Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 1 (2024)

Adaptation Strategy for Structural and Non-Structural Floods on the Pantura Coast

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Abstract - Flood is a natural phenomenon in Indonesia, including the Pantura coastal area. It is a complicated problem for the government and must be handled appropriately. The causes of Pantura coastal flood are high rain intensity, climate, land change, tidal floods, etc. The government and residents need to address annual floods in coastal areas in terms of prevention and management strategies. Flood management strategies can be carried out structurally and non-structurally. This study aimed to identify and analyze indicators of structural and non-structural coastal flood management strategies. The research is quantitative through case studies and field observations. Data analysis used SPSS 25 with 183 respondents affected by the coastal flood. The results of the research validity test on structural and non-structural flood handling strategy variables are valid and reliable because the validity values are > 0.300 and reliability with Cronbach alpha > 0.700. Cronbach alpha >0.700. Structural coastal flood management is carried out with flood reduction, buildings damage reduction, damage impact reduction strategies, constructing flood control buildings, and flood control strategies. The Non-structural handling strategy is conducted by active and passive adaptation, socio-economic adaptation, cultural adaptation, watershed management, land use regulations, early warning systems, and community participation.

Keywords*- Coastal Flood, Flood Handling, Structural Strategy, Non- Structural strategy, Coastal, North Coast of Jawa, SPSS*

1. Introduction

Floods are a natural phenomenon in Indonesia, including the northern coast region, which is a thorny problem for the government because it has yet to be appropriately handled [1]. Rainwater and rob flooding caused Pantura coastal floods. It causes losses to humans and economic activities disturbance in coastal areas, causing material losses, damage to the building infrastructure, causing slum environment, and scarcity of clean water [2]. Floods in the Pantura coastal area (Demak, Semarang, Pekalongan, Pekalongan Regency, and Tegal) occur without rain and vary in in inundation heights that reach 20-75 cm[3]. In addition, coastal flooding occurs due to increased development [4]. Factors causing coastal flooding are rainfall, climate, soil subsidence and rob, river conditions, the influence of tides, slum areas, land changes, inappropriate flood control, damage to flood control buildings, excessive use of underground water, and improper flood management, river sedimentation, reduced water catchment areas, and post floods [5]. In handling coastal flooding, structural and non-structural strategies are needed [6]. The coastal flood management strategy is influenced by coastal resources (settlement conditions, facilities, settlement distance), buildings (area density, flood handling), and infrastructure (building feasibility and quick response to disasters) [7].

Numerous studies have discussed flood adaptation strategies tailored for coastal regions. In his 2018 study titled "Risk-Based Flood Management for Climate Change Adaptation," Toshio Okazumi explored a comprehensive approach to coping with floods, encompassing structural and non-structural methods. Yuliadi (2017) research presents an urban coastal tidal flood adaptation model, focusing on examining this model within the context of coastal areas, albeit with a specific constraint: it pertains solely to urban areas along Jakarta's northern coastline [8].

Furthermore, we delve into David Demmerit's 2015 study, focusing on exemplary flood risk communication and management approaches. This research focused on policy models linked to flood adaptation within the Canadian context. The outcomes spotlighted policy models that hold promise for implementation within coastal communities [9]. Turning to the work of Hiroaki I Yukiko and colleagues (2017), their research delved into developing and applying a model in Bangladesh. This model addressed flood adaptation strategies in response to cyclone storms, encompassing physical and non-physical adaptations [10]. Drawing insights from a series of past events and flood management strategies outlined in previous studies, it becomes evident that a deeper exploration of flood adaptation strategies that are better suited and more optimal is essential. Hence, there exists a pressing need for research in this direction.

The significance of conducting this research lies in its capacity to aid pertinent stakeholders in addressing the pervasive issue of coastal flooding. This challenge has risen to the forefront as a considerable concern, exerting adverse effects on the economic fabric of communities. The primary objectives encompass mitigating the detrimental impact of coastal flooding on the economic sector, curbing losses incurred due to inundation along the North Coast of Java, and formulating efficacious strategies encompassing structural and non-structural facets within coastal regions.

