

**MINISTRY OF EDUCATION
AND TRAINING**

**MINISTRY OF
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HANOI ARCHITECTURE UNIVERSITY

HUYNH TRONG NHAN

**PROVINCIAL URBAN DRAINAGE
MANAGEMENT TOWARDS SUSTAINABLE
DEVELOPMENT IN MEKONG DELTA**

**SUMMARY OF DOCTORAL THESIS
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INTRODUCTION

Necessity of research

Mekong Delta plays an important role for the Southern and Vietnam in economic development, investment and world trading. However, Mekong Delta is one of the most regions extremely affected by climate change and sea level rise. In which, the medium-sized, densely populated cities face many challenges, especially inundation during heavy rains and high tides, causing serious damage to urban residents.

The existing condition of urban drainage systems in Mekong Delta is still weak and inconsistent. Urban drainage management has many limitations, such as: drainage management is still in the process of reorganization; investment allocation and implementation are still scattered; socialization and investment attraction face many difficulties; urban policies and regulations related to drainage management are not suitable with the individualities of Mekong Delta, especially the challenges of climate change and sea level rise. The urban spatial development orientations in planning are not associated with rain water drainage solution, and regulations associated to the implementation of sustainable drainage solutions have not yet updated.

In the world, various urban drainage management approaches towards sustainable development have been successfully applied, but have not been widely applied in urban areas of Mekong Delta. Therefore, it is essential to research the topic *"Provincial urban drainage management towards sustainable development in Mekong Delta"*.

Research objective

Based on the synthesis assessment of current condition of provincial urban drainage management towards sustainable development in Mekong

Delta, the study 's objectives are proposing solutions for drainage management suitable to the individualities of Mekong Delta, reducing the risk of flooding and evolving a sustainable drainage system.

Subject and scope of the study

Research subject: urban drainage management, focuses on rain water drainage. Scope of spatial: 12 provincial cities in the Mekong Delta, including: Bac Lieu, Ben Tre, Ca Mau, Cao Lanh, Long Xuyen, My Tho, Rach Gia, Soc Trang, Tan An, Tra Vinh, Vi Thanh, Vinh Long. Scope of time: to 2035 and vision of 2050.

Research methods

There are 08 main research methods: (1) investigation, survey; (2) analysis and synthesis; (3) system assessment; (4) SWOT; (5) forecasting; (6) inheritance; (7) expert method; (8) application - validation.

Research contents

- Evaluate the existing condition and identify the specific factors of urban drainage management in Mekong Delta;
- Synthesize and systematize scientific theories and experiences for urban drainage management towards sustainable development;
- Propose solutions for provincial urban drainage management towards sustainable development in Mekong Delta.

Research results

- An overview assessment of urban drainage management towards sustainable development and identification of problems to be solved for provincial urban drainage management towards sustainable development in Mekong Delta;
- Synthesized and systematized scientific theories and experiences for urban drainage management towards sustainable development;

- Three groups of proposed solutions for provincial urban drainage management towards sustainable development in Mekong Delta, application and validation of a case study of Vinh Long city.

Novelty contributions of research

- Propose management criteria frame and assessment content for provincial urban drainage management towards sustainable development in Mekong Delta which based on the results of SWOT analysis, including 3 groups of criteria: (1) Organization management institutions, mechanisms and policies, management capacity and community participation, (2) Integrating drainage towards sustainable development in the planning and (3) Technical management.
- Propose to supplement the provisions of the regulation related to urban drainage management, including: (1) the process and content of integrating sustainable drainage solutions in urban planning; (2) supplementing contents related to rain water drainage management towards sustainable development in Decree 80/2014/ND-CP and local regulations of drainage management.
- Propose solutions for provincial urban drainage management towards sustainable development in Mekong Delta, including: (1) zoning for sustainable drainage solutions for the Mekong Delta based on the existing condition of each city, (2) propose application processes and validation of Sentinel-2 remote sensing analysis results, applied for Vinh Long city permeable area analysis, support to evaluate the rain water drainage capacity toward sustainable development.

Scientific and practical meaning of research

- Complete the content of theoretical bases on rain water drainage management towards sustainable development and coordinate to urban development plan and management that accordance with the individualities of Mekong Delta.

- Contributing to the renewal and improvement of urban drainage management capacity in provincial cities of Mekong Delta.
- Practical meaning: support provincial urban in Mekong Delta to develop orientations for the development of efficient drainage systems, respond to urbanization, reduce risks of climate change.

Thesis structure

Includes introduction, main content (Chapter 1: 44 pg, Chapter 2: 42 pg; Chapter 3: 50 pg), conclusions and recommendations, published scientific studies of author related to the topic, references and appendices.

Key concepts and terms

Urban rain water drainage towards sustainability: the development orientation of urban rain water drainage system based on related theories such as sustainable drainage system (SUDS), low impact development (LID) to model simulate the natural water cycle, reducing the risk of flooding and using rainwater more efficiently.

