

Drainage Development in Padang Cermin Village for Regional Development of Langkat Regency

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Abstract

The development of a drainage system is an essential component in supporting regional development, particularly in rural areas that face problems of waterlogging and environmental degradation. This study aims to analyze the existing condition of the drainage system in Padang Cermin Village, identify the factors causing its ineffectiveness, assess the impact of drainage development on regional growth, and formulate strategies to enhance the effectiveness of the system sustainably. The research employs a qualitative approach using a case study method. Data were collected through field observations, interviews with village officials and local residents, and documentation from the Public Works and Spatial Planning Office (PUPR) of Langkat Regency. Data analysis was carried out descriptively by interpreting the physical, functional, and social conditions of the drainage system. The results of the study indicate that the drainage system in Padang Cermin Village has not functioned optimally due to limited planning, lack of maintenance, and minimal community participation. This condition has led to frequent waterlogging at several points, disrupting residents' social and economic activities. However, planned drainage construction and improvement can have positive impacts on regional development, enhance environmental quality, and strengthen village infrastructure. The study recommends several strategies to improve drainage effectiveness, including the implementation of an integrated drainage system, strengthening of institutional management, utilization of environmentally friendly technologies, community empowerment, and integration of drainage planning with the village's spatial development plan. These strategies are expected to foster sustainable and environmentally resilient regional development in Padang Cermin Village and Langkat Regency in general.

Keywords: Drainage, Regional Development, Village Infrastructure, Water Management, Sustainable Development.

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Introduction

Infrastructure development is one of the key factors in driving regional growth, particularly in developing rural areas such as Padang Cermin Village in Langkat Regency. One of the infrastructure components that plays a strategic role in supporting environmental quality and community well-being is the drainage system [1]. Drainage functions to channel and control excess surface water to prevent flooding or waterlogging, which can disrupt social and economic activities and reduce the environmental quality of residential areas [2].

However, the existing drainage system in Padang Cermin Village is not yet functioning optimally in managing surface water problems, especially during the rainy season with relatively high rainfall. Geographically, the village has a mix of flat and slightly sloping areas, which requires a well-planned and integrated drainage system [3]. Current issues include waterlogging at several village road points, blocked channels due to sedimentation, and the absence of a comprehensive final discharge system [4].

These conditions have disrupted community activities, degraded road infrastructure, and increased environmental damage risks. This situation indicates that the development and improvement of the drainage system are urgent needs to support sustainable spatial planning and regional development. From a regional development perspective, a well-functioning drainage system has a positive correlation with improved accessibility, environmental health, and the area's economic value [5]. Properly managed drainage enhances the capacity of other infrastructures such as roads, housing, and public facilities. Furthermore, drainage development supports the Langkat Regency Government's policy on equitable development and improving rural environmental quality, in line with the Regional Medium-Term Development Plan (RPJMD). Thus, the construction of the drainage system in Padang Cermin Village is not only a technical necessity but also a strategic effort in the broader context of regional development.

Table 1. Existing Condition of the Drainage System

Component	Existing Condition	Main Issues
Total length of primary channels	of ± 4.5 km	Not yet fully connected between blocks
Length of secondary channels	± 7.2 km	Many sections are clogged with sediment and waste
Tertiary channels	± 2.8 km	Poorly maintained and partially damaged
Average channel depth	0.5 – 1.2 m	Irregular depth causing flow obstruction
Identified inundation points	5 main locations (around Dusun I, II, and III roads)	Causing traffic disruption and road damage

Based on field surveys and reports from the Langkat Regency Public Works and Spatial Planning Agency (PUPR, 2023), the drainage system in Padang Cermin Village remains suboptimal in performing its function as a surface water control facility. In general, the existing drainage network consists of primary, secondary, and tertiary channels, but these have not been fully integrated across all residential areas of the village. The primary channels, with a total length of approximately 4.5 km, serve as the main discharge routes directing water to main drainage lines or nearby water bodies. However, field observations indicate that these networks are not yet fully connected between housing blocks, resulting in poor water flow in several areas. Consequently, water flow from secondary and tertiary channels is often obstructed, causing puddles and flooding in low-lying zones. This condition indicates that the design of the

primary drainage network requires improvement to accommodate surface runoff effectively from the entire village area.

