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Study on Flood Control of the Sumber Pinang River in Sidogiri, Pasuruan Regency through River Normalization, Levees, and Parapet Walls

Imroni Arif[1]✉, **Vita Ayu Kusuma Dewi**[2]

[1] S1 Civil Engineering, Engineering, Universitas Negeri Malang, Indonesia
[2] Civil Engineering, Engineering, Universitas Negeri Malang, Indonesia

✉ **Corresponding Author :** Imroni Arif (e-mail: imroniarif27@gmail.com)

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ABSTRACT

The Sumber Pinang River in Pasuruan Regency frequently experiences flooding due to its insufficient capacity. This study aims to analyze flood control measures using hydrological and hydraulic approaches with the HEC-RAS 6.4.1 software. The data used include maximum rainfall, river cross-section profiles, and land use. The planned flood discharge was calculated using the Nakayasu Synthetic Unit Hydrograph (SUH) method, resulting in a peak discharge of 442.823 m^3/s. The analysis results indicate that 81% of the river cross-sections are prone to overflow. Proposed control measures include river normalization and the construction of levees and parapet walls. River normalization is planned for the entire river body, while levees and parapet walls are proposed at critical points to enhance the river's capacity. This study provides recommendations for more effective flood control planning in the future.

INTRODUCTION

Rivers play an important role in ecosystems and human life, particularly in providing clean water. However, due to climate change, which has resulted in increased rainfall, and changes in land use, many rivers can no longer accommodate water flow optimally, leading to flooding (Desrina, 2014). One of the rivers hit by flooding due to climate change and land use issues is the Sumber Pinang River, located in Sidogiri Village, Pasuruan Regency. Situated within the Welang River Basin (DAS Welang), this river frequently overflows during the rainy season, causing damage to infrastructure and disrupting community activities, including those at the Sidogiri Islamic Boarding School, which lies within this village.

According to reports from the Regional Disaster Management Agency (BPBD) of East Java and the Public Works Water Resources Agency (PU SDA), the Sumber Pinang River frequently experiences flooding due to its capacity being unable to accommodate the existing river discharge, particularly during the rainy season (Badan Nasional Penanggulangan Bencana, 2023; Direktorat Jendral Sumber Daya Air, 2020). To analyze and plan optimal flood control measures, this study utilizes HEC-RAS 6.4.1 software, which can simulate river flow based on hydrological and hydraulic data. The river flow simulations were used to identify potential overflows that may occur during specific return periods.

As a reference in determining the method used to calculate the planned flood discharge and its return period, previous research is needed as a comparison. In the study Nisa (2019) titled "Planning Study of River Cross-Section Normalization Capacity for Flood Control of the Semajid River in Pamekasan Regency", the method used to calculate the planned flood discharge was the Nakayasu method, while the capacity of the existing channel for a 10-year return period (Q10) was

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analyzed using the HEC-RAS 5.0.6 program. The return period used in that study differs from the return period applied by the researchers for the Sumber Pinang River, resulting in significant differences in the peak flood discharge outcomes. The return period used by the researchers refers to the design discharge criteria for hydraulic structures as outlined by Loebis (2000).

The primary objective of this study is to determine the most effective flood control measures based on the magnitude and behavior of flood discharge. Additionally, the selection of flood control measures considers the existing river conditions to ensure that the analysis aligns with the actual conditions in the field (Andriawan, 2021). Technically, non-structural flood control measures are carried out through river normalization, while structural flood control measures involve the construction of retention structures such as levees, parapet walls, and pump houses. The results of this study are expected to serve as a reference for addressing flood problems in Sidogiri Village, Pasuruan Regency.

RESEARCH METHODS

Study Area

This flood control study was conducted on the Sumber Pinang River, which is administratively located in Sidogiri Village, Kraton District, Pasuruan Regency. The river is one of the tributaries of the Welang River Basin (DAS Welang). The map of the Welang River Basin is shown in Figure 1. The map of the Sumber Pinang River in Sidogiri Village, Pasuruan Regency, is shown in Figure 2.

