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# Development Of Urban Drainage To Improve Water Quality And Prevent Damage To Urban Infrastructure (Case Study: Tanjungbalai City, North Sumatra)

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***Abstract* — This research discusses the development of a sustainable drainage system that is adaptive to climate change and the growth of Tanjungbalai City, with the aim of improving water quality and preventing damage to urban infrastructure. The implementation of effective and environmentally friendly drainage systems is critical in addressing challenges related to flooding, pollution, and infrastructure damage caused by the increasing volume of rainwater. The concept of sustainable drainage includes the design of flexible drainage channels, the use of technology for real-time monitoring, as well as the implementation of green infrastructure such as infiltration gardens and retention ponds. In addition, the separation of rainwater flows from domestic waste, region-based management, and community involvement are also important elements in improving drainage effectiveness. This study suggests that the Tanjungbalai City government and the community work together in designing and managing a sustainable drainage system to create a more resilient and environmentally friendly Tanjungbalai City.**

***Keywords: Sustainable Drainage, Climate Change, Urban Growth, Green Infrastructure and Drainage Maintenance***

## I. INTRODUCTION

The development of Tanjungbalai City brings major challenges in infrastructure management, especially the drainage system (Sugiarto, Yamin s, et al., 2024). Many cities in Indonesia face serious problems due to inadequate drainage systems, ranging from waterlogging during rain, water quality pollution, to damage to roads and other public facilities. Poor drainage causes rainwater to not be drained quickly and effectively, thus accelerating the degradation process of roads, sidewalks, and buildings. In addition, water runoff mixed with domestic waste increases the potential for pollution of groundwater and surrounding water bodies, which negatively impacts public health and the environment (Muhammad Aris et al., 2024). This problem is exacerbated by global climate change which causes rainfall intensity to become increasingly erratic and extreme. Without a drainage system that is designed in a sustainable and adaptive manner, the risk of flooding and infrastructure damage will be even higher. On the other hand, the growth of settlements, commercial areas, and industries that are not accompanied by good drainage planning also adds to the load on the existing system, thereby accelerating the decline in water quality and increasing the cost of maintaining city infrastructure, especially Tanjungbalai City.

Therefore, the development of drainage in Tanjungbalai City is an urgent need. Effective drainage not only serves to drain rainwater, but also contributes to improving water quality, reducing flood risk, and extending the life of urban infrastructure. This development must pay attention to the principles of sustainability, integration with natural environmental systems, and adaptation to climate change. This effort is expected to be able to create a Tanjungbalai City that is more resilient to disasters, healthy, and comfortable for all its residents. In recent years, many cities in Indonesia have experienced an increase in the incidence of local flooding, prolonged waterlogging, and widespread infrastructure damage. Every time the rainy season arrives, major roads are flooded, sidewalks are damaged, and many public facilities become unusable. This problem not only disrupts the social and economic activities of the community, but also causes a decline in the quality of the overall environment.

One of the main causes of this condition is the drainage system in Tanjungbalai City which is no longer able to accommodate the increased volume of rainwater due to climate change. In addition, the blockage of drainage channels by garbage, sedimentation, and lack of routine maintenance exacerbate the performance of existing systems. Many urban areas of Tanjungbalai City have also experienced massive land conversion into built-up areas, thereby reducing water catchment areas and increasing surface runoff (Syahputra & Sugiarto, 2024). As a result, rainwater can no longer be absorbed into the soil naturally, but instead flows directly into the streets and inundates settlements. These conditions create a cycle of repeated damage: water stagnates, infrastructure breaks down quickly, repair costs swell, and environmental water quality continues to decline. In the end, people have to face health risks, economic losses, and a decline in overall quality of life. This phenomenon emphasizes the importance of real efforts in developing urban drainage systems that are more modern, sustainable, and adaptive to the dynamics of the urban environment.

