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Water-Trap Series and City Pond to Control The Destructive Power of Runoff Water from Mbay Hills

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Abstract: Weworuwet Hill, which is part of the Mbay hillside in Flores – NTT has sparse vegetation, only a stretch of grass that covers it, and is dry in the dry season like a barren teletabic hillside. This has the potential for surface water runoff, which has high destructive power, especially in the lowlands of Mbay City. To overcome this problem, a study to control the destructive force of water runoff was carried out by applying a water-trap series system, so that the potential for the destructive power of water can be reduced. Tertiary, secondary and primary runoff analysis studies are carried out to determine the location of the required water-traps. This study was conducted using a geographic information system-based program. Furthermore, the hydrological analysis of the area is carried out to determine which flood discharge can be controlled, and the volume of water that can be used for greening hills so that it can reduce the potential for damage to water runoff. The remaining water discharge in the downstream will be accommodated in the city pond, which functions as water conservation infrastructure. Finally, by applying a series of water traps on the tertiary, secondary and primary runoff from the Mbay hilly area, the destructive power of the runoff can be controlled, so that it does not impact and burden the residential plains of the town of Mbay.
Keywords: water-trap series, city lake, the destructive power of water, geographic information system.

1. Introduction

The city of Mbay is a plain that lies under bare hills with minimal vegetation. Weworuwet Hill is one part of these hills, only covered with grass, which is a tourist destination (Figure 1). The grass dries up during the dry season, like a row of barren teletabis hills (Figure 2).

Figure 1. The Weworuwet Hill, Mbay-Flores, NTT [1]

Figure 2. Teletabis Hillside Dry Grass [1]

This situation has the potential for surface water runoff [2], which has high destructive power [3], especially in the lowlands of the city downstream, which are affected by flooding every year during the rainy season [4]. The city of Mbay which is an alluvial lowland is flanked by a row of hills on its upstream and a stretch of rice fields downstream (Figure 3).

Figure 3. Mbay City With Its Hills and Rice Fields (1. Mbay Hills / The Weworuwet Hill; 2. The Alluvial Plain of the Mbay City; 3. The Right Mbay Rice Fields) [5]

The local government conducted a study on the Mbay city drainage master plan in 2010 [6] and design review in 2013. The crucial problem is the destructive power of surface water runoff from bare hills [3][6], resulting erosion and flash floods occurring when the rain arrives and give an impact [7].

This prompted a study to implement water-trap series system in hilly natural drainage channels to reduce the destructive power of surface water runoff [8][9]. Meanwhile, the remaining runoff water downstream of the lowlands is collected in a city pond so that the potential for water damage to the urban lowlands can be controlled [10]. So the purpose of this study is to determine the points of the chain water traps with the help of SIMODAS software.

The literature review carried out includes: 1) analysis of tertiary, secondary and primary water runoff analysis using geographic information system, which will become the basis for the construction of the SIMODAS. 2) the hydrological analysis of the catchment area is carried out to determine the flood discharge that can be controlled, 3) the location of required water-trap series along tertiary, secondary and primary natural drainage, which already analysis before to find the volume of water that can be used for greening hills, and finally 4) the remaining water discharge downstream will be captured in a city pond, which functions as water conservation infrastructure.

All analysis was conducted using a program based on a geographic information system. The detail analysis is illustrated in Figure 4.