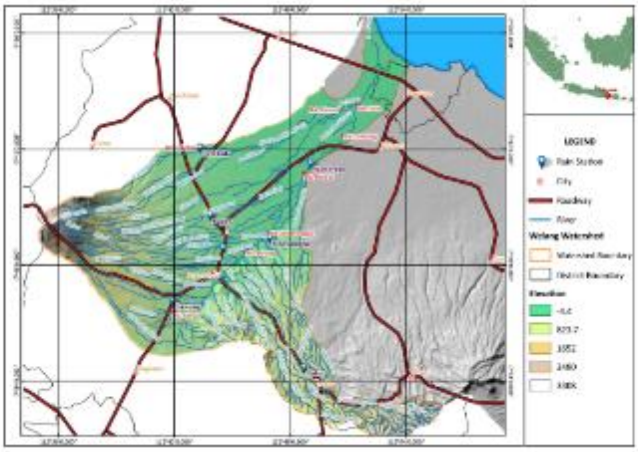

Figure 1. Welang River Basin

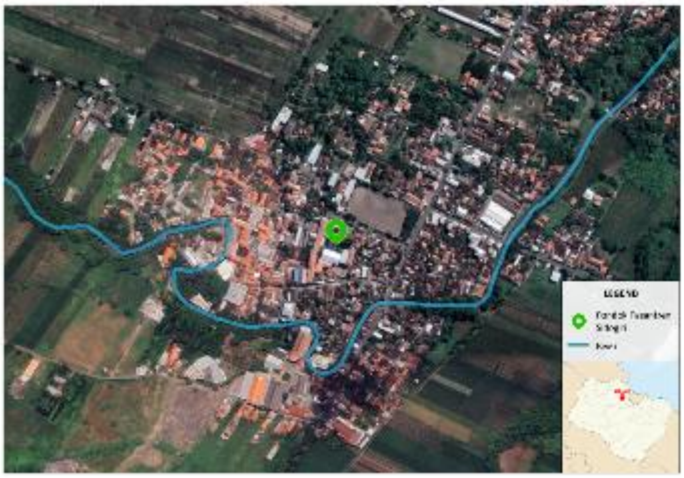

Figure 2. Map of the Sumber Pinang River

Research Stages

This study aims to identify optimal flood control measures using hydrological and hydraulic approaches with the assistance of HEC-RAS 6.4.1 software. The stages of this research are illustrated in Figure 3.

