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The Green Infrastructure Model Based On Waterlogging Mitigation In The Street Landscape Of Sungai Penuh City, Jambi Province

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Abstract:
Background*: In many cases, the planning of public and social space in Indonesia is not accompanied by the planning of green open space, which is their functions as a healthy environmental balancer. One of the public spaces is the street landscape. This results in to the impact of natural phenomena such as floods, waterlogging in the rainy season, and hot weather in summer. The purpose of this study is to provide an overview of the Green Infrastructure model of roads, can also function as a place to anticipate waterlogging, flooding, air quality improvement, and human-friendly designation.*
Materials and Methods*: The methodology was carried out through field inventory, mapping based on Shp ArcGis data, and a modified literature study. The location of the research is on roads spread across 8 sub-districts of Sungai Penuh City, Jambi Province.*
Results*: Based on government administration and axis content, the public roads of Sungai Penuh City are categorized into class III Provincial Roads. The number of road sections in Sungai Penuh City is 49 (forty-nine) road sections. The details are that the primary collector road landscape consists of 11 road sections, the secondary collector road landscape consists of 12 road sections, and the local road landscape is very dominant, which is as many as 26 roads. The total length of the entire Sungai Penuh City road section is 51.43 km with an average width of 6 meters. Based on the level of urgency, the results of the assessment of priority sub-districts determined 31 road sections spread across Sungai Penuh District, Sungai Bungkal District, and Pondok Tinggi District as priority sub-districts for the implementation of the Green Infrastructure system. Based on hydrological calculations of rainfall for the last 20 years (2003-2023).*
Conclusion: *The Green Infrastructure Model is prioritized for 3 sub-districts. Based on the assessment of the Green Infrastructure Implementation Indicator, two green infrastructure concepts are applied, namely Green Stormwater Infrastructure 1 (GSI 1) and Green Stormwater Infrastructure 2 (GSI 2) which are equipped with the Complete Street concept. The GSI 1 system is applied on 24 roads in Sungai Penuh City using the Stormwater Tree Trench and planter. The GSI 2 system consisting of Stormwater Bump-Out, Stormwater Tree Trench, and Stormwater Planter and the Complete Street concept will be applied on 7 roads in Sungai Penuh City.*
Key Word*: Run-off, Ecology, Green Infrastructure, Complete Street, Stormwater Management.*

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I. Introduction

Based on the 2021-2026 Sungai Penuh City Regional Medium-Term Development Plan, the concentric structure of Sungai Penuh City tends to lead to an integrated sectoral mixing pattern without zoning whose boundaries are not so clear. Activities with a high concentration occur in the city center, such as trade activities, offices, hospitality, tourism, education, and health. The street landscape of Sungai Penuh City as a circulation space area is a space affected by this less than optimal urban planning. That areas built without careful planning can potentially cause discomfort to its residents[1]. The factor of increasing the population is also a primary factor in the increase in land needs. The results have an impact on decreasing environmental quality such as environmental degradation and natural disasters, for example the occurrence of waterlogging on the road body in the rainy season (Yetty et al. 2018), then in terms of comfort, the unsafe existence of pedestrian and bicycle paths, makes people tend to use motorized vehicles and has an impact on air pollution[2].

In the coming centuries, city streets will have multiplied challenges in terms of quantity and complexity. The growth of the urban population will demand that the streets not only serve as corridors for the

transportation of people, goods, and services, but as front yards, a small park, playground, and public space. Streets must accommodate a series of needs in order to continue to develop. In addition to accommodating comfort, roads must also be safe, resilient, economically profitable, traffic-accommodating, and sustainable[3]. Streets are the source of people's livelihood and the foundation of the urban economy. Street landscapes make up 80 percent of public spaces in urban areas. Street landscapes have the potential to encourage business activities. The vital role of roads for urban life is influenced by a design approach that is sensitive to the diverse roles of roads in cities[3].

Currently, there are three types of road networks spread across Sungai Penuh City, the three types of roads are divided into primary collector roads, secondary collector roads, and local roads. The scattered road sections do not have an integrated green lane system and pedestrian space. To suppress the monotony and make the road circulation look fresh, the Sungai Penuh City government built a green open space in the form of a green lane median of the road and a footpath or pedestrian path. The median green lane of the road divides the primary and secondary collector roads into two lanes. The existence of the median green lane along the collector's road in the center of Sungai Penuh City does not support climate amelioration and the process of water absorption into the soil in the rainy season. Aesthetically, the physical plants on the road median are also poorly maintained. Several points of the median green lane body of the road were also damaged. The existence of pedestrian paths also does not help pedestrians to be safe on the road, because the area is widely used for trading, both by motorcyclists and street vendors. To answer the above problems, Green Infrastructure in the street landscape in the city of Sungai Penuh needs to be studied to minimize this imbalance, Green Infrastructure is expected to be part of the positive impact of the rapid development of built space and social space. The implementation of green infrastructure is described in the Ecological Security Pattern (ESP). The city's ecological security pattern consists of a security pattern against water and flood problems, air, geological disasters, biodiversity, cultural heritage, and recreation[4].

