



Resilience and Green Infrastructure Environmental Road Design and Disaster-Responsive Drainage in the Paser Urban Area According to Circular Letter of the Director General of Human Settlements 30/2020

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ARTICLE INFO	ABSTRACT
Published Online: 28 November 2025	The sustainable improvement of slum settlements is crucial, aligning with Minister of PUPR Regulation No. 2/PRT/M/2016. The settlement in Desa Muser, Muara Samu District, Paser Regency, East Kalimantan, designated as a slum by Paser Regent Decree No. 653/KEP-116/2021, faces extreme vulnerability to disasters, notably major floods with a distinct 5-year cycle. This risk is exacerbated by inadequate environmental roads and conventional drainage systems. This study aims to analyze the integration of Resilience and Green Infrastructure (GI) principles into the design of basic infrastructure within this specific area. The analysis is guided by the technical provisions outlined in the Director General of Cipta Karya Circular Letter No. 30/SE/DC/2020 (RP2KPKPK guidelines). The Resilience approach focuses on enhancing the settlement's capacity to swiftly recover from recurring flooding, while GI offers sustainable, nature-based solutions for managing water flow and reducing risks. The findings indicate that the environmental road design must prioritize emergency accessibility (supporting fire mitigation efforts) and utilize permeable paving materials to minimize surface runoff. Concurrently, the drainage system requires a shift from conventional structures to GI solutions, specifically integrating biopores and rain gardens. These nature-based elements are essential for localized rainwater harvesting and infiltration, effectively anticipating and managing the high-volume discharge associated with the 5-year flood events. The adoption of Resilience and GI design principles ensures compliance with regulatory standards for physical quality improvement while fundamentally enhancing the long-term resistance and adaptability of Desa Muser settlements against severe hydrometeorological disasters. This approach provides a robust framework for sustainable slum management in East Kalimantan's urban context.
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I. INTRODUCTION

The rapid urbanization across Indonesia has inevitably led to the proliferation of slum settlements, challenging the nation's commitment to sustainable development and equitable housing access. These areas are characterized by substandard housing, poor sanitation, and, critically, inadequate infrastructure that significantly increases community vulnerability to environmental threats. Addressing this challenge is a national priority, crystallized through the issuance of the Minister of Public Works and Housing Regulation Number 2/PRT/M/2016 concerning the Improvement of Slum Housing and Slum Settlements. This regulation provides the overarching legal framework for

regional governments to initiate comprehensive slum quality improvement programs.

The issue is particularly acute in Desa Muser, Muara Samu District, Paser Regency, East Kalimantan, an area officially designated as a slum location under Paser Regent Decree Number 653/KEP-116/2021. Beyond typical structural deficiencies, the Muser settlement is highly susceptible to recurring hydrometeorological disasters, notably severe floods that historically occur in a five-year cycle. The primary physical deficiencies contributing to this chronic vulnerability include outdated environmental road networks that impede emergency access and conventional, often clogged, drainage systems that fail to handle peak rainwater discharge, thus

exacerbating flood damage and slowing post-disaster recovery.

To effectively break this cycle of vulnerability and recurring damage, intervention must move beyond conventional physical rehabilitation. There is a critical need to integrate forward-looking concepts of Resilience and Green Infrastructure (GI) into the core infrastructure design—specifically for roads and drainage. This necessity aligns perfectly with the technical guidance provided by the Director General of Cipta Karya Circular Letter Number 30/SE/DC/2020. The SE emphasizes a holistic approach in the RP2KPKPK (Slum Housing and Settlement Prevention and Quality Improvement Plan), advocating for infrastructure solutions that are not only structurally sound but also environmentally sustainable and functionally adaptive to disaster risk.

Based on this urgent need for resilient and sustainable solutions, this article aims to analyze the integration of Resilience and Green Infrastructure principles into the design of the environmental road network and drainage system within the Desa Muser settlement. By referencing the framework of SE Dirjen Cipta Karya 30/2020, this study seeks to propose technical recommendations that transform vulnerable slum areas into resilient settlements, thereby minimizing disaster losses and ensuring long-term environmental sustainability in the urban areas of Paser Regency.