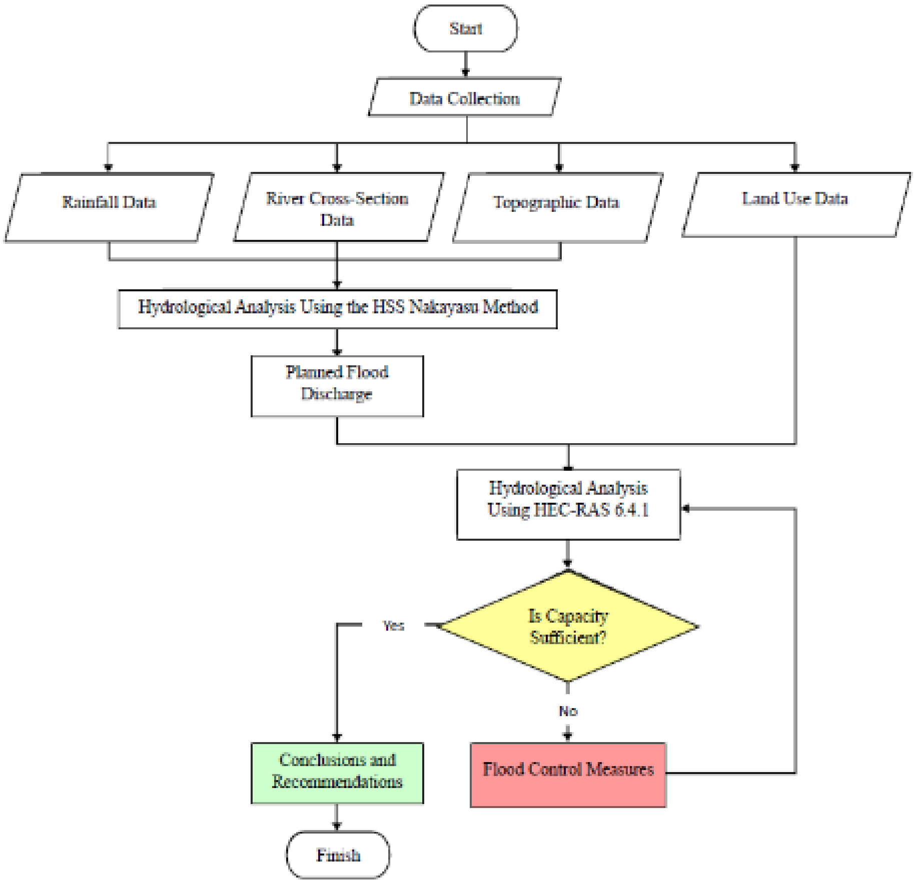

Figure 3. Research Stages

The data used in this study consisted of primary data collected through field observations and secondary data obtained from the Public Works Water Resources Agency (PU SDA) of East Java Province. For the hydrological and hydraulic analysis, the collected data included hydrological data (rainfall from 4 rainfall stations), river cross-section data, land use data, and topographical data (Makbul, 2020).

In the hydrological analysis, the planned flood discharge was calculated using the Nakayasu Synthetic Unit Hydrograph (SUH) method. Maximum rainfall data were analyzed using the Thiessen Polygon method, and the design rainfall was calculated using the Log Pearson Type III Distribution Method. Verification was conducted using the Chi-Square and Smirnov-Kolmogorov tests. Once the planned flood discharge was determined, a hydraulic analysis was done to evaluate the river's capacity using HEC-RAS 6.4.1 software. This analysis aimed to assess the river's storage capacity and identify areas prone to flood overflow.

Flood Control Analysis Techniques

The analysis was conducted using a quantitative approach based on the output from HEC-RAS 6.4.1 simulations. The data generated by this model were used to numerically evaluate the effectiveness of various flood control methods, such as changes in river storage capacity, water surface elevation, and the extent of areas protected by flood infrastructure. The simulation results were analyzed to determine the most efficient and optimal flood control methods for different regional conditions (Ekawati, 2017).

The planned flood control measures included river normalization, the construction of levees, and parapet walls. The process for determining flood control measures is illustrated in Figure 4.

