Volume 4, Issue 4 (Page 62-90)
ISSN: 2709-0248

Characteristics and Management of Drainage Infrastructure in Medan Sunggal District, Medan City

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Abstract

Climate change, characterized by high-intensity rainfall, coupled with inadequate drainage systems, small and shallow river dimensions, and a lack of community awareness, has caused flooding and inundation in Medan Sunggal District. This study aims to understand the characteristics and management of drainage infrastructure in Medan Sunggal Subdistrict, Medan City, to identify its characteristics and implement suitable management efforts. The research adopts a positivism paradigm with a positivistic approach, relying on empirical facts (sensual empiricism). The research methodology used is purely qualitative descriptive, focusing on an in-depth understanding related to the characteristics, context, and research subjects. Data collection methods include Guest Tour and comparative techniques. The results of this study show that the characteristics of drainage infrastructure in the study area form a network pattern. The types of channels in the study area are primary channels, secondary channels, and tertiary channels. They consist of artificial channels with open concrete construction, located above the ground with a combined drainage system. While most of the physical conditions are good, some exhibit minor damage. A significant portion of the drainage water is stagnant. Flood-prone areas constitute 41%, areas with infrequent flooding are at 43%, and areas that have never experienced flooding are at 16%. Management recommendations for the study area include providing green open spaces, creating biopore infiltration holes, constructing detention and retention ponds, using paving blocks/grass blocks, conducting maintenance (normalization and rehabilitation) of drainage, and involving the community in each management aspect.

Keywords: System, Drainage, Characteristics, Management

Received : October 15, 2023
Received in Revised: November 24, 2023
Accepted: December 16, 2023

Introduction

Flood is defined as the overflow of river water beyond its capacity (Khotimah, et al, 2013). Ponding is a condition where water accumulates in a relatively flat, low, or concave area. This condition occurs after heavy rainfall or due to inadequate drainage. One step that can be taken to address flooding or ponding is the management of drainage infrastructure by providing pathways to channel water through the provision of adequate clean water channels. These channels can handle rainwater, runoff, and reduce water ponding. Clean water channels or ditches are currently known as drainage. Drainage is defined as the science that studies efforts to divert excess water for specific purposes (Hasmar, 2012; Milanie, 2014 et al, 2014).

DOI: https://doi.org/10.47667/ijpasr.v4i4.259

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Drainage is a system designed to address unwanted excess water, whether it is above or below the ground surface. This excess water can originate from excessive rainfall or waste from settlements. Flooding often occurs when drainage channels do not function properly in handling this excess water, due to a lack of channel capacity or blockages caused by debris.

Saidah, et al (2021), urban drainage is part of the discipline that studies the technical aspects of drying urban areas related to environmental health issues and the aesthetics of urban areas. The definition of urban areas is described based on the number of residents with building distances not exceeding 200 meters and a population of more than 2,000 people (Angelakist et al., 2017). Urban drainage can be considered as a drainage system and a system for channeling water from urban areas, including Residential Areas, Industrial and Commercial Areas, Campuses and Schools, Hospitals and Public Facilities, Sports Fields, Parking Lots, Military Installations, Electricity, Telecommunications, and Airports (Hasmar, 2012). The issues related to facilities in the community environment should always consider their occupants, as management and supervision must always involve the local community (Nuraini & Suprayitno, 2021; Nuraini, 2019). Theoretical and practical development must be able to accommodate the activities of the community, as well as the development of drainage (Abdiyanto, 2015; Abdiyanto & Warokka, 2015),

Medan Sunggal Subdistrict, Medan City, is an area with a relatively high population of 135,635 people, covering an area of 13.90 km2 or about 5.24% of the total area of Medan, which is 265.10 km2. Administratively, Medan Sunggal Subdistrict is divided into 6 sub-districts, namely Sunggal, Tanjung Rejo, Babura, Simpang Tanjung, Sei Sikambing B, and Lalang. The largest area is in the Sunggal sub-district, covering 4.93 km2 or 34.90%, while the smallest area is in the Simpang Tanjung sub-district, covering 0.32 km2 or 2.30%.

The development of drainage systems began with the evolution of time, as the number of settlements increased and spread throughout the region, leading to the construction of cross-cutting drainage channels based on residential needs, subsequently affecting surface flow rates. This is evident in Medan Sunggal Subdistrict, as indicated by the proximity of the Belawan River in the Lalang and Sunggal sub-districts to the Sikambing River in Simpang Tanjung, which is only approximately ±4 km apart. Despite this proximity, the surrounding areas often experience flooding and ponding.

The increase in population has raised population density over the last 10 years, altering land use, exerting pressure on the environment, and reducing environmental sustainability. Climate change, with its high and unpredictable rainfall intensity, coupled with insufficient water infiltration areas, inadequate drainage systems, lack of proper planning or management in drainage system development, small and shallow river dimensions, and community neglect of the environment, has led to frequent flooding and ponding in this area (Sugiarto & Ramadania, 2023b).

In recent years, efforts have been made to improve the drainage system in Medan Sunggal Subdistrict, followed by maintenance efforts at several locations that have experienced flooding and ponding. However, these efforts cannot yet be considered successful, as floods and water ponding still cover primary, secondary, and tertiary road areas, as observed on Raya Sunggal, PAM Tirtanadi Street, Amal Street, Beo Street, Kapuas Street, Setia Budi Street, Kasuari Street, Merak Street, Gatot Subroto Street, Taman Elok Complex Intersection, and Puskesmas Street. Although the floods and ponding are short-lived (recede within 4-5 hours), they can be quite disturbing for the community when frequent rainfall occurs every month, affecting the health and economy of the residents (Milanie et al, 2014)

DOI: https://doi.org/10.47667/ijpasr.v4i4.259

In response to this issue, the government has issued regulations detailing the Implementation of Urban Drainage Systems, as outlined in the Regulation of the Minister of Public Works of the Republic of Indonesia Number 12 of 2014. Therefore, effective efforts are needed to improve Drainage Infrastructure, such as effective drainage system management, proper drainage system maintenance, and water source protection.

Efforts that can be undertaken include using alternative methods like ecodrain, such as infiltration wells, detention or retention ponds, biopore infiltration holes, paving blocks, or grass blocks (Lukman, 2018). Additionally, constructing new drainage or widening existing drainage, maintaining drainage channels, creating drainage plans based on drainage techniques to form regulations and institutions overseeing drainage management (Haq, 2015). The management can be prioritized based on the severity of historical flooding impact, ranging from the worst to the least affected areas (Guntoro, 2017; Sugiarto & Ramadania, 2023a).

This research focuses on the characteristics of drainage in Medan Sunggal Subdistrict, describing the drainage conditions and flood conditions to identify areas that are likely to experience flooding/ponding based on specific months and rainfall conditions. Moreover, it proposes appropriate management solutions that can be considered by the government and accepted by the community.

The study utilizes the latest field data from 2023, including an analysis of the study location based on primary, secondary, and tertiary roads in each sub-district. Data on drainage conditions and flood conditions are obtained through direct field observations. The analysis results are compared with related studies to identify similar drainage conditions and proper management that can be implemented in the study location.

The issues in the study location require an analysis of the characteristics and management of Drainage Infrastructure to understand its characteristics and implement proper drainage infrastructure management. This research serves as information and a reference for the government, the community, and relevant stakeholders.

Literature Review

Flood is defined as the flow of river water that exceeds the normal water level, overflowing from the riverbanks and causing inundation on the side of the river (DPU No. 12/PRT/M/2014). Inundation is defined as a condition where an area is filled with water due to the absence of drainage directing the water out of the area (Sobirin, 2007). The parameters for inundation are outlined in the following table (DPU No. 12/PRT/M/2014).

Kuswandi, et al (2021) stated that rainfall is essential for the development of flood control plans and is the average rainfall across the entire relevant area, not the rainfall at a specific point. This rainfall is referred to as regional rainfall expressed in millimeters (Sosrodarsono, 1987:27). One millimeter of rain means that the rainfall over an area of one square meter has a height of one millimeter if the rain does not seep, flow, or evaporate. The prediction of accumulated rainfall over 24 hours in Indonesia is based on numerical weather prediction model data. The threshold values used to determine rainfall intensity are as follows (Meteorology Climatology Geophysics Agency): (a) 0 mm/day (gray): Overcast; (b) 0.5 – 20 mm/day (green): Light rain; (c) 20 – 50 mm/day (yellow): Moderate rain; (d) 50 – 100 mm/day (orange): Heavy rain; (e)100 – 150 mm/day (red): Very heavy rain; (f) >150 mm/day (purple): Extreme rain.