Research on the development of urban drainage to improve water quality and prevent damage to urban infrastructure is becoming particularly urgent amid the current challenges of urbanization and climate change. Without an effective and sustainable drainage system, Tanjungbalai City will continue to face flood problems, environmental pollution, and infrastructure damage that have a direct impact on the quality of life of the community and economic growth of Tanjungbalai City. The social and economic costs due to infrastructure damage and disruption of community activities are much greater than the initial investment in the development of a good drainage system. In addition, the increasing volume of waste and the decline in the function of catchment land make the quality of surface water and groundwater increasingly threatened. This condition poses public health risks, worsens environmental sanitation, and accelerates environmental degradation in Tanjungbalai City. Therefore, a new approach is needed in drainage planning and management that not only focuses on the technical aspects of water flow, but also pays attention to the ecological, social, and adaptation to climate change aspects.

Various previous studies have discussed the management of drainage systems in urban areas. For example, research by Siregar (2018) focuses on the analysis of drainage channel capacity to rainwater discharge in several major cities, with the main focus on technical calculations and proposals to improve the physical capacity of channels. Another study by Putra and Rahmawati (2019) emphasizes more on drainage revitalization strategies based on community participation, where social aspects and residents' behavior are the center of attention in efforts to maintain channel cleanliness. In addition, a study by Anwar (2020) examined the impact of poor drainage systems on the occurrence of urban flooding, but this study is still limited to cause-and-effect relationships without developing a sustainable drainage management model. Meanwhile, research by Fitriani (2021) focuses more on integrating drainage systems with green open spaces to increase water catchment areas, but does not examine aspects of improving water quality and protecting infrastructure simultaneously.

Although many studies have addressed drainage from technical, social, and environmental perspectives, most still look at drainage issues partially—either in terms of flood control, community participation, or ecology—without integrating the three in a holistic framework. In addition, previous research has not significantly linked drainage development with efforts to improve water quality and protect urban infrastructure in an integrated and sustainable manner. The research gap that this study aims to answer is the need for an approach to urban drainage development that is not only effective in managing water runoff, but also able to improve environmental water quality and actively prevent damage to urban infrastructure. This research will try to offer a drainage development model that is sustainable, adaptive to climate change, and integrated with infrastructure protection and water quality management, which until now has not been studied comprehensively.

### *A. Problem Identification*

1. The occurrence of waterlogging and local flooding in urban areas due to the inability of the existing drainage system to accommodate rainwater discharge.
2. Decrease in surface water and groundwater quality due to pollution of drainage streams by domestic waste and sedimentation.
3. Damage to road, sidewalk, and public facilities infrastructure due to repeated waterlogging.
4. Lack of planning and management of drainage systems that are adaptive to climate change and growth of built-up areas.
5. Lack of integration between drainage systems, efforts to improve water quality, and protection of urban infrastructure.
6. Not yet optimal participation community and Innovation technology in the development of sustainable drainage systems.

### *B. Problem Formulation*

Based on the above identification, the formulation of the problem in this study is:

1. What are the existing conditions of the drainage system in Tanjungbalai City in managing rainwater and domestic waste?
2. What are the factors that cause a decrease in the effectiveness of drainage in preventing stagnation and water pollution?
3. What is the relationship between suboptimal drainage systems and the level of damage to urban infrastructure?
4. What kind of drainage development strategy can improve water quality while preventing sustainable damage to Tanjungbalai City's infrastructure?
5. How is the application of the concept of sustainable drainage that is adaptive to climate change and the growth of Tanjungbalai City?

## II. LITERATURE REVIEW

### **2.1** *Definition of City Drainage*

According to Suharyanto (2019), urban drainage is a runoff water management system, both from rain and other sources, to reduce the risk of inundation and protect the quality of the urban environment. Drainage not only functions to drain water, but also plays an important role in maintaining soil stability and protecting buildings from damage due to excess moisture. Meanwhile, according to

Yulianti and Pratama (2019), the development of urban drainage must pay attention to sustainability factors, namely not only disposing of water quickly, but also considering environmental aspects, such as water pollution control and water resource conservation.

### 2.2 *Purpose and Function of Urban Drainage Systems*

According to Putra (2019), the main purpose of a municipal drainage system is to manage surface water so as not to cause flooding, inundation, or erosion that can damage infrastructure such as roads, buildings, and public facilities. This system also serves to improve the quality of life of the community by creating a healthy and safe environment. In line with that, Arifin and Wibowo (2019) stated that a good drainage system must be able to support sustainable water management, including filtering rainwater before it is released into natural water bodies, to prevent pollution.