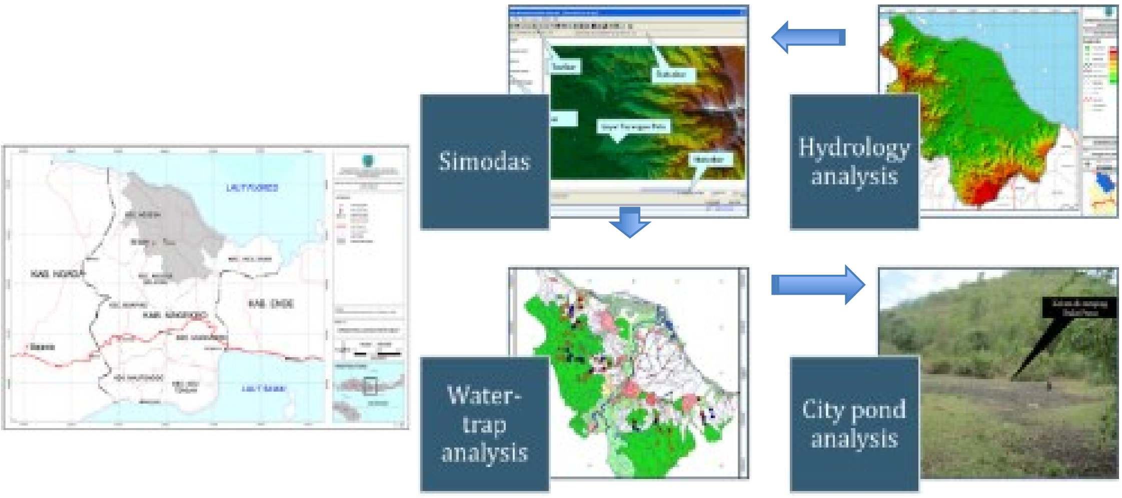

Figure 4. The Analysis Process Detail of Water-Trap Series and City Ponds Control of Mbay Hills

SIMODAS is software that can be used as information systems and hydrologic models for watershed management [11]. This software is developed by integrating hydrologic models and spatial spread of Geographical Information Systems (GIS) [12]. The system output from one river basin system is the flood discharge river, which is the integrator that influenced by catchment area [13]. The SIMODAS hydrological model is able to estimate rainwater runoff and investigate the use of storage wells to control this runoff [14]. From the hydrological analysis and SIMODAS, it was developed for water-trap series analysis, namely analysing the height of the trap embankment. Then, the relationship between the area-volume of puddle water can be found [15] [16]. This puddle water is controlling the flash runoff, which means reducing the destructive power of runoff water.

2. Material and Methods

The methodology in this study can be described as shown in the Figure 5. First of all, has to be collected the data, which consist of rainfall data and digital map data (must be compatible for Arc-View GIS application.

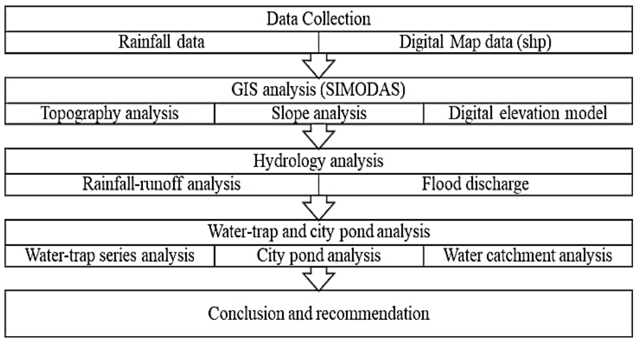

Figure 5. The Methodology in This Study

2.1. GIS Analysis (SIMODAS)

GIS analysis method in the form of DEM analysis using Arc-View GIS software, which is supported by the Visual Basic programming language to add rain data. Software map-objects are combined to give a better view of the map [17]. The DEM analysis consists of topographic analysis of the location from art-view map data, which can then be followed by analysis of the slope of the location and analysis of the elevation model. The end analysis can produce a digital map of the elevation model (DEM) which becomes the basis for further analysis.

2.2 Hydrology Analysis

Hydrological analysis includes analysis of the relationship between rainfall - runoff. Hydrological analysis method using the Art-View GIS software facility to determine the rain catchment area from digital map data. By entering the results of the rain data analysis (wet-dry-normal yearly rain), it can be found the volume of inundation that occurs. From the analysis of the relationship between rainfall - runoff, it can be continued to flood discharge analysis or water flow that needs to be controlled so that it does not have the potential destructive force of water.

2.3 Water-Trap and City Pond Analysis

This analysis of water traps and city pond includes analysis of the location of the water-traps, which are determined from the analysis of the catchment area of the DEM map. From the DEM map, it can be continued to the location of water traps analysis in tertiary, secondary and primary natural drainage flows. By determining the required embankment, it can be found the relationship between the area and volume puddle water caused by the embankment of the water trap.

