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PRECIPITATION DATA FROM GOOGLE EARTH ENGINE (GEE) IN REVETMENT DRAINAGE EVALUATION IN KALIANDA

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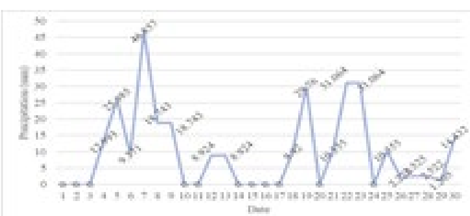
Graphical abstract



Abstract

Floods can occur frequently if there are no organized and constant changes in land use. Flood issues in Waymuli, South Lampung, has been occurring due to changes in land use in the area. Prior studies regarding drainage of coastal revetments may have been done before. However, the analysis was done using precipitation data from GEE and therefore, new findings as the solution for the flood problems in the region were necessary. The main objective of this research is to assess the extent of success of drainage system management using rainfall information obtained via GEE. The method used was by evaluating the capability of the drainage system using data from GEE, which involve identifying and measuring the drainage capacity with the HEC-RAS application. This study conclude that the use of GEE can be accurately used to evaluate revetment drainage. Rainfall in the last two years were 54.0340 mm, 81.8905 mm in the last five years, and 104.0784 mm in the last ten years. However, GEE results show that the highest rainfall recorded in September 2022 was 46.857 mm. Based on the HEC-RAS evaluation, it was also found that the drainage system does not have the capacity to drain rain within a 2-year period. It can be concluded that the function of the drainage system in this area is to support the coastal revetment system, not as the main drainage system.

Keywords: Land use, flood, drainage, GEE, coastal revetment

1.0 INTRODUCTION

Land use is a necessary aspect in order to understand how human action can turn the environment. Monitoring and identifying important changes in environmental conditions is a major factor in maintaining good environmental sustainability in every city [1]. Assessing land change uses is a necessary step in enhancing hydrologic condition appraisal [2]. If there is no thorough drainage planning, it is likely that the risk of flooding will increase as a result of changes in land use after the construction of a coastal revetment. Revetment is a type of structure used to protect coasts from erosion [3]. With changes in land use, nature's ability to be able to absorb and hold rainfall efficiently will decline, which in the end can increase flood problems in urban regions. Changes in land use patterns without paying attention to effective river drainage and drainage systems can also result in fragmentation of water flow and ultimately increase the chance of flooding. Therefore, it is necessary to consider land use changes in the construction of coastal revetment carefully. This includes planning an efficient drainage system and maintaining areas that can absorb water well to reduce the possibility of flooding.

One of the causes of floods is the occurrence of natural phenomena that occur quickly and uncontrollably, resulting in casualties to human life and community property [4]. To achieve maximum efficiency and sustainability, it is important to integrate urban drainage control with the system of sanitation, waste utilization, urban flood control, and other relevant components [5]. The rise of urban development, growing agriculture, and logging have decreased the nature's potential to absorb water. Consequently, the water cannot be absorbed effectively when the rain falls heavily. Therefore, an analysis to lower the possibility of flood in the future is necessary [6]. This is what causes the river flow to become swift and to overflow, so that the flood rate will be higher and become more violent. To overcome this situation, it is imperative to control land use continuously so as to minimize the risk of flooding.