### 2.3 *The Impact of Poor Drainage on Urban Infrastructure*

According to research by Santosa (2019), infrastructure damage such as road cracks, building collapses, and disruption of underground utilities (clean water pipes, power cables, gas lines) are often caused by drainage system failures. Poorly managed water can seep into the soil, leading to a decrease in the carrying capacity of the soil and ultimately damaging the foundations of the structure. The results of research from Widodo (2019) also emphasized that the cost of infrastructure maintenance due to poor drainage systems tends to be higher compared to the initial investment in adequate drainage system development.

### 2.4 *Urban Drainage Development Strategy*

According to Hasanah and Nugroho (2019), the city's drainage development strategy must focus on the concept of eco-drainage. This includes the application of technologies such as bioretention, infiltration wells, and the use of green open spaces as natural infiltration areas. In addition, Sari and Hidayat (2019) emphasized the importance of integration between drainage systems and wastewater management systems. This combination aims to reduce the burden of water pollution and support a more natural water cycle in cities. The development of modern drainage must also take into account climate change predictions, where the intensity of rainfall tends to increase. Therefore, according to Firdaus (2019), drainage systems must be designed to be more adaptive and flexible to variations in water volume.

### 2.5 *The Role of the Community and Government in Drainage Management*

According to Ismail (2019), the success of urban drainage management does not only depend on technical aspects, but also on active community involvement and policy support from the government. Community participation is needed to keep the canal clean of garbage, while the government must provide adequate regulations, planning, and budgets for drainage development and maintenance. Furthermore, based on a study by Fauziah (2019), collaboration between the public and private sectors in the form of corporate social responsibility (CSR) programs can also be an alternative financing and innovation in the development of a more effective and sustainable drainage system.

### 2.6 *Frame of Mind*

Effective urban drainage has an important role in managing rainwater and surface water to improve the quality of the urban environment. An imoptimal drainage system can cause flooding, decreased water quality, and damage to infrastructure such as roads, buildings, and public utilities (Lubis & Sugiarto, 2024). Therefore, the development of modern drainage systems needs to consider technical, environmental, and social aspects.

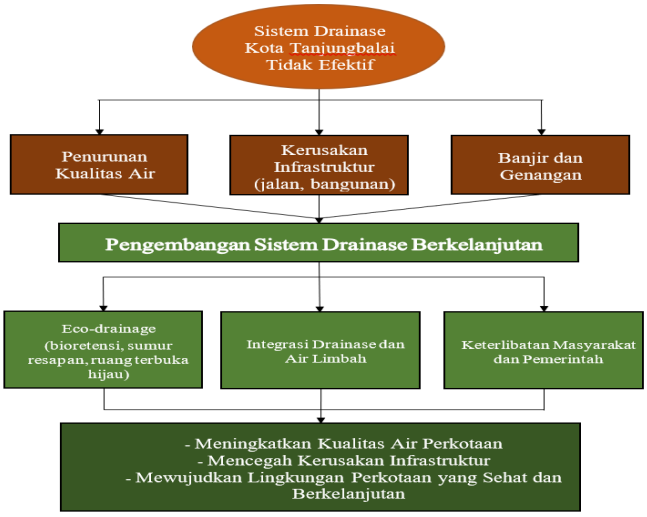


Figure 2.1 Frame of Mind
(Source: Author's Thoughts, 2025)

According to Suharyanto (2019), drainage management must be directed not only to dispose of water quickly, but also to maintain water quality through pollution control and the application of the concept of eco-drainage (Hasanah & Nugroho, 2019). This approach involves the creation of infiltration wells, bioretention, green open spaces, and integration with wastewater management systems (Sari & Hidayat, 2019). In addition to technical aspects, community involvement and government support are important factors in maintaining the sustainability of the

drainage system (Ismail, 2019). The active participation of the community in maintaining the cleanliness of the channel and government policies in planning and financing drainage infrastructure are determinants of the success of the system (Ramadhani & Nuraini, 2024). Thus, the development of drainage in Tanjungbalai City contributes directly to improving environmental water quality and preventing damage to urban infrastructure, which ultimately improves the quality of life of the people of Tanjungbalai City