II. Material And Methods

The research location is centered in Sungai Penuh City, Jambi Province. This research was conducted from November 2022 to March 2023. Based on the direction of the research boundary marked in red (Figure 1), the research area only covers low-lying areas in Sungai Penuh City with an altitude of 500 to 1000 meters above sea level (BPS Kota Sungai Penuh 2022). Four villages in the highlands with an altitude of more than 1000 mpdl marked in yellow were not included in the study area. The lowlands (red) in the center of Sungai Penuh City are focused on research because lowland areas are often targeted by floods and waterlogging. The limitations of the study focus on the classification of Sungai Penuh City roads based on their functions, namely: primary collector roads, secondary collector roads, and local roads.

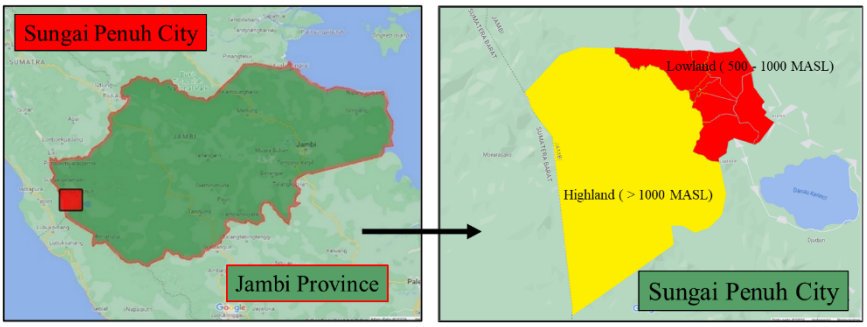


Figure no 1. Map of Research Locations

Tools and materials: The tools used for this research are laptops, mobile phones, supporting applications such as ArcGIS 10.8, AutoCAD 2018, Photoshop, Sketchup, and Microsoft Office. The materials used are direct inventory data and literature studies related to the theme of this research.

Data collection: Data collection is carried out in several stages. The first stage is a literature study. The literature study aims to obtain information related to Green Infrastructure and guidelines for the practice of Green Infrastructure products that will be implemented in Sungai Penuh City. After seeking information about the type of Green Infrastructure, the second stage process was carried out, namely making limits on the research area. The third stage is the observation of the type of road in Sungai Penuh City using references from google maps or openstreet maps. The street landscape was processed using the Arcgis 10.8 and Autocad 2018 applications. Based on its function, the public roads of Sungai Penuh City are divided into Primary Collector Roads, Secondary Collector Roads, and Local Roads.

Data analysis: The first stage of data analysis is to mapping roads in Sungai Penuh City using secondary data such as googlemap.com and openstreetmap.com. The road data is equipped with Sungai Penuh City shp data and then processed using the Arcgis 10.8 and AutoCad 2018 applications. Based on the shp data, Sungai Penuh City roads can be identified as Primary Collector Roads, Secondary Collector Roads, and Local Roads.

The second stage is to determine the Green Infrastructure Design Priority District. Each street in Sungai Penuh City is given a ranking of the priority assessment of the road landscape design of Sungai Penuh City. Each street is represented by one sub-district. The assessment indicators needed are priority indicators developed from flood vulnerability and population density indicators. Flood vulnerability indicators are processed from data on the slope slope of Sungai Penuh City, land use or land cover data of Sungai Penuh City, and rainfall data of Sungai Penuh City[5]. Three data were processed using Arcgis 10.8 software and then overlayed to produce a Flood Vulnerability Map in Sungai Penuh City. The second indicator is the condition of population density in Sungai Penuh City. Population density data was obtained from BPS data for Sungai Penuh City and Regulation of the Head of BPS No. 37 of 2010 concerning Urban and Rural Classification in Indonesia. Both data were processed using Arcgis 10.8 and produced a Population Density Map (people/km^2). The Flood Vulnerability Map and Population Density Map are then overlayed to produce a Green Infrastructure Design Priority Map for the Sungai Penuh City Street Landscape.

The third stage is to analyze the Road Landscape in the Priority District of Sungai Penuh City. The items analyzed were soil type distribution, road landscape drainage, social landscape, hydrological analysis uses four rainfall distribution methods. The fourth stage is to provide recommendations for the Green Infrastructure Model of the Road Landscape in Sungai Penuh City which will be applied to the landscape of road sections in the priority districts of Green Infrastructure. Each road in the priority sub-district is grouped into three types of roads, Primary Collector, Secondary Collector, and Local. Three types of roads are assessed using the Likert scale, namely High (3), Medium (2), and Low (1). This number is then made a range from the highest and lowest scores. Each road will get a score in the category of implementing two Green Infrastructure concepts, namely, a score of 6-11 for Green Stormwater Infrastructure 1 (Stormwater Tree Trench, Paving Block Permeable), and a score of 11-15 for Green Stormwater Infrastructure 2 (Bump-out, Stormwater Tree Trench, Planter, Paving Block Permeable) or GSI complete and there are paths that will be applied to the Complete Street concept.