Water resources control planning, climate and flood assessment, and characterization of precipitation are only a few of the many uses for rainfall data in hydrometeorology [7]. However, in some regions, sometimes insufficient data resources are still a problem. One way to solve the problem of lack of rainfall data is to use remote sensing technology via satellite. Recently, there are more and more cloud-based platforms that everyone can use for free, such as Global Earth Engine (GEE). This platform is a cloud platform designed to carry out geospatial assessments at a global level. Furthermore, this platform also provides a multi-petabyte earth data catalog that can be accessed by all users [8]. The importance of drainage system efficiency cannot be underestimated in overcoming the risk of flooding in coastal areas. In this research, satellite data was chosen as the main data due to advances in remote sensing technology that have occurred. In prior research [9], Using Tropical Rainfall Measuring Mission (TRMM) satellite data, the scientists analyzed the occurrence and frequency of rain in Indonesia. They examined the Indonesian rainfall patterns using data from the Global Satellite Mapping of Precipitation (GSMaP) initiative [10,11]. Long-term extreme precipitation patterns can be evaluated with data from the Climate Hazard Group InfraRed Precipitation with Station (CHIRPS) satellite in addition to the Tropical Rainfall Measuring Mission and the Global Precipitation Monitoring Array [12]. Therefore, the usage of the data of satellite as the main data source has become an essential choice. The validation and utilization of satellite data can increase the accuracy and comprehensiveness in studying rainfall patterns in Indonesia. Examining data collected by TRMM, GSMaP, and CHIRPS satellites provides an opportunity to gain a comprehensive understanding of rainfall and study extreme rainfall patterns over long time periods.

Prior studies regarding drainage of coastal revetments may have been carried out. However, in this research, research involving precipitation data from GEE was used. Therefore, novelties to flood issues solution were found. With the integrated precipitation data available from GEE, using this technology, it is feasible to find rain patterns in an area and predict the risk of flooding or water overrun which can impact the drainage system of the revetment. Therefore, the utilization of GEE rainfall data provides important and relevant information about various weather conditions and water-flow patterns that can be used to assess effectiveness of drainage in revetments.

The objective of this research is to evaluate the strength of drainage management through rainfall data obtained from GEE. It is hoped that through this research, a deeper understanding will be gained about how the existing drainage system can overcome flooding problems in the area.

2.0 METHODOLOGY

2.1 Research Location

Due to its proximity to Muli Beach and the coastal road along Way Muli Village in Rajabasa District, South Lampung Regency, Lampung Province, Indonesia 35552 was selected as the study location (Figure 1).