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Table 1. Inundation Parameters

a. Flood Height • 0,50 m Percentage Value 100 • 0,30 m – 0,40 m Percentage Value 75 • 0,20 m - < 0,30 m Percentage Value 50 • 0,10 m - < 0,20 m Percentage Value 25 b. Flood Area • > 8 ha Percentage Value 100 • 4 – 8 ha Percentage Value 75 • 2 - < 4 ha Percentage Value 50 • 1 - < 2 ha Percentage Value 25	c. Duration of Flooding • > 8 hours: Percentage Value100 • 4 – 8 hours: Percentage Value 75 • 2 - < 4 hours: Percentage Value 50 • 1 – 2 hours: Percentage Value 25 d. Frequency of Flooding • Very Often (10 times/year): Percentage Value 100 • Often (6 times/year): Percentage Value 75 • Less Often (3 times/year): Percentage Value 50 • Rarely (1 time/year): Percentage Value 25

Parameter of slope inclination in the city of Medan is classified into three classes: Very steep (>40%), Steep (25-40%), Moderately steep (15-25%), Gentle (8-15%), and Flat (0-8%). The overall slope inclination in the city of Medan is considered flat (0-8%) and gentle (8-15%) (Anggraini, et al, 2021).

According to Edial, et al (2008), soil permeability is the ability of water or air to flow through biopore spaces in a saturated condition. Moisture in the soil section and ponding in paddy fields can create an impermeable layer, leading to the retention of percolation and surface water ponding (Boorman and Breeman, 1978).

Characteristics describe distinctive features or patterns that can be used to identify or describe something. According to the KBBI (Indonesian Dictionary), characteristics are defined as distinctive properties in accordance with certain characteristics. These characteristics differentiate an object, individual, or group from others. This includes the physical dimensions of the channel, channel structure and conditions, surface roughness, or structural damage.

Drainage infrastructure is one of the essential types of basic infrastructure required in every developing area. The drainage system is designed to channel surface water, rainwater, and wastewater from the ground surface to a safer or more suitable location, such as rivers, seas, or wastewater treatment systems. Drainage is constructed to prevent flooding, control wastewater, protect infrastructure, maintain water quality, and preserve public health.

The components of the drainage system include the channel system and complementary structures (Ministry of Public Works, 2012; Suripin, 2004). The drainage network pattern is shown in the following table (Wesli, 2008): (a) L-Shaped Pattern (Formed between branch channels and main channels; Applicable in areas with a topography higher than the river); (b) Parallel Pattern (Main channels are parallel to branch channels; In urban development, channels may separate from branch (secondary) channels, which are numerous and short); (c) Grid Iron Pattern (Channels are directed in areas where the river is located on the outskirts of the city; Branch channels are collected first in the collecting channel and then directed to the main channel); (d) Natural Pattern (Similar to the L-shaped pattern, the flow system does not always form right angles on the main channel; River loads in natural patterns are usually larger); (e) Radial Pattern (The drainage network pattern spreads in all directions); (f) Mesh Pattern (The network pattern follows the direction of roads and is suitable for flat topography areas).

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Types and Classifications of Drainage, (Buttler et al., 2018; Wesli, 2008):

According to the Formation Process: 1) Natural Drainage: Drainage formed naturally; 2) Artificial Drainage: Drainage created by human intervention. Based on the Drainage System: 1) Combined System: Rainwater and domestic wastewater flow together; 2) Separate System: Rainwater and domestic wastewater flow separately; 3) Hybrid System: Combination of both combined and separate systems. Based on Location: 1) Surface Drainage: Drainage located above the ground surface; 2) Subsurface Drainage: Drainage located beneath the ground surface. Drainage According to Construction: 1) Open Channel Drainage: Open water channels like ditches or small rivers; 2) Closed Channel Drainage: Covered water channels, such as pipe systems or tunnels.

In accordance with Ministerial Regulation No. 12 of 2014, drainage standards can be observed based on open channels located on the left and right sides of roads, which function to collect rainwater from the road, with dimensions depending on the road width. Road drainage cannot be standardized if it also serves to collect rainwater from the surrounding environmental areas. The dimensions of these channels depend on the area of the Watershed (Daerah Tangkapan Air or DTA), the return period, and the shape of the Watershed (DTA) or Drainage Area (DPSal). Environmentally friendly drainage is defined as efforts to manage excess water (rainwater) through various methods, including direct storage in water tanks for immediate use, storage in artificial reservoirs or natural water bodies, infiltration, and discharge into the nearest river without adding a burden to that river, while continuously maintaining the system for sustainable utility.

Primary channels are drainage channels receiving water from secondary channels and directing it to the receiving water bodies. Secondary channels receive water from tertiary channels and direct it to the primary channels. Tertiary channels receive water from capture channels and direct it to the secondary channels.

The main drainage system consists of the primary, secondary, and tertiary drainage channel networks, along with their complementary structures. Flood management/control is the responsibility of the city government. The organization of Urban Drainage Systems is an effort to plan, construct, operate, maintain, monitor, and evaluate the physical and non-physical urban drainage systems. New development includes activities such as building channels, increasing channels, extending channels, diverting flows, polder systems, elongated storage ponds, and retention ponds. Normalization includes activities to repair channels and other drainage facilities, including complementary structures, according to planning criteria. Maintenance is the activity carried out to ensure the function of urban drainage infrastructure in accordance with the plan. Routine maintenance includes manual/automatic garbage collection, sediment dredging from channels, and mechanical/electrical maintenance. Periodic maintenance includes dredging sediment from channels/ponds/control basins/drains/syphons/storage ponds/retention ponds and mechanical/electrical maintenance. Rehabilitation is the activity to repair channels and other drainage facilities, including complementary structures, that have experienced a decrease in condition and function to ensure their performance according to planning. Rehabilitation includes replacement or repair of channels, pumps/gates, embankment repairs, replacement or repair of trash screens, reservoir repairs, and repairs to storage pond/retention pond due to decreased function. A storage pond is drainage infrastructure designed to collect rainwater for use as a raw water source. A retention pond is drainage infrastructure designed to collect and infiltrate rainwater in an area. A detention pond is a temporary storage pond before water is discharged or pumped to a river or sea.

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According to the Indonesian National Standard (SNI) No. 03-2453-2002, the general requirements that must be met by an infiltration well for a residential yard are as follows: the infiltration well must be located on flat land, away from waste disposal areas, far from the septic tank (a minimum of 5 m measured from the edge), and at least 1 m away from the building foundation. Excavation for the infiltration well can reach sandy soil or a maximum of 2 m below the groundwater surface. The soil structure must have greater permeability.

Natural biopores are formed due to the activities of living organisms in the soil, such as earthworms, termites, and the movement of plant roots. The activities of living organisms in the soil result in the formation of small holes that can be penetrated by air and water. As a result, water is absorbed into the soil due to the presence of natural biopores rather than entering drainage channels when it rains. The infiltrated rainwater accumulates to become groundwater (Kurniastuti, 2014). Artificial biopores are infiltration holes made perpendicular into the soil at a height of 80-100 cm (not exceeding the depth of the groundwater) with a diameter between 10-30 cm. These holes are then filled with organic material where worms enter, initiating a natural decomposition process that does not cause environmental pollution (Gholam et al., 2021; Kurniastuti, 2014).

Paving Block or Grass Block has good water absorption capacity, thereby preventing the occurrence of water puddles on the surface area. Paving Block or Grass Block covers the ground surface and helps maintain the water supply in the soil, making it useful for implementation in urban areas (Ministry of Public Works and Housing, KOTAKU-NSUP Program Infrastructure Unit KMP-2, 2018).

Community Roles involve providing Infiltration Wells, Reservoir Ponds, Retention Ponds, according to the characteristics of the area. Preventing waste and wastewater from entering the drains. Conducting maintenance and cleaning of local drainage in the environment. Preventing the construction of buildings above inspection channels and roads. Managing the regional drainage system voluntarily and/or providing information on drainage management to the district/city government (Ministry of Public Works Regulation No. 12 of 2014).

Green Open Space is divided into Public Green Open Space and Private Green Open Space. Green Open Space should constitute at least 30% of the City Area or Urban Area. Public Green Open Space should be at least 20%, and Private Green Open Space should be at least 10%.

Related research is a previous study that examines aspects related to drainage infrastructure. In the title "Management of Drainage Systems in Sungai Pinang Sub-district by the Public Works and Irrigation Office of Samarinda City (Study on Drainage System Maintenance) and Inhibiting Factors," Sitohang (2015) employed a descriptive qualitative method for independent variables, utilizing techniques such as purposive sampling, accidental sampling, and interviews. The research's focus on routine maintenance includes waste removal, culvert repair, and channel repair. The data analysis technique used is the qualitative data analysis model, an interactive model by Miles and Huberman. The results of this study indicate that the management of the drainage system in the Sungai Pinang Sub-district is not yet optimal due to obstacles such as budget constraints, a lack of community awareness in environmental preservation, and insufficient coordination among relevant agencies.