Meanwhile, the secondary drainage channels, measuring about 7.2 km, have experienced a decline in function due to sediment buildup and accumulated waste. Many sections have become shallow and clogged, reducing their ability to channel water effectively, particularly during heavy rainfall. This issue reflects the lack of regular maintenance activities and the absence of a community-based sustainable drainage management system. As for the tertiary channels, which stretch approximately 2.8 km, most have suffered from physical deterioration such as cracked walls, edge erosion, and loss of function due to soil sedimentation. This highlights weak infrastructure management at the neighborhood level and the urgent need for comprehensive revitalization so that tertiary drains can again function effectively to carry water from households or agricultural land into secondary channels.

In terms of physical dimensions, the average drainage depth ranges between 0.5–1.2 meters, and is inconsistent across different sections. These irregular dimensions create imbalanced water flow, leading to stagnant water that drains slowly. The inconsistency in channel dimensions also demonstrates insufficient technical planning relative to local rainfall runoff capacity. Furthermore, field surveys identified at least five main inundation points, mainly located along Dusun I, II, and III roads. These water puddles not only disrupt community mobility and traffic but also accelerate road damage and degrade the quality of the residential environment. If left unaddressed, these conditions could negatively affect residents' economic productivity and hinder regional development in Padang Cermin Village.

Considering these findings, it can be concluded that the drainage system in Padang Cermin Village has not yet functioned effectively as a water control infrastructure. Therefore, the study on "Drainage Development in Padang Cermin Village for Regional Development in Langkat Regency" is highly relevant. This research is expected to provide a comprehensive analysis of the existing conditions, the causes of drainage inefficiency, and policy directions for effective and sustainable drainage development. Additionally, the results will support local government efforts to accelerate equitable basic infrastructure development and improve environmental quality in Langkat's rural areas.

The study on Drainage Development in Padang Cermin Village within the Context of Langkat Regency's Regional Development is of high urgency because it directly relates to improving environmental quality, community well-being, and accelerating rural development. Drainage is one of the essential infrastructure components with a vital function in controlling surface runoff, preventing flooding, and maintaining the sustainability of land and other infrastructure. However, the existing condition in Padang Cermin Village shows that the drainage system does not yet function optimally due to limited channel capacity, sedimentation, and weak maintenance and technical planning. Empirically, the frequent flooding in several hamlets demonstrates that drainage issues have had direct impacts on economic activity, accessibility, and public health. Flooding during the rainy season not only damages roads and public facilities but also reduces agricultural productivity and worsens residential environmental quality. If these issues are not promptly addressed, they will hinder the local government's efforts to promote equitable and sustainable regional development in Langkat Regency.

From a development planning perspective, this research is crucial as it provides a scientific basis for local governments to design more targeted and sustainable drainage infrastructure policies. So far, drainage projects at the village level have often been carried out in a fragmented manner, without thorough technical studies of existing conditions, hydrological capacity, or long-term regional needs. Through this study, it is expected that data-driven and field-based recommendations can be produced to design an integrated drainage system that fits the topographic characteristics and land-use patterns of Padang Cermin Village. Furthermore,

the urgency of this research also lies in its contribution to comprehensive rural regional development. A well-managed drainage system not only reduces the risk of flooding and environmental damage but also supports residential development, increases land value, and creates a conducive environment for local investment and economic growth [6]. More broadly, this study can serve as a model for basic infrastructure management in other villages in Langkat Regency with similar characteristics.

From an academic standpoint, this research is strategically significant as it enriches the study of the relationship between basic infrastructure development and regional growth, particularly in the context of rural Indonesia [7]. The findings can serve as a reference for developing theories and practices of environmentally based regional planning and as a foundation for formulating regional development policies. Thus, this research is highly justified both theoretically, practically, and from a policy perspective. The results are expected to make a tangible contribution toward achieving effective drainage governance, a healthy environment, and sustainable, inclusive regional development in Langkat Regency.