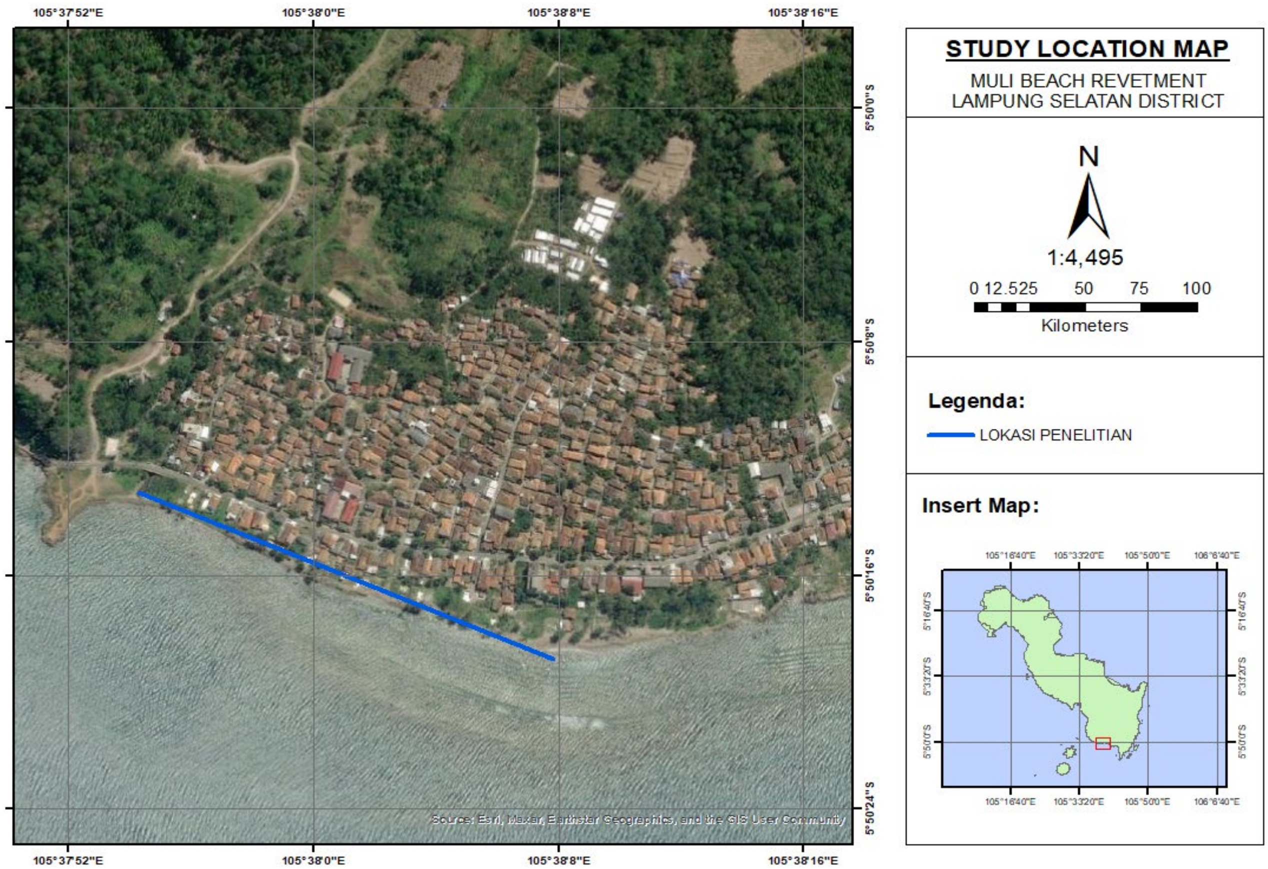


Figure 1 Map of Research Locations

2.2 Research Data

The time span between the onset and cessation of rain is known as the "duration" and is often quantified in hours. The September 2022 rainfall data from GEE of Muli was used for this analysis. Rainfall data from TRMM and GPM are only two examples of the many satellite data sources that are accessible through GEE. This information is crucial for analysing rainfall patterns and intensities. Understanding hydrological characteristics and making informed decisions in drainage system planning and management are aided by the analysis of rainfall data.

2.3 Data Collection

The steps to obtain rainfall data from GEE are as follows:

1. Opening Google Chrome
   Type in https://code.earthengine.google.com/ to open GEE.
2. Input the Formula to the Script
   Var image=ee.ImageCollection("UCSB-CHG/CHIRPS/DAILY") var data=image.filterDate ('2022-09-01','2022-10-01') print (data) var preci=data.map(function(data){returdata.clip (roi)}) var precipitation=preci.select('precipitation')print (precipitation,'precipitation')Map.addLayer(precipitation)
3. Choose the Location for assessment
   Create the polygon (put it on the region whose data will be taken), then, substitute “geometri” with “roi” in the second line of the script. Next, click “Run”, choose “inspector”, and click the polygon on the map. Click “pixels”, “layer”, and “series” afterwards. In order to get a clearer graph, click the “zoom” icon on top right-hand corner of the graph.
4. Saving the Data
   Save the data according to the needs. Three saving formats are available, i.e. CSV, SVG and PNG.

Data is then analyzed using the Rational method so as to figure out the planned flood debit. Then, the debit is referred to in the hydrologic analysis using HEC-RAS. The following are the flow chart (Figure 2) and GEE screen display (Figure 3).

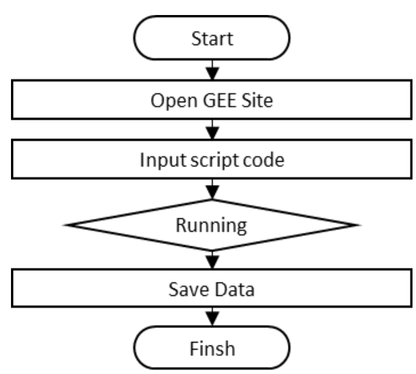


Figure 2. Flow Chart of Data Collection Process from GEE.