The remaining water discharge in the downstream will be accommodated in the city pond, which functions as water conservation infrastructure.

2.4 Data Analysis

The results of this analysis are in the form of the location of the water-traps series map, which needed to control the flow of surface runoff that has destructive power due to barren mountain range. That also give the location of the city pond, which is needed for conservation water so as to protect the city from flash floods caused from the upstream.

3. Results and Discussion

The description of the area of the Mbay city and its surroundings can be depicted as in Figure 6. First, a barren mountain range has the potential for heavy rainwater runoff to cause erosion and damage along its flow. Downstream, which is the second area, is a large plain which is the location of the Mbay city, so that every year with long flood of inundation experience and has an impact on both economic losses and health decrease. Leading up to the estuary lay extensive rice fields, which are described as the third area.

Figure 6. The Description of Mbay City and Its Surroundings

The description of the area of the Mbay city and its surroundings can be depicted as in Figure 6. First, a barren mountain range has the potential for heavy rainwater runoff to cause erosion and damage along its flow. Downstream, which is the second area, is a large plain which is the location of the Mbay city, so that every year with long flood of inundation experience and has an impact on both economic losses and health decrease. Leading up to the estuary lay extensive rice fields, which are described as the third area.

3.1 GIS Analysis (SIMODAS)

The digital topographic map data is inputted into SIMODAS, so that this topographic map can be read in the SIMODAS version as described in Figure 7. The next step is to analyse the slope of the land through SIMODAS software as well as from the input of the topographic map. The results of this slope analysis are shown in Figure 8. Furthermore, the DEM analysis is carried out in this SIMODAS application. SIMODAS will provide a DEM map as shown in Figure 9.

Figure 7. Topography Map of Mbay

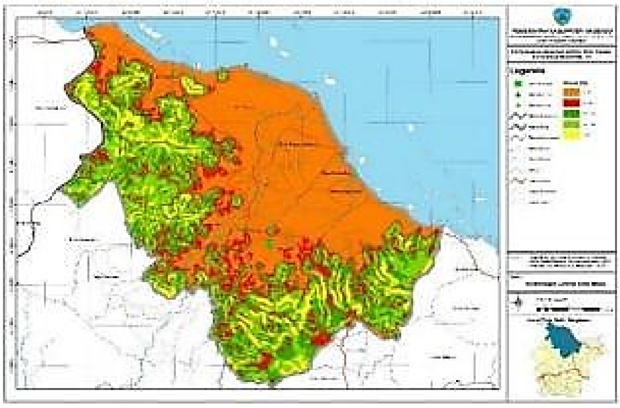

Figure 8. Slope Map of Mbay

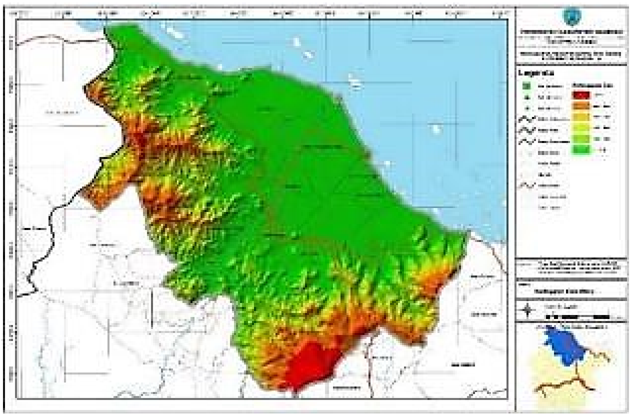

Figure 9. DEM Map of Mbay

This DEM map will serve as a starting point for further analysis related to rainwater catchment analysis.

3.2 *Hydrology: Water-Trap. and City Pond Analysis*

Hydrological analysis includes: 1) water catchment areas in primary, secondary and tertiary natural drainage streamflow; 2) determine the location of the water trap; 3) inundation water caused by water-traps and the relationship between area-volume of inundation.

The results of the wet-dry-normal yearly rainfall analysis are shown as in Figure 10.