Problem Identification

Based on the background described above, several key issues can be identified as the foundation for conducting this research, including the following:

1. The existing drainage system in Padang Cermin Village is not functioning optimally. Many of the primary, secondary, and tertiary channels are poorly connected, shallow due to sedimentation, and have suffered physical damage.
2. High rainfall intensity and flat topography frequently cause waterlogging. The drainage channels are unable to accommodate stormwater discharge, resulting in local flooding in several hamlets, particularly along main roads and densely populated residential areas.
3. Lack of integrated planning and maintenance of the drainage system. Drainage construction is still carried out in a fragmented manner without regular maintenance programs or adequate waste and garbage management.
4. Waterlogging creates social and economic impacts on the community. Community activities are disrupted, road infrastructure deteriorates rapidly, and land productivity decreases, all of which negatively affect residents' quality of life.
5. Absence of comprehensive technical studies and policies on drainage planning based on regional development. Drainage development has not yet been directed as part of a sustainable rural regional development strategy in Langkat Regency.

Research Problem

Based on the problem identification above, the research questions in this study can be formulated as follows:

1. What is the existing condition of the drainage system in Padang Cermin Village, Langkat Regency, in terms of its physical structure, functionality, and maintenance?
2. What factors contribute to the suboptimal performance of the drainage system in Padang Cermin Village?
3. How does drainage development influence regional development in Padang Cermin Village, Langkat Regency?
4. What strategies can be implemented to improve the effectiveness of the drainage system in supporting sustainable regional development in Padang Cermin Village?

Literature Review Concept of Drainage and Surface Hydrology

Drainage at the village scale functions to collect, convey, and control stormwater runoff to prevent flooding that can negatively impact socio-economic and environmental functions.

The basic principle of surface hydrology emphasizes the relationship between rainfall intensity, land cover characteristics, soil permeability, and topography all of which determine the magnitude and velocity of runoff [8]. Changes in land use from percolative (open/permeable) areas to impervious surfaces (roads, buildings) increase the runoff coefficient, rendering existing drainage systems originally designed for natural conditions inadequate [9]. From a technical planning perspective, channel dimensions, slopes, and interconnections between the primary, secondary, and tertiary levels must be adjusted according to local rainfall data and the characteristics of the small watershed (catchment area) that serves the village (see studies on urban hydrology and modern drainage design).

Sustainable Approaches: SuDS (Sustainable Drainage Systems) and Nature-Based Solutions

In the past two decades, there has been growing academic and practical consensus that drainage solutions are more effective when integrating engineering measures with NatureBased Solutions (NbS) such as infiltration basins, vegetated swales, bioretention areas, and local infiltration systems collectively known as Sustainable Urban Drainage Systems (SuDS) or SUDS [10]. This approach not only detains and attenuates peak flows but also improves water quality, provides aesthetic and ecological value, and enhances local climate resilience. In rural contexts, the implementation of SuDS should be adapted to local wisdom, agricultural land-use patterns, and community maintenance capacity. Recent review studies highlight the multiple benefits of SuDS as well as implementation challenges (policy gaps, technical capacity, funding constraints) that are highly relevant in designing the drainage system for Padang Cermin Village.

Integrated Watershed Management (IWM)

Village drainage should not be viewed separately from upstream–downstream watershed management. The Integrated Watershed Management (IWM) approach emphasizes synergy between soil and water conservation, land-use regulation, vegetation rehabilitation, and interagency coordination to reduce flood risks and improve water resilience [11]. In Indonesia, IWM is regarded as a framework for integrating climate change adaptation and disaster mitigation into basic infrastructure planning, including rural drainage systems. Strengthening local institutions and ensuring policy synchronization between national and local governments are key success factors [12]. Therefore, drainage planning in Padang Cermin Village should ideally incorporate a small-watershed perspective and upstream land conservation measures.