Guntoro (2017), in the paper titled "Integrated Drainage Management for Flood Control in Sidokare Area." The management employs a combination pattern, including channel design, retention ponds, and pumps. The Mononobe formula is used to calculate rainfall intensity with a specific return period using the Log Pearson Type III method. The research findings indicate that the historical floods in the Sidokare Area are caused by a 1.01-year return period of rainfall

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with an intensity of 17.55 mm/hour. Efforts to address the issue through integrated drainage management in the Catchment Area (DTA) can reduce floods by up to 100%, encompassing a combination of existing drainage channels, retention ponds, and flood pumps.

Djamaluddin (2020), in the paper titled "Urban Drainage Management as an Effort for Flood Mitigation in Makassar City." The method used is the Aquapond method, involving the construction of Aquapond retention pond facilities connected to water drainage facilities. The research results include a drainage management system in the form of retention pond facility planning, planning procedures, reviewing the results of precast concrete Aquapond construction work, and maintenance.

Lukman (2018), Evaluation of Drainage System in Helvetia District, Medan City. The method used is the surface runoff discharge calculation method, namely the rational method, and Log Pearson Type III distribution to calculate rainfall. The hydrological analysis results and distribution spread test using Log Pearson Type III distribution revealed the maximum rainfall intensity (I max) to be 14.644 mm/hour, the maximum planned flood discharge (Q) to be 5.646 m^3/sec, and the concentration time (tc) to be 1.087 hours. A comparison of the design flood discharge (Q) analysis results and the channel capacity analysis results was made to determine the condition of the primary drainage area. From the analysis results, it was found that the Primary Drainage is 1.7188 m^3/sec at the Existing Channel Q. For the Design Q, it is known to be 0.5646 m^3/sec under the 10-year condition.

Sari (2019), Evaluation of Urban Drainage Management Sustainably in Pekanbaru City. The method used is a survey and experimental method with a quantitative and mixed-method qualitative research design. Data collection is carried out through field surveys, documentation, and interviews. The experimental method involves finding the influence of specific variables on drainage functions such as dimensions, land use, and influencing factors. The research findings indicate that the current capacity of existing drainage channels cannot accommodate the maximum water discharge (Existing Q is smaller than Design flood Q) during high-intensity rainfall with a duration of < 1 hour. The disruption of drainage functions has a high impact on ecology, economy, and society in the range of 65-100%. Therefore, evaluations can be conducted using several ecodrain methods, including infiltration wells, infiltration ponds (detention or retention), biopore infiltration holes, paving blocks, and grass blocks.

Haq (2015), Drainage Management Strategy for Palapa Traditional Market in Pekanbaru City. Utilizing SWOT analysis by examining government policies in drainage management, identifying strengths, weaknesses, opportunities, and threats, and formulating drainage management. Efforts to improve drainage service systems by constructing new drainage or expanding existing ones to stimulate the participation of traders in the operation and maintenance of market drainage channels. Developing a drainage plan based on drainage techniques to establish regulations and institutions overseeing drainage management systems and penalizing drainage offenders.

Gholam, et al (2021), Creation and Education on the Importance of Biopore Infiltration Holes (LRB) to Enhance Awareness of Organic Waste and Groundwater Availability in Tumang Sari Hamlet, Cepogo. The method used includes socialization and material delivery, training and assistance in creating Biopore Infiltration Holes, as well as monitoring and post-activity evaluation. The results obtained include increased knowledge, understanding, and skills of the community, and it is expected that this program can reduce the volume of water puddles and organic waste in Biopore Infiltration Holes as they decompose, making them usable as compost fertilizer.

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Based on previous research, to achieve the objectives of this study, it will discuss several variables suitable for the location and conditions of the study. Two variables with two indicators were found to determine the current characteristics of drainage and appropriate management efforts, as listed in Table.

Table 2. Variables and Indicators

<table>
<tr><th>No.</th><th>Variable</th><th>Indicator</th><th>Reference</th></tr>
<tr><td>1.</td><td>Data</td><td>1. Characteristics</td><td rowspan="2">Sari (2019), Guntoro (2017), Djamaluddin (2020), dan Sitohang (2015), Gholam (2021)</td></tr>
<tr><td>2</td><td>Technical</td><td>2. Management (Soakwells, Biopore Infiltration Holes, Retention/Detention Ponds, Paving Blocks, Grass Blocks, Constructing New Drains, Widening Existing Drains, and Drainage Channel Maintenance)</td></tr>
</table>

Source: Author's, 2023

Methods

This research adopts a positivistic paradigm with a positivistic approach. It relies on empirical facts (sensual empiricism) obtained through sensory observation and is supported by theoretical foundations as the main source of information in the research. The research methodology used is a pure qualitative descriptive research methodology, describing field observation data that focuses on a deep understanding of the characteristics, context, and research subjects, as proposed by Muhajir (2000) and (Abdiyanto, 2020). The data collection method employs the Guest Tour technique, involving the determination of existing conditions and direct field observations. Data are specifically examined and gathered from the study location to determine the characteristics of its drainage infrastructure using purposive sampling technique, selecting samples randomly or based on primary, secondary, and tertiary road segments. Samples are chosen to represent areas experiencing flood impacts with a minimum radius of 1-<2 ha. Subsequently, based on their characteristics, an analysis of drainage infrastructure management is conducted until an appropriate management approach is identified. Literature review is utilized to study relevant literature, and a comparative technique is employed to compare the analysis results of drainage infrastructure characteristics and management with established standards and previous research.

Results and Discussion

Geographically, the Medan Sunggal Subdistrict in the city of Medan is located at 3.5810° N latitude and 98.6149° E longitude, covering an area of 13.90 km2, which is approximately 5.24% of the total area of Medan city, amounting to 265.10 km2. Based on its geographical location, Medan Sunggal Subdistrict shares boundaries with other regions as follows: to the north, it borders the Medan Helvetia Subdistrict; to the south, it borders the Medan Selayang Subdistrict; to the east, it borders Medan Petisah; and to the west, it borders the Deli Serdang Regency.

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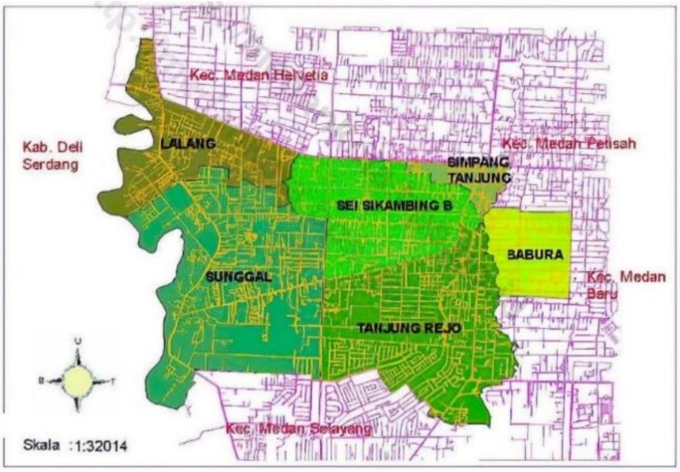

Figure 1. Map of Administrative Boundaries and Sub-Districts in Medan Sunggal

Source: Central Statistics Agency (Badan Pusat Statistik)

The Medan Sunggal Subdistrict is divided into six sub-districts, namely Sunggal, Tanjung Rejo, Babura, Simpang Tanjung, Sei Sikambing B, and Lalang. The largest area is in Sunggal Subdistrict, covering 4.93 km2, which constitutes 34.90%. Tanjung Rejo Subdistrict follows with an area of 3.50 km2, accounting for 25%, Lalang Subdistrict with 1.25 km2 at 8.9%, and Babura Subdistrict with 1.06 km2 at 3.7%. The smallest area is in Simpang Tanjung Subdistrict, covering 0.32 km2, which is 2.30%. The distance from the sub-districts to the sub-district capital ranges from one to four kilometers, and the distance from the sub-districts to the district capital ranges from four to nine kilometers.

The population growth rate in the Medan Sunggal Subdistrict from 2012 to 2023 has experienced significant increases each year over the last ten years. The highest increase occurred in 2020, with an additional population of 11,528, and in 2021, the population increased by another 6,572. This significant population increase happened in five sub-districts: Sunggal, Tanjung Rejo, Babura, Simpang Tanjung, and Lalang. In Sei Sikambing B Subdistrict, the population increase was not significant, reaching 342 people in 2020 but increasing to 2,336 people in 2021. In 2015-2016 and 2020-2021, the population remained relatively stable in Simpang Tanjung Subdistrict.