Table no 1: Indicators of the Implementation of Green Infrastructure on Sungai Penuh City Roads

No.	Indicator	Assessment Scale	Source
1	Population Density	Height (3) Medium (2) Low (1)	*Downtown Core Area*
2	Waterlogging Levels	Height (3) Medium (2) Low (1)	*Designing Rain Gardens in London 2015*
3	Commercial Level Area	Height (3) Medium (2) Low (1)	*Downtown Core Area, Montgomery County Complete Street*
4	Possible Plant Paths	Height (3) Medium (2) Low (1)	*Montgomery Complete Street, Complete Street by Nacto*
5	Road Width (Existing)	Width from 10 meters (3) Enough with 10 meters (2) Narrow from 10 meters (1)	*Complete Street by Nacto, Montgomery Complete Street, Philadelphia Complete Street*

III. Result And Discussion

Priority District for Green Infrastructure Landscape of Sungai Penuh City Road

In accordance with the Law of the Republic of Indonesia Number 38 of 2004 concerning Roads and Government Regulation Number 34 of 2006 concerning Roads, then in accordance with the authority/status, based on government administration, the public roads of Sungai Penuh City are categorized into Provincial Roads. Based on the Axis Load Class, Sungai Penuh City's public roads are included in class III roads (BPS 2022)[6]. Class III roads mean local and environmental roads that can be passed by motorized vehicles, including those with a width not exceeding 2100 mm, a length size not exceeding 900 mm, and a maximum weight of 8 tons. Based on its function, the public roads of Sungai Penuh City are divided into Primary Collector Roads, Secondary Collector Roads, and Local Roads. Based on the explanation above, the categories of roads in Sungai Penuh City were obtained by following the research limits. The number of road sections studied in the lowlands of Sungai Penuh City is 49 road sections. The details are that the primary collector road landscape consists of 11 road sections, the secondary collector road landscape consists of 12 road sections, and the local road landscape

is very dominant, which is as many as 26 roads. The total length of the entire Sungai Penuh City road section is 51.43 km with an average width of 6 meters.

Primary Collector Roads is the main road in Sungai Penuh City. This road network runs longitudinally from the north of Sungai Penuh City (Pesisir Bukit District) to the south of Sungai Penuh City in Kumun Debai and Tanah Kampung Districts. The Sungai Penuh Primary Collector Road consists of 11 road sections, has an average width of 5 meters, and a total length of 23.09 km. Secondary Collector Road is the second collector road built in Sungai Penuh City. The function of this secondary collector road is as an alternative route for the development of the primary collector road in Sungai Penuh City. Secondary collector roads play a role in dividing the density of vehicle flows in the center of Sungai Penuh City. Based on the 2021-2026 Sungai Penuh City Regional Medium-Term Development Plan, secondary collector roads are part of the Sungai Penuh City ring road. Local roads are the first access for the people of Sungai Penuh City in their activities. Most of the local roads are in densely populated residential areas. There are 25 local roads in Sungai Penuh City, with a road width of 4 m with a total length of 15.23 km. The assessment of the Green Infrastructure priority sub-district aims to determine which areas must be handled to prevent inundation and flooding that occur in the Sungai Penuh City road landscape. The indicators used are flood vulnerability data and population density data. These two data are presented in the form of a Flood Vulnerability Map and a Population Density Map in Sungai Penuh City.