Urban rain water drainage management towards sustainable development: management work based on planning, technical, organization policy and financial aspects to improve urban rain water drainage management capacity and contribute to sustainable development.

CONTENT

CHAPTER 1. OVERVIEW OF MEKONG DELTA PROVINCIAL URBAN DRAINAGE MANAGEMENT TOWARDS SUSTAINABLE DEVELOPMENT

1.1. Overview of urban drainage management towards sustainable development in the world and in Vietnam

Urban drainage management towards sustainability in the world

In the late 1970s, worldwide urban drainage systems were designed to integrate with urban planning, in order to reduce the impact on the natural water cycle through control solutions at source, storage and infiltration. Based on 3 terms: LID, BMP (USA), SUDS (UK) and related approaches, urban drainage management towards sustainable development has been implemented in many parts of the world.

Urban drainage management towards sustainability in Vietnam

In Vietnam, urban drainage management towards sustainable development is only initially approached. The implementation of urban drainage management in Mekong Delta province is mostly structural solutions and flood control. Source control measures are still limited and only a small-scale pilot has been applied. Sustainable drainage system has not been specified in regulations and standards.

1.2. Existing condition of urban drainage management in the Mekong Delta provincial cities

Existing condition of drainage system in Mekong Delta provincial cities

The provincial cities in Mekong Delta have low urbanization rates, unfavorable traffic conditions, insufficient investment and limited urban function. The drainage system of Mekong Delta provincial cities are mostly a combine drainage system, connected with the network of rivers and canals. They play a large role in rain water drainage, but undergoes from many risks of pollution and encroachment. The drainage solutions towards sustainable development have been piloted on a small scale in Ca Mau, Long Xuyen, and Rach Gia.

Existing condition of urban drainage management organization

Organization of urban drainage systems management follow the direct structure. The management effectiveness assessment has not been

clearly quantified. The programs and plans for the development of urban drainage systems are often linked with the technical criteria of urban planning but lack of tools for evaluation and monitor. The coordination between specialized departments is not really effective, especially in 3 stage: planning, construction investment and operation management. Local officers in charge of drainage management is almost nonexistent.

Urban drainage planning is a content of master planning, zoning planning and detailed planning. The content of the planning has not yet proposed specific solutions to control the change of water circulation and the change of urban permeable surface. Regarding database management, Mekong Delta provincial cities do not have a complete urban drainage system database.

Regarding local community, the collection and reuse of rainwater is frequently invested by households and businesses in urban areas, but the support policies are not specific. In addition, encroachment on canals poses challenges for urban drainage management.

1.3. Related research studies

Related research studies in the world: Including 3 studies in America, 2 studies in Africa, 1 study in Europe, 2 studies in Asia.

Related research studies in Vietnam: Including 4 research projects and 3 published doctoral theses.

General mention: related studies show many non-structural approaches and enhance community participation. These are the values that this thesis will inherit.

1.4. SWOT analysis results and encountered issues

Based on SWOT analysis results, this thesis focuses on the following encountered issues: 1. Studying the suitability of the proposed solutions

with the institutional, regulation and specific conditions of the region; 2. Determine the initial content of urban drainage planning taking into account spatial planning, climate change and integrating ability; 3. Determine organizational solutions and local capacity to improve the efficiency of urban drainage management toward sustainability; 4. Determine technical solutions according to sustainable drainage system in accordance with urban planning and related alignments; 5. Determine and develop policy framework to enhance community participation.

CHAPTER 2. SCIENTIFIC BASIS OF MEKONG DELTA PROVINCIAL URBAN DRAINAGE MANAGEMENT TOWARDS SUSTAINABLE DEVELOPMENT

2.1. Theoretical basis for urban drainage management towards sustainable development

The role of the drainage system for urban development

The task of the rainwater drainage system is to conveyance rain water out of cities, residential areas, industrial zones quickly and in an organized manner to flood proofing. Urban drainage system is essential for human activity and the natural water cycle.

The importance of urban rainwater drainage management

The main reason of flooding in urban areas is due to the issue of cover surface concreting, so most of the rainwater flows directly into the drainage system that causing overloading and flooding. Rainwater management needs to be integrated into urban planning, protecting biodiversity and reducing the risk of flooding more sustainably.

The principles of urban drainage management towards sustainable development must consider rainwater as a resource. Prioritize stormwater source control to reduce runoff and control pollution.

In order to manage sustainable drainage system, it is necessary to add prescribe charter of coordination among stakeholders, develop an assessment framework to develop sustainable solutions for urban drainage management; supplement the organization regulation that allow the community contribute in urban drainage management toward sustainable development.