The outcomes of this research are poised to offer valuable insights to a broad spectrum of beneficiaries, including local communities, stakeholders, and academia. These insights, centered around apt flood adaptation strategies, can potentially tangibly contribute to the discourse on sustainable coastal flood management. Furthermore, this research can serve as a tool to inform governmental decision-making processes related to coastal flood management strategies. By furnishing inputs concerning viable coastal flood adaptation approaches, governmental bodies and communities can collaboratively implement effective flood management measures.

Given the challenges above, the necessity for flood adaptation strategies becomes evident. In this context, adaptation refers to the adjustments made to one's environment, practices, and knowledge, all of which are geared toward survival strategies. Flood adaptation strategies can be classified into various dimensions, namely: social aspect (community safeguarding and active involvement), technical and non-technical aspect encompassing both structural and non-structural approaches (addressing flood repercussions, evaluating construction viability, assessing facility feasibility, prompt recovery responses, and post-flood urban planning), economic aspect (expediting post-flood development, enhancing capacity), and environmental aspect (ensuring both quality and quantity of the environment) [11]. Efforts in devising flood adaptation strategies, by Kodoatie (2006), can be executed through both structural and non-structural means [12].

Structural flood controls are repairing rivers and constructing flood embankments to reduce flood risk, constructing canals to drain water, and regulating drainage systems to reduce peak flood discharge by building dams and retention ponds [13]. Non-structural methods of handling floods include managing floodplain areas, regulating land use in watersheds, planning flood preparedness movements, and operating flood control procedures [14]. This research aims to find out the strategies for coping with physical and non-physical floods.

Based on previous studies, indicators of physical flood management are strategies to reduce floods by constructing flood control buildings [13], strategies to reduce the impact of damage, and mitigating the effects of floods [14]. Meanwhile, non-structural strategy flood management indicators include community participation, socio-economic adaptation [15], watershed management, land use regulations, and early warning systems [16]. Based on the indicators in previous studies, indicators related to flood adaptation strategies can be seen in Table 1.

Table 1. Indicators of structural and non-structural flood management strategies

No	Variable	Indicator
1.	Structure adaptation strategy	Strategies to reduce flooding, Strategies to reduce flood damage to buildings, Strategies to reduce the impact of damage, Construction of flood control buildings [17], and Flood control strategies.
2.	Non-structural adaptation strategies	Active and passive adaptation, Socio-economic adaptation, Cultural adaptation [18], Watershed management, Land use regulation, Early warning system, and Community participation [19]

Furthermore, these indicators were tested for validity and reliability using SPSS 25.

2. Research Methodology

The research is quantitative, in case studies based on descriptive assessments and quantitative data on numbers. The research is carried out by observation, data collection techniques, and data analysis with SPSS Version 25.00 [20]. The research location is Pantura coastal area—the primary data collection methods with questionnaires, interviews, observation, and documentation. The number of respondents in this study was 183 based on the number of people affected by coastal flooding using the Slovin formula (Table 2). The number of the sample was obtained from the Slovin formula, as follows [21]

N/(1+n (e)2) …………..(1)

Where :

n = Number of Samples

N = Number of Population

e = Error rate in sampling

The population (N) is people, with an error rate (e) of 10% [19].

Table 2. The number of Flood-affected population

No	Regency/City	Flood-affected population (people)	The number of samples (n)
1.	Demak Regency	19.261	50
2.	Semarang City	16.754	43
3.	Pekalongan Regency	10.644	28
4.	Pekalongan City	17.258	45
5.	Tegal City	6.151	17
	Total	70.068	183

Central Java BPS, 2020

Respondents were administered questionnaires containing specific inquiries concerning flood vulnerability indicators, rated on a Likert scale ranging from 1 (disagree) to 5 (strongly agree). The study stipulated specific prerequisites for participants, necessitating that respondents be aged over 17 years, possess a minimum of a high school education, and have resided in flood-affected areas for at least 5 years. Two hundred questionnaires were disseminated to respondents encompassing governmental and non-governmental entities within flood-affected communities. Of the 200 questionnaires distributed, 17 were not returned, accounting for an 8.5% non-return rate. This indicates that 91.5% of the questionnaires were successfully collected, reflecting a favorable response rate classified as "good" (>90%) [21]. An example of the questionnaire is provided in Table 3.

