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Performance and Effectiveness of Drainage Systems in Densely Populated Residential Areas

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ABSTRACT: Drainage systems were an important component of urban infrastructure for controlling rainwater runoff and minimizing the risk of flooding, especially in densely populated residential areas. However, in many urban areas, flooding still occurred repeatedly despite the availability of drainage networks. This study aimed to evaluate the performance and effectiveness of drainage systems in the Pelita residential area and to identify technical and non-technical factors that affected the occurrence of inundation. This study used a quantitative approach with a descriptive-evaluative method supported by qualitative data. Technical performance analysis was carried out through channel dimension measurements, hydrological analysis using the rational method, and hydraulic analysis using Manning's equation. In addition, community perceptions and levels of participation were analyzed through questionnaires that had been tested for validity and reliability and analyzed using Pearson correlation. The results of the study showed that the capacity of drainage channels was not sufficient to accommodate peak runoff discharge, as reflected in the relatively high frequency of flooding (3–4 times per year) and the relatively long duration of inundation. Statistically, the physical condition of the drainage system had a strong correlation with flood frequency, while community participation was moderately correlated with drainage effectiveness. These findings confirmed that the effectiveness of drainage systems in densely populated areas was strongly influenced by a combination of technical and social factors, indicating that an integrated drainage management approach was needed.

KEYWORDS: Drainage effectiveness; drainage performance; densely populated areas; urban flooding

1. Introduction

Urban flooding remained a major problem in densely populated residential areas, even though drainage systems were available and operational [1]. In residential areas with high building density, changes in land use and the increasing proportion of impervious surfaces led to reduced soil infiltration capacity and increased surface runoff [2, 3]. As a result, the capacity of existing drainage systems was often unable to accommodate runoff discharge during moderate to high rainfall intensity, resulting in inundation and recurrent flooding [4]. This condition not only caused infrastructure damage and economic losses but also reduced environmental quality and

increased the risk of public health problems [5, 6]. Although extensive research had been conducted on urban drainage systems, most studies still focused primarily on planning and technical design aspects or on hydrological and hydraulic analyses conducted separately [7]. Empirical evaluations that examined the performance and effectiveness of existing drainage systems in an integrated manner, particularly by linking channel technical conditions, flood events, and community perception and participation in densely populated residential areas, remained relatively limited [8, 9]. This research gap highlighted the need for a more comprehensive investigation to understand why flooding persisted despite the availability of drainage infrastructure [10]. Based on these issues and research gaps, this study aimed to analyze the performance and effectiveness of drainage systems in densely populated residential areas, using the Pelita residential area as a case study. The objectives were to evaluate the technical performance of the drainage system based on channel capacity and runoff discharge, to analyze the effectiveness of the drainage system in reducing flood frequency and duration, and to examine the relationship between the physical condition of the drainage system, flood frequency, and the level of community participation in drainage maintenance.

The hypothesis proposed in this study was that better physical performance of drainage systems was associated with lower flood frequency and duration and that higher levels of community participation in drainage maintenance contributed positively to increased drainage system effectiveness [11, 12]. With these objectives and hypotheses, this research was expected to contribute scientifically to the evaluation of urban drainage systems and to provide a basis for practical recommendations for technically sound and participatory drainage management [13]. The novelty of this research lay in its integrated evaluation approach, which combined an assessment of technical drainage performance through hydrological and hydraulic analyses with an analysis of community perception and participation, subsequently tested using statistical correlation analysis. This integrated approach distinguished the study from previous drainage research that generally focused on technical aspects alone, thereby providing a more comprehensive understanding of urban drainage system effectiveness in densely populated residential areas.

2. Methodology

2.1. Types and approaches to research.

This study used a quantitative method with a descriptive-evaluative approach to assess the performance and effectiveness of drainage systems in densely populated residential areas [14]. The quantitative approach was selected because it enabled analysis based on measurable data, including channel dimensions, runoff discharge, rainfall intensity, and the frequency and duration of inundation [15]. The descriptive approach was applied to describe the existing conditions of the drainage system, while the evaluative approach was used to assess the adequacy and effectiveness of the drainage system in conveying rainwater runoff [16].

2.2. Study area.

The research was conducted in the Pelita residential area, which had a high population density and frequently experienced inundation during moderate- to high-intensity rainfall events. The study area was selected based on characteristics such as significant land-use changes, the presence of existing drainage systems with varying physical conditions, and a relatively high

frequency of flood events. Research activities included field surveys, measurements and observations of drainage channels, distribution of questionnaires to the community, and interviews with relevant stakeholders.