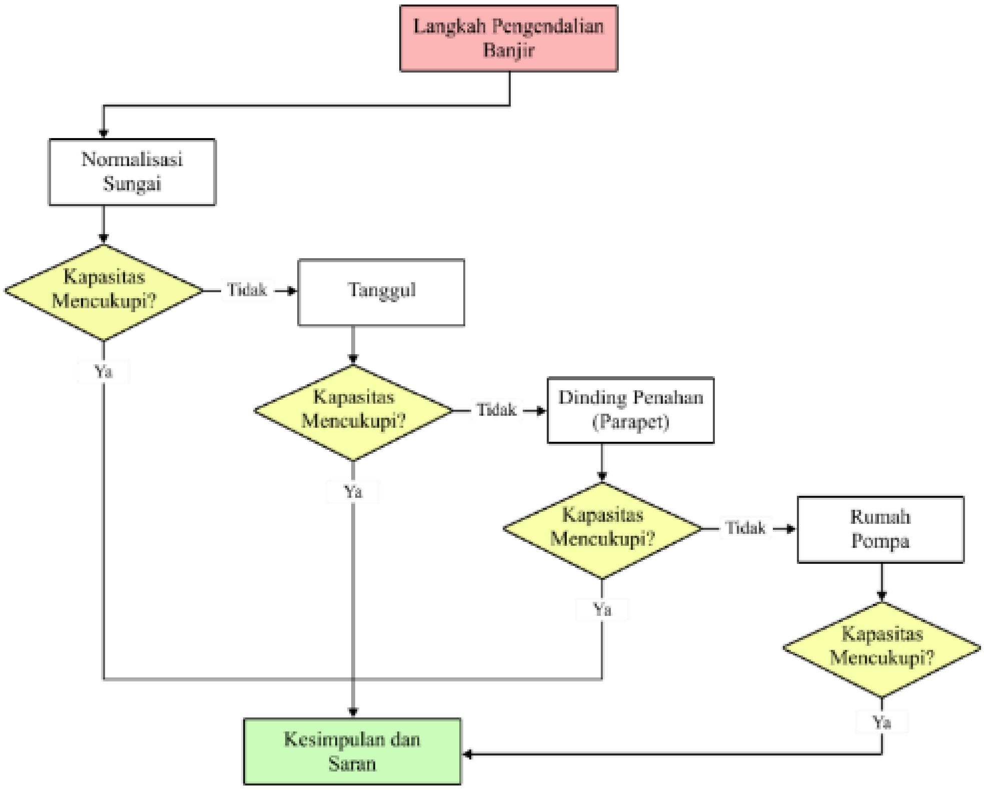

Figure 4. Flood Control Planning Process

The determination of flood control measures began with identifying various flood discharge behaviors and existing field conditions. Subsequently, an analysis was conducted on the river normalization solution for this river. Normalization was carried out to increase the river's storage capacity by widening and deepening its cross-section (Ananda Malik et al., 2020). This solution was analyzed based on its feasibility in the river area and its effectiveness in mitigating flood impacts. If this solution was considered insufficient to fully address the flood problem, further analysis was conducted on additional solutions, including the planning of levees, parapet walls, and the construction of pump houses.

The results of each flood control method were compared based on their effectiveness in reducing flood impacts while considering existing field conditions, such as topography, hydrology, and socio-economic factors. Additionally, the findings were correlated with theoretical studies on flood risk management, focusing on mitigation and adaptation to climate change (Tyas et al., 2021).

RESULTS AND DISCUSSION

Hydrological and Hydraulic Analysis Results

In the hydrological analysis, the average rainfall was calculated using the Thiessen Polygon Method based on data from four rainfall stations, namely Wonorejo, Telebuk, Selowongko, and Lawang, with 20 years of rainfall data (2003–2022). The calculated planned flood discharge indicated that the peak flood discharge for a 25-year return period (Q25) was 442.823 m^3/s. This discharge was then used as input in the hydraulic analysis to evaluate the river's capacity. The HEC-RAS 6.4.1 software was used in the hydraulic analysis to assess the river cross-section's capacity to accommodate the planned flood discharge. The analysis revealed that 81% of the river cross-sections experienced overflow, with an average flood height of 1.5 meters.

At certain points along the river, the capacity was insufficient to handle the flood discharge, resulting in water overflow into residential areas and public facilities, including the Sidogiri Islamic Boarding School. These findings align with the research by Hidayah (2023), where the Animator RAS Mapper concluded that flooding in the Welang River Basin (DAS Welang) reached heights exceeding 1.5 meters. These results are also consistent with the Indonesian Daily Disaster Report (Laporan Harian Bencana Indonesia, 2022), which documented that during the flood event on March 12, 2022, water levels ranged from 30 to 130 cm, causing material losses to residential units and agricultural land.

River Normalization

Flood control through river normalization was carried out by dredging sediment at the bottom and sides of the river body, which included eroded riverbanks, sedimentation in the inner bends of the river, and scouring in the outer bends. River normalization was undertaken to restore the function of the river body and its surrounding areas, which had been affected by human activities or natural events (Solon et al., 2023).