II. LITERATURE REVIEW

This literature review aims to identify, analyze, and synthesize literature relevant to the concepts of Resilience, Green Infrastructure, Environmental Road Design and Disaster Responsive Drainage, and their implementation in Urban Areas according to SE Dirjen Cipta Karya 30/2020, with a focus on case studies in Muser Village, Paser Regency.

1. Basic Concepts and Policy Framework

This section reviews the key definitions and principles underlying the research.

1.1. Understanding Urban Resilience

- Definition and Principles of Urban/Settlement Resilience: "Urban resilience is defined as the capacity of urban systems—including individuals, communities, institutions, businesses, and systems—to withstand, adapt, and recover from a range of stresses and shocks, both chronic and acute, and to maintain their essential functions (Rockefeller Foundation, 2016)."
- Disaster Vulnerability and Risk Assessment in Urban Areas: "The failure of physical infrastructure, such as roads and drainage systems, is a major contributor to the increased vulnerability of urban settlements to flooding. Rigid and non-adaptive designs exacerbate the impacts of disasters (OECD, 2018)."

1.2. Green Infrastructure (GI) as a Resilience Strategy

- Excerpt on the Function of GI in Rainwater Management:

"Green Infrastructure berfungsi meniru proses hidrologi alami dengan mengelola air hujan sedekat mungkin dengan sumbernya. Ini dilakukan melalui infiltrasi, evaporasi, dan penahanan, yang secara signifikan mengurangi volume run-off permukaan yang memicu banjir perkotaan (Ignatieva et al., 2019)."

-Quotes about GI and Nature-Based Solutions:

"The Green Infrastructure approach is seen as one of the most effective forms of Nature-based Solution (NbS) in urban contexts for climate change adaptation and disaster mitigation, offering multiple benefits (multi-functionality) compared to grey infrastructure (Cohen-Shacham et al., 2016)."

1.3. Review of Circular Letter of the Director General of Human Settlements No. 30/SE/DC/2020

-Excerpts on the Resilience Mandate in Circular Letter 30/2020:

"In the preparation of the Slum Prevention and Improvement Plan (RP2KPKPK), one of the aspects that must be achieved is the realization of settlements that are resilient to ecology and disasters. This includes planning basic infrastructure that can withstand the impacts of climate change, including adequate and adaptive drainage systems (SE Director General of Human Settlements No. 30/2020, Attachment II)."

2. Disaster-Responsive Road and Drainage Infrastructure Design

2.1. Environmental Road Design with Green Infrastructure Principles

-Quote on Permeable Pavement:

"The use of permeable pavement on environmental roads in densely populated residential areas has been shown to reduce runoff loads by an average of up to 60% compared to conventional pavements, while also helping recharge shallow groundwater (Ahiablame et al., 2012)."

2.2. Disaster-Responsive Drainage Systems (Eco-Drainage)

-Quote on the Bioswale Concept:

"A bioswale system is a green drainage element designed to slow the flow of water, filter pollutants through the growing media and vegetation, and encourage infiltration, which is crucial as a first-line defense against flash flooding in urban environments (Hunt & Doll, 22)."

3. Location Context and Gap Analysis

3.1. Characteristics of the Paser Urban Area and Muser Village

-Quote on Flood Challenges in East Kalimantan (regional context):

"Although Paser is part of East Kalimantan, intense rainfall patterns and land-use changes have increased the frequency and intensity of flooding in downstream areas, requiring conservation-based infrastructure solutions in residential areas (East Kalimantan Provincial Government, 2023 Disaster Report)."

3.2. Research Synthesis and Gap

- Research Needs Synthesis:
 "The adoption of Green Infrastructure Principles in environmental road and drainage design, which is explicitly directed at achieving resilient settlement status, as mandated by Circular Letter of the Director General of Human Settlements 30/2020, still requires a specific implementation model in the Paser area. This is a crucial need to transform planning documents into concrete actions (Researcher, 2024)."

III. RESEARCH METHODOLOGY

A. The Urgency of Slum Quality Improvement and Regulatory Framework.

The global discourse on Sustainable Development Goals (SDGs), particularly Goal 11, underscores the need for safe, resilient, and sustainable cities [1]. In Indonesia, the legal mandate to achieve "zero slums" is formalized under Minister of PUPR Regulation No. 2/PRT/M/2016. This regulation shifts the paradigm from simple relocation to comprehensive physical and non-physical quality improvement, targeting multiple aspects including housing quality, environmental roads, and drainage [2]. The operational guide for local governments is further clarified by the Director General of Cipta Karya Circular Letter No. 30/SE/DC/2020, which mandates the preparation of the RP2KPKPK. This technical guide ensures that local interventions are planned systematically and align with broader national standards, including disaster risk reduction [3].