## III. METHOD

### 3.1 *Approaches and Types of Research*

This study uses a descriptive qualitative approach. According to Sugiyono (2019), the qualitative approach aims to understand the phenomenon in depth through a systematic description of the actual conditions in the field. The focus is not on the measurement of numbers, but on understanding the meaning, process, and perspective of the subject being studied (Moleong 2000 in Nuraini, 2019; Turio & Nuraini, 2024; Nuraini 2024b; Nuraini et al., 2024b). This approach is used to explain the "how" and "why" of things happening in a natural context, by exploring the views, experiences, and social interactions of individuals or groups (Yin, 1999 in Azmi & Nuraini, 2024; Suprianto & Nuraini, 2024; Rambe & Nuraini, 2024). The results are narrative, profound, and contextual (Groat and Wang, 2000 in Nuraini, 2024b; Yin, 2000 in Laia et al., 2024a; Laia, 2024b). In this context, the research is focused on exploring how urban drainage development strategies can improve water quality and prevent damage to urban infrastructure.

The type of research used is a case study. Case studies focus on one or more specific cases, such as individuals, groups, institutions, events, or communities to understand the dynamics and complexities that exist (Yin, 2000 in Marbun et al., 2025; Muazro & Nuraini, 2024; Praja & Nuraini, 2024). Creswell (2019) stated that case studies allow researchers to explore one or more cases in depth in a real context, making them very suitable for understanding the dynamics of drainage management in a particular urban environment.

### 3.2 *Research Location and Time*

The research location is focused on the urban area of Tanjungbalai which has challenges in drainage management and water quality problems, namely in the city center or dense residential areas. The research period lasted for three months, starting from the observation stage, interviews, to data analysis. According to Moleong (2019), the selection of qualitative research locations must consider the ease of access to information and relevance to the focus of the problem.

### 3.3 *Data Collection Sources and Techniques*

#### 3.3.1 Data Source

There are two data in this study, namely primary data and secondary data. Primary data is data obtained directly from the first source through direct interaction with the research subject (Yin, 2000 in . Nuraini, 2023; Nuraini, 2024b). This data can be obtained through direct field observation and in-depth interviews with related parties such as public works officials, drainage project managers, and local communities. Secondary data is data that is already available and collected from other sources, not from direct interaction (Moleong, 2000 in Nuraini et al., 2024a). This data can be obtained from official documents, drainage project reports, urban spatial plans, and relevant scientific studies.

#### 3.3.2 *Data Collection Techniques*

According to Nawawi (2019), data collection techniques in qualitative research include: Observation: Observing drainage conditions, water quality, and its impact on infrastructure. Interviews: Conduct structured and semi-structured interviews with stakeholders. Documentation study: Collect documents such as annual reports on infrastructure development and local regulations related to drainage management.

### 3.4 *Data Analysis Techniques*

The data obtained will be analyzed using an interactive analysis model proposed by Miles, Huberman, and Saldaña (2019), which includes: Data reduction: Filtering and summarizing important information from field data. Data presentation: Organize data in the form of narratives, tables, or graphs to make it easier to understand. Drawing conclusions: Making interpretations of the patterns found in the data. The analysis was carried out simultaneously from the time data collection began until all data was collected thoroughly (Sugiarto, Kamakaula, et al., 2024).

### 3.5 *Data Validity*

To maintain the validity of the data, this study uses source triangulation techniques and triangulation methods as described by Patton (2019). Triangulation is carried out by comparing the results of observations, interviews, and documentation to obtain a more complete and objective understanding.