Table 3. Increase in Population in 2012 - 2016

No	**Village**	**Population (Individuals)**				
		2012	**2013**	**2014**	**2015**	**2016**
1.	Sunggal	30.599	30.782	31.338	31.365	31.379
2.	Tanjung Rejo	31.094	31.280	31.841	31.867	31.882
3.	Babura	9.214	9.270	9.436	9.444	9.448
4.	Simpang Tanjung	863	868	884	885	885
5.	Sei Sikambing B	23.146	23.285	23.703	23.722	23.733
6.	Lalang	18.051	18.159	18.485	18.502	18.510
Total		112.967	113.644	115.687	115.785	115.837

Source: Data from the Medan Sunggal Subdistrict in Figures for the Years 2013-2017

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Table 4. Increase in Population in 2017 - 2021

No	Village	Population (Individuals)				
		2017	2018	2019	2020	2021
1.	Sunggal	31.633	31.843	31.949	37.358	38.280
2.	Tanjung Rejo	32.139	32.185	32.270	35.123	36.712
3.	Babura	9.524	9.540	9.567	10.804	11.215
4.	Simpang Tanjung	892	899	903	1.282	1.282
5.	Sei Sikambing B	23.925	23.966	24.031	24.373	26.709
6.	Lalang	18.660	18.756	18.815	20.123	21.437
Total		116.773	117.189	117.535	129.063	135.635

Source: Data from the Medan Sunggal Subdistrict in Figures for the Years 2018-2022.

The population density in the Medan Sunggal Subdistrict from 2012 to 2021, based on the area of each village, reveals that the highest population density occurred in the year 2020 and increased again in 2021. The highest population density was recorded in Lalang Village in 2020, reaching 16,098 individuals per square kilometer with an area of 1.25 square kilometers. Following closely was Babura Village in 2020, with a population density of 10,192 individuals per square kilometer over an area of 1.06 square kilometers, and Tanjung Rejo Village in 2020, registering a population density of 10,035 individuals per square kilometer with an area of 3.50 square kilometers. In 2021, Sei Sikambing B Village experienced a population density of 9,405 individuals per square kilometer covering an area of 2.84 square kilometers. Sunggal Village in 2020 had a population density of 7,578 individuals per square kilometer with an area of 4.93 square kilometers, while Simpang Tanjung Village in 2020 recorded a population density of 4,006 individuals per square kilometer over an area of 0.32 square kilometers.

Table 5. Population Density In 2012 - 2016

No	Village	Population Density (km^2)				
		2012	2013	2014	2015	2016
1.	Sunggal	6.206	6.244	6.356	6.362	6.365
2.	Tanjung Rejo	8.884	8.937	9.097	9.104	9.109
3.	Babura	8.692	8.745	8.901	8.909	8.913
4.	Simpang Tanjung	2.696	2.713	2.762	2.765	2.766
5.	Sei Sikambing B	8.150	8.199	8.346	8.352	8.357
6.	Lalang	14.440	14.527	14.788	14.801	14.808
Total		8.127	8.176	8.375	8.382	8.386

Source: Data from the Medan Sunggal Subdistrict in Figures for the Years 2013-2017.

Tabel 6. Population Density In 2012 - 2016

No	Village	Population Density (km^2)				
		2017	2018	2019	2020	2021
1.	Sunggal	6.416	6.459	6.480	7.578	7.765
2.	Tanjung Rejo	9.183	9.196	9.220	10.035	10.489
3.	Babura	8.985	9.000	9.025	10.192	10.580

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4.	Simpang Tanjung	2.788	2.809	2.821	4.006	4.006
5.	Sei Sikambing B	8.424	8.439	8.461	8.582	9.405
6.	Lalang	14.928	15.005	15.052	16.098	17.150
Total		8.401	8.431	8.456	9.285	4.828

Source: Data from the Medan Sunggal Subdistrict in Figures for the Years 2018-2022.

The increase in the population from 2012 to 2021 has significantly impacted the population density in the Medan Sunggal Subdistrict. Lalang Village stands out as the area with the highest population density compared to other villages, reaching 17,150 individuals per square kilometer. This rapid increase started in 2020 and continued through 2021. Sunggal Village, Tanjung Rejo Village, Babura Village, Simpang Tanjung Village, and Sei Sikambing B Village also experienced an increase from 2020 to 2021. This growth has influenced the surrounding environment, leading to a decline in groundwater quality, water pollution, and damage to drainage infrastructure. Consequently, these factors have triggered flooding and an increase in the spread of diseases in the area.

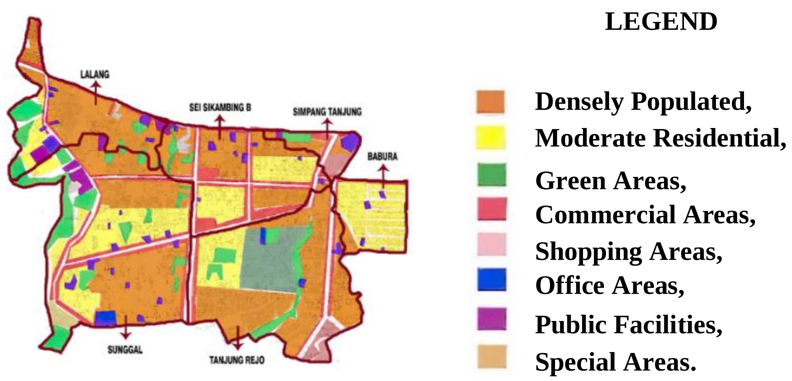

Figure 2. Land Use Map of Medan Sunggal Subdistrict

Source: Arini, 2022.

Population Growth and Increased Population Density in Medan Sunggal Subdistrict as Evident in the Above Image. The growth in population has led to an augmented population density in the Medan Sunggal Subdistrict, as depicted in the above image. The subdistrict is characterized predominantly by densely populated residential areas, followed by moderately populated residential areas, supported by commercial areas along primary and secondary roads, shopping areas, office areas, and public facilities. Dominant green areas are present in Tanjung Rejo, Sunggal, Lalang, and Simpang Tanjung Villages.

Lalang Village is an area with the highest population density, predominantly characterized by densely populated residential zones. Babura Village is the second most densely populated area, dominated by moderate residential zones. Meanwhile, the third is Tanjung Rejo Village, an area predominantly characterized by densely populated residential zones, complemented by moderate residential areas, commercial zones, and shopping areas. Lalang, Babura, and Tanjung Rejo Villages should be noted, as these areas are prone to frequent flooding and inundation based on the land use map.

Sei Sikambing B Village is an area predominantly characterized by densely populated residential areas and moderate residential zones. Sunggal Village is dominated by densely

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populated residential areas and moderate residential zones. Meanwhile, Simpang Tanjung Village is characterized by shopping areas and densely populated residential zones.

The land cover in the Medan Sunggal Subdistrict has a significant environmental impact as it is dominated by densely populated residential areas, which have very limited water absorption capacity. Consequently, the water drainage system is directed to the existing drainage channels, designed based on the road width. If the urban drainage system relies on the existing drainage system, it cannot accommodate the entirety of water drainage. This situation results in inundation in the Medan Sunggal Subdistrict, particularly on roads such as Sunggal, Beo, Kapuas, and around the Health Center.

Figure 3. Flooding on Sunggal Road in Densely Populated Residential Area

Source: Author's Documentation, 2023.

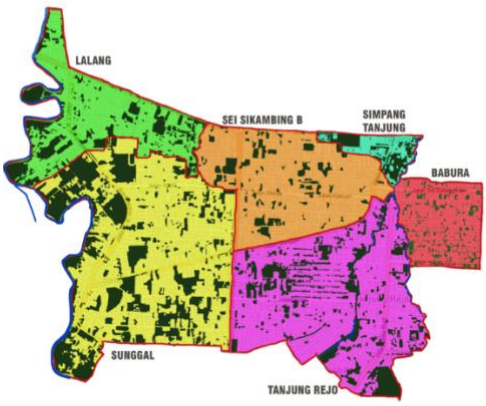

Figure 4. Green Open Space in Medan Sunggal Subdistrict

Source: Arch GIS Field Maps, Author, 2023.

Dark areas indicate Green Open Spaces in the Medan Sunggal Subdistrict. Green areas are prominently visible in Sunggal, Tanjung Rejo, Lalang, and Simpang Tanjung Villages, indicating that these areas still have space to absorb water into the ground. However, in Sei Sikambing B and Babura Villages, green open spaces are scarce, suggesting limited capacity for water absorption. Therefore, it can be analyzed that Sei Sikambing B and Babura Villages are prone to flooding and inundation.