2.3.Hydrological and hydraulic analysis.

Hydrological analysis was performed to calculate the design runoff discharge using the rational method, considering rainfall intensity, runoff coefficient, and catchment area [17, 18]. The rational method was chosen because it was suitable for relatively small catchment areas and widely applied in urban drainage system evaluations [19]. Hydraulic analysis was subsequently conducted using the Manning equation to evaluate the capacity of existing drainage channels to convey the generated flows [20, 21]. The results of hydrological and hydraulic analyses were used to assess the compatibility between channel capacity and runoff discharge, thereby determining the technical performance level of the drainage system [22].

2.4.Data collection and field observation.

Primary data were collected through field observations to obtain information on the physical condition of drainage channels, including measurements of channel width and depth, channel bed slope, structural conditions, sedimentation levels, the presence of garbage and vegetation, and flow performance under dry conditions and after rainfall. Observation points were determined purposively along primary and secondary channels in locations that frequently experienced inundation, based on information obtained from the local community. Social data were obtained through questionnaires distributed to heads of households, which measured public perceptions of drainage conditions, flood frequency and impacts, and the level of community participation in drainage maintenance. Prior to analysis, the questionnaire instruments were tested for validity and reliability to ensure accurate and consistent measurement of research variables [23, 24].

2.5. Statistical analysis and respondent selection.

Statistical analysis was performed using IBM SPSS Statistics software on interval-scale quantitative data obtained from field measurements and questionnaires. The relationships among drainage physical condition, flood frequency, and community participation were analyzed using Pearson correlation at a significance level of $\alpha = 0.05$, following standard practices in urban drainage and flood management research [25]. The number of respondents was determined based on sample representativeness, time, and resource constraints, resulting in 43 heads of households from a total population of 162 households. Respondents were selected purposively according to their willingness to participate and suitability with the research criteria, which was considered sufficient to describe community perception patterns and participation levels in drainage maintenance.

3. Results and Discussion

3.1. Drainage system capacity limitations.

The results of the analysis showed that the limited capacity of the drainage system was the main factor causing repeated floods in densely populated residential areas. The relatively small

cross-sectional area of the channels and the low slope of the channel bed led to reduced flow velocities, and the ability of the channels to drain runoff discharge was limited [26]. This condition was consistent with the findings of [27], which stated that mismatches between channel capacity and design discharge were a common cause of urban drainage system failures. In addition, increased surface runoff due to the high proportion of impervious surfaces in densely populated residential areas worsened the performance of the drainage system. Land-use changes without a corresponding increase in drainage capacity had been widely reported as a dominant factor causing urban flooding [28]. Thus, the results of this study reinforced the empirical evidence that evaluation of existing channel capacity was essential in urban drainage management.

3.2. Factors that trigger recurrent floods.

The relatively high frequency of floods and the long duration of inundation indicated that drainage problems were not only derived from technical aspects but were also influenced by operational and environmental factors. Based on the results of the questionnaires, flooding events in the study area occurred on average 3–4 times per year, with inundation lasting approximately 5 hours. Sedimentation, garbage accumulation, and a lack of regular maintenance of drainage channels contributed to the decrease in the hydraulic capacity of the channels. This condition was consistent with the findings of [29], which confirmed that maintenance factors played an important role in the effectiveness of urban drainage systems. In addition to internal channel factors, the occurrence of high-intensity rainfall over a short duration also increased the risk of overflow. Study [30] suggested that urban drainage systems in densely populated areas tended to be more vulnerable to extreme rainfall due to limited space for additional infrastructure development. These findings indicated the need for an adaptive approach in drainage planning and management, particularly in the context of climate variability.

3.3. The role of community participation and its implications for urban drainage management.

The results of statistical analysis showed that community participation had a significant relationship with the effectiveness of drainage systems. The level of community participation, which was categorized as fairly active, indicated awareness of the importance of drainage maintenance, even though the implementation was not optimal. These findings were consistent with research [31], which stated that community involvement played a role in maintaining channel cleanliness and preventing blockages. However, the correlation results indicated that community participation alone was insufficient to address the flood problem comprehensively. Support for technical improvements and government policies was still needed to increase the capacity and sustainability of the drainage system. A collaborative approach between government and society, as proposed by [32], was a relevant strategy to enhance the effectiveness of urban drainage management. Based on the results and discussion, the practical implications of this study included the need for integrated management of drainage systems that combined technical and social aspects. Increasing channel capacity through rehabilitation or redesign needed to be balanced with regular maintenance programs and increased community participation. The findings of this study supported a sustainable drainage

management approach that emphasized synergies among technical planning, public policy, and community engagement [33].

