. To be more specific, in terms of doing research, there is not many researchers who are willing to do scientific research in this topic. Also, there is currently no official platform for local researchers to share ideas and have a discussion. Furthermore, gathering data from governmental agencies and companies related to research topic and problem is not an easy task as information sharing is not yet a culture in Vietnam. During the process of data gathering, there are several staffs from several companies who are willing to share information and have an informal discussion; however, they just represent a small number. This challenge has hindered the researcher in having a broader view towards research problem and research topic.

In this research, I, as a researcher, I also would like to discover governance contexts, financial conditions and public participation regarding nature-based solutions in Ho Chi Minh City. To be more specific, whether legal frameworks support the development of nature-based solutions, governmental officers are having knowledge, capacity and incentives to implement nature-based solutions in flood management and are willing to do that and whether local residents are fully aware of flood management and nature-based solutions. Also, whether financial conditions in HCMC are adequate to implement the solutions. However, I only had the opportunity to suggest potentially appropriate solutions to District 2 and District 7 but do not elaborate on how to turn them into reality or which challenges implementers might face while putting these solutions into application. For example, how different stakeholders such as local people see nature-based solutions is not developed and included in the research.

However, I myself, along with the assistance of different helpful and enthusiastic individuals, have tried my best within limited time availability to create the best result of the research. Once the data is not available related to current situation in Vietnam, data from other countries (which are relatively similar to Vietnam) is gathered then analyzed. Every result in this research is backed up by different scientific facts and figures; in conclusion, the above-mentioned challenge does not affect the reliability of research's results.

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Appendix 1. Activity Planning and Time Schedule

Activities	Year 2018																							
	March				April				May				June				July				August			
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Research preparation																								
Developing research idea																								
Develop research proposal																								
Submit research activity in work plan																								
Submit draft research proposal plan																								
Submit final proposal																								
Research Activity																								
Data collection																								
Flood management analysis																								

Nature-based solutions analysis (different discipline)																								
Economic, Social, Aesthetic and Environmental Analysis																								
Lessons and Experiences from NYC and Rotterdam																								
Conclusion and Recommendation																								
Writing Activity																								
Finalizing chapter 1,2,3																								
Draft Chapter 4																								
Draft Chapter 5 & 6																								
Draft Chapter 7 & 8																								
Submission of Chapter 4,5,6, 7																								
First Draft of Master Thesis																								

Ongoing feedback and revision																								