Factors affecting urban drainage management towards sustainable development in Mekong Delta: 1. Spatial physiognomies of urban areas in the delta; 2. System of canals and rivers; 3. Climate change and impact on the drainage system of Mekong Delta; 4. The practice of floods adaptation of Mekong Delta people; 5. Effectiveness of urban planning and urban drainage planning; 6. Organization and application of science and technology in urban drainage management in Mekong Delta.

SWOT analysis and management by objectives, evaluate by criterias in urban technical infrastructure management

The SWOT method is the foundation in the overall analysis of the research problem to determine the initial steps of the urban management process. The development of a set of criteria in the management of urban technical infrastructure ensures transparency and accountability, thereby improving the efficiency of urban drainage management.

Sustainable Drainage Solutions (SUDS)

Sustainable Drainage Systems - SUDS is designed to maximize the opportunities and benefits of surface water management. There are four main types of benefits that can be achieved by SUDS: water quantity, water quality, amenity, and biodiversity. Regarding structure, the SUDS system is organized with various measures in three levels: source control, site control, and regional control (Fig 2.1). These measures link together to increase drainage efficiency in a sustainable way.

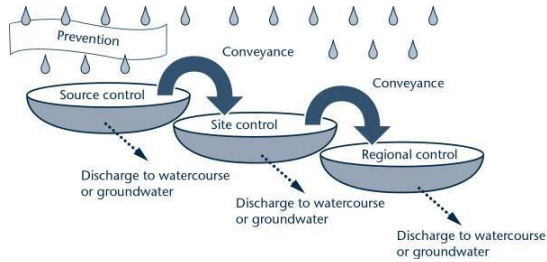


Figure 2.1 Structure of SUDS measures

GIS remote sensing technology in urban land cover management

Analysis of remote sensing data allows to determine the extent of flooded areas, industrial and civil works at risk of flooding. In this thesis, Sentinel-2 is an effective choice for remote sensing analysis the changes in urban land cover properties.

Community participation in urban drainage management

The principle of community and stakeholder participation needs to strike a balance of benefits and clearly define the appropriate method and programme for the most effective participation.

2.2. Legal basis for urban drainage management in Mekong Delta towards sustainable development

National level regulations

Law on Urban Planning (30/2009/QH12); Law on Construction (50/2014/QH13); Law on Water Resources (17/2012/QH13); Law on Natural disaster prevention and control (33/2013/QH13); Law on Environmental Protection (72/2020/QH14); Decree No. 80/2014/ND-CP on drainage and wastewater treatment; QCVN 01:2021/BXD National Technical Regulation on Construction Planning; QCVN 07-2:2016/BXD: National technical regulation "Technical infrastructure works - Drainage construction".

Decision No. 245/QĐ-TTg of Prime Minister approving the master plan on socio-economic development of Mekong Delta up to 2020, vision to

2030; Decision No. 287/QĐ-TTg of Prime Minister approving the Master Plan for the Mekong Delta in the period of 2021-2030, vision to 2050.

Provincial Regulations: Regulations on drainage management: An Giang (Decision 57/2017/QĐ-UBND), Bac Lieu (Decision 22/2015/QĐ-UBND), Ca Mau (Decision 28/2018/QĐ-UBND), Dong Thap (Decision 17/2020/QĐ-UBND), Hau Giang (Decision 30/2017/QĐ-UBND), Kien Giang (Decision 01/2018/QĐ-UBND), Long An (Decision 75/2016/QĐ-UBND), Soc Trang (Decision 18/2017/QĐ-UBND), Tra Vinh (Decision 19/2016/QĐ-UBND).

2.3. Experience in urban drainage management towards sustainable development

Urban drainage management towards sustainability in the world

- London, UK: experience in authorization distributing drainage management with the Lead Local Flood Authorities (LLFA) and implementing SUDS.
- Melbourne, Australia: experience in applying Water-Sensitive Urban Design (WSUD) and constituting/evaluating the effectiveness of urban drainage management according to set of criteria.
- Wuhan, China: experience in integrating sponge city concept in urban planning and applying technical standards based on local individualities; zoning sponge city measures by the set indicators.

Urban drainage management towards sustainability in Vietnam

- Ho Chi Minh City: experience in restoring canals, rivers and sewers and propagate people to protect drainage system; concentration resources and linkages between drainage constructions.
- Tuy Hoa city, Phu Yen: experience in applying integrated urban drainage planning, solutions of underground rainwater storage tanks and temporary rainwater storage.

CHAPTER 3. PROPOSED SOLUTIONS FOR MEKONG DELTA PROVINCIAL URBAN DRAINAGE MANAGEMENT TOWARDS SUSTAINABLE DEVELOPMENT

3.1. Standpoint and orientation

1) Urban rainwater drainage management towards sustainability based on aspects of planning, technique, organization and finance policy.

2) In urban rainwater drainage management towards sustainability, initial step is urban planning and suitable with management capacity level.

3) Drainage technical solutions towards sustainability must be suitable with specific factors of Mekong Delta provincial cities and adaptability to climate change.