Climate Change Impacts on Drainage Design

Empirical evidence and projections indicate an increase in high-intensity rainfall events and instability in rainfall patterns across many tropical regions, including Southeast Asia [13]. These changes alter the traditional Intensity–Duration–Frequency (IDF) relationships used in drainage design; as a result, channels designed using historical data may no longer be adequate for current or future extreme events. Modern drainage planning should therefore adopt an adaptive design approach, incorporating up-to-date local climate data, extreme-event scenario analysis, and safety margins in channel dimensions, along with the integration of retention and infiltration measures as buffers. For Padang Cermin Village, this means reassessing the capacity of primary and secondary channels and introducing infiltration features at strategic locations.

Community Participation and Operational Management

The long-term functionality of drainage systems depends heavily on routine maintenance such as sediment removal, waste management, and structural repair. Top-down approaches often fail to sustain infrastructure performance when community participation is low. Participatory

literature emphasizes methods such as Participatory Action Research (PAR), community-based maintenance, and local incentive programs to encourage shared responsibility [14]. Evidence shows that community-led maintenance programs can significantly extend the technical lifespan of drainage systems and reduce blockages that cause flooding. Therefore, strategies to improve drainage in Padang Cermin Village should include capacity-building programs, solid waste management mechanisms, and strengthening of village-level institutions.

Spatial Planning Policy and Integration of Drainage in Regional Development

Drainage planning must align with spatial planning policies (RTRW), the Regional Medium-Term Development Plan (RPJMD), and sectoral technical plans under the Public Works and Housing Agency (PUPR). Numerous studies show that fragmented or partial drainage investments are less effective when not integrated with land-use planning and environmental management policies. A policy-based approach ensures long-term budget allocation, standardized design criteria (including SuDS standards where applicable), and interagency coordination mechanisms [15]. For Langkat Regency, synchronizing village-level and regency-level planning is crucial to ensure that drainage development supports broader regional development goals.

Research Methodology Research Approach

This study employs a qualitative approach using the case study method. This approach was chosen because the research focuses on gaining an in-depth understanding of the conditions, problems, and significance of drainage development in Padang Cermin Village within the broader context of regional development in Langkat Regency. According to Creswell and Poth (2020), qualitative research is used to explore complex and contextual phenomena in which the researcher serves as the primary instrument for data collection through interviews, observations, and documentation. This approach is highly relevant because drainage development is not only viewed from a physical or technical standpoint but also involves social, environmental, and policy dimensions. Furthermore, Miles, Huberman, and Saldaña (2020) emphasize that qualitative research helps researchers understand social dynamics and processes involving multiple actors in the field. Therefore, in this study, the qualitative approach provides space to comprehend how drainage development influences environmental quality, community well-being, and its linkage to regional development.

Research Location and Duration

The research was conducted in Padang Cermin Village, Selesai Sub-district, Langkat Regency, North Sumatra Province. This location was chosen purposively because it is one of the areas experiencing drainage and waterlogging issues that affect the community's socio-economic activities. According to Sugiyono (2020), purposive sampling is conducted based on specific considerations deemed most relevant to the research objectives, particularly locations that can provide in-depth information about the studied phenomenon. The research was carried out over three months, starting from the preliminary observation phase, field data collection, to data analysis and report preparation.

Types and Sources of Data

The types of data used in this study consist of:

1. Primary data, obtained directly through field observations and in-depth interviews with residents, village officials, and representatives from the Langkat Regency Department of Public Works and Housing (PUPR).
2. Secondary data, obtained from official documents such as the 2023 Annual Report of the PUPR Office, rainfall data from the Meteorology, Climatology, and Geophysics

Agency (BMKG), and regional development planning documents (RPJMD Langkat Regency 2021–2026).

According to Bungin (2021), the combination of primary and secondary data is essential to ensure validity and enrich understanding of the studied phenomenon.