Table 3. Sample Questionnaire of Coastal flood adaptation strategies

No	Indicator	Operational Definition	Option				
			NIA	NI	SI	I	HI
			1	2	3	4	5
Flood Adaptation Strategy (Physical)							
1	Flood reduction strategies	Raising the road, constructing a temporary embankment, backfilling the					

No	Indicator	Operational Definition	Option				
			NIA	NI	SI	I	HI
			1	2	3	4	5
		inundation area with soil					
2	Strategies to reduce the damage impacts	Preservation of natural resources due to flooding, post-flood recovery					
3	Construction of flood control structures	Polder systems, retention ponds and other flood control structures					
Flood Adaptation Strategy (Non Physical)							
1	Active and passive adaptation	Human activity in changing the environment after the flood, people change themselves according to the environment					
2	Social and economic	Community activities in fulfilling					

No	Indicator	Operational Definition	Option				
			NIA	NI	SI	I	HI
			1	2	3	4	5
	adaptation	clothing and food needs, and forms of side jobs and activities to maintain income levels when flooding occurs.					
3	Land use regulations	The existence of clear and written land use regulations from relevant stakeholders					
4	Early warning system	Local government conducts early warning when flooding occurs					
5	Community participation	Communities participate in flood prevention efforts					

Information: 1 = Not influential at all (NIA); 2 = Not influential (NI); 3 = Slightly influential (SI); 4 = Influential (I); 5 = Highly influential (HI).

From the questionnaire in Table 3, the following analyses were conducted for the validity and reliability. The validity test was to check the validity of the question items in the questionnaire. If the items are invalid, they must be discarded and replaced with other questions. The measurement standards used in this study were to determine the validity of the items in the social support research questionnaire. Self-efficacy is 0.300, and the item is considered valid if $rix > 0.300$ [20]. Reliability means an instrument can be trusted enough to be used as a data collection tool. The data must also be trustworthy and dependable. The required reliability value uses the Cronbach Alpha reliability coefficient of 0.700. Validity and reliability tests were conducted with SPSS Version 25 [21].

This research was carried out in several stages, starting from the field observation to the validity and reliability tests. Details of the research stages can be seen in Figure 1.

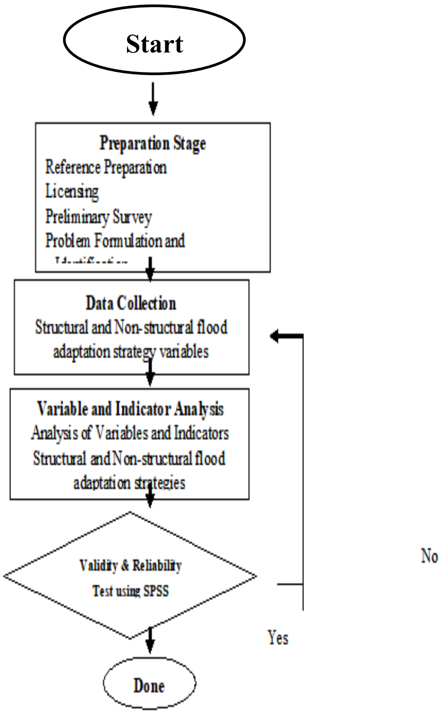

Figure 1: Research flow chart

3. Result and Discussion

3.1 Validity and Reliability Test

The validity test aimed to assess the validity of the questionnaire's question items. If any items were found invalid, they would need to be replaced with alternative questions [22]. Consequently, a higher validity of the measuring instrument indicates greater accuracy and alignment with the intended measurement. This study determined the validity of items in the social support and self-efficacy research questionnaire using a measurement standard of 0.300. An item is considered valid if its correlation coefficient (r) exceeds 0.300. However, if the number of valid items falls short of the desired number, the criterion may be slightly lowered to 0.250 or 0.200.[23].

Table 4. The results of the answers to the strategies of structure and non-structure handling.

No	Indicator	Options				
		1	2	3	4	5
The strategy of structure handling						
1	Strategies for reducing floods	2	20	54	88	19
2	Strategies for reducing the impact of damage	2	20	56	82	23
3	The strategy for the construction of flood control buildings	2	20	53	87	21
The strategy of non-structure handling						
1	Active and passive adaptation	0	11	65	77	30
2	Socio-economic adaptation	1	12	66	76	28
3	Land use regulation	1	10	64	76	32
4	Early warning system	0	15	54	77	37
5	Community participation	0	6	57	89	31

Description: 1 (not influential); 2 (limited influential); 3 (less influential); 4 (influential); 5 (very influential).

