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Research on sustainable drainage solutions for Thai Nguyen area

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Abstract: *Drainage, wastewater treatment, as well as other urban technical infrastructure issues, need to be solved synchronously. The earlier these issues are integrated from the planning stage, the lower the investment costs. Applying integrated approaches, basin management is essential. The author pointed out that the current drainage situation of Thai Nguyen has many shortcomings, is not synchronized, and needs to be approached in the direction of sustainable drainage SUDS. In the article, the most reasonable SUDS sustainable drainage solutions for Thai Nguyen are currently written. These are rainwater collection and reuse, green roofs, infiltration systems, filter soil strips, filter ditches, bio-storage systems, lakes and wetlands, permeable pavements, and application of control solutions at the source.*

Keywords: *Drainage, Sustainability, Thai Nguyen, Solutions, SUDS.*

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I. INTRODUCTION

Thai Nguyen city has a hilly topography, alternating with low-lying fields that are prone to flooding when there is heavy rainfall. Construction foundation elevation is from 26 m to 27 m. The lowest natural elevation is from 20m to 21m. The highest elevation is from 50m to 60m. Thai Nguyen city has a hot and humid tropical monsoon climate. It is divided into four distinct seasons: Spring - Summer - Autumn - Winter. It has quite a lot of rainfall. There are 198 rainy days on average in a year. The rainy season lasts from April to October and accounts for 80-85% of the total annual rainfall. Average annual rainfall H=2007mm. Maximum annual rainfall H_{max}=3008mm. Minimum annual rainfall H_{min}=977mm. It is less directly affected by storms because it is far from the sea. The average annual temperature is 220 – 230C. Minimum absolute humidity 2 - 2.5 millibars. The highest absolute humidity is 30-32.5 millibars. The average relative humidity is ~80%. The number of hours of sunshine in the year is 1690 hours. Cloudy days ~ 200 days in a year. Thai Nguyen city is located between the two rivers Cau and Cong rivers. Therefore, it is influenced by the hydrological regime of these two rivers, especially the Cau River - the main drainage place of Thai Nguyen city. Song Cau: Flv = 3489 Km2. The length of the section through Bac Thai province L=206Km; The length of Cau River, the section through the city, is L=19Km. The average slope is large i=1.75% and the elevation of the basin gradually decreases from north to south. In the North, there are many waterfalls and rapids, in the rainy season, the water flows violently, and in the dry season, many passages are easy to wade through. In the section from Thai Nguyen to the end of the province, the river bed is wide open, the deep stream has a lower velocity than the upstream but there is inundation when there is a big flood. Cong River: Originating from Polish mountain in Dinh Hoa district, basin area F= 951Km2 with average slope i=1.03%.Length L=96Km. On the Cong River, there is Nui Coc lake used to regulate water for agriculture and daily life of Thai Nguyen city, as well as a tourist area of the city. The total area of Thai Nguyen City: 17,707 ha. The inner-city area is 5,931 ha (accounting for 33.5%).

Drainage and wastewater treatment, environmental sanitation are important contents in urban planning, construction, and management. They aim to minimize the negative aspects caused by waste generated from urban activities, as well as natural processes (rain, storm, drought, etc.), contributing to improving the quality of life. In areas facing poor infrastructure, polluted environment, the spread of diseases, inundation, or flooding, the importance of this sector is even more apparent. For new urban areas and residential areas, the quality of technical infrastructure, including rainwater and wastewater drainage, contributes to determining the attractiveness to customers, as well as the sustainable development. of the urban area in the long run. In addition, climate change is increasingly becoming a huge challenge for urban planning and the construction of urban technical infrastructure systems.

In Vietnam, so far, in most urban areas, the common drainage system is being used for all types of wastewater and stormwater. Sewer drainage routes are patchy, lacking in length, diameter, and inappropriate elevation. The proportion of households connected to the drainage network in many places is still very low. In many new urban areas, although domestic wastewater has been separated from rainwater from within the construction site, however, when it reaches the external drainage network, these wastewaters have not been treated yet. connected to a common sewer, causing pollution and waste. Poor waste and sludge management also negatively affect the drainage system. Drainage fee or environmental protection fee due to wastewater is too low, not enough to cover the cost of system management.

The causes of flooding from rainwater and wastewater in Vietnamese cities are usually: inadequate drainage system; the original design did not match; runoff coefficient in drainage basin increases due to change of cover surface; clogged drains, gradually accreted over time of use; damaged drainage works; incidents at pumping stations to drain rainwater and wastewater; due to climate change leading to increased rainfall and irregular urban hydrology, sea-level rise.