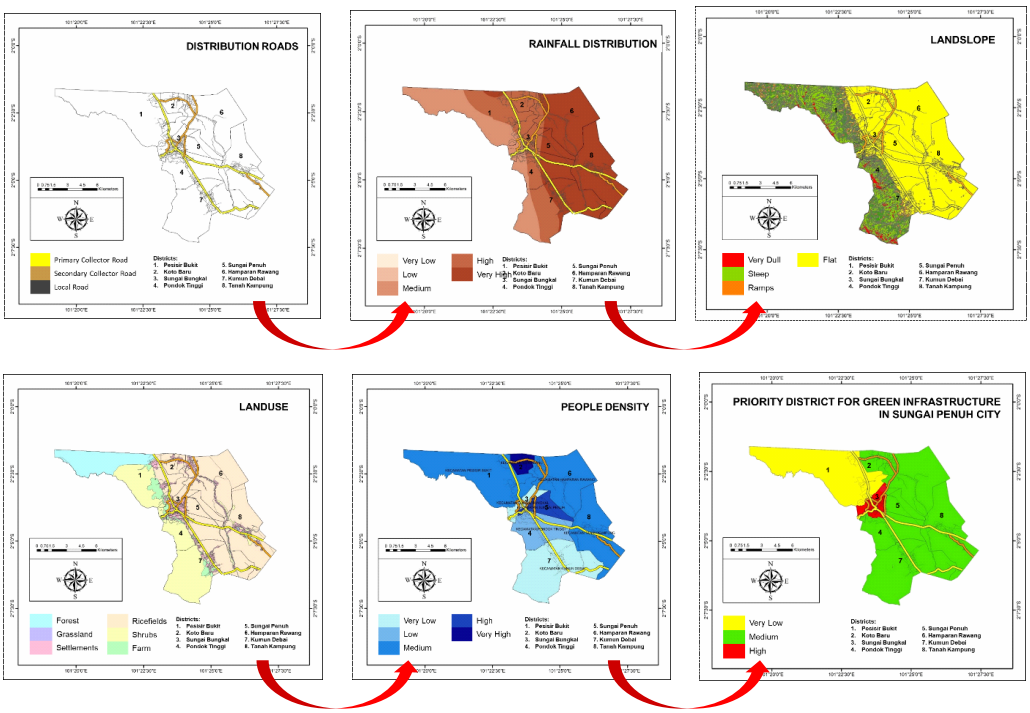


Figure No 2. Map of the Process for Determining Green Infrastructure Priority Districts for Sungai Penuh City

The results of processing the Climate Hazards Group InfraRed Precipitation with Station data or CHIRPS for Sungai Penuh City, obtained information on annual rainfall in Sungai Penuh City. The classification of rainfall is represented by five criteria. The number 2800 (Very Low), the number 2900 (Low), the number 3000 (Medium), the number 3100 (High), and the number 3200 (Very High). Rainfall data processing using Arcgis 10.8 with the IDW method. Processing with the IDW method is quite representative if an area does not have a meteorological station. Based on the data above, the roads affected by the highest rainfall are roads in the sub-districts, namely Pondok Tinggi and Tanah Kampung, the roads affected by high rainfall are Jalan Collector Primer Kumun Debai and Pondok Tinggi District. Rainfall with moderate criteria passes through the roads of Pesisir Bukit District, followed by roads in Pondok Tinggi District. Most of the collector roads affected by moderate rainfall are on roads in Hamparan Rawang and Koto Baru Districts, a small part is in Sungai Penuh District, and Sungai Bungkal District.

The results of processing DEMNAS images from the USGS or United States Geological Survey were obtained from the slope of the land of Sungai Penuh City. About 52.59% of the area is at an altitude of more than 1000 meters above sea level, making Sungai Penuh City the highest city on the island of Sumatra. The average city altitude is at 500 – 1000 m above sea level (masl). The geographical conditions of Sungai Penuh City are quite diverse. About 12.3% of the city area is on relatively flat land, 28.2% is hilly land, and there is

24.3% land with steep slopes. The city center is located on a valley plain surrounded by hills to the West, North and East. Based on the scope of the research, most of the slope conditions in the center of Sungai Penuh City are flat with a slope of 0-8%. The sub-districts that enter the flat land are Sungai Penuh District, Tanah Kampung District, Hamparan Rawang District, and Tanah Kampung District. With flat land, in these 4 sub-districts there is often land cover in the form of rice fields, patches of shrubs in rice fields, and residential areas. The road network is also mostly located in this flat area.

Table no 2. Landuse of Sungai Penuh City

No.	Item of Landuse	Total Area (hectares)	Percentage (%)
1	Forests	7,128	14.91
2	Settlements	5,376	11.25
3	Farm	2,039	4.27
4	Rice fields	21,381	44.73
5	Shrubs	11,875	24.84
Total		47,799	100

The results of the processing of the Shp image of Sungai Penuh City from the Geospatial Information Agency, classify the land use or land cover in Sungai Penuh City. The land surface of Sungai Penuh City by the community is divided into five types of land cover. The five land covers are Forest, Settlements, Rice Fields, Shrubs, and Farms. The type of land cover that dominates Sungai Penuh City is a rice field landscape with a total area of 21,381 hectares. If percentaged, the rice field landscape has an area of 44.73 percent of the research area of Sungai Penuh City. The second area that dominates is the Bush cover with a total area of 11,875 hectares. This means that the area of the bush covers 24.84 percent of the total research area of Sungai Penuh City. The moor/field area is the smallest area with an area of only 4.27 percent of the total area of Sungai Penuh City (Table no 2). If it is projected on the road network in Sungai Penuh City, then the road sections are more in the middle of community settlements and rice fields. The pattern of settlements and buildings of the people of Sungai Penuh City tends to develop from the roads, after which they develop another land cover, namely the rice field landscape.

The assessment of the priority design of the Green Infrastructure design of the Sungai Penuh City street landscape is also influenced by the number of residents. The population of Sungai Penuh City in 2021 is 97,770 people. The male population is 48,947 people, and the female population is 48,823 people. The average population density of Sungai Penuh City in 2021 is 249.73 people/km^2, where the highest population density is in Koto Baru District at 5,616.46 people/km^2. Meanwhile, the smallest population density is in Kumun Debai District at 72.35 people/km^2. The dense population in Sungai Penuh District is due to the existence of the sub-district as the central point of the local government. The dense population in Koto Baru District is caused by the sub-district being a transitional area from Sungai Penuh City to Air Hangat District in Kerinci Regency. Most of the people of Sungai Penuh City carry out activities such as trading, entrepreneurship, services, private/public offices, civil servants, and farming. These activities are linked to the existence of the primary collector and secondary collector road network