Based on the results of the respondents' answers, the next stage was to examine the validity of the indicators with SPSS 25, with the following SPSS analysis results (Table 4) and validity results (Table 5).

Table 4. Validity test results of flood adaptation strategy indicators with SPSS

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Strategies for reducing floods	7.14	3.068	.970	.991
Strategies for reducing the impact of damage	7.13	2.961	.982	.983
The strategy for the construction of flood control buildings	7.13	3.001	.984	.982

Reliability Statistics

Cronbach's Alpha	N of Items
.736	5

Reliability Statistics

Cronbach's Alpha	N of Items
.990	3

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Active and passive adaptation	18.46	7.800	.493	.694
Socio-economic adaptation	18.51	7.460	.557	.674
Land use regulation	18.45	7.953	.434	.711
Early w arning system	18.41	7.925	.412	.718
Community participation	18.36	7.968	.509	.691

Table 5. Summary of the validity results of the indicators

I Indicator	*Corrected Item-Total Correlation*	*Batas Valid*	*Conclusion*
Physical flood adaptation strategy			
Strategies for reducing floods	0.970	0.300	Valid
Strategies for reducing the impact of damage	0.982	0.300	Valid
The strategy of constructing flood control buildings	0.984	0.300	Valid
Non-physical flood adaptation strategy			
Active and passive adaptation	0.493	0.300	Valid
Socio-economic adaptation	0.557	0.300	Valid
Land use regulation	0.434	0.300	Valid
Early warning system	0.412	0.300	Valid
Community participation	0.509	0.300	Valid

As indicated in Table 5, the validity assessment of structural and non-structural flood adaptation strategy indicators demonstrates their validity, as their validity values exceed 0.300. Additionally, the reliability assessment of the instrument yields a reliability coefficient surpassing the stipulated Cronbach's alpha threshold of 0.700. This leads to the conclusion that the reliability test results for the research instrument are acceptable.

Following the validation and reliability tests, the subsequent phase involves ranking indicators based on the mean values of the questionnaire responses. The ranking of indicators is presented in Table 6.

Table 6. Ranking Analysis of coastal flood adaptation strategies

No.	Indicator	Mean	Ranking
Structural flood adaptation strategy			
1.	Strategies to reduce the damage impacts	3.57	1
2.	Strategies to reduce the impact of flooding	3.57	2
3.	Construction of flood control structures	3.56	3
Non-structural flood adaptation strategies			
1.	Community participation	3.79	1
2.	Early warning system	3.74	2
3.	Land use regulations	3.70	3
4.	Active and passive adaptation	3.69	4
5.	Social and economic adaptation	3.64	5

Based on the ranking in Table 6, the strategy indicator to reduce the impact of flooding has the highest rank, with the highest Mean for the structural flood adaptation strategy variable. On the other hand, for the non-structural flood adaptation strategy variable, the community participation indicator has the highest mean. Furthermore, from these results, a discussion of each indicator are presented in the next sub section.

Structural coastal flood adaptation strategies

The validity test of the structural and non-structural flood handling strategy items showed that all item numbers were valid because the validity value was > 0.300, and reliability had a higher reliability coefficient value than the required Cronbach Alpha, which was 0.700.

1. Strategies for reducing floods

The strategy to reduce coastal flooding due to rain and rob is conducted based on the Decree of the Minister of PUPR number 355/KPTS/M/2017, May 30, 2017, for flood control by integrating the construction of the Semarang city sea wall with the construction of the Semarang Demak toll road. The sea wall construction from the east-to-east flood canal baboon river was canceled and replaced by the construction of a toll embankment along ± 9.5 km. Therefore, the initial concept of flood and rob control in Semarang was only normalization and elevation of the Sringin River parapet (open system) and the Tenggang River parapet (open system), the construction of a kistdam on the new Sringin River, accompanied by a pump capacity of 1,350 lps. Manufacture of a kistdam on the old Sringin River by a pump with a capacity of 1,000 lps, construction of a tidal embankment at the Terboyo Terminal towards the Sringin River (concrete sheet pile and soil pile) 520 m long, construction of unisula tidal embankment (concrete sheet pile and soil pile) 320 m long. In addition, making emergency pumps (temporary pumps) is a strategy to reduce the flooding impact at Semarang coastal area, which resulted from the collaboration between the local community and BBWS Pemali Juana as stakeholders (Figure 2).