3.4. Community participation and maintenance.

Table 1 presented a summary of the condition of the drainage system based on objective data from field measurements and community perception data obtained through questionnaires. The results of the questionnaire analysis showed that the level of community satisfaction with the drainage system was in the medium category. Community assessments included the physical condition of the channels, drainage cleanliness, flow smoothness, and response to inundation. The average score of satisfaction with the physical condition of the drainage was 3.2 (adequate category), channel cleanliness was 3.5 (moderate), and the level of community participation in drainage maintenance was 3.4 (moderately active) on a Likert scale of 1–5. Pearson correlation analysis showed a moderate relationship between community participation rates and the effectiveness of drainage systems. This indicated that community involvement in maintaining the cleanliness and function of the channels played a role in improving drainage performance, although technical capacity enhancement through local government intervention was still needed.

Table 1. Drainage system conditions based on field data and community perception.

Variable	Mean	Description	Source
Physical Condition of Drainage	3.2	Normal	Field Measurement and Survey
Flood Frequency per Year	3.8	Frequent	Respondent Questionnaire
Flood Duration (hours)	5.2	Prolonged	Observations and Questionnaires
Drainage Channel Hygiene	3.5	Clean	Community Surveys and Inspections
Community Participation	3.4	Quite Active	Focused Group Interviews and Discussions

3.5. Statistical analysis results.

The results of the validity test showed that all questionnaire items had an item-total correlation value above the minimum threshold ($r > 0.30$; $p < 0.05$), so all indicators were declared valid. The reliability test yielded a Cronbach's Alpha coefficient of 0.81, indicating that the questionnaire instrument had a good level of reliability. Pearson correlation analysis showed a strong positive relationship between the physical condition of the drainage channels and the frequency of flooding events ($r = 0.68$; $p < 0.01$), indicating that the worse the physical condition of the channels, the higher the frequency of flooding. In addition, there was a moderately strong positive association between community participation levels and drainage system effectiveness ($r = 0.55$; $p < 0.05$), suggesting that increased community involvement in drainage maintenance contributed to improved system effectiveness. These findings confirmed that drainage management in densely populated residential areas required a synergy between technical improvements and community participation.

4. Conclusions

This study showed that the performance and effectiveness of drainage systems in densely populated residential areas were still not optimal. Technical performance evaluation indicated that the capacity of existing drainage channels was insufficient to accommodate rainfall

discharge, so floods continued to occur repeatedly. In addition, the effectiveness of the drainage system was also influenced by non-technical factors, particularly the level of community participation in channel maintenance. Statistical analysis confirmed a significant relationship between the physical condition of drainage channels and the frequency of flood events, as well as a positive relationship between community participation and the effectiveness of drainage systems. These findings indicated that improvements in the technical performance of the drainage system needed to be balanced with active community involvement to achieve more effective drainage management. The practical implications of this study included the need for capacity building and maintenance of drainage systems integrated with community-based management approaches. Synergy between technical improvements, increased awareness and community participation, and support from local government policies were key factors in enhancing drainage effectiveness and reducing flood risk in densely populated urban areas. Further research was suggested to examine the spatial and temporal aspects of drainage systems and to involve a larger number of respondents to strengthen the generalizability of the findings.

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Author Contribution

The authors contributed to this study in the following ways: Khusnul Khotimah was responsible for conceptualization, investigation, data collection, and writing the original draft. Jody Martin Ginting contributed to validation, methodology, data analysis, and writing, including review and editing. Sri Anggreini provided support in data collection, technical assistance, validation, and funding acquisition. All authors reviewed and approved the final manuscript.

Competing Interest

The authors declare that they have no known competing financial or personal interests that could have appeared to influence the work reported in this paper.

References

[1] Kolondam, S.B.N.; Pangkey, M.S.; Helly, F. (2023). Analisis Perencanaan Revitalisasi Infrastruktur Drainase pada Dinas Pekerjaan Umum dan Penataan Ruang Kota Manado *(Analysis of Drainage Infrastructure Revitalization Planning at the Public Works and Spatial Planning Office of Manado City)*. *Jurnal Administrasi Publik*, *IX*(4), 596–607. https://doi.org/10.35797/jap.v9i4.52064.