Data Collection Techniques

Data were collected through several methods:

1. Observation. The researcher conducted direct observations of the physical condition of drainage channels, inundation points, and community activities around the drainage system. According to Spradley (2019), participatory observation allows researchers to understand social contexts and natural interactions as they occur in real settings.
2. In-depth Interviews. Conducted with key informants such as the Village Head, affected residents, and PUPR officials. The interviews were semi-structured to ensure that the information obtained remained relevant to the research focus while allowing flexibility. Flick (2020) states that qualitative interviews provide opportunities for respondents to express their experiences and perceptions in depth.
3. Documentation. The researcher collected supporting documents such as drainage maps, technical reports, field photographs, and rainfall data. According to Creswell (2020), documentation serves as supporting evidence that strengthens the validity of data obtained from interviews and observations.

Data Analysis Techniques

Data analysis was carried out using the interactive model developed by Miles, Huberman, and Saldaña (2020), which includes three main stages:

1. Data Reduction – the process of selecting, focusing, and simplifying raw field data.
2. Data Display – presenting data in narrative, table, or map form to make relationships between variables easier to understand.
3. Conclusion Drawing – the final interpretation that explains the significance of drainage development for regional development in Padang Cermin Village.

This approach helps the researcher understand causal relationships and the social context underlying the existing drainage conditions.

Results

What factors contribute to the suboptimal functioning of the drainage system in Padang Cermin Village?

The drainage system is a crucial infrastructure that functions to channel and control surface water runoff to prevent localized flooding or puddles. However, field observations and a report from the Langkat Regency Public Works and Public Housing Agency (2023) indicate that the drainage system in Padang Cermin Village is still not functioning optimally. This condition is caused by various interrelated factors, including technical, environmental, social, and local government institutional aspects.

1. Technical Factors: Design Limitations and Physical Condition of Channels

The main factors contributing to the suboptimal functioning of drainage in Padang Cermin Village are technical design limitations and inadequate physical conditions of the channels. Based on existing data, the primary, secondary, and tertiary drainage channels have a total length of approximately 14.5 km, but not all of these channels are systematically connected between residential blocks. Most of the channels have uneven dimensions and depths (0.5–1.2 meters), causing flow obstructions and puddles at certain points. According to Rizal and Sari (2021), drainage designs that fail to adhere to hydrological and topographical analyses result in the

channel's capacity not matching the actual volume of rainwater. This situation is exacerbated by the large amount of sediment and debris clogging the water flow. Furthermore, some sections of the channel have experienced structural damage due to aging and lack of maintenance. At some points, tertiary channels have even been blocked by land or buildings, causing water to flow onto the road.

2. Environmental Factors: Topography and High Rainfall

Environmental factors also significantly impact drainage system performance. Topographically, Padang Cermin Village is located in an area with a low slope (0–3%), which causes surface water flow to move slowly. This condition causes rainwater to easily pool, especially in densely populated residential areas around Hamlets I and II. Furthermore, data from the North Sumatra Meteorology, Climatology, and Geophysics Agency (BMKG) (2023) shows that Langkat Regency has an average annual rainfall of 2,800 mm/year, which is considered high. When drainage capacity is not commensurate with rainfall intensity, flooding becomes difficult to avoid. According to Rahman and Syafitri (2020), drainage systems in lowland areas need to be supported by adequate collection channels and final discharge outlets to allow water to flow by gravity. However, in Padang Cermin Village, the final discharge channel leading to the river has not been optimally developed, resulting in water often settling in the neighborhood ditches.

3. Social Factors: Low Community Behavior and Participation

Social factors are one of the most obvious obstacles to maintaining the sustainability of drainage functions. Many people still dispose of household waste into drains, block ditches with buildings without drains, and do not regularly participate in community service activities to clean the drains. According to Wulandari and Putra (2021), low public awareness and participation are the main causes of environmental drainage damage, especially in rural areas that lack integrated waste management systems. Lack of education and outreach from the village government leads to a lack of public understanding that drainage is a public asset that must be collectively maintained. Furthermore, a "reactive" culture towards flooding remains strong, with people only cleaning drains after inundation occurs, rather than as a preventative and sustainable activity.