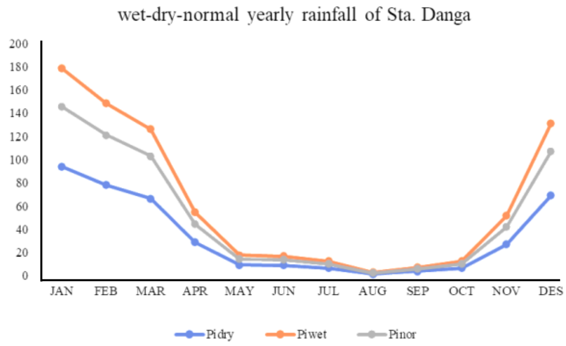

Figure 10. Yearly Rainfall Analysis

The Mbay area is divided into 4 hydrological areas as shown in Figure10. Then each hydrological area will be done the DEM analysis as shown in Figure 11.

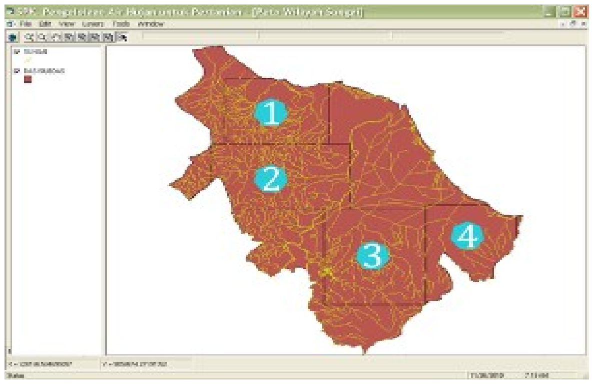

Figure 10. The Four Hydrological Areas of Mbay

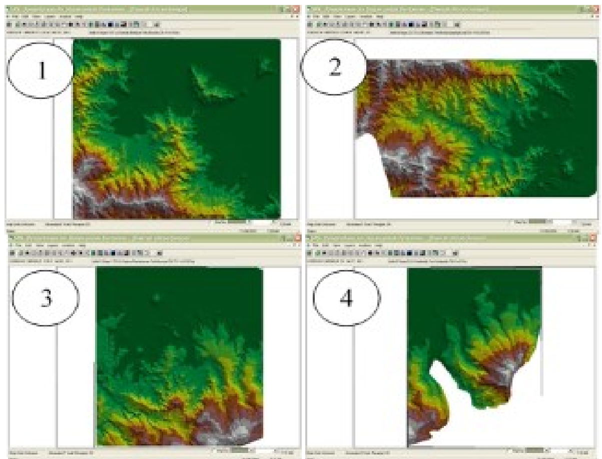

Figure 11. The DEM Map of Four Hydrological Area of Mbay

The first step in using the SIMODAS application is: determine the outlet point on the DEM map by clicking on that point, then the rainwater catchment area will automatically be formed, as shown in Figure 12. The size of the area can also be read in the dialog box that appears.

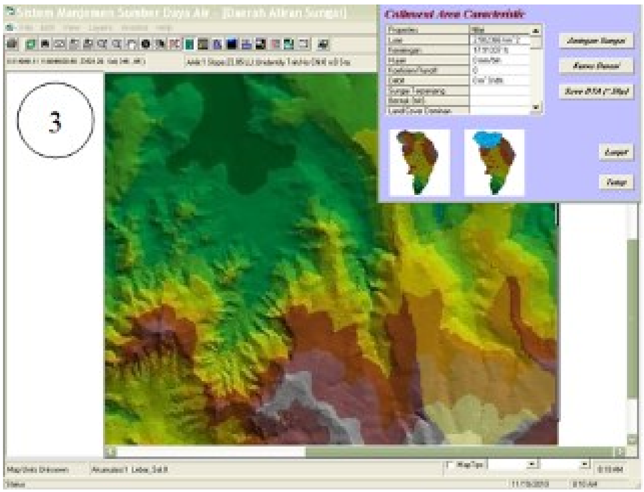

Figure 12. The Water Catchment Area Analysis

Then describe the location of the embankment by drawing a line through the outlet point, and re-clicking the outlet point on the map, it will automatically form an inundation area in a process that takes a while. After the process is complete, a dialog box will appear regarding the relationship between embankment height, inundation area and inundation volume. By setting the embankment height as needed, the graph of relationship between embankment height-inundation area-inundation or the area-volume of inundation formed by the water trap will be found as shown in Figure 13.