The Population Density Indicator and the Flood Vulnerability Indicator produce a priority Map scale for the Green Infrastructure of the roadscape in Sungai Penuh City. The three scales are Low Priority, Medium Priority, and High Priority. These three priority scales are shown in the Green Infrastructure Design Priority Map for the Sungai Penuh City Street Landscape. The road sections that received medium and low priority values were Pesisir Bukit District, Kumun Debai District, and Tanah Kampung District. The low priority value is in Pesisir Bukit District, because it is dominated by forest cover. High priority that is influenced by high population density (people/km^2) and dominated by residential land cover is in Sungai Penuh District, Sungai Bungkal District, and Pondok Tinggi District. Based on the assessment of the priority of the desig31 out of 49 road sections spread across three sub-districts are priority areas for the implementation of Green Infrastructure. The three sub-districts are Sungai Penuh District, Sungai Bungkal District, and Pondok Tinggi District.

Analysis of Road Landscape in Sungai Penuh City Priority District

Based on data from DEMNAS-USGS or the United States Geological Survey, the center of Sungai Penuh as a research boundary area located in the lowlands is an area dominated by Fluvisol soil. This is because the lowland area of the center of Sungai Penuh City is surrounded by watersheds, thus allowing this city to be dominated by Aluvial land (Figure no 3). Aluvial Soil is a mixture of clay with fine black and gray sand, so it has a high potential for mineral and organism content[7]. This kind of property causes alluvial soil to have good water retention and absorption. This land form also has soil material that is quite fine to coarse so that the water absorption capacity is quite diverse[8]. According to the World Reference Base for Soil Resources (WRB), fluvisol is genetically included in young soils found in alluvial deposits[9]. Aluvial soil is classified as young soil, which is formed from fine deposits in river flows, has a solid soil structure and is classified as clay or sandy clay

with a sand content of less than 50%. Aluvial soil has benefits in the agricultural sector, one of which is to facilitate the irrigation process on agricultural land and has a relatively high nutrient content[10].

The drainage channel of the road landscape in Sungai Penuh City is located on the same path, which is under the pedestrian path. Information obtained from the Sungai Penuh City Green Garden Master Plan Preparation Document states that the lack of infiltration areas, siltation of sediment in drainage channels, the number of sand particles and garbage are the causes of drainage channel blockages. High rainfall is also the cause of water discharge in drainage channels also increasing (secondary inlet). The increased water discharge also comes from the primary inlet, namely a network of small rivers from the hills of Sungai Penuh City, to the secondary outlet (Sungai Bungkal River) and the primary outlet (Batang Merao River). In the central part of the city of Sungai Panjang, the existing urban drainage network empties into the nearest outlet, namely Sungai Bungkal. In the eastern part of Sungai Penuh City, which is lower in topography than the western part of Sungai Penuh City, urban drainage leads to the nearest outlet, namely the Batang Merao River (Figure no 3).

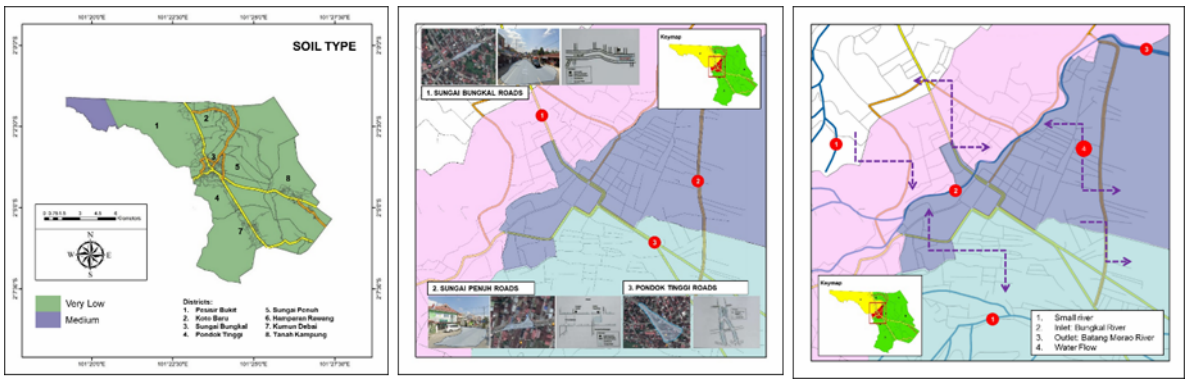


Figure no 3. Soil Type (Right), Runoff and flood point (Center), and Waterflow existing (Left)