Medan Sunggal Subdistrict has a flat and gently sloping topography, with elevations ranging from approximately 17 to 28 meters above sea level. The lowest elevation is in Lalang Village, while the highest elevation is in Sunggal Village.

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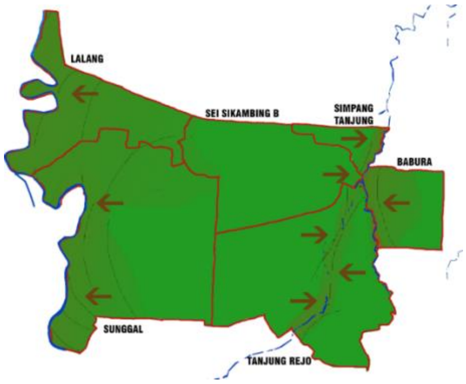

Figure 5. Flood/Inundation Area Analysis Based on Topography

Source: Author's Analysis, 2023

According to the map, areas prone to frequent flooding and inundation include Lalang Village, the northern part of Sunggal Village, and the western part of Sei Sikambing B Village. Medan Sunggal Subdistrict is situated in a tropical climate with two seasons: the rainy season and the dry season. Rainfall and rainy days data according to BMKG Region I are as follows.

Table 7. Rainfall and Rainy Days Data in BMKG Region I.

Moon	**Month Rainfall and Number of Rainy Days in BMKG Region I**					
	Rainfall			**Rainy Days**		
	2020	**2021**	**2022**	**2020**	**2021**	**2022**
January	87	519	213	13	23	17
February	79	88	296	15	7	18
March	104	201	232	11	15	13
April	326	300	169	21	17	17
May	486	146	134	23	13	15
June	615	231	319	23	16	17
July	300	127	150	24	12	15
August	196	378	514	15	16	23
September	336	287	243	21	19	15
October	466	260	376	21	17	30
November	337	494	526	22	25	27
December	397	174	321	24	16	23
Annual	3.729	3.205	3.495	233	196	230

Source: Deli Serdang Climatology Station 2020-2022

Based on the Table above, the highest rainfall occurred in 2020 with a total of 3,729 mm over 233 rainy days, followed by a decrease in 2021 with 3,205 mm over 196 rainy days. Subsequently, there was an increase in 2022 with 3,495 mm of rainfall over 230 rainy days.

In 2020, the highest monthly rainfall was in June at 615 mm, while the lowest was in February at 79 mm. The month with the highest number of rainy days was July with 24 days, and the lowest number occurred in March with 11 rainy days. For 2021, the highest monthly rainfall was in January at 519 mm, and the lowest was in February at 88 mm. The month with the highest number of rainy days was November with 25 days, and the lowest number occurred in

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February with 7 rainy days. In 2022, the highest monthly rainfall was in November at 526 mm, and the lowest was in March at 134 mm. The month with the highest number of rainy days was October with 30 days, and the lowest number occurred in March with 13 rainy days.

Table 8. Calculation of the Rainy Season.

Moon	**Rain Intensity**					
	2020	**Condition**	**2021**	**Condition**	**2022**	**Condition**
January	50	Light Rain	271	Extreme Rain	115	Very Heavy Rain
February	47	Light Rain	48	Light Rain	157	Extreme Rain
March	58	Heavy Rain	108	Very Heavy Rain	123	Very Heavy Rain
April	174	Extreme Rain	159	Extreme Rain	93	Heavy Rain
May	255	Extreme Rain	80	Heavy Rain	75	Heavy Rain
June	319	Extreme Rain	124	Very Heavy Rain	168	Extreme Rain
July	162	Extreme Rain	70	Heavy Rain	83	Heavy Rain
August	106	Very Heavy Rain	197	Extreme Rain	269	Extreme Rain
September	179	Extreme Rain	153	Extreme Rain	129	Very Heavy Rain
October	244	Extreme Rain	139	Very Heavy Rain	203	Extreme Rain
November	180	Extreme Rain	260	Extreme Rain	277	Extreme Rain
December	211	Extreme Rain	95	Heavy Rain	172	Extreme Rain
Annual	**165**	Extreme Rain	**142**	Hujan Sangat Lebat	**155**	Extreme Rain

Source: Author's Calculation, 2023.

Based on the table above, it can be observed that the types of rainfall in the study area include light rain, heavy rain, very heavy rain, and extreme rain. In 2020, the rainy season with extreme rain conditions occurred in June, May, October, December, November, September, April, and July. Very heavy rain conditions occurred in August, while heavy rain conditions occurred in March, and moderate rain conditions occurred in January and February.

In 2021, the rainy season with extreme rain conditions occurred in January, November, August, April, and September. Very heavy rain conditions occurred in October, June, and March, while heavy rain conditions occurred in December, May, and July. Moderate rain conditions only occurred in February.

In 2022, the rainy season with extreme rain conditions occurred in November, August, October, December, June, and February. Then, very heavy rain conditions occurred in September, March, and January. Meanwhile, heavy rain conditions occurred in April, July, and May.

Based on the above data, rainfall and the number of rainy days in the study area cannot be predicted well on a monthly or yearly basis. However, it can be predicted that the frequency of rain that will occur will fall within the range of 50 mm/day to >50 mm/day or in the conditions of heavy rain to extreme rain.

Medan Sunggal Subdistrict is an area with high rainfall. Based on the rainfall data from 2020 to 2022 above, the rainfall intensity is extremely high, on average occurring in the condition of extreme rain. The drainage infrastructure facilities available to handle rainfall cannot cope with it, resulting in frequent waterlogging in areas with the highest rainfall intensity. Therefore,

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there is a need for action to address the extreme rainfall that will affect Medan Sunggal Subdistrict.

Based on rainfall data and land cover areas such as commercial areas, shopping areas, public facilities areas, and office areas, these are areas that are likely to experience flooding and/or inundation, especially in residential areas with the highest population density. These areas may experience flooding and/or inundation in certain months, namely January, June, and November. However, caution is needed due to the frequent occurrence of extreme rainfall in November.

In the city of Medan, there are various types of soil such as inceptisols, oxisols, ultisols, and entisols. However, the dominant soil types are inceptisols and entisols, which fall into the category with moderately high infiltration capacity (Anggraini, et al., 2021).

The vegetation types in the green areas of the study location include rain plants (bamboo and palm), ground cover plants (grass, red asoka, bougainvillea, baluntas, privet shrub, red shoots, sugarcane, and other plants), and tree plants (acacia, avocado, angsana, fan camar, guava, white teak, longan, small mahogany, mango, melinjo, mulberry, jackfruit, Chinese stink bean, hibiscus, rain tree, and other plants).

Figure 6. Vegetation in the Study Location

Source: Author's Documentation, 2023

If each area, both residential and commercial, allocates or releases land for green open spaces amounting to at least 10% of the built-up area, it can contribute to increasing green open spaces. This can help mitigate environmental issues, including reducing pressure on the environment due to significant population growth, alleviating stress on existing drainage systems, minimizing flooding in flat and sloping areas, and decreasing high surface water runoff during heavy to extreme rainfall. Additionally, it allows the soil infiltration system to function effectively.

Drainage Characteristics

The drainage channel pattern in the study location follows a network pattern aligned with the direction of roadways, given the flat topography. This network pattern directs tertiary channels to secondary channels and then to primary channels, ultimately flowing into rivers in an organized and permanent manner.

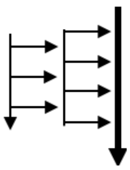

Figure 7. Network Pattern in the Study Location

Source: Author's Analysis, 2023

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The types of drainage channels in the study location include primary channels, secondary channels, and tertiary channels situated along the main roads, arterial roads, and local roads. Primary channels in the study location are located on Jl. PAM Tirtanadi (Kel. Sunggal), Jl. Perjuangan, and Jl. Abadi (Kel. Tanjung Rejo), Jl. Sei Batang Hari, Jl. Kapuas, and Jl. Sei Brantas (Kel. Babura), and Jl. Jenderal Gatot Subroto (Kel. Simpang Tanjung).

Secondary channels in the study location can be found on Jl. Bunga Raya, Jl. Abadi, Jl. Patriot, Jl. Amal, Jl. Seroja, Jl. Sunggal, and Jl. Gagak Hitam (Kel. Sunggal), Jl. Setia Budi, and Jl. Sei Belutu (Kel. Tanjung Rejo), Jl. Sei Bilah, Jl. Sei Ular, Jl. Sei Mencirim, Jl. Inti Sari, Jl. Sei Bengawan, Jl. Sei Musi, Jl. Sei Serayu, and Jl. Darussalam (Kel. Babura), Jl. Cendrawasih, Jl. Murai, Jl. Pesantren, Jl. Garuda, Jl. Merpati, Jl. Beo, Jl. Kutilang, Jl. Rajawali, Jl. Merak, Jl. Kaswari, Jl. Balam, Jl. Kiwi, Jl. Tempua (Kel. Sei Sikambing B), as well as Jl. Kelambir V, and Jl. TB. Simatupang (Kel. Lalang).