4) Organize the urban drainage management of Mekong Delta provincial cities leanly, accompanying with the improvement of local regulation and management capacity; community participation.

The proposed rainwater drainage management strategies for Mekong Delta provincial cities towards sustainability as shown in Fig 3.1.

3.2. Propose a set of criteria and evaluation contents

The proposed set of criteria for stormwater drainage management is based on the strategies of the results of the SWOT analysis (Figure 3.1). In which, the contents and evaluation scale are divided into three groups: (1) Management organization, policy, local capacity and community participation; (2) Integrate drainage towards sustainability in urban planning; (3) Technical management. Evaluation method according to the scale of each criterion from 0 to 5, which based on the level of implementation of drainage management objectives towards sustainable development. Evaluation results must be according to urban planning timelines (2035, 2050).

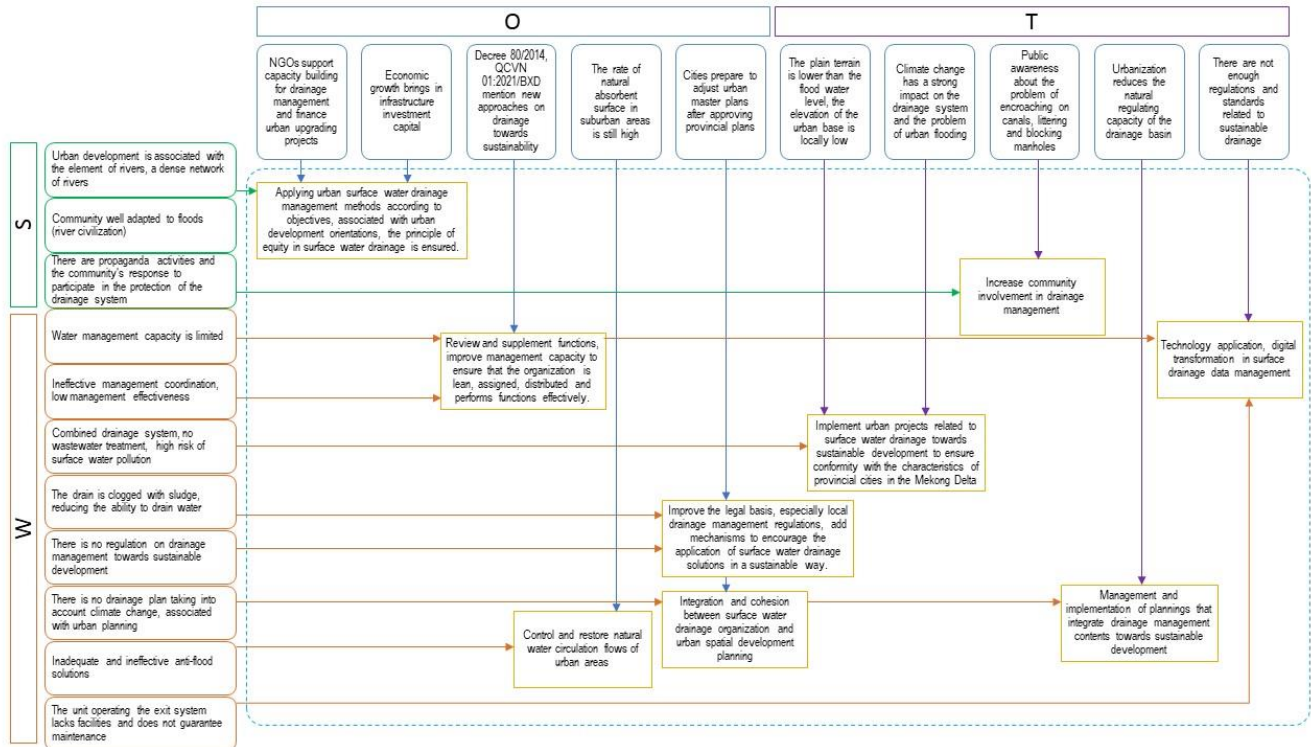


Figure 3.1 Proposed drainage management strategies for Mekong Delta provincial cities towards sustainability

Table 3.1 Set of criteria for drainage management towards sustainable development for Mekong Delta provincial cities