II. METHODOLOGY

2.1 Current status of the drainage system of Thai Nguyen city

The existing drainage system is of general type (rainwater and wastewater). In all networks, rainwater flows by itself by gravity. The drainage routes mainly serve to collect rainwater from the road surface and roadside houses. Rainwater, after being discharged into the fields, will flow through natural drainage channels, irrigation culverts, streams, and then into the Cau River. There is currently about 39.7 km of ditches. Since 2003, 21.1km of new or renovated ditches have been built. The water collection pit system has a large distance, and the rainwater collection efficiency is poor. Cong Ngua, Cactus 1 and Cactus 2 springs have a total length of 4 km. The stream is narrow. The rainwater drainage basins to 3 main discharge gates are Mo Bach, Cong Ngua, and Xuong Rong bridge.

Point 1: Near the white mine cutting point, opposite the University of Pedagogy On Luong Ngoc Quyen Street

The drainage system at Luong Ngoc Quyen street has been renovated with box culverts B1000. All the water flows to a low point near the market, next to the University of Education. However, the renovation has not been synchronized, so flooding still occurs every time there is heavy rain.

Point 2: Crossing between Minh Cau Street and Hoang Van Thu street (At kindergarten May 19).
The flooding point opposite the kindergarten 19-5 is caused by the small diameter of the existing sewer.
Point 3: Minh Bridge Road
At the Department of Electricity, the drainage network of Minh Cau street flows to a low point which is the starting point of Xuong Rong stream 1. The drainage along the road is carried out by box culverts B600 and is scattered connected to the Cuong Rong lake. Currently, the entire canal leading to Cactus Lake has been renovated. However, the actual sewer line has not been renovated.

Figure 1. The gate of the Central General Hospital

Figure 2. Hoang Van Thu Street

Figure 3. Water outlet into Cactus Lake
(*White Bridge section when there is no rain)*

Figure 4. Water outlet into Cactus Lake
(White Bridge section after the rain)

Although the drainage system has been upgraded, flooding still occurs due to the following reasons: Rapid urbanization has increased population density in the area, leading to an increase in drainage demand. Meanwhile, most of the drainage system was built a long time ago. They have a small size, small culvert cross-section, and uneven bottom elevation. There are no regulating reservoirs in each area, so all domestic and production wastewater and rainwater are drained into the common drainage system when it rains. Therefore, the drainage system of the area cannot meet the drainage demand, leading to local flooding.

The hydrological regime of the Cau River depends mainly on rain on the basin and wastewater in the process of domestic production. The total amount of wastewater produced and daily activities mainly affect the water quality and the surrounding environment, and has almost no effect on the city's inundation. Concentrated rains with volume or intensity exceeding the drainage capacity of the system are the main causes of flooding in the area. The rains that exceed the design often cause widespread flooding. With a smaller rain than designed, but with great intensity, it can cause flooding in many places in the area.

After a period of development, many areas have lower terrain than the surrounding area. Streets and construction systems are not conveniently arranged for drainage, so there is a possibility that rainwater cannot escape to the drainage system, they often cause local flooding. Nowadays, the population in the city center is increasing, people's awareness is not high, in many places people still dump construction waste, litter, encroach, fill in streams, reducing the drainage capacity of the system. Many new urban areas were built, the natural land area was gradually lost, the drainage capacity of the old sewer system was both collapsed, degraded, and unable to drain. That is one of the reasons that make flooding worse. The management and operation of the system, the organization of updating, exchanging, and dealing with flooding is still situational and have not met the increasing requirements of the City. The most noticeable thing is that along flooded routes, the outlet to Cuong Rong lake is deeply flooded even before it rains. So upgrading and renovating the current drainage system if only increasing the diameter of the sluice or building more sewer lines is not effective. The application of a sustainable drainage system for Thai Nguyen city is an option that should be considered.

2.2 Sustainable approaches to urban drainage

Drainage and wastewater treatment

Wastewater can be collected and treated in various types of shared, separate, semi-private, or mixed drainage systems, according to centralized or distributed drainage organization models. Centralized drainage systems are usually built for urban centers with high population density and synchronous construction conditions. However, this traditional drainage method has many limitations. Therefore, today in the world, people encourage the application of the distributed model. Especially for new urban areas, suburban areas, and rural areas. This model has the following main advantages:

- Reduce investment costs in construction, operation, and maintenance
- Allows the use of simple, low-cost technology solutions. Make full use of natural conditions for wastewater treatment. The technologies as well as the management models and financial mechanisms applied are also very flexible for different regions, depending on specific conditions.
- Easy to plan and implement. The investment scale is also closer to the requirements, avoiding waste.
- Allows maximum mobilization of community participation in the management of the drainage system at all stages of the project.