Table 1. The Urgency of Slum Quality Improvement and Regulatory Framework for Muser Village Slum Area.

Aspect	Urgency in Muser Village Slum Area	Relevant Regulatory Framework (Indonesia)
1. Flood Vulnerability	Muser Village experiences cyclical 5-year flooding; existing basic infrastructure (environmental roads and drainage) cannot accommodate peak discharge	- PUPR Regulation No. 2/2016: Quality improvement of basic infrastructure (roads, drainage, sanitation) - Circular Letter 30/2020: RP2KPKPK must integrate disaster-risk mitigation
2. Degraded Environmental Roads	Earthen/gravel roads deteriorate due to runoff; impassable during	- PUPR 2/2016: Upgrading environmental roads including

	rainy seasons; limits mobility, logistics, and emergency access	structure, surface, and connectivity - RP2KPKPK (SE 30/2020): Strategic roads must support evacuation routes
3. Inadequate Drainage System	Frequent inundation (30–50 cm+); high sedimentation; absence of secondary/covered drains; affects houses and public facilities	- PUPR 2/2016: Drainage improvement as a primary slum indicator - SE 30/2020: Mandates risk-based drainage planning
4. Poor Settlement Layout and Spatial Quality	Irregular building patterns; lack of infiltration areas; high density accelerates runoff and reduces environmental resilience	- PUPR 2/2016: Building and environmental arrangement (layout, accessibility, KDB/KLB) - SE 30/2020: Risk zoning and limited relocation recommendations
5. Limited Green Infrastructure (GI)	Minimal infiltration spaces; no biopores/rain gardens; stormwater directly flows to the road surface	- PUPR 2/2016: Includes non-physical improvements such as environmental awareness - SE 30/2020: GI integration allowed as a quality-improvement strategy
6. Socio-Economic Impacts	Frequent disruptions to daily activities during floods; reduced mobility; potential household asset losses	- PUPR 2/2016: Enhancing quality of life and reducing social risk - SE 30/2020: Requires community participation in

		the RP2KPKPK process
7. Need for Integrated Planning	Absence of a dedicated technical plan leads to unsynchronized sectoral interventions	- SE 30/2020: RP2KPKPK must be prepared as the master document for slum-area improvement - PUPR 2/2016: Provides guidelines for physical and non-physical upgrading

B. Defining Urban Resilience

Urban Resilience is defined as the capacity of systems, communities, and structures within a city to survive, adapt, and grow despite chronic stresses and acute shocks [4]. In the context of the Muser settlement, a location vulnerable to major floods with a 5-year cycle, resilience translates to three key capabilities: (1) Resistance (ability to withstand the initial flood event), (2) Recovery (speed of returning to normal function), and (3) Adaptation (adjusting infrastructure design to future risks) [5]. Infrastructural resilience, therefore, is paramount, particularly for essential networks like roads and drainage that are crucial for post-disaster response and recovery, directly linking to the survival and safety of the population.

Table 2. Critical Role of Infrastructure Resilience for Post-Disaster Response and Community Safety

Infrastructure Component	Resilience Function	Post-Disaster Impact if Resilient	Consequences if Not Resilient	Relevance to Community Survival & Safety
1. Environmental Roads	Structural durability, accessibility during extreme weather	vacuation routes remain open emergencies (ambulances, fire brigade) can enter Logistics and aid	Roads become impassable Delayed evacuation emergencies services unable to reach affected residents	Directly affects mortality risk Mobility determines the speed of rescue Reduces isolation of vulnerable

		distribution continued uninterrupted		populations
2. Drainage Systems	Ability to convey, retain, and infiltrate stormwater; prevent inundation	Reduced flood depth and duration Lower damage to houses, public facilities, and road surfaces	Severe surface flooding Accelerated road failure (potholes, erosion) Increased exposure to waterborne diseases	Prevents life-threatening flood exposure Protects critical access roads Maintains sanitary condition
3. Integrated Road-Drainage Network	Combined performance ensuring infrastructure continuity	Stable mobility network during disasters Faster recovery of daily activities Lower repair and rehabilitation costs	Network failure leads to cascading impacts Community remains paralyzed longer Economic and social losses escalate	Community resilience depends on the system's continuity Determines the time required for recovery
4. Green Infrastructure (GI) Support	Enhances infiltration, reduces peak runoff, protects built infrastructure	Roads remain drier and more durable Drainage load significantly reduced	High runoff overloads drainage Roads flood quickly Increase	GI increases resilience of both roads and drainage Strengthens long-term