## IV. RESULT AND DISCUSSION

### *A. The existing condition of the city drainage system in managing rainwater and domestic waste in the city of Tanjungbalai*

In general, the existing condition of drainage systems in many cities in Indonesia still faces various serious problems in managing rainwater and domestic waste. The existing drainage system is largely designed based on past capacity calculations, which have not taken into account the dynamics of rapid urban growth and changes in rainfall patterns due to climate change. As a result, the capacity of the channel is often no longer adequate to accommodate high rainwater discharges, especially when there is heavy rain in a short period of time. In addition, many drainage networks are subject to sedimentation, blockage by garbage, and structural damage due to lack of routine maintenance. Drainage channels that are supposed to function to drain water

quickly, instead become a place where water is held and overflowed, causing inundation in streets, residential areas, and public areas.

Another problem that emerged was the mixing of rainwater with domestic waste in many urban areas, especially in Tanjungbalai. This is due to the lack of an effective separation system, household wastewater such as washing water, used bath water, and even toilet waste flows directly into the drainage channel without going through treatment first. This causes the quality of water in the channel to become polluted, produces unpleasant odors, threatens public health, and worsens the pollution of surrounding water bodies, such as rivers and lakes. In addition to capacity and pollution issues, the physical design of drainage that does not take environmental sustainability into account also worsens conditions. Many canals are built conventionally without considering the concept of water infiltration, the use of green spaces, or nature-based drainage systems, thereby accelerating surface flow and reducing the ability of Tanjungbalai City to absorb rainwater naturally.

In general, the existing condition of the drainage system in Tanjungbalai City shows that without planned development and revitalization, this system will be increasingly vulnerable to urbanization pressures, climate change, and the growth of domestic waste volume. Therefore, a comprehensive improvement with a sustainability-based approach is an urgent need to ensure that drainage conditions in Tanjungbalai City can carry out their functions optimally.

Figure 1. a) The existing condition of the Tanjungbalai City Drainage is covered with sediment and wild plants; b) drainage in the residential environment of one of the sub-districts in Tanjungbalai City where several channels have not been connected and the environment is often flooded; c) condition of damaged stone pairing channels; d) Drainage conditions with water runoff mixed with domestic waste increase the potential for groundwater pollution and surrounding water bodies (Source: Tanjungbalai City PUTR Office Documentation, 2024-2025)

*B. Factors that cause the decline in drainage effectiveness in preventing inundation and water pollution in the city of Tanjungbalai*

The decline in the effectiveness of drainage systems in preventing inundation and water pollution in urban areas, especially in Tanjungbalai City, is caused by various interrelated factors. One of the main factors is the very rapid growth of built-up areas without being balanced with an increase in the capacity and quality of drainage systems. Increasing the area of watertight areas, such as paved roads and concrete buildings, reduces the soil's ability to absorb rainwater, so that the volume of surface runoff increases sharply and burdens existing drainage channels. In addition, the design and technical capacity of drainage in Tanjungbalai City still refers to old standards that do not take climate change into account, such as increasing the intensity and frequency of extreme rainfall. As a result, channels that were once sufficient for normal weather conditions are now no longer able to handle larger volumes of rainwater in a short period of time.

Another crucial factor is poor waste management and low public awareness. Many residents dump garbage into drainage channels, which causes blockages, slows down water flow, and increases the risk of inundation. The build-up of sedimentation due to soil erosion and household waste that goes directly into the channel also exacerbates this problem, making the water in the channel polluted quickly. The lack of regular drainage maintenance and revitalization programs is also a major cause. Many drainage lines are left without regular cleaning, suffering structural damage such as cracks, collapses, or narrowing, all of which hinder their hydraulic function. Without prompt repair interventions, these conditions continue to worsen the effectiveness of drainage systems.

In terms of policies and planning issued by the Tanjungbalai City government, it is also still not optimal. Such as weak coordination between agencies and the lack of integration of drainage with urban spatial planning also contribute to this problem. Drainage is often considered a supporting infrastructure that lacks priority in development, so the development of the system lags behind the physical growth of the city. All of these factors reinforce each other and create conditions where drainage in Tanjungbalai City not only fails to manage water runoff effectively, but also becomes a source of new environmental pollution, increases the risk of flooding, and accelerates the degradation of the quality of life of urban people in Tanjungbalai.