The implementation of flood control measures through river normalization is deemed highly appropriate for this study. Observations conducted during primary data collection revealed substantial sedimentation along the flow of the Sumber Pinang River. The sedimentation primarily consisted of riverbank erosion, as well as the accumulation of debris and waste obstructing the river channel (Ulfa & Fahmi Arif Kurnianto, 2023). The existing condition of the Sumber Pinang River during the observation is shown in Figure 5.

(a) (b)

Figure 5. (a) Landslide on Existing Riverbanks (b) Waste Accumulation in the Existing River
Source: Field Observation, 2024

River normalization planning using HEC-RAS 6.4.1 software. The longitudinal and cross-sectional dimensions of the river after normalization are planned automatically via the Channel Modification feature in the HEC-RAS program. Predictions of changes in cross-sectional dimensions after normalization must be adjusted to existing conditions in the field. Based on the river normalization planning results using the HEC-RAS 6.4.1 application, the water surface profile under existing conditions after normalization is presented in Figure 6.

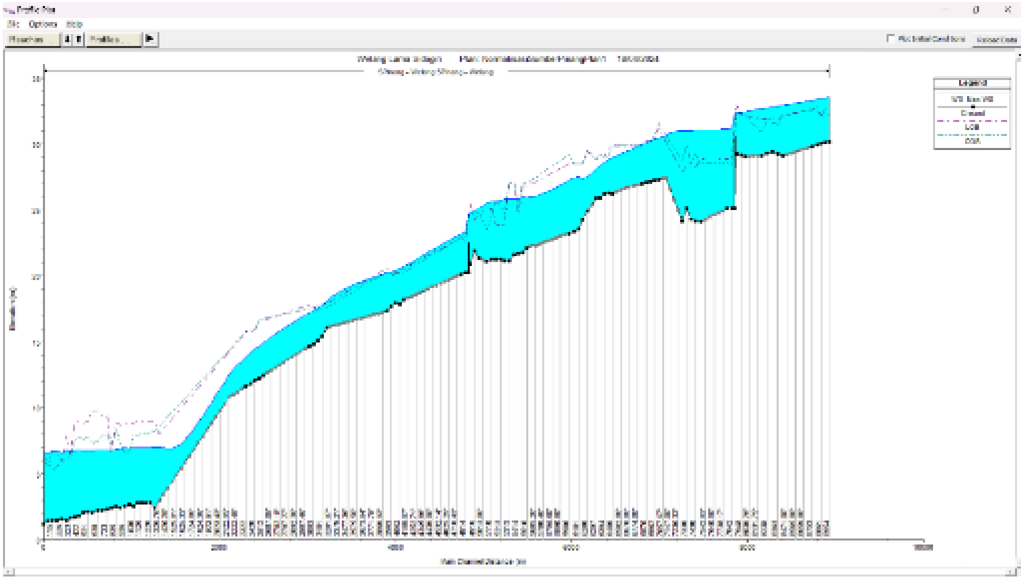

Figure 6. Existing Water Level Profile After Normalization
Source: Analysis Result, 2024

It can be observed that water still overflows at certain station points (STA). With the river normalization solution, 39% of the STA in the Sumber Pinang River no longer experience overflow, but 41% of the STA still experience overflow, with an average floodwater level of 80 cm. Similarly the study by Nisa (2019), it was found that several points along the normalized river still had potential overflow, necessitating the addition of levees. The normalized flow of the Sumber Pinang River is still unable to fully accommodate the planned flood discharge, indicating the need for additional flood control measures, including the construction of levees and parapet walls.

Construction of Levees and Parapet Walls

Structural flood control measures involving levees and retaining walls, or parapet walls, aim to elevate riverbanks in areas where flooding persists despite river normalization. The levees are typically constructed using soil excavated during the normalization process (Sari & Gunawan, 2020). Levees are planned for station points (STA) experiencing overflow but are located far from densely populated areas. Conversely, parapet walls are proposed for STAs prone to flooding where the right and left sides of the river are close to residential areas and roads, making levee construction infeasible.