4. Institutional Factors: Budget Limitations and Government Coordination

Institutional factors also play a significant role in the weak drainage management in Padang Cermin Village. According to the Langkat Regency Public Works and Public Housing Agency (2023), the budget allocation for village drainage maintenance is still very limited, and channel normalization activities are carried out in stages based on urgency. The lack of coordination between the village government, sub-district, and technical agencies also results in the absence of a planned routine maintenance system. According to Sari and Rahmat (2022), effective drainage management must be based on collaborative institutions between the government, the community, and the private sector to ensure sustainability and shared responsibility. Furthermore, the lack of an integrated drainage system map leads to development being carried out sectorally without considering the natural flow direction and storage capacity of the surrounding area.

5. Regional Planning Factors: Lack of Integration of Spatial Planning and Drainage

Another contributing factor is the lack of integration between village spatial plans and the existing drainage system. New residential development and road improvements are often carried out without considering the direction of water flow or the capacity of the existing drainage channels.

How does drainage development impact regional development in Padang Cermin Village, Langkat Regency?

Drainage infrastructure development plays a strategic role in supporting regional development, particularly in rural areas such as Padang Cermin Village, Langkat Regency. Drainage not only serves as a technical means of channeling rainwater but also as a crucial component in creating a healthy, safe, and productive residential environment. By improving the quality of the drainage system, regional development can be more sustainable by supporting the social, economic, and ecological aspects of the community.

1. Impact on Environmental Aspects and Residential Quality

The development of a good drainage system has a direct impact on improving the quality of the residential environment. Prior to development, Padang Cermin Village frequently experienced waterlogging in several areas, such as Hamlets I, II, and III. This condition not only reduced comfort but also posed health risks due to the puddles, which became breeding grounds for mosquitoes and a source of disease. With the improvement and construction of more planned drainage channels, rainwater flow can be effectively controlled, reducing the frequency of flooding and improving environmental sanitation. This aligns with Rahman and Sari's (2022) opinion, which states that a good drainage system can efficiently control surface water, reduce the risk of flooding, and maintain the balance of the environmental ecosystem. From a regional development perspective, a clean, water-free environment will increase the attractiveness of settlements and support more orderly village spatial planning efforts. Communities are also encouraged to maintain a clean environment because they experience the tangible benefits of well-functioning drainage infrastructure.

2. Impact on Economic Aspects and Community Activities

Previously, poor drainage conditions often disrupted economic activities, especially for farmers and small traders. Waterlogging on main roads often hampered community mobility, the distribution of agricultural products, and access to village markets. After the construction of drainage at several strategic locations, road access became smoother and community economic activity increased. Well-functioning drainage supports the smooth transportation of goods and services, ultimately accelerating local economic growth. According to Puspitasari and Hidayat (2023), improving drainage infrastructure contributes to increased community economic productivity by supporting inter-regional connectivity and reducing maintenance costs for road infrastructure damaged by flooding. Furthermore, a more organized environment also attracts people to make small investments, such as opening stalls, workshops, or home businesses along the main village routes. Thus, drainage development has a dual effect: improving the physical condition of the environment while also encouraging microeconomic growth at the village level.

3. Impact on Social Aspects and Community Welfare

From a social perspective, drainage development has a positive impact on community welfare and participation. Before drainage improvements, residents often complained about local flooding that disrupted daily activities. Now, they feel more comfortable and safe, especially during the rainy season. The drainage development process, which involves the community, also increases a sense of ownership and social responsibility. According to Wulandari and Putra (2021), community involvement in environmental infrastructure development can strengthen social solidarity and increase collective awareness in maintaining public facilities. Furthermore, with a healthier, flood-free environment, the risk of environmental-related diseases such as dengue fever and diarrhea also decreases. This impacts work productivity and the quality of life of village residents.