		Reduced flash flood likelihood	d infrastructure damage	environmm ental safety
5. Resilient Design Principles	Applicati on of resistance , recovery, and adaptatio n	Infrastru cture withstan ds initial shock (resistan ce) Rapid functiona lity restoratio n (recovery) Improve d future protectio n (adaptati on)	Repeat failures each rainy season Chronic deteriora tion and high maintena nce burden	Ensures long-term security and quality of life

Here we create a 5×5 risk matrix (Likelihood vs Impact) with examples of risks: road failure, drainage overflow, power outages, disruption of health services, and landslides.

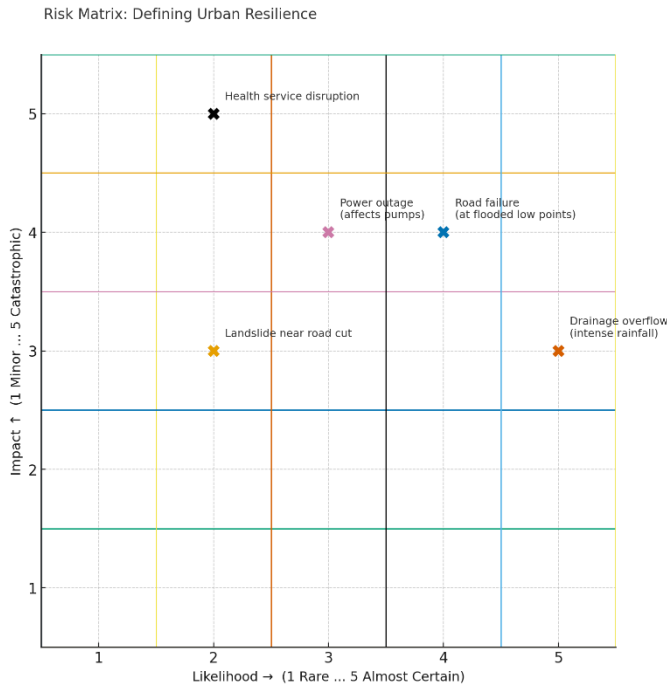


Figure 1. Defining Urban Resilience

C. Green Infrastructure (GI) as a Resilience Tool

Green Infrastructure (GI) refers to a strategically planned network of natural and semi-natural areas that are designed to deliver a wide range of ecosystem services, primarily in urban environments [6]. Unlike conventional gray infrastructure (concrete pipes and impermeable surfaces), GI utilizes natural processes—such as soil filtration, plant absorption, and infiltration—to manage stormwater. Key GI components relevant to slum improvement include:

1. Permeable Pavement: Allows rainwater to infiltrate the ground, reducing surface runoff and minimizing the burden on the main drainage system [7].
2. Biopores and Rain Gardens: Simple yet effective in-situ techniques used for localized water harvesting and infiltration, significantly mitigating the risk of flash floods at the micro-scale [8].

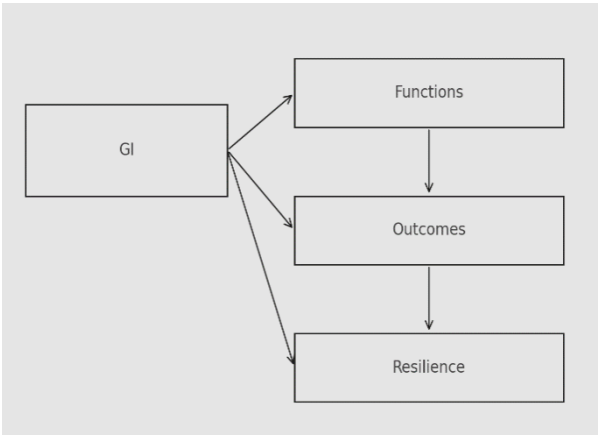


Figure 1. flow diagram of Green Infrastructure (GI) as a Resilience Tool

Which describes how Green Infrastructure elements provide ecological and hydrological functions, which then produce outcomes of flood risk reduction, increased infiltration, and ultimately increased settlement resilience.