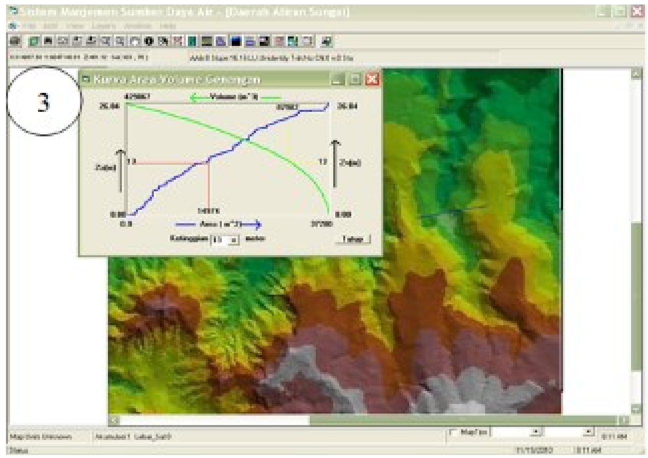

Figure 13. The Area-Volume of Inundation Water Analysis

The analysis process through the SIMODAS application is carried out for all outlet points in primary, secondary and tertiary natural drainage channels for the four hydrological categories of areas that have been defined as in Figure 10 or Figure 11.

3.3 *Result Analysis*

From these four hydrological areas, a catchment area analysis was carried out in the primary (Figure 14), secondary (Figure 15) and tertiary (Figure 16) natural drainage streamflow. The location of the water-trap in the primary, secondary and tertiary streamflow is shown as in Figure 17, while the location of the city pond is shown in Figure 18.