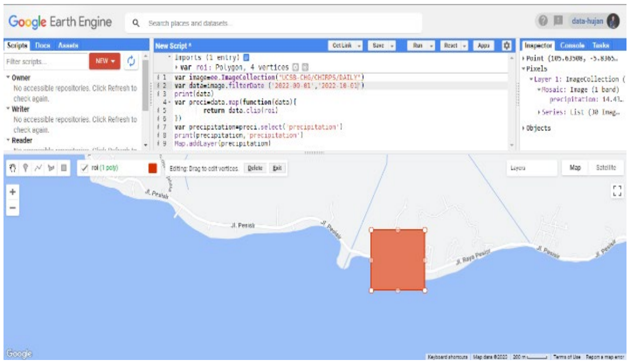


Figure 3. GEE Screen Display of Rainfall Data Collection.

2.4 Frequency Analysis

Frequency analysis method is a statistical approach in analyzing hydrological data with the aim of predicting the level of rain intensity or rain fall debit over a certain time period [13]. The rainfall data used in this research was the data from 2011 – 2020 from the rainfall station of Penengahan. Frequency analysis aims to examine the relationship between events that rarely occur and how often they occur using a continuous probability distribution model. These calculations require mean, standard deviation, skewness, kurtosis, and variation are examples of such variables. Normal, log-normal, Pearson log, and Gumbel distributions are just some of the most often utilized types of distributions in evaluating hydrological frequencies [14].

In carrying out analysis of the fit of data distribution types, variables such as mean, standard deviation, skewness, kurtosis, and variation. In assessing hydrologic frequencies, there are several types of distribution that are commonly used, such as normal, log normal,Pearson log, and Gumbel distributions [14].

1. Average Value

$$\bar{X} = \frac{\sum_{i-1}^{n} X_i}{n} \quad (1)$$

2. Standard Deviation

$$Sd = \sqrt{\frac{\sum_{i-1}^{n} (X_i - \bar{X})^2}{n-1}} \quad (2)$$

3. Skewness Coefficient

$$Cs = \frac{n \sum_{i-1}^{n} \{(X_i) - \bar{X}\}^3}{(n-1)(n-2)Sd^3} \quad (3)$$

4. Kurtosis Coefficient

$$Ck = \frac{\frac{1}{n} \sum_{i-1}^{n} \{(X_i) - \bar{X}\}^4}{Sd^4} \quad (4)$$

5. Variation Coefficient

$$Cv = \frac{Sd^4}{\bar{X}} \quad (5)$$

Where:
X = Variant Average Value
Sd = Standard Deviation
Cs = Skewness Coefficient
Ck = Kurtosis Coefficient
Cv = Variation Coefficient
X_i = i Variant Value
n = Total Data

Comparison of statistical parameters with the distribution requirements in question was carried out. In frequency analysis, we can identify and use the probability distribution that is closest to the existing data. [15] (Table 1).

Table 1 Statistical Parameter Requirements

Type of Distribution	Requirement
Normal	Cs = 0 Ck = 3
Log Normal	Cs = 3Cv + Cv^3 Ck = $Cv^8 + 6Cv^6 + 15Cv^4 + 16Cv^2 + 3$
Gumbel	Cs = 1,14 Ck = 5,4
Log Person	Other than the values above

Source: Triatmodjo, 2008

2.5 Rational Method

Calculating the peak surface flow rate logically is possible. Rational method is a quick and simple approach. This, however, is limited to smaller watersheds (those with an area of 300 ha or less) [16].

This method for assessing peak flow is commonly known to be one of the leading and most convenient way to estimate the peak runoffof a small watershed. The calculations are not complicated and are appropriate for watersheds that are quite small in size. [17]. This method is considered one of the most efficient and easy to use methods. [18]. In addition, the way of applying it in Indonesia can still be developed. This method is suitable for regions or countries that has tropical climate such as Indonesia. Some of the hydrological factors involved include intensity, duration, and frequency of the rain, size of the watershed, water reduction due to evaporation, absorption, infiltration, and reservoirs, and density of the water flow. The rational method can be formulated as below [19]:

$$Q = 0.2778.C.I.A \quad (6)$$

Where:
Q : Peak Surface Flow Rate (m^3/s),
C : Rainfall Intensity (mm/hr),
I : Watershed Width (km^2),
A : Surface Flow Coefficient ($0 \leq C \leq 1$).