*C. The relationship between a suboptimal drainage system and the level of damage to urban infrastructure in the city of Tanjungbalai*

An suboptimal drainage system has a very close relationship with the level of damage to urban infrastructure, both in the short and long term. Poorly functioning drainage causes prolonged standing water on road surfaces, sidewalks, and other public facilities. This stagnant water, especially if it occurs repeatedly, can damage the physical structure of existing infrastructure. One of the most frequent forms of damage is on the road

surface (Sugiarto, Yamin s, et al., 2024). When rainwater that cannot flow smoothly is stagnant for a long time, the pressure and friction caused by this inundation causes asphalt and concrete to become brittle, cracked, or even eroded. In the long term, damage to the highway due to waterlogging will shorten the life of the road, increase maintenance and repair costs, and disrupt the mobility and comfort of road users.

In addition, constant waterlogging also damages sidewalks and urban buildings. Building materials, especially those made of concrete or stone, can be weathered due to continuous exposure to water, which reduces the durability of the building's structure. Even in extreme cases, the foundation of a building can be affected, causing more severe damage or even a safety threat. Damage to the drainage itself also has the potential to increase the level of infrastructure damage in Tanjungbalai City. When drainage channels are blocked or structural damage, the water flow is no longer smooth, so water overflows into roads and public areas. This exacerbates the inundation situation and accelerates damage to existing infrastructure.

On the other hand, poor drainage management that causes water pollution also has an impact on the surrounding environment. Sewage and dirty water mixed with rainwater in drainage channels can damage groundwater quality, contaminate water resources, and worsen urban sanitation conditions. This pollution will ultimately affect various other elements of infrastructure, such as clean water systems and health facilities. Thus, the relationship between suboptimal drainage systems and the level of damage to urban infrastructure is clear. When drainage does not function properly, it not only increases the risk of flooding and pollution, but also accelerates the degradation of infrastructure quality, increases maintenance costs, and decreases the quality of life of the people of Tanjungbalai City.

### *D. Drainage development strategies that can improve water quality while preventing infrastructure damage in Tanjungbalai City in a sustainable manner*

The development of a drainage system that can improve water quality while preventing damage to existing infrastructure in Tanjungbalai City requires an integrated, sustainable, and based approach based on environmental sustainability principles. There are several strategies that can be implemented to achieve this goal, which include planning, designing, and managing drainage that is more holistic and adaptive to climate change and the growth of urban areas, especially in Tanjungbalai City.

**1. Application of Nature-Based Drainage Systems**

Nature-based drainage systems involve the utilization of natural elements such as infiltration gardens, bioswale (plant infiltration channels), and retention ponds to manage rainwater flow. This concept not only serves to drain water, but also improves water quality by filtering pollutants through plant roots and soil media. This system also serves to increase soil permeability and reduce inundation. The main advantage of this approach is not only to reduce the risk of flooding, but also to improve the quality of water entering the drainage channels and reduce damage to existing infrastructure in Tanjungbalai City.

**2. Use of *Integrated Drainage Systems***

Integrated drainage systems involve the combination of conventional drainage and more advanced rainwater management technologies, such as rainwater harvesting and wastewater treatment. In this system, the collected rainwater can be used for household or irrigation needs, while domestic waste can be treated first before it enters the drainage canal. This integrated approach can reduce the volume of water that must be managed by municipal drainage and at the same time improve the quality of water discharged into the environment.

**3.** *Drainage Design with Attention to Wastewater and Rainwater Separation System*

One way to improve water quality in drainage systems is to ensure the separation between rainwater and domestic wastewater. In many cities, household wastewater often mixes with rainwater in drainage channels, which causes pollution and worsens the quality of water in the canals. Therefore, the drainage design that separates these two types of water is essential. The use of separate drainage channels for rainwater and wastewater will reduce the risk of pollution and ensure that rainwater can flow smoothly without contamination (Lubis & Sugiarto, 2024).

**4.** *Routine Maintenance and Repair of Drainage Systems*

Regular maintenance and repair of the drainage system is essential to ensure that the drainage remains functioning properly. This includes the cleaning of channels from garbage, sedimentation, and vegetation that block the flow of water, as well as the repair of damaged or clogged channels. Good maintenance will extend the life of the drainage infrastructure and prevent damage from uncontrolled waterlogging. In addition, this treatment program can also prevent water quality degradation by ensuring that drainage channels remain clean of waste and pollutants.