The primary collector road of Sungai Penuh is the road with the busiest traffic volume flow every day. Traffic flow volume points occur at 07.00 am and 17.00 pm. Most of the vehicle flow is in Sungai Penuh District (city center), namely, Jalan Muradi, Jalan Diponegoro, Jalan Imam Bonjol, Jalan Jenderal Sudirman, and Jalan RE Martadinata. From 07.00 to 17.00 is the highest time for the intensity of community activities. In terms of design and design, the road markings are not clear and the width of the sidewalks is very narrow with a width of less than 0.20 cm and a height of about 40 cm. The narrow width of the pedestrian creates a non-safety atmosphere. The condition of the pavement paving block is not visible in its original formation and tends to be closed. There is no zoning of business spaces, businesses, shops, offices, schools, and the large number of vehicles makes the condition of the road landscape experience congestion at certain points. The pattern of people who still prioritize the use of private vehicles makes the streets of Sungai Penuh City more dominated by motorized vehicle users. Sidewalks are also used by street vendors and as a parking lot for vehicles for roadside building business actors. As a result, the street landscape of Sungai Penuh City has been chaotic for some time, crowded with pedestrians, motorized vehicle users, and buying and selling activities on the roadside. This condition certainly limits pedestrians from using this infrastructure. Several points of the median green lane body of the road also suffered damage in terms of physical and vegetation. This is due to the behavior of people who like to cross the road carelessly, step on plants, and take the plants.

The rainfall data used was obtained from online data from the Methodology, Climatology and Geophysics Agency (BMKG) of the Depati Parbo station for the Kerinci Regency and Sungai Penuh City areas. The daily rainfall used is the last 20-year period from 2013 to 2023. Sungai Penuh City with an area of 391.5 km² is included in the Medium/Small City so the reage used is 5 to 10 years. The calculation of planned rainfall is carried out using a reage of 2, 5, 10, 25, 50, and 100 years. The return *period* is a hypothetical time when the occurrence of rain is equal to or exceeded by a certain amount. This means that rain with a 10-year recurrence does not mean that it will occur every 10 years, but it has the possibility that it will occur repeatedly in a certain period of time[11]. After obtaining the planned rainfall with the four methods, matching and comparison with probability distribution parameters are carried out as a condition for the permissible use of the distribution type (Table no 4).

Table no 3. Planned rainfall frequency result (mm)

Rain recalculation (year)	**Rainfall Plan (mm)**			
	Log Normal	Gumbel	Log Pearson III	Normal
2	74.70	71.19	264.91	74.70
5	79.69	96.30	368.27	79.69
10	82.30	112.95	458.72	82.30

50	84.43	128.91	734.78	84.43
100	86.87	149.57	889.67	86.87

Source: Calculation results

Table no 4. Requirements for the type of rainfall distribution

Spread Name	Condition	Calculation Results		Information
Gumbel	Cs ≈ 1.14	Cs =	145,327,737,319.43	no
	Ck ≈ 5.4	Ck =	129,658,761,641,870,000.0 0	no
Log Pearson III	Cs ≠ 0	Cs =	1.08	approach
	Cv ≈ 0.05 or other than this value	Cv =	0.06	approach
Normal	Cs ≈ 0	Cs =	0.19	no
	Ck ≈ 3	Ck =	0.33	no
Log Normal	Cs ≈ 0.43	Cs =	1.08	no
	Ck ≈ 3.33	Ck =	6.20	no

Source: Calculation results

Based on Table no. 4, the Pearson III Log method was chosen because it meets the requirements for the use of the spread type. The Pearson III Log Method is almost not theoretically based so it can be used for almost all empirical probability distribution data. Pearson III logs are commonly used to analyze planned flood discharge, planned rainfall, and annual average rainfall. This test is conducted to see if the match of the distribution of opportunities is expected to describe or represent the distribution of those frequencies[11]. So that the planned rainfall value used is 458.72 mm per 10 years. The calculation of the number of reservoirs is known after using the sketchup application (Table no. 5). Yos Sudarso road has a large number of tubs influenced by the road area factor so that it can store a large amount of water. The amount of water in each reservoir on this road is small due to the dimensional factor of the reservoir. In contrast to Diponegoro street, the dimensions of the reservoir are affected by the area of the road, and Diponegoro street has wider road dimensions than Yos Sudarso street. Jalan Kamarudin and Jalan Lima Lurah have a volume of water in each reservoir and the little water harvest is also caused by the dimensions of the road. The dimensions of the road affect the number of reservoirs and the dimensions of the reservoirs.

Recommendations for Green Infrastructure of Sungai Penuh City Road Landscape

In this recommendation, two Green Infrastructure concepts are described, namely Green Stormwater Infrastructure 1 and Green Stormwater Infrastructure 2 or GSI complete because there will be a path that will be applied to Complete Street concept. Based on the assessment of the priority sub-district for the design of Green Infrastructure for the road landscape in Sungai Penuh City, 31 road sections were obtained spread across the three sub-districts. The three sub-districts are Sungai Penuh District, Sungai Bungkal District, and Pondok Tinggi District. The GSI 1 system applied in 24 roads in Sungai Penuh City consists of a Stormwater Tree Trench and a planter. Finally, the GSI 2 concept consisting of Stormwater Bump-Out, Stormwater Tree Trench, and Stormwater Planter and equipped with the Complete Street concept will be applied on 7 sections of Kota Sungai Penuh roads.