The basic preconditions to use the rational method are as follows:

1. Rainfall remains stable with the same intensity over a certain period of time, at least during one concentration period.
2. If the rain duration has a stable intensity during the concentration time, direct runoff will reach its maximum value.
3. During the rainfall duration, the runoff coefficient remains the same.
4. During the rainfall duration, the watershed width remains constant.

2.6 HEC-RAS

Is a state-of-the-art software for analysing river systems [20]. Geometric and flow data are essential for HEC-RAS [21]. Length of the river's channel and banks, the height of the flood on the banks, and the profile of the river's cross section are all included in this basic geometric data. From the data provided, HEC-RAS should be able to do hydrological calculations both in one or two dimensions to examine the profile of the water surface [22].

The 1D model operated by HEC-RAS has a number of limitations although it provides useful hydrological analysis results. 1D models usually do not consider losses that may arise due to friction, the size of the flooded area, and often cannot produce accurate predictions of flood movement [23]. In the event of a complicated hydrologic occurrence, the 1D model generated by the hydrologic analysis may not deliver correct and holistic results.

HEC-RAS is user-interactive, integrated software developed for collaborative work [24]. The graphical user interface (GUI), components for hydrological analysis, data storage, control, and graphics are all a part of this system. The core of HEC-RAS is the following three 1D hydrologic analysis tools:
1. Calculation of constant flow water surface.
2. Simulation of unsteady flow.
3. Calculation of movement of sediment.

2.7. Research Flowchart

Figure 4 summarizes the three stages of this study. In the first stage, the data on rainfall was gathered. The second factor was the calculation of the anticipated flood's deficit. The information was 55tilized to determine the anticipated flood debit. The purpose of this debit is to learn more about the likelihood of flooding under extreme situations. Step three entails actually entering information into HEC-RAS.

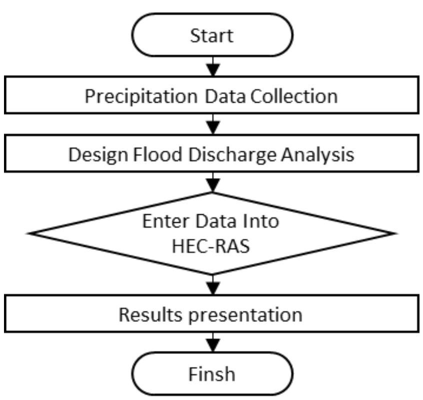


Figure 4 Stages in Flood Simulations with HEC-RAS

3.0 RESULTS AND DISCUSSION

3.1 Coastal Revetment

The structural integrity and efficiency of a revetment depend on the interplay of its many parts. Coastal revetment is useful because it acts as a physical barrier, preventing harm to the coastline even when waves are high. With proper upkeep and careful planning, coast revetments can safeguard specific locations for decades. Figure 5 is a cross-section of a coastal revetment.

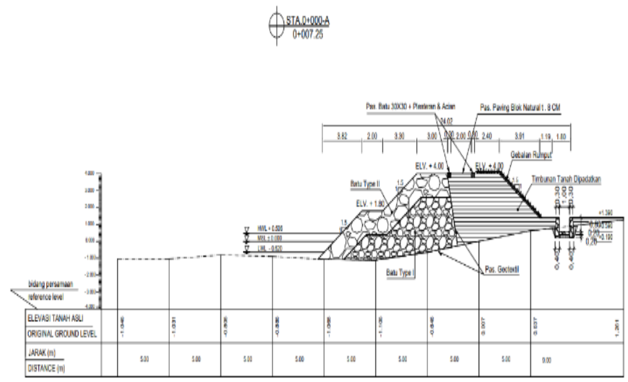


Figure 5. Cross-Section of the Study Area Coastal Revetment

In the picture, the drainage at the back of the revetment is visible. These results show that apart from acting as a water drainage system, it also plays a role as protection for the revetment structure. The drainage revetment is aligned to the coast. The primary drainage must be in a vertical position relative to the coastline.