Tertiary channels in the study location are present on Jl. Palem Mas, Jl. Sehat, Jl. Perwira, Jl. Puskesmas, Jl. Balai Desa, Jl. Beringin (Kel. Sunggal), Jl. Sei Padang, Jl. Kentil, Jl. Sei Asahan, Jl. Sei Silau, Jl. Karyawan, Jl. Taqwa, Jl. Legawa Barat, Jl. Ampera, Jl. Ksatria (Kel. Tanjung Rejo), Jl. Sei Simare (Kel. Babura), and Jalan Elang (Kel. Sei Sikambing B).

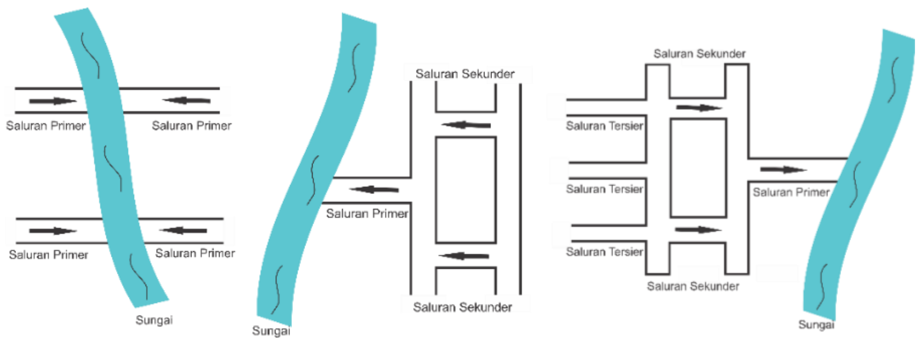

Figure 8. Analysis of Primary, Secondary, and Tertiary Channels

Source: Author's Analysis, 2023

The types of drainage channels based on the formation process in the study location as a whole are artificial drainage systems. Their construction is tailored to water management systems for specific purposes. Based on the construction, the upper part of the drainage system is open, allowing the flow of rainwater and household wastewater simultaneously. The overall structure predominantly uses concrete materials.

In terms of location, the channels are above ground level and are used to drain surface runoff, prevent surface water stagnation, and facilitate gravity-based flow. Regarding the water drainage system, a combined system is employed to manage both rainwater and household wastewater simultaneously through open channels.

The drainage water condition in Kecamatan Medan Sunggal is generally stagnant. Smooth drainage conditions are observed on Jalan Abadi in Kelurahan Sunggal, Jalan Kapuas, and Jalan Sei Brantas in Kelurahan Babura, and on Jalan Rajawali in Kelurahan Sei Sikambing B. The physical condition of drainage in the study location is 38% slightly damaged and 62% in good condition. Thus, the overall physical condition of drainage in the study location is considered good.

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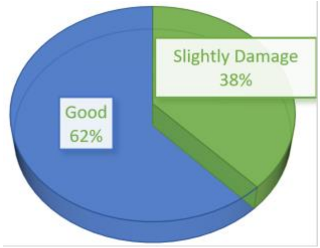

Figure 9. Percentage of Drainage Physical Conditions

Figure 10. Drainage Conditions on Jalan Abadi (Left) and Jalan Sehat (Right) in Kecamatan Medan Sunggal

Source: Author, 2023

When comparing the physical condition of drainage in the study area, which is generally good, but based on the waterlogged drainage conditions, it means that the physical condition of drainage in the study area is not the main issue causing floods and/or inundation. However, addressing the flooding or inundation can be achieved through drainage maintenance, such as clearing wild plants or dredging sedimentation. When comparing the physical condition of drainage with its combined water flow system, it can be understood that floods or inundations may occur if the physical condition of drainage cannot accommodate all of its water discharges, namely rainwater and household wastewater, especially during extreme rainfall conditions when people dispose of household waste into drainage channels.

Flood-Affected Area

The flooding or inundation conditions that occurred in Kecamatan Medan Sunggal in 2023 indicate that, on average, the district has experienced flooding or inundation. Approximately 75% have experienced flooding or inundation, while 25% have not. Based on the flood or inundation conditions, areas that have not experienced flooding and inundation account for 25%, areas that have experienced inundation make up 59%, areas that have experienced flooding amount to 14%, and areas that have experienced both flooding and inundation represent 2%.

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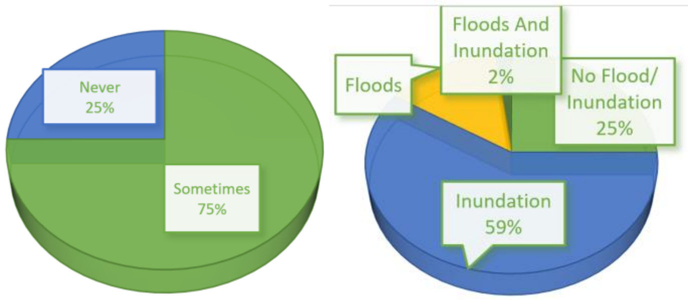

Figure 11. Percentage of Flood and Inundation Areas

Based on the frequency of floods/inundations in the study area, 25% Never experienced floods/inundations, namely on Bunga Raya Street, Patriot Street, Gagak Hitam Street, Kentil Street, Asahan Street, Sei Silau Street, Karyawan Street, Taqwa Street, Jendral Gatot Subroto Street, Cenderawasih Street, Murai Street, Pesantren Street, Merpati Street, and T.B. Simatupang Street; 5% Rarely experienced floods/inundations on PAM Tirtanadi Street, Sei Belutu Street, and Sei Simare Street; 27% Infrequently experienced floods/inundations on Abadi Street, Perjuangan Street, Ampera Street, Ksatria Street, Sei Batang Hari Street, Sei Mencirim Street, Inti Sari Street, Sei Bengawan Street, Sei Musi Street, Sei Serayu Street, Darussalam Street, Merak Street, Kasuari Street, Balam Street, Tempua Street, Murai Batu Street, and Kelambir V Street; 30% Often experienced floods/inundations on Amal Street, Seroja Street, Balai Desa Street, Sunggal Street, Abadi Street, Setia Budi Street, Sei Padang Street, Legawa Barat Street, Kapuas Street, Sei Brantas Street, Sei Bilah Street, Sei Ular Street, Elang Street, Beo Street, Kutilang Street, Rajawali Street, and Kiwi Street; and 13% Very Often experienced floods/inundations on Palem Mas Street, Sehat Street, Perwira Street, Puskesmas Street, Beringin Street, and Garuda Street. This indicates that Medan Sunggal District is an area that frequently experiences floods and inundations.

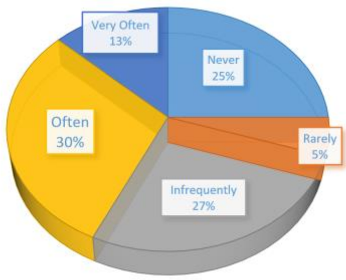

Figure 12. Percentage of Flood/Inundation Frequency in the Study Area

On average, flooding and inundation in the study area persist for 2 to 5 hours until the water recedes. The flood/inundation depth ranges from 20 cm to 50 cm. The affected areas cover main roads, arterial roads, neighborhood roads, complexes/residential areas, commercial areas, and other locations, especially those situated near riverbanks.

Flooding and inundation in the study area occur during heavy rainfall, causing an increase in surface water runoff, leading to overflowing drains and rivers that inundate urban areas. Overall, the inundated area in the study is predominantly influenced by intense rainfall, accounting for 44%, followed by heavy rainfall at 18%, and extreme rainfall at 14%. The unaffected areas, in terms of rainfall intensity, constitute 24%. Very Heavy Rainfall significantly affects flooding and inundation in Jl. Abadi, Jl. Palem Mas, Jl. Amal, Jl. Beringin, Jl. Seroja, Jl. Balai Desa, Jl. Sunggal, Jl. Sei Padang, Jl. Legawa Barat, Jl. Sei Brantas, Jl. Sei Simare, Jl. Sei Bilah, Jl. Sei Mencirim, Jl. Inti Sari, Jl. Sei Bengawan, Jl. Sei Musi, Jl. Sei Serayu, Jl. Darussalam, Jl. Jend.