- Allows on-site reuse of treated wastewater (washing, irrigation, replenishing groundwater) and separated nutrients (fertilizing crops)... In some cases, wastewater can be treated at stations dispersed and then discharged into the stormwater drainage network, thereby significantly saving the construction cost of sewer lines.

Sustainable surface drainage and rainwater reuse in cities

The process of urbanization has caused adverse effects on the natural drainage process: natural flows are changed, the process of storing surface runoff naturally by the loss of vegetation and soil, instead of impervious coated surfaces such as roofs, concrete, and asphalt roads, increasing surface runoff. These flows are often polluted by garbage, mud and other impurities washed away from the road surface. The amount of surface runoff and the intensity of the runoff cause erosion and sedimentation. All these factors cause adverse impacts on the environment, causing flooding, water pollution, affecting aquatic ecosystems.

Traditional drainage systems are typically designed to transport stormwater away from its source as quickly as possible. In these systems, the costs for construction, operation, and maintenance of sewer lines are often very large, while their capacity is limited and not easy to upgrade. This practice leads to an increased risk of flooding, soil erosion, and pollution in downstream areas. It is often difficult to treat rainwater at the end of the pipeline, because of the rapid change in flow rate as well as contaminant concentration. The long-distance diversion and discharge of surface runoff also destroy the ability to replenish valuable groundwater aquifers in situ.

Detecting and overcoming the above shortcomings, people have researched and applied alternative technical solutions, according to a new approach: towards maintaining the natural characteristics of the flow in terms of capacity, intensity and quality; Maximize control of direct drainage areas, store water in place and allow it to seep into the ground while controlling pollution. Those are the principles of sustainable urban drainage solutions (SUDS).

The approach of sustainable stormwater drainage SUDS is to drain slowly, not quickly, to avoid large concentrations of rainfall in a short time. The sluice section will be difficult to meet if the rainfall is heavy and costly, but the water still overflows the culvert, causing flooding of roads and houses. Therefore, rainwater drainage must be organized, combining different measures synchronously, so that the concentrated flow is slow. Using regulation ponds on rainwater collection and transmission areas to store water is a common practice. In addition, using the city's surface area itself, enhancing the natural infiltration of rainwater into the ground through the green grass, while improving the landscape and regulating the microclimate. Absorbing rainwater also helps effectively replenish groundwater resources that are increasingly scarce and depleted.

In cases where the ability to control flows in situ is limited, it is possible to disperse the flow in small basins, direct water by solutions using open and shallow canals, and store rainwater in lakes. stored and allowed to seep into the ground in suitable areas. To prevent and control pollution, it is possible to apply on-site treatment solutions in permeable soils, settling lakes, underground filter fields for planting trees, etc.

III. RESEARCH RESULTS

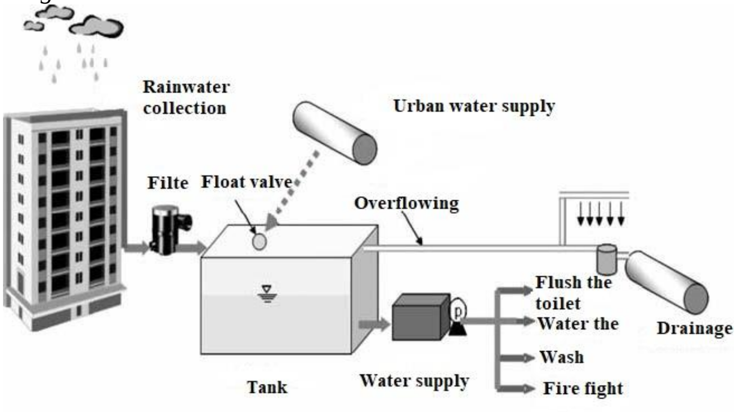
Proposing sustainable drainage solution SUDS for Thai Nguyen

Rainwater collection and reuse:

The basic formula for determining the amount of rainwater to be drained is Q = ø.q.F (l/s), where: ø is the flow coefficient, depending on the type of surface covered; q is rainfall intensity (l/s/ha) and F is rainwater drainage catchment area (ha).

The controllable factor to significantly reduce the instantaneous concentration of rainwater flowing into the drainage network is the runoff coefficient ø. Roof, asphalt road, concrete surface with coefficient ø = 0.9 - 0.95; dirt road: 0.4 - 0.5; parks, flower gardens, lawns: 0.1 - 0.3. Just change the flow factor from 0.4 to 0.8, the flow will change by 2 times. Assuming that with an urban drainage basin of 100 ha, a 1-day rain with a rainfall of 120 mm corresponds to a repetition period P = 1 year, average flow coefficient 0.6. We have: The volume of rainwater to be drained is W1 = 72,000 m3. If there are 7.0 ha of lakes in the basin, with a water regulation height of 0.5 m before and after rain, we have: conditioning capacity W2 = 35,000 m3. The actual volume of rainwater that needs to be drained then is only W3 = 37,000 m3. Thus, if the urban surface water area reaches 7.0% of the basin area, the amount of water that needs to be drained immediately will be halved. That is not to mention the important effects of the regulation lake such as improving microclimate conditions, increasing the value of tourism, landscape, ecology...