3.2 Rainfall Data

Based on the GEE data, the maximum rainfall, with an intensity According to information provided by GEE, on September 7 2022 the highest rainfall intensity was recorded at 46.857 mm (reference in Figure 6). Based on Figure 6, it can be concluded that when the rainfall intensity reached its peak of 46.857 mm, the area experienced flooding. However, with a debit of 31.064 mm, not all rain causes flooding. It can be concluded that common rain does not have the potential to trigger flooding. However, when rainfall increases by 20 mm, the existing capacity is not enough to accommodate the rain effectively.

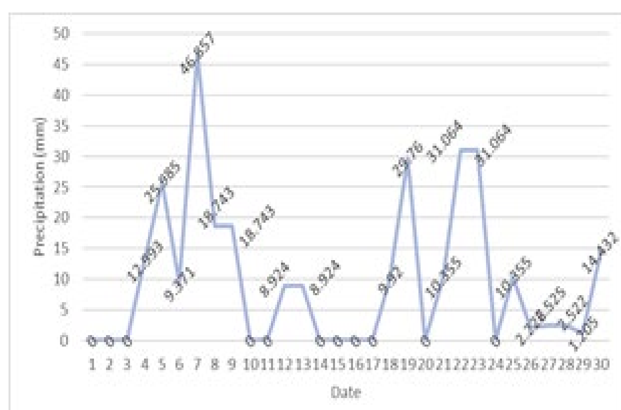


Figure 6. Way Muli's Rainfall Graph of September 2022

3.3 Calculation of Planned Flood Debit

The flood debit calculation with the rational method results is shown in Table 2. It was found from the estimation that the flood debits in each channels of 1, 2, 3, and 4 were 0.434 m^3/s, 0.499 m^3/s, 0.766 m^3/s and 1.062 m^3/s

Table 2. Flood Debits with Rational Method

Channel	A (km^2)	R24 (mm)	L (Km)	H (Km)	C	Tc (hour)	I (mm/hour)	Q (m^3/s)
S1	0.124	46.857	360	0.110	0.60	0.682	20.981	0.434
S2	0.063	46.857	120	0.096	0.60	0.202	47.211	0.499
S3	0.028	46.857	80	0.063	0.60	0.149	57.900	0.766
S4	0.032	46.857	90	0.078	0.60	0.157	55.860	1.062

Table 3 Annual Maximum Rainfall Data (mm)

No	Year	Xi (mm)
1	2011	127.00
2	2012	100.00
3	2013	50.10
4	2014	31.00
5	2015	40.00
6	2016	33.50
7	2017	60.00
8	2018	78.00
9	2019	61.00
10	2020	41.00

Judging from Table 3, the debit flowing through channel 1 at the mouth of the river is lower compared to channel 4 which was at the bottom of the river. The calculation results show the amount of flood water that flows through each channel at the time of maximum rainfall. After that, a hydrological assessment was carried out using HEC-RAS software.

3.4 Drainage Function Analysis

a. Rainfall

The frequency analysis relates to information regarding the maximum daily rainfall amount recorded at the Penengahan rainfall station by BBWS-MS. The information about rainfall in question covers the period 2011 – 2020 (see Table 3).

From the graph in Figure 7, it is known that the maximum rainfall in 2011 was 127 mm, while in 2014, the lowest rainfall was 31 mm. This data was then referred to by the frequency analyses with recurrence intervals of 2, 5, and 10 years.

Based on the frequency analyses, the rainfalls in the recurrence intervals of 2, 5, and 10 years were 54.0340 mm, 81.8905 mm, and 104.0784 mm respectively (see Table 4), while from the GEE results, the maximum rainfall in September 2022 was 46.857 mm. The results prove that, in the period of 2 years, the region encountered the peak debit one time at least. As for

The primary drainage needed the debit in the recurrence interval of 10 years. This proves that the revetment drainage could not function as primary drainage.