[2] Eswirielda, G.; Sarminah, S. (2024). Uji Coba Variasi Lubang Resapan dalam Upaya Mengurangi Limpasan Permukaan di Permukaan Remaja Permai Kota Samarinda *(Experimental Study of Infiltration Hole Variations to Reduce Surface Runoff in Remaja Permai Area, Samarinda City)*. *Agrifor: Jurnal Ilmu Pertanian dan Kehutanan*, *23*(2), 203–214. https://doi.org/10.31293/agrifor.v23i2.7609.

[3] Jenny; Rifai, A.I.; Ginting, J.M.; Prasetijo, J. (2024). The bibliometric study of blood discharge by unit hydrograph method Nakayasu synthetic (HSS) and Soil Conservation Service (SCS). *Journal of Social Research*, *3*(7), 1–10. https://doi.org/10.55324/josr.v3i7.2095.

[4] Saputra, A.J.; Lestari, S.D.; Ginting, J.M. (2025). Analisis faktor-faktor yang mempengaruhi pencemaran sumber daya air di wilayah sungai: Systematic literature review *(Analysis of factors affecting water resource pollution in river basins: A systematic literature review)*. *Jurnal Teknik Sipil dan Arsitektur*, *30*(2), 119–127. https://doi.org/10.36728/jtsa.v30i2.4806.

[5] Idrus, I.; Umar, B. (2024). Mitigasi bencana banjir akibat longsor pada daerah aliran sungai terhadap ketersediaan air bersih di Kecamatan Dondo *(Flood disaster mitigation due to landslides in watersheds on clean water availability in Dondo District)*. *Jurnal Bangunan Konstruksi*, *I*(2), 46–52. https://doi.org/10.63877/jbk.v2i1.47.

[6] Zhou, Q. (2014). A review of sustainable urban drainage systems considering the climate change and urbanization impacts. *Water*, *6*(4), 976–992. https://doi.org/10.3390/w6040976.

[7] Gusri, L.; Abiyoga, N.P.; Manab, A.; Putra, T.S.; Nuklirullah, M. (2025). Pemeliharaan saluran sistem drainase melalui manajemen partisipatif di RT 7 Kelurahan Legok, Kota Jambi *(Drainage system maintenance through participatory management in RT 7 Legok Village, Jambi City)*. *Jurnal Akademik Pengabdian Masyarakat*, *3*(3), 308–315. https://doi.org/10.61722/japm.v3i3.6125.

[8] Fanani, F.; Kurniati, A.C.; Asih, A. S. (2025). Kebutuhan infrastruktur air minum, drainase, dan air limbah sebagai instrumen perencanaan pembangunan wilayah *(Drinking water, drainage, and wastewater infrastructure needs as instruments for regional development planning)*. *Prosiding Nasional Rekayasa Teknologi Industri dan Informasi*, *20*, 235–243.

[9] Haddad, H.; Bryden, J.; Connop, S. (2025). Practitioner Perceptions of Mainstreaming Sustainable Drainage Systems (SuDS): A Mixed Methods Study Exploring Direct Versus Indirect Barriers. *Sustainability*, *17*, 2093. https://doi.org/10.3390/su17052093.

[10] Kurniawan, A.T.; Ariansyah, Solihin, I.; Perta, M.A.; Ikbal, M.; Azi, T.; Situmorang, M.T.N (2024). Strategi mitigasi bencana berbasis masyarakat dalam menghadapi risiko banjir di daerah perkotaan *(Community-based disaster mitigation strategies in addressing urban flood risk)*. *Journal of Scientific Research and Development*, *6*(2), 1117–1125. https://doi.org/10.56670/jsrd.v6i2.796.

[11] Sharma, Z.Y.A. (2015). Urban drainage system planning and design – challenges with climate change and urbanization: A review. *Water Science and Technology*, *72*(2), 165–179. https://doi.org/10.2166/wst.2015.207.

[12] Sohn, W.; Brody, S.D.; Kim, J.-H.; Li, M.-H. (2020). How effective are drainage systems in mitigating flood losses? *Cities*, *107*, 102917. https://doi.org/10.1016/j.cities.2020.102917.

[13] Guptha, G. C.; Swain, S.; Al-Ansari, N.; Taloor, A. K.; Dayal, D. (2021). Evaluation of an urban drainage system and its resilience using remote sensing and GIS. *Remote Sensing Applications: Society and Environment*, *23*, 100601. https://doi.org/10.1016/j.rsase.2021.100601.