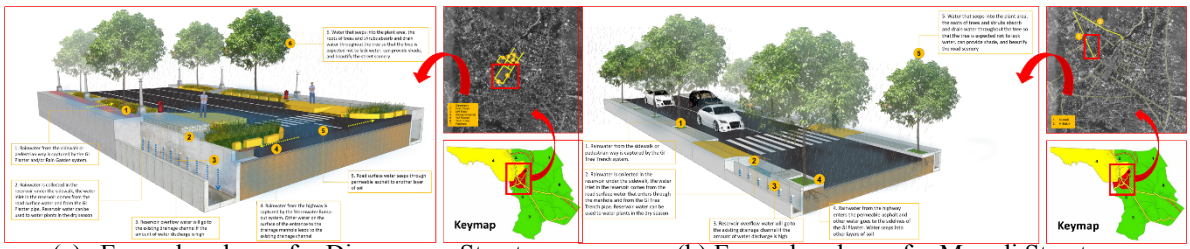
The component in this recommendation consists of hardscape elements consisting of existing drainage channels, reservoir basins, Paving Block Permeable, and Asphalt Permeable. While the softscape element consists of vegetation, trees and shrubs. Permeable Paving Block is a type of GI that has a material surface that absorbs water freely. This method can eliminate or reduce water runoff compared to waterproof road materials. Technically, the surface of the Permeable Paving Block is added with stone elements below the surface, this system provides structural support to the pavement that can temporarily hold rainwater[12].

Rainwater that falls, enters through manholes or inlet holes to the reservoir basin. The reservoir basin is placed under the pedestrian path, next to the existing drainage channel. The reservoir tub is designed with molded concrete in the form of a block with dimensions following the width of each road section. Rainwater and runoff will be helped to be absorbed by plants and soil engineering layers before heading to the reservoir basin. If the amount of water discharge is high, the overflow water from the reservoir will go to the existing drainage channel. The reservoir uses the principle of rainwater harvesting, so that water can be used to water plants during the dry season. Drainage channels use a combined sewer overflow (CSO) system, which is a system where drainage channels receive runoff and household waste disposal[13]. In addition to coming from excess runoff water that cannot be absorbed by the Green Infrastructure system, the water in the reservoir basin also comes from nearby water sources such as PDAM or Drinking Water District Center pipes. This can help the availability of water discharge to water the plant in the dry season.

Soft elements are divided into two groups, namely the tree group in the GI Tree Trench system and the Rain Garden shrub group in the GI Planter system. The existence of trees is very important in protecting the

environment. Tree vegetation contributes to reducing flood risk and erosion control by absorbing runoff, and reducing the rate of water inflow. Roots create additional soil pores and can break down dense sub-soils, improving drainage and water-holding capacity[14]. Trees are elements whose appearance individually or in groups can affect visual appearance and give different impressions from different observation distances of a landscape[15]. The presence of trees in urban environments fulfills three main functions, namely (1) structural functions, as walls, roofs, and floors in forming space and can affect the scenery and direction of movement; (2) environmental functions, improving air and water quality, preventing erosion, and playing a role in climate modification; (3) visual function, as the dominant point and visual link through the characteristics of plants such as shape, size, texture, and color[16].

Tree plants with branches that are more than 2 metres tall can provide shade and resist the glare of sunlight for pedestrians[17]. Trees can be placed on plant paths with a width of at least 1.5 m, the shape of the trunk branching is not drooping, dense leaf masses and planted in rows. The air temperature in the shadow of the tree canopy can be 8°C lower than in an open space[18]. This condition is ideal for highway users, especially for pedestrians. the surface temperature of the elements under the canopy of trees can reach 28-29°C[19], the surface temperature of shrubs can reach 28-33°C, and the surface temperature of ground cover plants and grasses can reach 35-36°C compared to the surface temperature of asphalt reaches above 50°C. Good tree vegetation in green open spaces in urban areas, namely tree vegetation that has the characteristics of a wide canopy, a high canopy and small canopy porosity. Vegetation must pay attention to the types of trees that will provide ecological services to green open spaces, because the quality of green open spaces will depend on the growth of trees in green open spaces. Things that can affect the quality and quantity of green open space are the size of the tree, the shape of the canopy, and the color during its growth[20].



(a) Example schema for Diponegoro Street (b) Example schema for Muradi Street

(c) Example Schema for Yos Sudarso Street

Figure no 4. Schema system of Green Stormwater Infrastructure

Table no 5. Reservoir needs and Green Infrastructure Implementation Indicators for roads in Sungai Penuh City

Roads	A	B	C	D	E	Green Infrastructure Implementation Indicators					∑	Rank	GSI
	m^2	m^3	tank	m^3	Mm/month	P	Q	R	S	T			
Diponegoro	4,281	416.16	28	15	0.5	3	3	3	3	3	15	1	GSI 2
Imam Bonjol	4,080	396.61	48	8	0.28	3	3	3	3	3	15	2	GSI 2
M HA Thalib	3,222	313.21	64	5	0.16	3	2	3	2	3	13	3	GSI 2
Sisingamangaraja	1,447	140.64	28	5	0.17	3	2	3	2	3	13	4	GSI 2
Teuku Umar	4,171	405.44	76	5	0.18	3	2	3	2	3	13	5	GSI 2
Dr. WS Husodo	1,189	115.56	24	5	0.16	3	2	3	2	3	13	6	GSI 2
Pattimura	2,566	249.46	48	5	0.17	3	2	3	2	3	13	7	GSI