Table 4 Results of Frequency Analyses with Recurrence Intervals of 2, 5, and 10 years

No	Recurrence Interval (Year)	R24 (mm)
1	2	54.0340
2	5	81.8905
3	10	104.0784

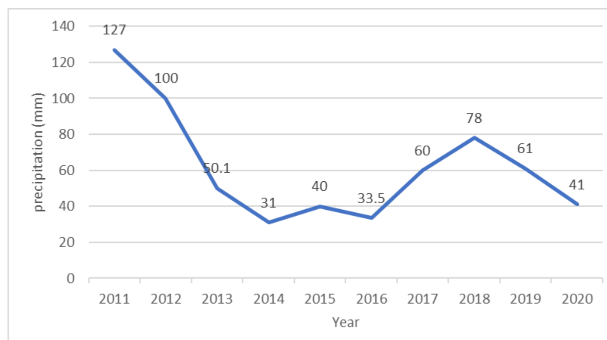


Figure 7 Annual maximum rainfall graph

b. Areas of Water Catchment

Through the use of Google Earth Pro, we can gain a detailed understanding of the topography or altitude of areas within the water catchment area. The area of water captured is 0.124 km^2 for the red area, 0.063 km^2 for the yellow area, 0.028 km^2 for the green area, and 0.032 km^2 for the blue area. Channel 1 is marked with a red area. This indicates that the flow direction is more inclined to the right side. Meanwhile, the yellow, green, and blue areas depict the second, third and fourth communication paths respectively. They provide evidence that the water flow is moving to the left (See Figure 8).

Figure 8. Catchment Area

c. Drainage Cross-Section Shapes

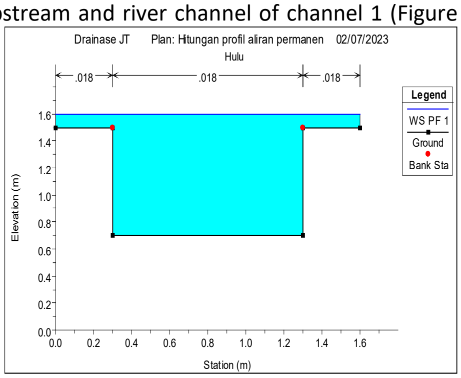
Revetment drainage is geographically parallel to the coastline. Although it was parallel to the coastline, this drainage was not the primary drainage that requires a 10-year recurrence interval. Based on HEC-RAS data processing, it was found that the drainage system does not have sufficient capacity to hold the amount of water that is expected to come within a two-year period.

The HEC-RAS application was used in the existing channel dimension assessment. In the illustration of the river flow profile of the upstream and river channel of channel 1 (Figure 9a and 9b), it can be seen that the amount of water flowing (Q = 0.434 m^3/s) outpace the capacity of the channel. Figure 9c and 9d show the river's initial flow profile and the bottom of river channel 2, respectively, revealing that the water flow (Q=0.499 m3/s) is very close to exceeding the channel's capacity. Channel 3 has a deficit (Q = 0.766 m3/s) that exceeds its capacity, as seen in Figure 9e and 9f, which depict the upstream and riverbed flow profiles, respectively. In Figure 9g and 9h, we see an illustration of the flow profile of the upstream river and river bed of channel 4. The debit (1.062 m3/s) follows the same pattern.

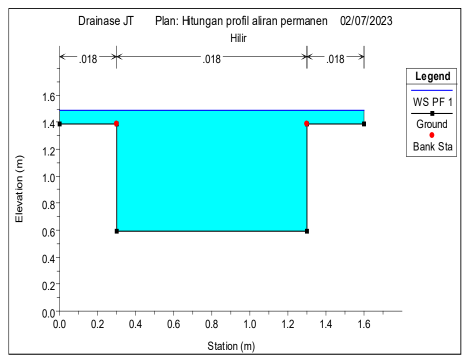
Using flood debit data at its peak, a horizontal flow profile can be generated via HEC-RAS as seen in Figure 9. From the illustration, it can be seen that several drainage areas have excessive capacity. By considering this aspect, it can be concluded that drainage only plays a supporting role in coastal revetments and not as the main drainage channel.

As the solution for flood issues in the area, a system of primary drainage that could manage massive and complex water stream is imperative.

The primary drainage system is designed to remove rainwater from a larger area. This system aims to reduce the risk of flooding by channeling rainwater away from residential areas and other crucial areas.