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Gatot Subroto (Simp. Tomang Elok), Jl. Elang, Jl. Beo, Jl. Rajawali, Jl. Merak, Jl. Kasuari, Jl. Balam, and Jl. Murai Batu. Heavy Rainfall affects flooding and inundation in Jl. Sehat, Jl. Perwira, Jl. Puskesmas, Jl. Sei Batang Hari, Jl. Kapuas, Jl. Sei Ular, Jl. Garuda, and Jl. Kiwi. Meanwhile, Extreme Rainfall affects flooding and inundation in Jl. PAM Tirtanadi, Jl. Perjuangan, Jl. Setia Budi, Jl. Sei Belutu, Jl. Ampera, Jl. Ksatria, Jl. Kutilang, Jl. Tempua, and Jl. Kelambir 5.

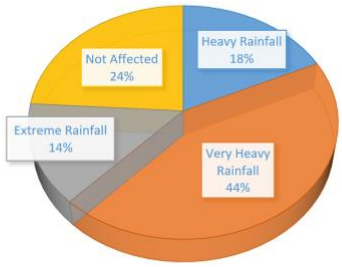

Figure 13. Percentage of Rainfall Impact on Flooding/Inundation in the Study Area

Another contributing factor to the issue of flooding and inundation in the study area is the overflowing of rivers (shallow rivers, rivers polluted with waste, and small rivers) and inadequate drainage systems (lightly damaged drainage, small drains, and drains filled with soil and waste), rendering them ineffective. Continuous development and the lack of water infiltration areas exacerbate the problem, causing water to flow into lower areas (residential zones).

Figure 14. River Conditions in the Sub-Districts of Babura, Simpang Tanjung, Tanjung Rejo, Sunggal, and Lalang

Source: Author's Documentation, 2023

Figure 15. Drainage Conditions in the Medan Sunggal Sub-District

Source: Author's Documentation, 2023

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Figure 16. Flood/Inundation Conditions in the Medan Sunggal Sub-District

Source: Author's Documentation, 2023

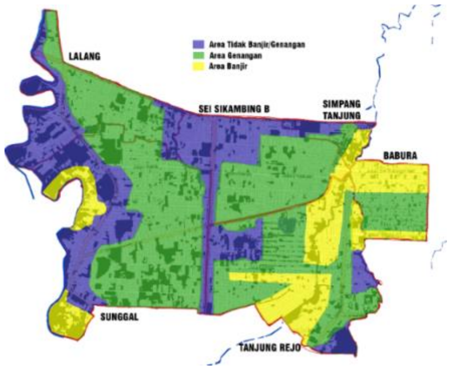

Figure 17. Flood and Inundation Areas in the Medan Sunggal Sub-District

Source: Arch GIS Field Maps, Author, 2023

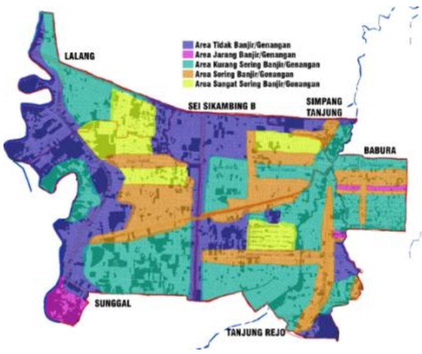

Figure 18. Frequency of Floods and Inundations in the Medan Sunggal Sub-District

Source: Arch GIS Field Maps, Author, 2023

Based on rainfall data and flood conditions in the study location, it can be analyzed that the Medan Sunggal Sub-District may experience flooding/inundation during heavy rainfall in the months of May, July, and December, lasting for 15 - 23 days; during very heavy rainfall in March, June, and October, lasting for 13 - 30 days; and during extreme rainfall in January, April, August, September, and November, with a duration of 15 - 27 days.

Extreme rainfall results in flooding and inundation in Jl. PAM Tirtanadi, Jl. Perjuangan, Jl. Setia Budi, Jl. Sei Belutu, Jl. Ampera, Jl. Ksatria, Jl. Kutilang, Jl. Tempua, and Jl. Klambir V in January, April, August, September, and November, for about 15-27 rainy days.

Very heavy rainfall leads to flooding and inundation in Jl. Abadi, Jl. Palem Mas, Jl. Amal, Jl. Beringin, Jl. Seroja, Jl. Balai Desa, Jl. Sunggal, Jl. Sei Padang, Jl. Legawa Barat, Jl. Sei Brantas, Jl. Sei Simare, Jl. Sei Bilah, Jl. Sei Mencirim, Jl. Inti Sari, Jl. Sei Bengawan, Jl. Sei Musi, Jl. Sei Serayu, Jl. Darussalam, Jl. Jend. Gatot Subroto, Jl. Elang, Jl. Beo, Jl. Rajawali, Jl. Merak, Jl. Kasuari, Jl. Balam, and Jl. Murai Batu in March, June, and October, for about 13-30 rainy

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days. Heavy rainfall leads to flooding and inundation in Jl. Sehat, Jl. Perwira, Jl. Puskesmas, Jl. Sei Batang Hari, Jl. Kapuas, Jl. Sei Ular, Jl. Garuda, Jl. Kiwi, and Jl. T.B. Simatupang in May, July, and December, for about 15-23 rainy days.

Management Analysis

Percolation wells help prevent rainwater from directly flowing out of residential yards, allowing the water to be reabsorbed into shallow ground as a source of clean water. Percolation wells are beneficial in reducing water volume during rainfall, preventing floods, increasing groundwater reserves, storing clean water, serving as a water source for irrigation, maintaining soil moisture, and preventing land subsidence. According to SNI No. 03-2453-2002, percolation wells cannot be constructed because the dominant land cover in the study area is more built-up than open green areas, especially in areas prone to inundation.

On average, septic tanks in the study area are located in the front or back yards of houses, which are mostly covered with concrete and/or turned into mini gardens. If percolation wells were to be constructed in the study area for each house, with one percolation well for one house, it would likely face rejection from the surrounding community. This is because, apart from the limited construction space, percolation well construction may disrupt the functionality, aesthetics, safety, and security of the surrounding community.

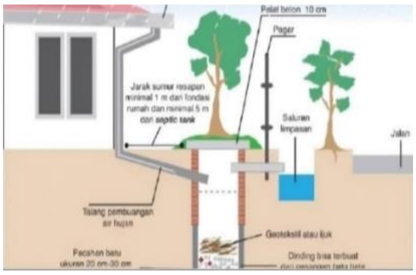

Figure 19. Infiltration Wells

Source: RSPN-DRH Guidelines, 2021

Biopore infiltration holes serve as water absorption points, aiding in the rapid infiltration of rainwater into the soil by creating entry points for rainwater, facilitating easier absorption, and increasing groundwater reserves. They reduce water puddles that contribute to floods, enhance water quality by reducing surface water pollution, improve soil fertility through the activities of microorganisms in the soil, and act as groundwater conservation, maintaining soil moisture and reducing water loss due to evaporation.

Figure 20. Biopore Holes on the Ground/Grass Surface

Source: Ismidayanti, 2019

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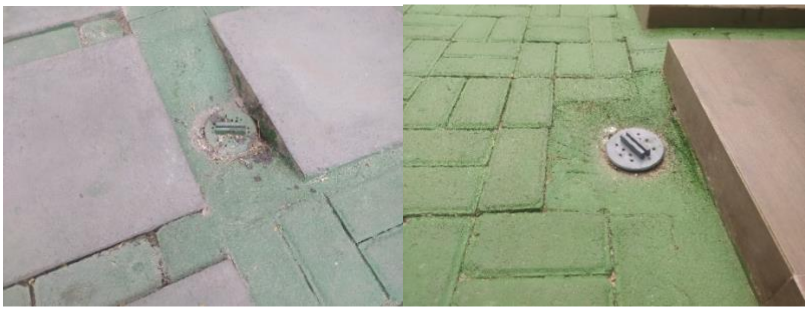

Figure 21. Biopore Holes on the Floor/Paving Surface

Source: Author's Documentation, 2023

The soil in the study area falls into the category of soil with relatively high infiltration capacity. Such soil conditions are suitable for the implementation of biopore infiltration holes. The diameter and depth of these holes are sufficient to address groundwater issues. The placement of Biopore Infiltration Holes can be strategically arranged to not only address inundation problems but also enhance aesthetics without disrupting land/space functionality. Digging Biopore Infiltration Holes in the study area can improve rainwater infiltration into the soil, enhance water circulation around plant roots, reduce surface water runoff, and stimulate the growth of beneficial microorganisms in the soil. In this regard, the implementation of Biopore Infiltration Holes may be considered and accepted by the community.