[14] Wulandari, A.P.; Andriyus. (2024). Evaluasi pelaksanaan tugas Dinas Pekerjaan Umum dan Penataan Ruang Kota Pekanbaru dalam pemeliharaan saluran drainase *(Evaluation of drainage maintenance duties of the Pekanbaru City Public Works and Spatial Planning Office)*. *Jurnal Mahasiswa Pemerintahan*, *1*(3), 378–389. https://doi.org/10.25299/jmp..18035.

[15] Srihayati, B.V.; Burhan, L.I. (2025). Kinerja dan kerentanan drainase permukiman Kota Mataram pada skenario RCP: Pendekatan SWMM–GIS *(Performance and vulnerability of residential drainage in Mataram City under RCP scenarios: A SWMM–GIS approach)*. *Jurnal Teknik Sipil dan Lingkungan*, *1*(2), 28–40. https://doi.org/10.63982/dinamika.tf8ja323.

[16] Juleha, S.; Mutia, E.; Lydia, N. (2024). Analisis sistem jaringan drainase di Kecamatan Langsa Barat, Kota Langsa *(Analysis of drainage network systems in West Langsa District, Langsa City)*. *Journal of Civil Engineering, Building and Transportation*, *8*(2), 263–271. https://doi.org/10.31289/jcebt.v7i2.9046.

[17] Prawira, H.; Rosadi, P.E.; Cahyadi, T.A.; Riyadi, F.A.; Herniti, D. (2024). Analisis hidrologi menggunakan metode rasional dan Nakayasu untuk sistem penyaliran tambang pada PT Trubaindo Coal Mining, Kabupaten Kutai Barat, Provinsi Kalimantan Timur *(Hydrological analysis using the Rational and Nakayasu methods for mine drainage systems at PT Trubaindo Coal Mining, West Kutai Regency, East Kalimantan Province)*. *Jurnal Teknologi Pertambangan*, *10*(1), 10–22. https://doi.org/10.31315/jtp.v10i1.13238.

[18] Galarza-Molina, S.; Torres-Lozada, P.; Galvis-Castaño, A. (2022). Incorporating urban drainage system resilience in public policies for a city in a developing country—Colombia. *Frontiers in Water*, *4*, 774154. https://doi.org/10.3389/frwa.2022.774154.

[19] Oktaviani, A.; Mahendra, M.O. (2025). Evaluasi sistem jaringan drainase jalan raya menggunakan software HEC-RAS (Studi Kasus: Jalan Baros, Kabupaten Serang–Banten) *(Evaluation of road drainage network systems using HEC-RAS software (Case study: Baros Road, Serang Regency–Banten))*. *Jurnal Konstruksi*, *23*(2), 56–67. https://doi.org/10.33364/konstruksi/v.23-2.2473.

[20] Ginting, J. M.; et al. (2022). Edukasi pentingnya menjaga kebersihan dan pelindungan terhadap lingkungan *(Education on the importance of maintaining cleanliness and environmental protection)*. *Proceedings of the National Conference on Community Service Projects (NaCosPro)*, *4*(1), 376–380. http://journal.uib.ac.id/index.php/nacospro.

[21] Arfaah, S.; Hidayat, R.; Cahyono, I. (2024). Analisa angka koefisien kekasaran Manning pada saluran terbuka akibat vegetasi *(Analysis of Manning roughness coefficient in open channels due to vegetation)*. *Jurnal Sains dan Teknologi*, *3*(1), 47–56. https://doi.org/10.32492/nucleus.v3i1.3106.

[22] Secilia, M.P.; Bisri, M.; Andawayanti, U. (2023). Studi evaluasi sistem drainase air limpasan permukaan di site Gurimbang Mine Operation PT Berau Coal *(Evaluation study of surface runoff drainage systems at Gurimbang Mine Operation site, PT Berau Coal)*. *Jurnal Teknologi dan Rekayasa Sumber Daya Air*, *03*(02), 719–732. https://doi.org/10.21776/ub.jtresda.2023.003.02.061.

[23] Hendrawan, F.M.P.; Putranto, L.S. (2024). Tanggapan masyarakat mengenai pengaruh faktor demografis dan geografis terhadap moda transportasi Biskita Trans Pakuan *(Public perception of demographic and geographic factors influencing Biskita Trans Pakuan transportation mode)*. *Jurnal Mitra Teknik Sipil*, *7*(2), 733–744. https://doi.org/10.24912/jmts.v7i2.27877.