Group	Criteria	Criterion
1. Organizational management, mechanisms and policies, management capacity and community participation	1.1 Managing urban rainwater drainage according to objectives, associated with urban development orientation, the principle of fairness in rainwater drainage is ensured	<ul style="list-style-type: none"> • Identify the target of rainwater drainage towards sustainable development in urban development orientation • Develop strategies and action plans for urban rainwater drainage management towards sustainability • Develop a financial mechanism to ensure fair rights and responsibilities of stakeholders • Develop a mechanism to ensure that the project in one area does not increase the flood level in other areas
	1.2 The management organization is lean, assigned, graded and effectively performs functions	<ul style="list-style-type: none"> • Develop regulations on subsidiarity and assignment of functions and tasks in rainwater drainage management • Develop a coordination mechanism between local specialized management authorities and operation management unit
	1.3 The legal basis is finalized and the local management capacity for urban drainage is improved	<ul style="list-style-type: none"> • Supplement and update local regulations on drainage management towards sustainable development • Develop programs and training plans on drainage management towards sustainable development to train and improve the capacity of officers annually.
	1.4 Communities are consulted and participated in urban drainage management	<ul style="list-style-type: none"> • Develop research plan for drainage management towards sustainability of local educational institutions • Introduce the sustainable drainage measures to local community and pursue consensus participation of them in the implementation.
2. Integrating drainage towards sustainable development in planning	2.1 The natural water cycle of city is controlled and restored	<ul style="list-style-type: none"> • The rainwater permeability of city is analyzed and evaluated in the urban master plan • Determine the percentage of collected rainwater, which is controlled by sustainable drainage solutions.
	2.2 Ensure rainwater drainage system in association with urban spatial development	<ul style="list-style-type: none"> • Urban spatial orientation in consideration of space for sustainable rainwater drainage measures • Tasks content, orientation content and solutions for water drainage towards sustainability are integrated in local construction planning at all levels. • Content related to sustainable drainage planning is integrated in the local climate change response and flood prevention plan.

Group	Criteria	Criterion
	2.3 Implementation management of the master plan must be integrated drainage management towards sustainability	<ul style="list-style-type: none"> • Constitute provisions on rainwater drainage management in detailed planning, project site plan, work construction permits in urban management regulations
3. Technical management	3.1 Urban projects related to rainwater drainage towards sustainability are assured to be suitable with the features of Mekong Delta provincial cities	<ul style="list-style-type: none"> • Urban projects are required apply drainage solutions towards sustainability, taking into account the process of urban expansion and environment protection • Implementation of drainage measures towards sustainability in accordance with natural conditions of Mekong Delta provincial cities, climate change and sea level rise • Study cost-benefit analysis of the selected sustainable drainage measures for upscale ability
	3.2 Application of technology, digital transformation in rainwater drainage data management	<ul style="list-style-type: none"> • Simulation tools are applied to develop scenarios of urban drainage system toward sustainability, evaluate the risk of inundation • Specialized management department applying GIS remote sensing to control the change of urban cover permeable surface • Management department applying IoT to monitor and evaluate the effectiveness of rainwater drainage measures towards sustainability

3.3. Proposing solutions to organization management and improve management capacity, community participation

Determine stakeholder responsibilities, distributing management and supplementing functions and tasks

Proposed distribution of drainage management as follows:

- Provincial People's Committee: Manage vision and goals on drainage towards sustainable development in climate change response planning and plans, flood prevention and control;
- Department of Construction: Manage the content related to drainage towards sustainable development in urban master plan, propose and monitor the implementation and evaluation of the set of criteria;

- City People's Committee: Manage contents related to drainage towards sustainable development in urban zoning plan, detailed plan, construction projects according to ability, inspecting implementation and evaluate effectiveness of sustainable drainage measures.

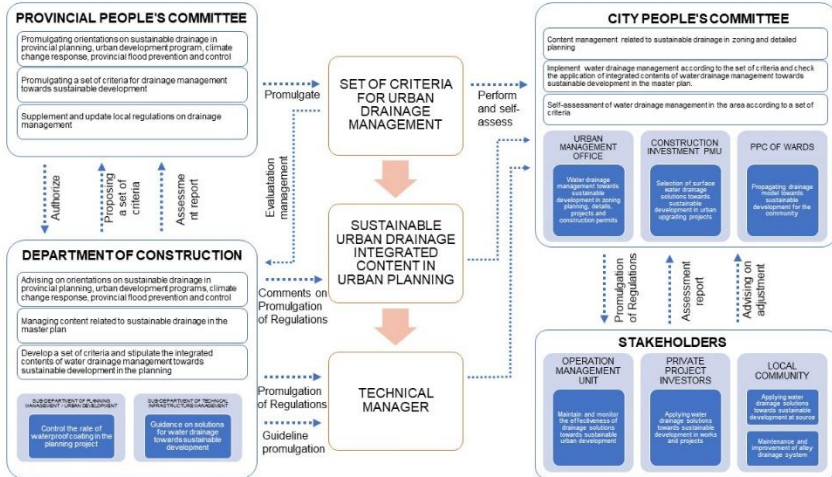


Figure 3.2 Proposal to supplement functions and tasks of organizing drainage management towards sustainable development

The tasks of urban drainage management in the provinces of the Mekong Delta towards sustainable development are proposed based on three main task groups (Fig 3.2): (1) constitute a set of criteria and evaluating rainwater drainage management implementation; (2) promulgating regulation, guideline and implement the integration of urban drainage towards sustainability in urban planning; (3) promulgating regulation, guideline, selecting and evaluating drainage measures towards sustainability in construction projects and residential communities.