D. Interconnectivity: Roads, Drainage, and Disaster Responsiveness.

The condition of environmental roads and drainage systems are intrinsically linked to disaster resilience. Poor road access not only hampers daily mobility but also critically delays emergency services during events like floods or fires [9]. Furthermore, poorly maintained drainage accelerates road degradation and contributes to surface water pooling. By integrating GI elements like permeable pavements with resilient drainage, the design shifts from merely moving water away quickly (disposal) to sustainably managing water resources (retention and infiltration), which is the core principle required for achieving structural and environmental resilience in densely populated, flood-prone areas like Desa Muser.

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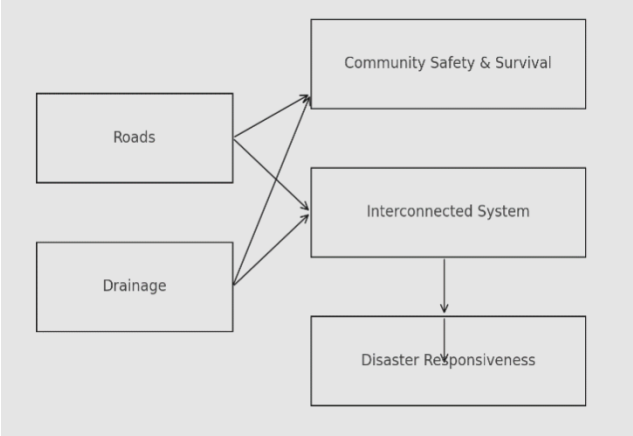


Figure 2. Interconnectivity Roads, Drainage, and Disaster Responsiveness.

IV. RESULT

The results of this discussion present a synthesis of disaster data, infrastructure conditions, and alignment with regulations that underlie the importance of implementing Resilience and Green Infrastructure in Muser Village.

1. Statistical Analysis (Supporting Quantitative Data)

This statistical data is used to support the argument that Muser Village (in Paser Regency) is located in a significant disaster risk context, thus requiring disaster-responsive infrastructure design (in accordance with Circular Letter 30/2020).

Table 3. Supporting Quantitative Data

Quantitative Indicators	Data Values in Paser Regency	Data Sources and Relevance
Average Annual Rainfall	222.9 mm	Wikipedia/Paser General Data (2024).
Flood Frequency (2024)	45 incidents (until April 2024)	BPBD Paser / Local News (2024).
Environmental Road Conditions	46.16% are in poor condition (out of 764 km)	Paser DKPP Data (2023)
Flood Impact (Case Study)	An average of 150-450 people were affected per incident.	BNPB/Ministry of Health Crisis Center Report (2021-2023).

2. Descriptive Analysis (Qualitative Synthesis)

Descriptive analysis presents interpretations of statistical and literature data, resulting in conclusions about design implementation strategies in Muser Village.

2.1. Infrastructure Design as an Implementation of Resilience

Based on Rockefeller Foundation and UNDRR literature, the design of neighborhood roads and drainage in Muser Village must meet the following resilience standards:

- **Robustness:**
The integrated drainage system (primary, secondary, and tertiary) must have sufficient design capacity to accommodate extreme rainfall (222.9 mm on average) without overflowing, in line with the design flood discharge calculations recommended in the Paser study (5-10 year return period).
 - **Redundancy:**
The implementation of Green Infrastructure (GI), such as Bioswales along neighborhood roads and the use of Permeable Pavement, serves as a backup system. When conventional drainage (concrete channels) is full, GI ensures water can be absorbed/retained, reducing the burden of surface runoff.
 - **Integration:**
The design must integrate infrastructure functions (roads) with environmental functions (drainage and infiltration), creating a holistic functional unit.
- 2.2. Alignment of Regulations and Implementation Strategy (SE Dirjen CK 30/2020)
- The main objective of this design is to fulfill the mandate of SE Dirjen Cipta Karya 30/2020 to create settlements that are 'Ecologically and Disaster-Resilient':
- **Slum Prevention Focus:**
Data shows that nearly half of the streets in Paser are in poor condition (46.16%), indicating the vulnerability of the settlements. The GI-Resilience design is used as a primary tool for prevention and quality improvement, not just physical improvements.
 - **Nature-Based Solutions (NbS):**
GI (such as small-scale retention ponds at the neighborhood level and rain gardens) is a direct manifestation of the principles of Ecological Resilience. This strategy counters the trend of conventional Grey (concrete) infrastructure that exacerbates flood risk, especially in areas that frequently experience 45 flood events a year.
- 2.3. Specific Design Recommendations for Muser Village
- Based on the needs and risk data synthesis, the Green Infrastructure design should prioritize:
- **Environmental Roads:**
Implementation of permeable pavement on low-traffic roads to increase infiltration and reduce stormwater runoff, in line with the Paser Regional Government's efforts to improve drainage (but with a GI upgrade).
 - **Drainage:**
Transition from conventional canals to Eco-Drainage/Bioswales. Canals in Muser Village should be designed with planting media and vegetation (swales) to slow water flow, filter pollutants, and maximize rainwater infiltration back into the ground.

V. CONCLUSIONS

These conclusions are summarized into three main points, reflecting the main focus of the discussion: (1) Conceptual and Regulatory Needs, (2) Technical Needs and Green Infrastructure, and (3) Implications for Local Context.

1. Conceptual Needs and Regulatory Compliance.

The conceptual and regulatory requirements for designing environmental roads and drainage in Muser Village, Paser Regency, are urgent and mandatory:

- Resilience Mandate: The design concept must shift from a conventional approach (grey infrastructure) to a resilient approach. This is achieved by ensuring infrastructure has robustness (design resilience) and redundancy (backup systems) to absorb and recover from disaster shocks, in accordance with the principles outlined by the Rockefeller Foundation and the UNDRR (Sendai Framework).
- Compliance with Circular Letter of the Director General of Human Settlements No. 30/2020: This design is a direct implementation of the mandate of Circular Letter of the Director General of Human Settlements No. 30/2020 to create settlements that are resilient to ecology and disasters. With the high frequency of flooding in Paser (for example, 45 incidents every four months), resilient design interventions are an absolute requirement in the efforts to Prevent and Improve the Quality of Slum Settlements (RP2KPKPK) in Muser Village.

2. Technical Needs and Implementation of Green Infrastructure (GI)

- Green Infrastructure is the most relevant and effective technical solution to achieve Resilience objectives in the study area:
- Hydrological Risk Reduction: The high average rainfall data in Paser requires a drainage system that not only drains but also infiltrates water. GI, such as Permeable Pavement on neighborhood roads and Bioswale in drainage channels, functions as a Nature-based Solution (NbS) that significantly reduces the volume of surface runoff that triggers flooding.
- Environmental Road Optimization: Given the high percentage of roads in poor condition in Paser, the repair or reconstruction phase should be utilized to integrate substations. The use of porous pavements on low-traffic environmental roads is a dual solution: improving road quality while increasing infiltration capacity.
- Drainage Transformation: The design should transition from rigid concrete channels to an Eco-Drainage/WSUD system. Bioswales will serve dual functions: serving as water transport channels, pollutant filters, and temporary storage areas (detention/retention) to increase overall system redundancy.

3. Implications of the Local Context of Paser and Muser Village

The success of the design implementation depends heavily on adapting to the specific characteristics of Muser Village, Paser Regency:

- Focus on Local Vulnerability: Substation design must be tailored to the soil type and settlement density of Muser Village. The selection of substation types (e.g., bioswale depth, permeable pavement type) must be based on the results of local vulnerability analysis and land availability, ensuring that the proposed solution is adaptive and technically feasible in the dense environment.
- Opportunities for Programmatic Intervention: This study identified opportunities for strategic intervention in Muser Village, particularly during the road and drainage infrastructure rehabilitation program. Incorporating substation principles into the design from the outset will be far more efficient and effective in the long term than separate implementation.
- Needs Synthesis: Overall, the design of road and drainage infrastructure in Muser Village is a model that integrates three pillars: Science (Resilience & GI), Policy (SE 30/2020), and Real Needs in the Field (Paser Flood Data), which ultimately aims to improve the socio-economic and physical status of the settlement to become a truly disaster-resilient area.

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