Figure 2. Strategies to reduce flooding on the coast of Semarang

Table 7 summarized the strategies to reduce the impact of flooding on the coastal areas of Pantura based on the observations made by the researchers.

Table 7. Strategies to reduce the impact of coastal flooding

No	Pantura Coastal Area	Strategy	Conclusion
1.	Pekalongan Coastal area	Construction of retention ponds, boat berth ponds, pump houses, motion weirs, 5 x (2.00 x 2.50 m) manual slide gates, 5,000 m of Parapet	This strategy is considered not optimal, in 2023 the construction of embankments and other buildings was carried out using the state budget fund under the

			Ministry of Public work and housing
2.	Semarang Coastal area	Construction of sringin river estuary pump, 2,100 m Terboyo tidal embankment, 66,000 m3 Rusanwa Kaligawe retention pond, 750 m Tenggang river normalisation, Tenggang- Pasar Waru interconnection channel	Handling is considered optimal to reduce flooding in the Semarang coastal area

Considering the actions undertaken for the Pantura coastal flood management strategy, it becomes apparent that the overall approach falls short of optimization, indicating a pressing need for sustainable flood management.

2. Strategies for reducing the impact of damage

Damage to flood control buildings can lead to the non-functioning of buildings and increase the number of floods. The community and the government must make some efforts to solve it. The examples of flood control efforts carried out since 2017 by the Central Java Provincial PSDATARU Service and the Pemali Juana River Basin in the Pekalongan coastal flood area are the construction of embankments and parapets, sheet piles, pumps, long storage, pump houses, and seawalls. The relevant agencies have carried out the level of improvement for coastal flooding. For example, coastal flooding in Semarang was improved on February 6, 2021, by repairing canals, dredging sediments, optimizing pumps, making polders, and constructing coastal embankments [24].

The field observations identified some strategies to reduce the impact of building damage due to flooding, including: 1) embankment of Slamaran beach in Pekalongan coastal area to reduce damage to buildings around the beach and the impact on local residents due to tidal flooding. This strategy is considered very effective in reducing the impact of flooding in coastal areas (Figure 3).

Figure 3. The construction of coastal embankments in the Pekalongan coastal area is one of the strategies to reduce the damage impacts.

3. Constructing control flood buildings

Some efforts for controlling flood in coastal areas have been conducted, including the construction of flood control buildings on the coast of Pekalongan, namely constructing opening door in Tratebang, Mrican, Silempeng emergency pumps (2 x 250 l/s), Silempeng pump houses (2 unit), Sengkarang pump house (capacity six m/s) and parapet along 600 m, right retention pond with a capacity of 1,796 Ha, weir, normalization of Loji river, Long storage along 2,075 km (Sibulanan River), 4,753 km (Susukan River) and 2,050 km (Clumprit River). Flood control structures have been constructed at Pekalongan coastal area by protecting the Meduri River with CCSP (Figure 4).

Figure 4. Protection of the Meduri River with CCSP for flood control.

Non-structural flood adaptation strategies

1. Active and passive adaptation

Community activity in influencing the environment is an active form of flood adaptation [25]. Coastal communities carried out active adaptations, such as increasing their income during the flood and renovating their houses for those who could afford them. Meanwhile, the passive adaptation of coastal communities is to understand the prediction of flood arrival. One of the active and passive adaptations that coastal communities have carried out is raising the construction of houses so they are not affected by coastal flooding (Figure 3).

Figure 5. The existence of Demak coastal houses that not carrying out active and passive adaptation.

The field observations identified the following active and passive forms of adaptation carried out by coastal communities.

- Pekalongan Coastal area: Building a temporary embankment in front of the house.
- Semarang Coastal area: Elevating the construction of the house, the addition of a wooden building barrier
- Demak Coastal area: Helping to evacuate during floods, raising the foundation of the house, providing facilities and infrastructure as an effort from the government.