Supplement human resources and improve local capacity of urban drainage managers towards sustainable development

- City People's Committee: supplement staff in charge of rainwater drainage management for Urban Management Department; raise awareness on sustainable drainage, guide the assessment of contributions and benefits of sustainable drainage; guide to supplement the content related to drainage towards sustainability in the construction certification.
- Department of Construction: supplement staff in charge of rainwater drainage management for Technical Infrastructure Management Department; raising awareness about sustainable drainage, methods of integrating sustainable drainage content in construction planning, guiding the use of GIS in observing and assessing the urban natural land cover, assessing impacts of sustainable drainage solutions; guide tools for initial selection of sustainable drainage measures in accordance with urban areas conditions.

Supplement and complete relevant legal documents and integrate the content of drainage towards sustainable development in urban planning

Supplement content of drainage towards sustainable development in Decree 80/2014/ND-CP (draft): instructing general principles of drainage management towards sustainable development, responsibilities of stakeholders for organization management of rainwater drainage towards sustainable development, support policies for projects applying sustainable drainage solutions and other related provisions.

The integrated contents of drainage towards sustainable development in urban planning projects are as follows:

- In urban master plan: supplementing the general solutions on drainage towards sustainable development: control and store water for the total

urban area and the connection between rivers and canals that play the role of the main drainage features in the urban area.

- In zoning planning: supplementing solutions as measures to control and temporarily store water in the basin, bio-infiltration and conveyance channels linked to main drainage system.
- In detailed planning and urban design: supplementing detailed solutions as measures for source control; collecting and bio-filtering rainwater on the street; conveyance channels linked to bio-infiltration and wetland area.

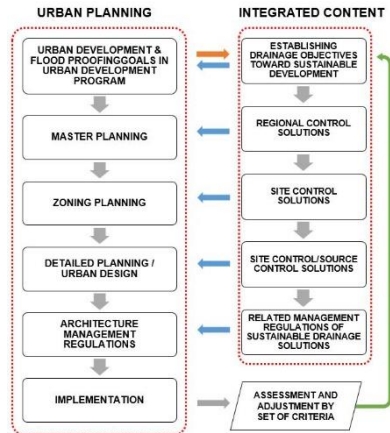


Figure 3.3 Proposed content to integrate drainage solutions towards sustainable development in urban planning

Enhance community participation in urban drainage management towards sustainable development

- Develop a program to instruct the role of rainwater in life, the benefits of rainwater management and reuse, and guideline to source prevention of overflow and pollution for local community.
- Enhance community participation in urban planning and drainage projects proposal towards sustainable development.
- Encourage the role of the community to participate in stormwater drainage management and protection of the drainage system in neighborhood areas (eg: do not throw garbage indiscriminately, participate in propaganda about rainwater collection and reuse, etc.)

- Projects on construction of stormwater drainage systems need to collect opinions based on questionnaires, interview affected households and collect comments on a large scale for affected communities, or benefit from the project.

3.4. Technical management solutions

To implement drainage solutions towards sustainable development, zoning and evaluating to select sustainable drainage solutions proper to the features of each city. Based on the natural conditions of for Mekong Delta provincial cities and region master plan for the period of 2021 - 2030 and vision to 2050 (Decision No. 287/QĐ-TTg), 4 zones are proposed to

apply drainage solutions towards to sustainability as follow: Region I: middle of the delta - low terrain: Tan An, Vinh Long, Vi Thanh; Region II: middle plain – medium terrain: My Tho, Ben Tre; Region III: middle of plain – high terrain: Long Xuyen, Cao Lanh; Region IV: coastal area: Rach Gia, Ca Mau, Bac Lieu, Soc Trang, Tra Vinh.

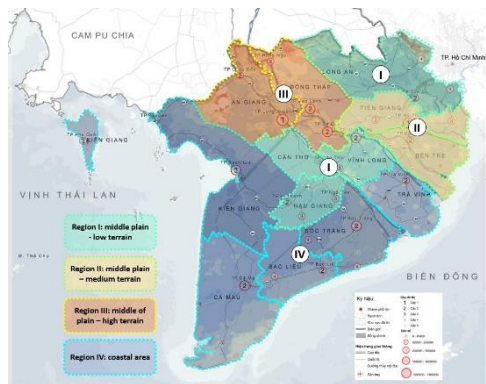


Figure 3.4 Proposed zoning to apply drainage solutions towards sustainable development for Mekong Delta municipal cities

In the implementation of sustainable drainage projects: Applying tools to evaluate and quickly select solutions, computer-based tools to simulate rain, flow, and natural infiltration models.