Flood mitigation through the construction of levees and parapet walls on the Sumber Pinang River is an appropriate approach based on the existing river conditions (Darmojo, 2019). Based on the existing conditions observed during the field study, several points along the riverbanks or levees were found to have experienced collapse or erosion. The planned riverbank structures were identified through analysis and validated against the field observations. According to the HEC-RAS simulation results shown in Figure 6, one of the river sections that still experienced flooding after normalization was located between STA 95 and STA 99. Field observations confirmed that the existing levees and parapet walls at this section were significantly damaged, exhibiting severe collapse and erosion, as illustrated in Figure 7.

(a)

(b)

Figure 7. (a) Condition of Existing River Levees (b) Condition of Existing River Parapet Walls
Source: Field Observation, 2024

Based on the planning results, the locations for levee and parapet wall construction were identified along the left and right sides of the river in sections that still experienced flooding despite river normalization. The selection of these construction sites also took into consideration the surrounding river conditions. The planned locations for levee and parapet construction are illustrated in Figure 8.

(a)

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(b)

Figure 8. (a) Planned Locations for Levees on the River (b) Planned Locations for Parapet Walls on the River
Source: Field Observation, 2024

The determination of levee and parapet wall heights at each overflow point was conducted by adding the floodwater surface elevation to the required structure height. Referring to the table of levee width and height standards by Sosrodarsono (2008), with a discharge of 442.823 m³/s, it can be concluded that the height of the levees and parapet walls above the water surface should be at least 0.8 m, with a levee crest width of 3 m. Among the various existing elevations at each STA, the highest levee is located at STA 182, with a height of 2.19 m and a crest width of 3 m. Meanwhile, the highest parapet wall is at STA 104, with a height of 2.79 m. Based on these results, the proposed levee and parapet heights are considered sufficient to accommodate flood fluctuations, as analyzed using the HEC-RAS 6.4.1 software.

CONCLUSION AND RECOMENDATION

Conclusion

The most effective flood control measures for the Sumber Pinang River, with a 25-year return period flood discharge (Q25) of 442.823 m³/s, include river normalization, levee construction, and parapet wall installation. River normalization is applied along the entire river body, while increasing the river's capacity requires the construction of levees and parapet walls at several critical points along the river.

Recomendation

1. River normalization of the Sumber Pinang River should be conducted to enhance the river's cross-sectional capacity and reduce flood risk.
2. The construction of levees and parapet walls at critical points, as recommended in this study, should be implemented to prevent water overflow, particularly in areas near residential zones and public facilities.
3. Flood control measures for the Sumber Pinang River must be carried out sustainably and integratively. These measures should include improving land use management in the upstream areas, implementing flood mitigation strategies in downstream regions, protecting and managing areas around the river, and involving local communities. Community involvement should focus on strict enforcement of regulations, monitoring, and maintenance of the river body and flood control structures that have been built.

4. This study focused solely on hydrological and hydraulic analysis. Further research is needed to include socio-economic and environmental impact analyses to ensure that the flood control measures adopted are more comprehensive.
5. The findings of this study are expected to serve as a reference for the Pasuruan Regency government or relevant agencies in selecting effective flood control measures for the Sumber Pinang River in Sidogiri Village, Pasuruan Regency.

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REFERENCES

Ananda Malik, D., Djamal Amin, M., & Jamanie, F. (2020). Studi Tentang Kebijakan Pemerintah Dalam Melakukan Normalisasi Sungai Karang Mumus. *EJournal Pemerintahan Integratif*, *8*(2), 809–817.