													2
RE Martadinata	5,565	540.93	144	4	0.13	3	1	1	3	3	11	8	GSI 1
Depati Parbo	4,140	402.41	168	2	0.08	2	3	2	2	2	11	9	GSI 1
Pancasila	3,170	308.12	132	2	0.08	2	3	2	2	2	11	10	GSI 1
Sriwijaya	2,014	195.72	36	5	0.18	2	2	1	3	3	11	11	GSI 1
Yos Sudarso	25,600	2,488.32	600	4	0.14	2	2	1	3	3	11	12	GSI 1
KH. Wahid Hasyim	2,814	273.49	132	2	0.07	3	2	3	2	1	11	13	GSI 1
Jend Ahmad Yani	6,106	593.48	72	8	0.27	2	1	2	3	3	11	14	GSI 1
Prof M Yamin	5,137	499.29	240	2	0.07	3	2	3	2	1	11	15	GSI 1
H. Agus Salim	2,234	217.17	132	2	0.05	3	2	3	2	1	11	16	GSI 1
Proklamasi	1,308	127.13	60	2	0.07	3	2	3	2	1	11	17	GSI 1
Arif Rahman Hakim	6,940	674.61	300	2	0.07	3	2	3	2	1	11	18	GSI 1
MH Thamrin	5,138	499.41	72	7	0.23	3	2	2	2	1	10	19	GSI 1
Hos Cokroaminoto	1,162	112.9	96	1	0.04	3	2	3	1	1	10	20	GSI 1
Muradi	6,240	606.53	240	3	0.08	2	2	2	2	1	9	21	GSI 1
H Bakri	5,283	513.53	252	2	0.07	2	3	1	2	1	9	22	GSI 1
H. Hasmi Muchtar	2,170	210.88	120	2	0.06	2	2	2	2	1	9	23	GSI 1
Gajah Mada	2,500	243	204	1	0.04	2	2	2	2	1	9	24	GSI 1
Jend. Sudirman	5,831	566.79	240	2	0.08	2	1	2	2	1	8	25	GSI 1
H Rusdi Sayuti	5,832	566.89	396	1	0.05	1	1	1	3	1	7	26	GSI 1
Usman Khalid	1,000	97.2	84	1	0.04	2	2	1	1	1	7	27	GSI 1
Kamarudin	2,000	194.4	204	1	0.03	2	2	1	1	1	7	28	GSI 1
Lima Lurah	962	93.55	96	1	0.03	2	2	1	1	1	7	29	GSI 1
Lingkungan 4	597	58.03	21	3	0.09	1	2	1	1	1	6	30	GSI 1
Depati Payung	1,334	129.63	48	3	0.09	1	2	1	1	1	6	31	GSI 1

Description: A: Street broad, B: Water stored on the street, C: Number of reservoirs, D: Water volume per reservoir number, E: Waterharvesting, P: Population Density, Q: Waterlogging Level, R: Commercial Level Area, S:Possible Plant Path, T: Road Width (Existing)

IV. Conclusion

Based on government administration, the public roads of Sungai Penuh City are categorized into Provincial Roads. Based on the Axis Load Class, the public roads of Sungai Penuh City are included in class III roads. Based on its function, the public roads of Sungai Penuh City are divided into Primary Collector Roads, Secondary Collector Roads, and Local Roads. The number of road sections in Sungai Penuh City is 49 (forty-nine) road sections. The details are that the primary collector road landscape consists of 11 road sections, the secondary collector road landscape consists of 12 road sections, and the local road landscape is very dominant, which is as many as 26 roads. The total length of the entire Sungai Penuh City road section is 51.43 km with an average width of 6 meters.

Based on the level of urgency, an assessment of the priority of implementing the Green Infrastructure system was carried out. The assessment was carried out in each sub-district. The results of the assessment determined 31 road sections spread across Sungai Penuh District, Sungai Bungkal District, and Pondok Tinggi District as priority sub-districts for the implementation of the Green Infrastructure system. The Green Infrastructure System is implemented in every primary collector road, secondary collector road, and local road in priority districts.

Based on hydrological calculations, the rainfall used is the last 20 years (2003-2023). The dimensions of the reservoir follow the area of the existing priority roads. The water that is stored can be used to water plants and other purposes in the dry season. The Green Infrastructure concept implemented is Green Stormwater Infrastructure 1 (GSI 1), and Green Stormwater Infrastructure 2 (GSI 2) which is equipped with the Complete Street concept. The GSI 1 system applied in 24 roads in Sungai Penuh City consists of a Stormwater Tree Trench and a planter. Finally, the GSI 2 concept consisting of Stormwater Bump-Out, Stormwater Tree Trench, and Stormwater Planter and equipped with the Complete Street concept will be applied on 7 sections of Kota Sungai Penuh roads.

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