(a)



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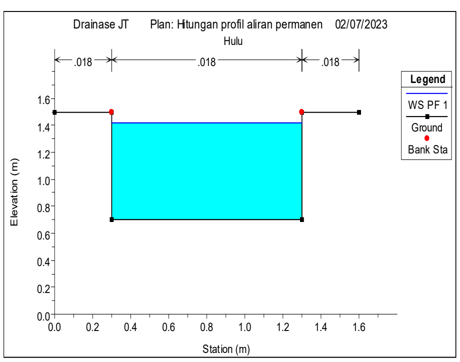
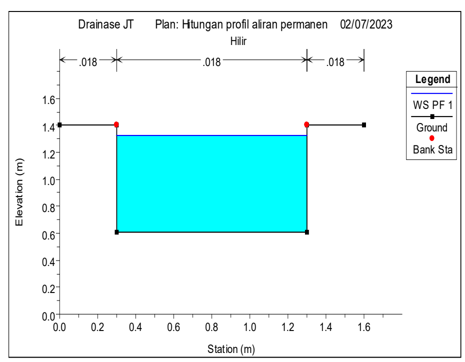


(c)



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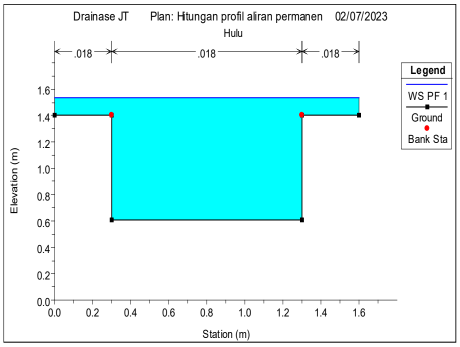

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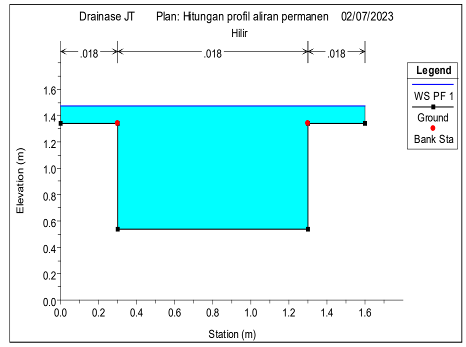

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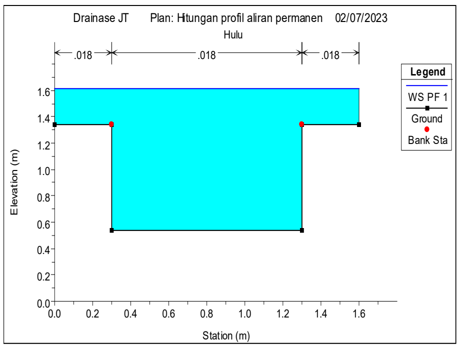

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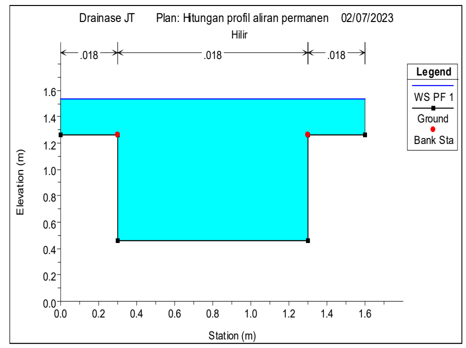

(h)

Figure 9. Flow Profiles of (a) Riverhead of Channel 1, (b) River Bottom of Channel 1, (c) Riverhead of Channel 2, (d) River Bottomof Channel 2, (e) Riverhead of Channel 3, (f) River Bottom of Channel 3, (g) Riverhead of Channel 4, and (h) River Bottom of Channel 4

4.0 CONCLUSION

In summary, with the success of creating this automatic measurement device, it is hoped that sedimentation measurements based on turbidity and flow velocity will become an effective and easy alternative for obtaining data efficiently and practically. It is hoped that by using this device, problems that occur in the field can be resolved perfectly. Apart from that, various other ways can be used to operate this series of devices. For example, such as predicting the possibility of flooding, applying certain methods in the field, and analyzing other imperative data.

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