Andriawan, A. (2021). Kajian Hidrologi Pada Sistem Pengendalian Banjir. *Rancang Bangun*, *07*, 1–7. http://ejournal.um-sorong.ac.id/index.php/rancangbangun

Badan Nasional Penanggulangan Bencana. (2022). *Laporan Harian Bencana Indonesia 12 Maret 2022*. pusdalops@bnpb.go.id

Badan Nasional Penanggulangan Bencana. (2023). *Laporan Harian Bencana Indonesia 19 Februari 2023*. pusdalops@bnpb.go.id

Darmojo. (2019). Analisis Penanganan Banjir Das Jatimulya. *Jurnal Teknik Sipil-Arsitektur*, *18*(2), 68–77. https://doi.org/10.54564/jtsa.v18i2.5

Desrina, R. (2014). Pemanasan Global Akibat Kegiatan di Sektor Minyak dan Gas Bumi. *Lembaran Publikasi Minyak Dan Gas Bumi*, *48*(2), 63–72. https://doi.org/10.29017/lpmgb.48.2.1213

Direktorat Jendral Sumber Daya Air. (2020). Rencana Strategis SPBE. *Portal SPBE Nasional*, *422*. http://spbe.go.id/renstra

Ekawati, R. (2017). Evaluasi Pengendalian Banjir Sungai Jragung Kabupaten Demak. *Prosiding Seminar Nasional Inovasi Dalam …*, 364–378. http://lppm-unissula.com/jurnal.unissula.ac.id/index.php/smartcity/article/view/1737

Hidayah, E., Halik, G., Indarto, I., & Khaulan, D. W. (2023). Flood hazard mapping of the Welang river, Pasuruan, East Java, Indonesia. *Journal of Applied Water Engineering and Research*, *11*(3), 333–344. https://doi.org/10.1080/23249676.2022.2114025

Loebis, J. (2000). *Banjir Rencana Untuk Bangunan Air*. BPPU. https://pu.go.id/pustaka/biblio/banjir-rencana-untuk-bangunan-air/J826D

Makbul, R. (2020). Sistem Drainase Tertutup Untuk Pencegahan Banjir di Wilayah Perkotaan Kabupaten Pinrang. *Seminar Nasional Perwujudan Pembangunan Berkelanjutan Berbasis Kearifan Lokal Di Era Revolusi Industri 4.0 Dan Era New Normal*, 17–24. https://ejournal.itn.ac.id/index.php/semsina/article/view/2907

Nisa, A. C. (2019). *Studi Perencanaan Normalisasi Kapasitas Penampang Sungai untuk Pengendali Banjir Kali Semajid Kabupaten Pamekasan*.

Sari, S. P., & Gunawan, R. (2020). Analisa Perbedaan Penggunaan Bronjong Km 11 dan Segmental Blok Km 7 pada Pekerjaan Perbaikan Lereng di Jalan Akses PLTA Musi. *STATIKA: Jurnal Teknik Sipil*, *6*(2), 1–12. http://ejournal.polraf.ac.id/index.php/JTS/article/view/65

Solon, T. H., Sela, R. L. E., & Warouw, F. (2023). Dampak Normalisasi Sungai Tondano Terhadap Kondisi Lingkungan, Sosial Dan Ekonomi Masyarakat Kota Manado. *Sabua : Jurnal Lingkungan Binaan Dan Arsitektur*, *12*(1), 1–10.

https://doi.org/10.35793/sabua.v12i1.48808

Sosrodarsono, S., & Tominaga, M. (2008). *Perbaikan dan Pengaturan Sungai*. PT. Pradnya Paramita. https://pu.go.id/pustaka/biblio/perbaikan-dan-pengaturan-sungai/2J826

Tyas, T. H., Sutisna, S., Supriyatno, M., Maarif, S., & Fikri, A. F. (2021). Penanganan Bencana Banjir di Kota Kediri Melalui Mitigasi Non-Struktural Guna Mendukung Keamanan Insani. *Jurnal Pembangunan Wilayah Dan Kota*, *18*(2), 178–191. https://doi.org/10.14710/pwk.v18i2.35564

Ulfa, M., & Fahmi Arif Kurnianto. (2023). Analisis Cut Bank dan Point Bar Pada Bentang Lahan Fluvial DAS Bedadung Jember. *Jurnal Ilmiah Multidisiplin Nusantara (JIMNU)*, *1*(1), 01–07. https://doi.org/10.59435/jimnu.v1i1.31