**5.** *Application of Water Flow Monitoring and Control Technology*

Modern technologies such as sensors and water flow monitoring systems can be used to monitor the condition of drainage channels in real-time. This system can provide the necessary data to identify points prone to inundation and pollution, as well as enable a quick response in dealing with drainage problems that arise, especially in Tanjungbalai City. In addition, water flow control technologies, such as automatic drainage systems that can adjust drainage capacity based on rainfall intensity, will help prevent infrastructure damage and reduce the risk of flooding.

**6.** *Education and Community Engagement*

The people of Tanjungbalai have a very important role in maintaining the cleanliness of drainage channels and supporting sustainable water management.

Therefore, educational campaigns that raise awareness about the importance of waste and household waste separation and rainwater management should be part of the drainage development strategy. The participation of the people of Tanjungbalai City in maintaining the cleanliness of drainage channels and following environmentally friendly practices can significantly increase the effectiveness of the drainage system in overcoming waterlogging and pollution (Saputra & Sugiarto, 2024).

**7.** *Development of Drainage Infrastructure Adaptive to Climate Change*

Drainage systems designed to adapt to climate change are essential in the face of increasingly frequent extreme weather, such as intense heavy rains. The existing drainage infrastructure in Tanjungbalai City must be designed to increase the capacity of the channel to be able to handle a larger volume of water, but must also pay attention to environmental and sustainability impacts. The use of eco-friendly materials and designs that support water absorption into the soil can reduce the adverse impacts of climate change on drainage systems and water quality.

Overall, the drainage development strategy in Tanjungbalai City is that by combining technical, ecological, and social aspects, it will be able to create a more effective city drainage system in improving water quality and preventing infrastructure damage. This approach is not only beneficial in the short term to address flooding and pollution, but also has a positive impact in the long term on urban resilience to climate change and rapid urban growth such as Tanjungbalai City.

### *E. The application of the concept of sustainable drainage that is adaptive to climate change and urban growth in Tanjungbalai*

The concept of sustainable drainage aims to create a rainwater management system that is not only efficient in preventing inundation and flooding, but also environmentally friendly, can adapt to climate change, and is able to support the growth of Tanjungbalai City which continues to grow. The application of this concept is very important, considering climate change that causes an increase in rainfall intensity and the increasingly rapid growth of Tanjungbalai City, which adds to the burden on the existing drainage system.

**1.** *Flexible and Responsive Drainage Design*

One of the key aspects of sustainable drainage is the flexible and responsive design to changing climatic conditions and the growth dynamics of Tanjungbalai City. Drainage systems should be designed with higher rainfall projections and more frequent extreme rainfall frequencies in mind in the future. Therefore, drainage channels need to have sufficient capacity to handle larger volumes of rainwater, but with an approach that does not rely solely on the physical capacity of the channel. The use of infiltration basins or infiltration gardens that absorb water into the soil is part of a sustainable solution that can reduce pressure on the main drainage system.

**2.** *Use of Technology for Monitoring and Management*

Advanced technology can be used to increase the effectiveness of sustainable drainage in the face of climate change and growth in Tanjungbalai City. Real-time monitoring systems using sensors and measurement devices can provide accurate data on water flow status, pollution levels, and potential inundation at various points of drainage channels. With this data, drainage managers can respond faster in dealing with potential disasters such as floods, and maintain the system more effectively. The technology also enables predictive analysis to plan future maintenance and development of drainage channels, given changes in rainfall patterns.

**3.** *Green Infrastructure to Reduce the Impact of Urbanization*

Sustainable drainage utilizes the concept of green infrastructure, such as infiltration gardens, retention ponds, and bioswales, which not only function to drain rainwater but also provide other environmental benefits. In the context of the ever-growing growth of cities, integrating green open spaces and natural elements in drainage design can reduce the negative impacts of urbanization, such as reduced soil absorption and increased surface flow that causes flooding. This green open space can also improve air quality and provide recreational space for the residents of Tanjungbalai City. In addition, the construction of green roofs on high-rise buildings and the use of permeable paving on sidewalks and roads can reduce the volume of water flow entering drainage channels and improve rainwater management at the surface level.