4. Impact on Spatial Planning and Regional Development

Planned drainage development also supports better and more sustainable village spatial planning. A drainage system integrated with roads and irrigation channels helps regulate water flow, prevent erosion, and maintain the balance of agricultural land. According to Sari and Rahmat (2022), drainage is an integral part of basic regional infrastructure, acting as a surface water control and supporting land use. In Padang Cermin Village, well-functioning drainage can provide the foundation for the development of new residential areas and the improvement of the local road network without worrying about flooding. Thus, drainage serves as a connecting element between physical (infrastructure), social, and economic aspects, all of which contribute to more harmonious and sustainable regional development.

5. Impact on Aspects.

Regional Resilience and Environmental Adaptation

Drainage development also contributes to increasing regional resilience to climate change and extreme rainfall. In the context of Langkat Regency, which experiences high rainfall (averaging 2,800 mm/year according to the BMKG, 2023), an adequate drainage system can reduce the risk of local disasters such as flooding and land erosion. As explained by Mulyani (2021), developing climate-resilient drainage is an adaptive measure that supports regional resilience, especially in rural areas. In Padang Cermin Village, increasing channel capacity and sediment control can be strategic efforts to address the impacts of future extreme weather changes.

Based on the discussion above, it can be concluded that drainage development in Padang Cermin Village has a significant impact on regional development, including:

1. Improving the quality of the residential environment and controlling flooding.
2. Increasing community economic activity through better transportation access.
3. Strengthening social cohesion and community participation in environmental management.
4. Supporting sustainable spatial planning and settlement development.
5. Increasing regional resilience to heavy rainfall and climate change.

Thus, drainage development is not only a physical infrastructure project, but also a social and environmental investment with a broad impact on the progress and independence of Padang Cermin Village as part of the regional development of Langkat Regency.

What strategies can be implemented to improve the effectiveness of the drainage system to support sustainable regional development in Padang Cermin Village?

The drainage system plays a vital role in maintaining environmental balance and supporting regional development. In Padang Cermin Village, Langkat Regency, drainage functions not only as a means of diverting surface water but also as infrastructure supporting residential development, agriculture, and community economic activities. However, the effectiveness of the drainage system is often hampered by technical, managerial, and social factors, such as sedimentation, lack of maintenance, and low community participation. Therefore, a comprehensive and sustainable strategy is needed to improve the effectiveness of the drainage system to optimally support village development.

1. Integrated Drainage Planning and Management Strategy

The first step that must be taken is the implementation of integrated drainage planning tailored to the topographic characteristics, water flow patterns, and land use of Padang Cermin Village. An effective drainage system must be designed based on hydrological mapping and regional contours, so that the direction of water flow can be efficiently controlled without causing new pooling in low-lying areas. According to Puspitasari & Hidayat (2023), integrated drainage management is an approach that combines technical, ecological, and social aspects

into a single, mutually supportive management system. In the context of Padang Cermin Village, the village government needs to collaborate with the Langkat Regency Public Works and Public Housing Agency to conduct technical studies on macro and micro drainage, so that each channel network can be properly connected. Furthermore, drainage management should not only focus on physical construction but also on long-term maintenance plans, such as regular cleaning and sediment monitoring, to ensure the system functions optimally throughout the year.

2. Institutional Strengthening Strategy and Multi-Stakeholder Collaboration

The effectiveness of a drainage system is also determined by a strong and participatory management institution. At the village level, an environmental drainage working group (Pokja) should be formed, comprising members from the village government, community members, and youth leaders. This group is tasked with monitoring channel conditions, reporting damage, and coordinating with the district government.

According to Wulandari & Putra (2021), community involvement in drainage management institutions increases a sense of ownership and social responsibility for public infrastructure. Village governments can incorporate regular community service activities into their drainage maintenance programs, for example through "Clean Friday" or "Stagnation-Free Village Movement." Furthermore, collaboration with technical agencies (PUPR, DLH, BPBD) and the private sector is needed, particularly with nearby companies that can provide CSR support for drainage channel repairs and the provision of supporting facilities (e.g., culverts, sedimentation tanks, or heavy equipment).