Figure 5. Solutions to collect and reuse stormwater in urban areas



Large public areas such as squares, parking lots, sidewalks, even roads, must use materials that allow surface water to seep down. They seep through the gravel layer below and then reach the underground pipes to collect water. The two sides and the middle of the highway must be designed concavely, planting grass and creating natural filter fields, both slowing down the flow and allowing the surface water to be cleaned from sediment, heavy metals, and grease. Do not raise up and collect rainwater right down the drain. In fact, the construction area for economic exploitation is occupying most of the land for percolation areas, vegetation and public works in urban areas of Vietnam has not yet been paid attention. Overall, doing so actually causes economic losses, when the city is flooded, flooded due to rain. Preliminary calculations have been made, showing that in the last rain of October 2008, Hanoi has lost over 8000 billion VND, which is approximately equal to the investment cost for the Hanoi drainage project phase 1 and 2 combined. (1996 - 2015).

Currently, many appropriate solutions can reduce flooding that each household can contribute to, such as making rainwater collection tanks in each family, each building. This approach not only allows the use of precious water sources for domestic use, garden irrigation, car washing... but also significantly reduces the amount of rainwater that concentrates on the urban drainage system. It is also an important solution when many cities are still short of clean water. According to calculations, with a rainfall of 1600 mm/year in Hanoi, each household only needs a 6 m3 rainwater tank, which is enough to flush the toilet for the whole year, and at the same time slow down the rainwater flow a lot. It is possible to build underground water tanks under each building and for the whole house or public areas, making rainwater collection regulation ponds. Stored water can be used to irrigate roads, wash plants, fight fires, etc., or let it seep down to replenish groundwater. In the world, many countries have developed very successful and increasingly popular models of ecological urban areas, in which the approach of sustainable urban drainage, collection, and reuse of rainwater is applied. , harmoniously integrated with other urban planning, architecture, and technical infrastructure solutions.

Green roof: A layer of potting soil is placed on the roof, creating a living surface. Water is stored in the soil layer and absorbed by vegetation.

Permeation Systems: These systems capture water, allowing it to seep into the soil. Surface vegetation and unsaturated soil below can protect groundwater from the risk of contamination.

Figure 6. Green roof solution

Figure 7. Solution using permeation system

Filter soil strip: Water from the impermeable area flows through the lawn or densely planted area to promote settling and filtration.

Filtration ditch: Water is temporarily stored below ground in a shallow gravel trench intended to impair flow, convey, and treat (through filtration).

Bio-storage system: A shallow depression that allows temporary storage of water above ground before it is filtered through vegetation and the subsoil.

Figure 8. Solution using filter soil strip

Figure 9. Solution using filter ditch

Figure 10. Solution using bio-storage system

Permeable pavement: Surface rainwater is permeable through the permeable artificial pavement. Sidewalks can be paving blocks with gaps between the blocks, or porous paving to ensure water seepage. Water can be stored in the subbase and can percolate into the soil.

Lakes and Wetlands: These permanent water holding areas can be used to weaken runoff and treat water, ensuring that flows are controlled and that water levels can rise with precipitation.


Figure 11. Solutions to use permeable pavement


Figure 12. Solutions to using lakes and wetlands

IV. CONCLUSION

Distributed drainage and wastewater treatment, or sustainable surface drainage, allows for the flexible application of different technological solutions. The proposed solutions are distributed wastewater management, with low-cost wastewater treatment and drainage technologies, sustainable surface water management in a natural way - slow draining, integrated drainage surface water with wastewater, garbage, sludge, and water supply management. Thoroughly apply the integrated approach, basin-based management. Drainage, wastewater treatment, as well as other urban technical infrastructure issues, need to be solved synchronously, and the earlier it is integrated from the planning stage, the lower the cost.

The drainage status of Thai Nguyen is still limited, and there is still serious flooding. The management and operation of the system, the organization of updating, exchanging, and dealing with flooding is still situational and have not met the increasing requirements of the City. Therefore, the application of a sustainable drainage system for Thai Nguyen city is an option that should be considered.

The most reasonable SUDS sustainable drainage solutions for Thai Nguyen today are rainwater collection and reuse, green roofs, permeation systems, filter soil strips, filter ditches, biological storage systems, lakes, and areas. wetlands, permeable sidewalks, and application of control solutions at the source.

Conflict of interest
There is no conflict to disclose.

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