Table 3. 2 Proposal for sustainable drainage measures selection and benefits evaluation by zoning for Mekong Delta provincial cities

Urban zoning	Characteristic	Drainage solution group					The benefits of the solution												
		Control at source	Swaile	Biocement ion	Infiltration	Temporary storage	Green roof	Rainwater collection system	Permeable coil, seepage hole	Permeable pavement	Filter range	Biofilter storage	Permeation and transmission	Underground storage tank	Wetland area	Lake Air			
Mid-plain region Low terrain • Tan An • Vinh Long • Vi Thanh	~ Altitude 0.8-2.0m The groundwater level is relatively high Partially flooded due to rain, partly due to high tide	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	● There are many benefits ○ There are several benefits Reduce peak flow rate Improve surface water quality Replenish groundwater Rainwater reuse Enhance biodiversity Education propaganda Enhance space comfort Create an open space Create the characteristic value of space Improved microclimate	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Middle Plains Medium Terrain • My Tho • Ben tre	Long-established urban development Altitude 1.7-2.4m Relative groundwater level Flooding mainly due to rain	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The middle of the plains – High terrain • Cao Lanh • Long Xuyen	Long-established urban development Average altitude 2.9m Relatively low groundwater level Flooding mainly due to rain	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Coastal area • Rach Gia • Ca Mau • Bac Lieu • Soc Trang • Tra Vinh	Low terrain 1.1-1.9m (Ca Mau 1.1-1.2m) High groundwater level Flooded mostly due to tides, the urban center is flooded due to rain & tides The influence of tides in the East Sea	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

In analyzing the current status of urban planning projects, remote sensing GIS is applied to map the urban cover, map the current status and forecast inundation. Urban drainage cover surface map helps to assess the natural rainwater infiltration capacity, control the process of increasing impermeable surface in urban areas. Thereby contributing to identifying the causes of flooding and prioritizing sustainable drainage solutions for areas with a high percentage of impervious surface coverage.

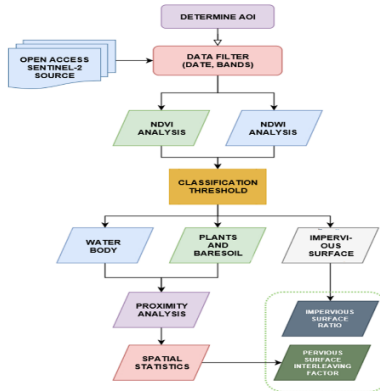


Figure 3.5 Proposed GIS analysis process for mapping of urban natural drainage capacity

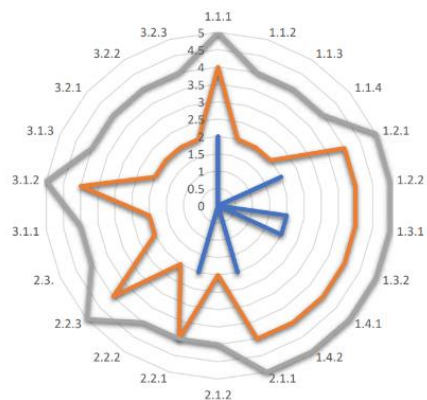
3.5. Application of research results to the case study of Vinh Long

Vinh Long city is a medium-sized provincial urban in Mekong Delta region, the situation of rainwater drainage and flooding proofing ability of city is still limited. It is affected by serious risks of flooding in comparison to other cities in Mekong Delta. Therefore, Vinh Long was selected as a case study to apply research's results. The main factors affecting the drainage management of Vinh Long:

- Low-lying terrain, high tidal range directly affected.
- The drainage system does not meet the existing requirements
- Flooding due to the process of construction and urbanization increases the area of lakes and canals, reducing the capacity of water storage.
- The awareness of some people is still limited in clearing the manhole water inlet.

Applying solutions to improve the capacity of water drainage management organization towards sustainability for Vinh Long

Apply a set of criteria and quantitative assessment of drainage management capacity to clearly identify the current situation and target. As a result, only the group of criteria for organization, mechanisms and policies, local capacity and community participation achieved 8/50, the criteria of integration in the planning achieved 4/30. It is expected that the proposed sustainable drainage management solutions will increase the assessment results up to 98/110 by 2035.



Applying remote sensing analysis and proposing solutions to integrate sustainable drainage measures in Vinh Long adjusted master plan

The results of GIS remote sensing analysis show that although the rate of impervious surface in the whole urban area is not high (16.28% of catchment area). But the uneven distribution of urban drainage spaces leads to an imbalance in the natural water circulation. In the central wards, the proportion of impervious surfaces is much higher than in the surrounding areas and corresponds to the level of flooding risk in these areas. Therefore, it is suggested that these following contents be integrated in Vinh Long city adjusted master plan:

- Assessment of the current state of surface water drainage needs to supplement the content of analysis, assessment of surface characteristics and risks of inundation and surface water pollution of basins in line with urban planning. Determine the percentage of impervious surface of the basin.
- Applying surface water drainage solutions towards sustainable development with site control and flow distribution to outfalls, prioritizing measure: source control and bio-infiltration.