Detention ponds, retention ponds, and water reservoirs can be utilized to protect downstream areas from damage caused by conditions where downstream channels cannot accommodate the flow from upstream channels. Detention ponds are feasible for implementation in the Tanjung Rejo and Babura sub-districts. These areas, based on land cover, have the largest green open spaces among other areas around the river basin in the study location. Considering their function, detention and retention ponds are highly suitable for implementation in the study area. Constructing detention and retention ponds can control and manage rainwater and surface water runoff, gradually allowing absorption into the soil and controlled release into drainage systems or rivers, thereby reducing the burden on drainage channels. However, water reservoirs are not suitable for implementation in the study area because they are specifically designed for long-term water storage and not for addressing drainage issues.

Figure 22. Detention Pond Analysis

Source: Author, 2023

DOI: https://doi.org/10.47667/ijpasr.v4i4.259

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Paving Blocks/Grass Blocks offer advantages such as water infiltration, reduced water waste, controlled water flow, effective heat absorption, high structural strength, resistance to traffic loads, and aesthetic enhancement of the environment. The application of Paving Blocks/Grass Blocks can be considered in the study area, especially in areas prone to inundation. The installation of Paving Blocks/Grass Blocks can be considered not only for their functionality in addressing inundation issues but also for enhancing aesthetics. Paving Blocks/Grass Blocks can replace land cover areas that previously used asphalt/concrete, introducing these materials can increase green open space.

Figure 23. Paving Blocks and Grass Blocks

Source: pavingblockindonesia.com, voireproject.com

New construction or widening of existing structures allows for systematic planning, considering existing land use, improving land use efficiency by directing water flow effectively, serving as flood control, and helping to restore land damaged by prolonged inundation. However, new construction or widening of existing structures may not be suitable in the study area due to the potential exacerbation of drainage issues in limited land conditions. In such cases, maximizing the use of existing green open spaces and implementing drainage solutions to enhance water infiltration into the soil, reducing surface water runoff, and controlling rainwater is more appropriate.

Figure 24. New Construction

Source: voireproject.com

Maintenance (Normalization and Rehabilitation), reutilizing existing land use and optimizing its use, repairing existing channels is generally more economical than building new channels from scratch, reducing environmental impact in areas with high environmental value. Normalization and rehabilitation of drainage are highly suitable for implementation in the study area as it optimizes and utilizes existing land use without adding to land cover, restoring drainage channels. While some drainage channels in the study area are slightly damaged, the majority are inundated. Therefore, maintenance in the study area is a suitable management practice.

DOI: https://doi.org/10.47667/ijpasr.v4i4.259

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Figure 25. Maintenance

Source: www.cakrawalamedia.co.id; mediacenter.palangkaraya.go.id

Green Open Spaces have the ability to absorb and infiltrate rainwater into the soil, reducing the volume of water flowing directly into drainage channels and lowering the potential for floods. Vegetation in Green Open Spaces can act as barriers to water flow, allowing more water to seep into the soil and preventing it from directly flowing onto road surfaces. Plants can help filter rainwater, improve water quality, and reduce the risk of pollution. The provision of Green Open Spaces also supports government programs in climate change mitigation efforts and achieving zero carbon emissions missions. Green Open Space provision can be an alternative to reducing flooding and/or inundation issues in the study area. Green Open Spaces should constitute a minimum of 30% of the Medan City Area. This means that Public Green Open Spaces should be at least 20%, and Private Green Open Spaces should be at least 10%. If each community land allocates or frees up space for private green open areas equivalent to 10% of the built-up land area, it can help alleviate the environmental problems in the study area.

Figure 26. Green Open Space

Source: https://theconversation.com/ini-pentingnya-ruang-terbuka-hijau

Communities can play a role in the routine maintenance and care of drainage channels, such as cleaning channels from debris and sediment, repairing or reporting channel damage, and ensuring water gates and flow control devices function properly. Communities can contribute by sorting and managing waste properly to prevent waste accumulation in drainage channels, understanding the causes of floods, and avoiding behaviors that worsen the situation. Communities can also report drainage issues to the government or relevant authorities if channels are blocked, damaged, or require immediate repair, or participate in the planning and decision-making process by providing input and perspectives in participatory forums. Through active community involvement and collaboration between the government and stakeholders, this will help create a more effective drainage system, improve environmental quality, and maintain environmental sustainability.

DOI: https://doi.org/10.47667/ijpasr.v4i4.259

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Figure 27. Community Role

Source: www.kampoengnews.com

Conclusion of Management Analysis

Based on the environmental conditions and characteristics of the drainage infrastructure in the study area, several management strategies can be implemented. These include the creation of Biopore Infiltration Holes, construction of Detention Ponds and Retention Ponds, utilization of Paving Blocks/Grass Blocks, drainage maintenance (Normalization and Rehabilitation), provision of Green Open Spaces by at least 10%, and Community Participation.

In this context, Infiltration Wells and water reservoirs are not viable options due to limited space. Infiltration Wells require more significant space to accommodate rainwater volume, while water reservoirs are typically used for water storage rather than addressing drainage issues. New construction is also not recommended as it would increase land cover and exacerbate drainage problems. Effective management practices will help enhance rainwater infiltration into the soil, reduce surface water runoff, and control the flow of rainwater. Additionally, it is crucial to raise public awareness about the importance of environmental preservation and water conservation to create a sustainable environment.

Data Comparison

Data comparison is conducted to understand the similarities and differences between previous research data and the study conducted in the research location. This allows the identification of similarities and differences, leading to appropriate management that can be implemented in the study area.

Based on previous research and the study location, there is similarity regarding the capacity of drainage channels that cannot accommodate maximum flood discharge, causing significant impacts on ecology, economy, and society. Effective management is required to maintain ecological functions, support economic growth, and preserve social well-being. The ecodrain method emerges as a potential ecological and environmentally friendly alternative, including the use of infiltration wells, detention or retention ponds, biopore infiltration holes, paving blocks, and grass blocks. Community participation and education in the study area are crucial factors in the success of drainage management.

In the effort to manage drainage in the study area, the use of detention and retention ponds, biopore infiltration holes, paving blocks/grass blocks can still be applied since detention and retention ponds temporarily hold water and then gradually release it, allowing it to infiltrate into the soil. Biopore infiltration holes are highly effective in enhancing rainwater percolation into the soil and improving water circulation around plant roots. Paving blocks/grass blocks enable rainwater to seep into the soil, reducing surface water runoff. However, infiltration wells and water reservoirs cannot be implemented in the study area due to the need for more significant space to accommodate a significant volume of water in limited land.

DOI: https://doi.org/10.47667/ijpasr.v4i4.259

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According to Minister of Public Works Regulation No. 12 of 2014, drainage management can be done by building channels, repairing channels, increasing channels, extending channels, diverting flows, implementing polder systems, elongated storage ponds, retention ponds, detention ponds, and water reservoirs. In this case, the drainage management plan in the study area to address floods and/or inundation aligns with Minister of Public Works Regulation No. 12 of 2014, focusing on channel repairs (maintenance/normalization/rehabilitation) and the construction of retention and detention ponds.

Based on the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency Regulation No. 14 of 2022, Green Open Spaces (RTH) are divided into Public RTH and Private RTH. RTH should constitute at least 30% of the total area of the city or urban area, with Public RTH comprising at least 20%, and Private RTH comprising at least 10%. Infrastructure Drainage Management in the study area, including the provision of 10% Green Open Spaces on each private land, aligns with the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency Regulation No. 14 of 2022.

Conclusion

Based on the comparative analysis above, the appropriate management in Medan Sunggal District involves the construction of detention and retention ponds, the creation of biopore infiltration holes, the use of paving blocks/grass blocks, maintenance (normalization and rehabilitation), the provision of 10% Green Open Spaces, and the active participation and support of the local community.

The conclusions of this research are as follows:

The increase in the population from 2012 to 2021 affects population density in Medan Sunggal District. Lalang Subdistrict has the highest population density compared to other subdistricts. The increase in population density lowers the quality of groundwater, causes water pollution, damages drainage infrastructure, triggering floods, and the spread of diseases. Rainfall in Medan Sunggal District cannot be accurately predicted, but the rainfall intensity tends to be in the category of heavy to extreme rain. Certain months have higher rainfall than others. The drainage system in Medan Sunggal District includes: (1) Having a network drainage channel pattern. (2) Types of channels in the study location are primary, secondary, and tertiary channels. (3) Consisting of man-made channels with open concrete construction. (4) Located above ground level with a combined drainage system. (5) Most of its physical conditions are good, but some experience minor damage. (6) Most of the drainage water conditions are in a flooded state. d. Areas that often experience floods are 41%, areas that rarely experience floods are 43%, and areas that have never experienced floods are 16%. Proper management is required to address drainage issues in Medan Sunggal District, including providing green open spaces, creating biopore infiltration holes, building detention and retention ponds, using paving blocks/grass blocks, maintaining (normalization and rehabilitation) drainage, and involving the community in every aspect of management.

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