**4.** *Separate Separation and Treatment of Waste*

One of the important principles in the concept of sustainable drainage is the separation of rainwater flow from domestic waste. Drainage systems should be designed to separate collected rainwater from household waste so that domestic waste can be better processed before being discharged into the environment. In this case, the use of separate drainage systems (dual drainage systems) that separate the flow of rainwater and wastewater can reduce surface water pollution and reduce the load on the wastewater treatment system. In addition, separated rainwater can be reused for non-potable needs such as irrigation or road cleaning.

**5.** *Area-Based Planning and Management*

The application of the concept of sustainable drainage also requires planning based on the scale of the area and not just on individual infrastructure. Sustainable drainage must be integrated with the spatial planning of Tanjungbalai City, paying attention to population density, land use, and geographical characteristics. For example, in areas with high density and limited green open space, good drainage planning can include technology-based solutions such as rainwater harvesting systems or centralized wastewater treatment. In addition, a zoning policy that requires the development of sustainable drainage infrastructure in each new area and proper maintenance of the old area will ensure drainage that is

adaptive to climate change and the growth of Tanjungbalai City.

**6.** *Education and Community Participation*

The people of Tanjungbalai City have a very important role in supporting the successful implementation of a sustainable drainage system. Therefore, education on the importance of maintaining the cleanliness of drainage channels, waste management, and understanding the benefits of green drainage systems must be carried out in a sustainable manner. The participation of the people of Tanjungbalai City in maintaining and maintaining the cleanliness of drainage plays a very important role in keeping the system functioning properly. With the active involvement of the people of Tanjungbalai City, in addition to extending the life of the drainage system, it can also increase awareness about more efficient and sustainable management of natural resources.

Overall, the implementation of the concept of sustainable drainage that is adaptive to climate change and the growth of Tanjungbalai City requires a comprehensive and integrated approach between planning, design, technology, and community participation. With this approach, the city can not only manage rainwater flow effectively, but also improve environmental quality and strengthen Tanjungbalai City's resilience to the impacts of climate change and rapid urban growth.

## V. CONCLUSION

### Conclusion

The implementation of a sustainable drainage system that is adaptive to climate change and growth in Tanjungbalai City is very important to manage rainwater, prevent damage to infrastructure, especially in Tanjungbalai City, and improve environmental quality. In facing the challenges of climate change, the existing drainage system in Tanjungbalai City must be designed with adequate channel capacity in mind, the implementation of green infrastructure, and the integration of more sophisticated water monitoring and management technology. In addition, the rainwater and wastewater flow separation system is also important to prevent surface water pollution. An area-based management strategy that pays attention to population density and geographical characteristics of Tanjungbalai City will strengthen Tanjungbalai City's resilience to floods and infrastructure damage.

### *A.* ***Suggestion***

1. Improving Green Infrastructure: The Tanjungbalai City Government needs to encourage the implementation of nature-based drainage systems such as infiltration parks, bioswales, and retention ponds to increase water catchment capacity and improve water quality.
2. Regular Maintenance and Repairs: Regular drainage maintenance is essential to ensure the system remains in optimal function. The Tanjungbalai City Government must provide a budget for drainage channel maintenance and sensor-based monitoring technology.
3. Education and Community Participation: Fostering awareness to the people of Tanjungbalai City about the importance of maintaining clean drainage channels and waste separation to support smooth water flow and environmental quality.
4. Inter-Agency Collaboration: Sustainable drainage development requires collaboration between the Tanjungbalai City Government, the private sector, and the community to create drainage solutions that are integrated with the better spatial planning of Tanjungbalai City.
5. Long-Term Planning: The construction and management of the drainage system carried out by the Tanjungbalai City Government must refer to a long-term plan that takes into account the projected climate change, the growth of Tanjungbalai City, and the future infrastructure needs of Tanjungbalai City

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