2. Social economy adaptation

Floods on the coast of Pantura increase community solidarity. Interaction between residents is well established in the form of mutual help. In addition, the community cooperates and gets involved in flood management with related stakeholders. The community is involved with stakeholders against Pantura coastal flooding by making temporary kisdam and embankments from sacks (Figure 6).

Based on the acquired primary data and observations, the losses inflicted by coastal flooding along the North Coast of Java fall within the moderate range. These losses encompass physical damages amounting to IDR 29,481,734.10 million and economic losses totaling IDR 97,270.00 million. To curtail the socio-economic repercussions, active community engagement is imperative. Community involvement to mitigate the socio-economic impact of flooding entails fostering collaboration and coordination between the community and stakeholders. This cooperative effort is directed towards countering coastal flooding along the Pantura region by establishing temporary sandbag wall structures, embankments using sacks (Figure 6).

Figure 6. Temporary Kisdam made by Pesisir Semarang residents as a form of handling the economic-social strategy.

3. Land use regulation

Changes in land use can exacerbate flooding problems in the coastal area of the Pantura due to increased flood flows caused by changes in land use for buildings. Central Java Province BPS data for 2020 indicated an increased population, including the Pantura coastal area and the Semarang City coast population [26]. This factor drives the increasing demand for land to provide food, housing, and infrastructure. The RTRW for the Pantura coastal area is considered one of the causes of coastal area floods.

This research found that land use regulations already in effect include: The regulation of Ministry of Public works and Housing No. 28 concerning river boundary line, Regional Regulation No. 9 of 2020 concerning Neighborhood Unit / Community Unit and Pekalongan District Regent Regulation No. 43 of 2019 concerning compensation for flood-affected residents.

4. Early warning system

An early warning system for coastal flooding is developed to improve an effective system to provide fast and accurate information to the community about potential flooding. Therefore, they can take appropriate preventive measures. In addition, the community gets an education about early warning, evacuation procedures, and other flood prevention measures to increase their awareness.

Based on on-site observations, the flood early warning system is the J-FEWS, designed to provide insights into flood occurrences across various coastal rivers. Nevertheless, the precision of this tool is not yet optimal, necessitating additional calibration using the most recent flood event data.

5. Community participation

Involve the community in planning, implementing, and monitoring flood prevention programs, river management, and drainage control by improving community coordination with relevant stakeholders.

The field observations identified the following forms of participation of coastal communities in flooding.

- Conducting post-flood recovery communal work activities
- The community supports the Presidential Regulation No. 79 of 2019 concerning the acceleration of post-flood development
- The community complies with the regulation of the Ministry of Public Works and Housing No.28 of 2015 concerning the prohibition of building construction in riparian areas
- The community adapts to flooding

4. Conclusion

The study yields the following conclusions:

1. The structural flood adaptation strategy indicators encompass strategies to mitigate damage impacts, alleviate flooding consequences, and flood control infrastructure strategies. The non-structural flood adaptation strategy indicators consist of community involvement, early warning systems, land use regulations, active and passive adaptation measures, and social and economic adaptations.

2. All variables investigated in this research demonstrate reliability, evidenced by their reliability coefficient values surpassing the prescribed Cronbach's alpha threshold of 0.700. Additionally, all research indicators are deemed valid, as signified by their validity values exceeding 0.300. When assessing mean values, the indicator of damage impact reduction garners the highest ranking within the structural flood adaptation variable.

Simultaneously, the indicator concerning community participation claims the top rank in the non-structural flood adaptation strategy variable.

5. Recommendation

This study puts forward the following recommendations:

1. For future research, it is advisable to expand the scope of the flood study beyond just the coastal areas to obtain more comprehensive and robust results.
2. The current study has a limited set of indicators. Future studies should incorporate a more comprehensive range of indicators to enhance the diversity and accuracy of the findings.
3. In subsequent research, the formulation of strategies can benefit from employing methods such as the SWOT analysis and Analytical Hierarchy Processes to facilitate more effective and systematic strategy development.

Acknowledgments

This research received support from various institutions, including the Pemali Juana River Basin Center (BBWS Pemali Juana), Central Java Provincial Office of Public Works and Spatial Planning (PSDATARU), Demak District Public Works Office, as well as the Semarang City and Pekalongan City authorities. Additionally, the research collaboration extended to the Sultan Agung Islamic University Semarang campus.

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