[24] Simanjuntak, M.R.A.; Tachlish, A.N. (2020). Hasil analisis korelasi dan interkorelasi risiko keterlambatan proses pelaksanaan konstruksi jalan tol *(Correlation and intercorrelation analysis of delay risks in toll road construction implementation)*. *Proceedings of the National Seminar on Civil Engineering*, *2020*, 404–412.

[25] Aritonang, D.N.S.; Susanti, R. (2024). Partisipasi masyarakat pada program Kampung Siaga Bencana di Kelurahan Meranti Pandak Kecamatan Rumbai *(Community participation in the Disaster-Resilient Village program in Meranti Pandak Village, Rumbai District)*. *Jurnal Sains Riset*, *14*(2), 606–617.

[26] Suprianingsih, N.W.; Dayanti, M.A.R.; Prakarsa, I.M.P.T.; Kardiyasa, K.A.P. (2025). Analisis hidrologi dan perencanaan sistem drainase menggunakan GIS di Sub DAS Melangit Kecamatan Bangli *(Hydrological analysis and drainage system planning using GIS in the Melangit Sub-Watershed, Bangli District)*. *Jurnal Teknik Sipil Terapan*, *7*(3), 147–158. https://doi.org/10.47600/jtst.v7i3.1228.

[27] Devedo, M.G.D.; Rahmawati, D. (2025). Analisis hidraulika dan inventarisasi saluran drainase daerah kawasan Bandara New Yogyakarta International Airport *(Hydraulic analysis and inventory of drainage channels in the New Yogyakarta International Airport area)*. *Jurnal Teknik Sipil*, *4*(1). 84−91. https://doi.org/10.30743/jtsip.v4i1.11460.

[28] Asrul; Eraku, S.; Agu, R.R.; Maini, A.A.; Lasamu, M.; Massi, S. (2025). Pengaruh alih fungsi lahan terhadap kejadian banjir di Kelurahan Leato Selatan Kecamatan Kota Timur Kota Gorontalo

(Effect of land-use change on flood occurrence in South Leato Village, East City District, Gorontalo City). *Geodika: Jurnal Kajian Ilmu dan Pendidikan Geografi*, *9*(1), 52–61. https://doi.org/10.29408/geodika.v9i1.29256.

[29] Kusryat, D.; Mintarsih, E. (2025). Efektivitas penyelenggaraan sistem drainase guna mengendalikan banjir di Kota Pontianak berdasarkan Perda Kota Pontianak Nomor 5 Tahun 2016 *(Effectiveness of drainage system implementation for flood control in Pontianak City based on Regional Regulation No. 5 of 2016)*. *Al-Suthaniyah*, *14*(2), 621–631. https://doi.org/10.37567/al-sulthaniyah.v14i2.4283.

[30] Hendryarto, K.T.; Suwandi; Setiadi, T. (2025). Pengembangan sistem drainase berkelanjutan untuk mengatasi banjir perkotaan *(Development of sustainable drainage systems to address urban flooding)*. *Jurnal Rekayasa Sipil dan Arsitektur*, *1*(1), 18–32. https://doi.org/10.51903/mmydj554.

[31] Bijak, B.; Zai, E.; Dapot, D.; Brain, B.; Ebenezer, E.; Efraim, E. (2025). Strategi pemeliharaan dan perawatan sistem irigasi di Desa Petane V *(Maintenance and management strategies for irrigation systems in Petane V Village)*. *Karawo Journal of Community Service*, *3*(1). 65−72. https://doi.org/10.62951/karawo.v3i1.118.

[32] Kusuma, E.; Sukwadi, R. (2024). Pengendalian banjir perkotaan di Pontianak melalui pendekatan sponge city: Sebuah tinjauan literatur dan virtual benchmarking *(Urban flood control in Pontianak through a sponge city approach: A literature review and virtual benchmarking)*. *Jurnal Perkotaan*, *16*(2), 110–133. https://doi.org/10.25170/perkotaan.v16i2.6154.

[33] Aditiya, M.I. (2024). Mengatasi Problematika Sains Modern dalam Pembangunan Banten Melalui Pendekatan Ekosistem dan Nilai Budaya Lokal (*Addressing the Challenges of Modern Science in Banten's Development through an Ecosystem-Based Approach and Local Cultural Values*). *Jurnal Insan Pendidikan Dan Sosial Humaniora*, *3*(4), 08–15. https://doi.org/10.59581/jipsoshum-widyakarya.v3i4.5812.