3. Strategy for Implementing Environmentally Friendly Technology and Green Drainage Innovation

Developing a sustainable drainage system in the modern era requires prioritizing a green drainage system approach. This concept emphasizes the use of natural and environmentally friendly technologies to channel rainwater while maintaining the water cycle in the soil. Examples of the application of this technology in Padang Cermin Village include:

- a) Construction of infiltration wells and biopores in residential areas and public facilities to increase groundwater infiltration.
- b) Construction of open vegetative channels (bioswales) along village roads to filter rainwater from sediment and pollutants.
- c) Utilizing ecologically sound drainage, namely channeling water to retention ponds or agricultural land as a secondary irrigation source.

According to Mulyani (2021), the application of green technology to drainage systems not only increases the effectiveness of water flow but also supports the principles of sustainable development by reducing surface runoff and improving environmental water quality.

4. Community Education and Empowerment Strategy

The success of an effective drainage system is inseparable from community behavior and awareness. Frequent problems, such as blockages in drains due to household waste or soil sediment, can be minimized through ongoing community education and empowerment.

Village governments can implement programs such as:

- a. Socializing waste and rainwater management to residents through regular village meetings.
- b. Simple technical training for the community on how to maintain environmental drainage.
- c. A "Don't Throw Trash in the Ditch" campaign using a local cultural approach and mutual cooperation.

As explained by Rahman & Sari (2022), public awareness is a key element in maintaining effective drainage, as 60–70% of flooding problems are caused by waterlogging. In rural areas stems from human behavior that ignores the function of water channels.

5. Drainage Integration Strategy with Spatial Planning and Regional Development

Effective drainage must be part of the village spatial planning (RTRDes). This integration ensures that every development of settlements, roads, and public facilities takes into account the main and secondary drainage routes. Padang Cermin Village can conduct integrated drainage system mapping as a basis for decision-making in new infrastructure development. This integration also serves to prevent overlapping development that can impede water flow. According to Sari & Rahmat (2022), synchronization between drainage systems and spatial planning is key to regional sustainability because it optimizes land use, reduces flood risk, and maintains the balance of the regional ecosystem.

6. Sustainable Funding and Maintenance Strategy

The main obstacle to the effectiveness of drainage systems at the village level is limited funds for maintenance. Therefore, innovative and sustainable funding strategies are needed, such as:

- a. Routinely allocating village funds (ADD/DD) for drainage maintenance activities.
- b. Submitting assistance for sustainable village infrastructure programs to the district or provincial government.
- c. Involve community participation through self-help and mutual cooperation models in minor maintenance activities.

With a sustainable funding strategy, drainage can function optimally without waiting for major damage that requires expensive repairs.

Conclusion

Based on the research and discussions conducted regarding drainage development in Padang Cermin Village, Langkat Regency, the following conclusions can be drawn:

1. The existing drainage system in Padang Cermin Village is still not functioning optimally. Observations indicate that most primary, secondary, and tertiary channels are clogged due to sedimentation and garbage accumulation, and several flooding points are present in densely populated residential areas and on main roads. This indicates that the drainage system is not yet fully integrated and requires structural and functional improvements.
2. Factors contributing to the ineffectiveness of the drainage system include a lack of technical planning based on hydrological data, a weak maintenance system, minimal community participation, and limited village funds for routine repairs and management. Environmental factors such as high rainfall and flat topography also exacerbate these conditions.
3. Drainage development has a significant impact on village development. Good drainage can improve the quality of the residential environment, reduce flooding, facilitate mobility, and support community economic activities. Indirectly, the existence of effective drainage also increases the competitiveness and attractiveness of Padang Cermin Village in the context of sustainable development in Langkat Regency.
4. Strategies to improve the effectiveness of the drainage system need to be implemented through an integrated approach, including: (a) hydrology- and spatial-based drainage planning, (b) strengthening village institutions and cross-sector collaboration, (c) implementing environmentally friendly technologies such as biopores and infiltration

wells, (d) community education and empowerment, and (e) allocating a sustainable budget for infrastructure maintenance.

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