3.6. Discussing research results

Compared with other sets of criteria for approaching sustainable drainage management such as WSUD in Australia and sponge city in China, the set of criteria proposed in the thesis includes not only technical criterion, but also criterion of management organization, mechanisms and policies, local capacity and community participation.

As for the management organization solution, unlike the management organization model in the United Kingdom, the thesis does not propose the establishment of new drainage management entities

independent from the current specialized management agencies but supplementing functions and tasks for a lean, associated organization with the improvement of local institutions and capacity building for officers.

For the integration of the content of rainwater drainage towards sustainable development in urban planning, the development of a process to integrate the criteria and technical solutions on water drainage towards sustainability to ensure conformity with the existing Vietnam's construction planning framework.

For the solution of applying GIS remote sensing to map urban cover, in low-lying terrain conditions of this region, the analysis of the degree of interlacing between permeable and impermeable surfaces is proposed in the thesis is an important factor to assess the potential of surface water drainage towards sustainable development.

For the case study of Vinh Long, applying the assessment according to the set of criteria shows the strength in the city's drainage management. Vinh Long currently only focuses on operation management, however, database management and the integration of sustainable drainage solutions in local construction planning projects at all levels are still limited. Apply management solutions, supplement functions and tasks related to surface water drainage management towards sustainable development and establish relevant management regulations to contribute to overcoming the above limitations in a comprehensive and synchronous manner. Applying the proposed solution on urban drainage management towards sustainable development in Vinh Long shows its practicality, feasibility and ensures the scientific basis for drainage management. Therefore, urban drainage management solutions towards sustainable development are high potential for upscale to other provincial cities of Mekong Delta.

CONCLUSION & RECOMMENDATION

This thesis achieves the following research results:

- Regarding regulations on drainage management: the study examined the suitability of the solutions compared with the legal and institutional conditions of these cities. The proposals to supplement content of sustainable drainage in current management regulations are suitable for specific features of Mekong Delta provincial cities.
- Regarding the content of drainage planning in the master plan: the relationship between land use planning and anti-flooding and climate change has been assessed. Proposed contents of the drainage planning taking into account spatial planning, climate change and related plans.
- Regarding technical management: zoning to propose technical requirements in selecting sustainable drainage solutions suitable to the characteristics of Mekong Delta cities. In the future, they need to be built into complete regulations to increase their effectiveness.
- About organization of local management for urban drainage: the set of criteria and solutions to organize the apparatus proposed in the thesis is an important foundation to improve the capacity of urban drainage management towards sustainable development.
- Regarding community participation: the reality shows that people's awareness in protecting the drainage system is still limited. Therefore, mechanism and policy solutions are essential to enhance community participation in drainage management towards sustainability.

The proposed contents are considered as novelty contributions:

1. Propose management criteria frame and assessment content for provincial urban drainage management towards sustainable development in Mekong Delta based on the results of SWOT analysis.

2. Propose to supplement the provisions of the regulation related to urban drainage management, including: (1) the process and content of integrating sustainable drainage solutions in urban planning; (2) supplementing contents related to rain water drainage management towards sustainable development in Decree 80/2014/ND-CP and local regulations of drainage management.

3. Propose solutions for provincial urban drainage management towards sustainable development in Mekong Delta, including: (1) zoning for sustainable drainage solutions for the Mekong Delta based on the existing condition of each city, (2) propose application processes and validation of Sentinel-2 remote sensing analysis support to evaluate the rainwater drainage capacity toward sustainable development.

Further recommendations:

1. Proposal to Ministry of Construction: supplementing the updated draft of Decree No. 80/2014/ND-CP on regulations related to water drainage management towards sustainable development as proposed by the thesis. Develop guidelines for integrating drainage content towards sustainable development in urban planning.

2. Recommendations to Department of Construction: supplementing the updated draft regulation on drainage management and submit to the Provincial People's Committee for approval, which considers additional recommendations of the thesis on urban urban drainage management towards sustainable development according to local conditions.

3. Recommendations to local communities of Mekong Delta: understand their rights and obligations to actively participate in the process of investment, construction, management and operation of the appropriate scale drainage system.

LIST OF AUTHOR'S PUBLISHED SCIENTIFIC STUDIES RELATED TO THE THESIS

1. Huynh Trong Nhan (2020), *Evaluation of sustainable drainage system application by pilot projects for urbans in Mekong Delta*, Construction Journal No. 07/2020, Ministry of Construction, ISSN 2734-9888.
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6. Trong Nhan Huynh, Eric CW Lou (2023), *Evaluation of Sustainable Drainage Systems in the Mekong Delta: A Case Study of Vinh Long City, Vietnam*, International Virtual Conference on Industry 4.0. IVCI 2021. Lecture Notes in Electrical Engineering, vol 1003. Springer, Singapore, ISSN 1876-1100.