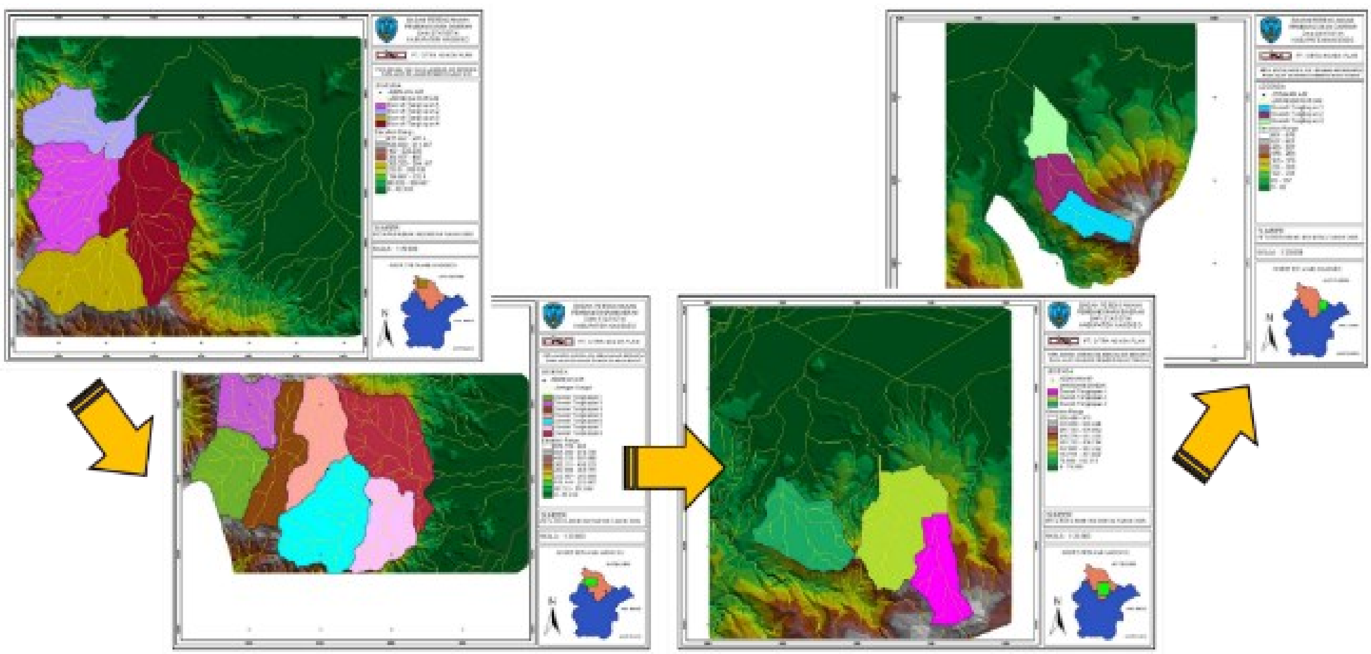

Figure 14. Primer Water Catchment Area

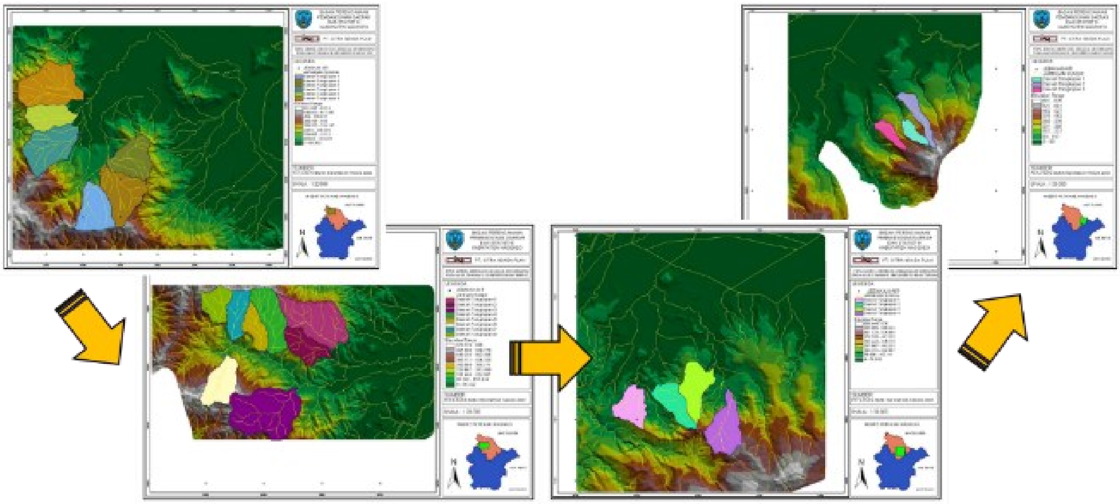

Figure 15. Secondary Water Catchment Area

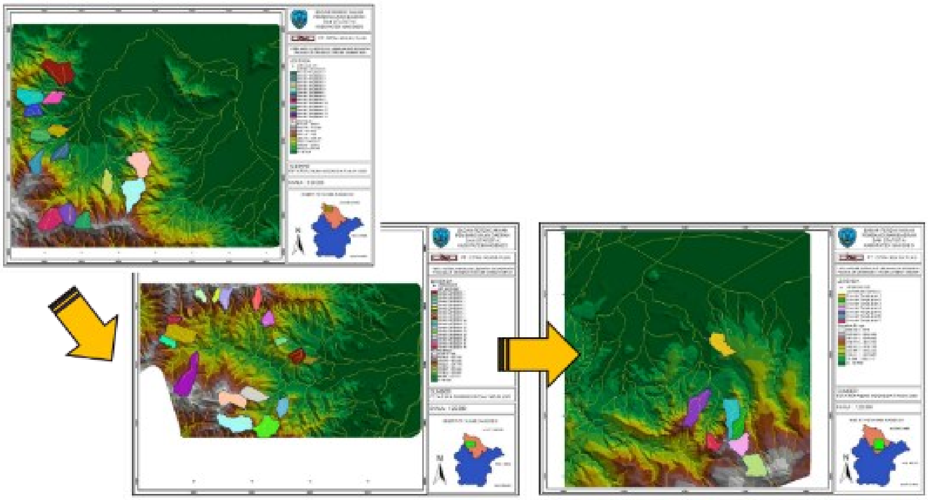

Figure 16. Tertiary Water Catchment Area

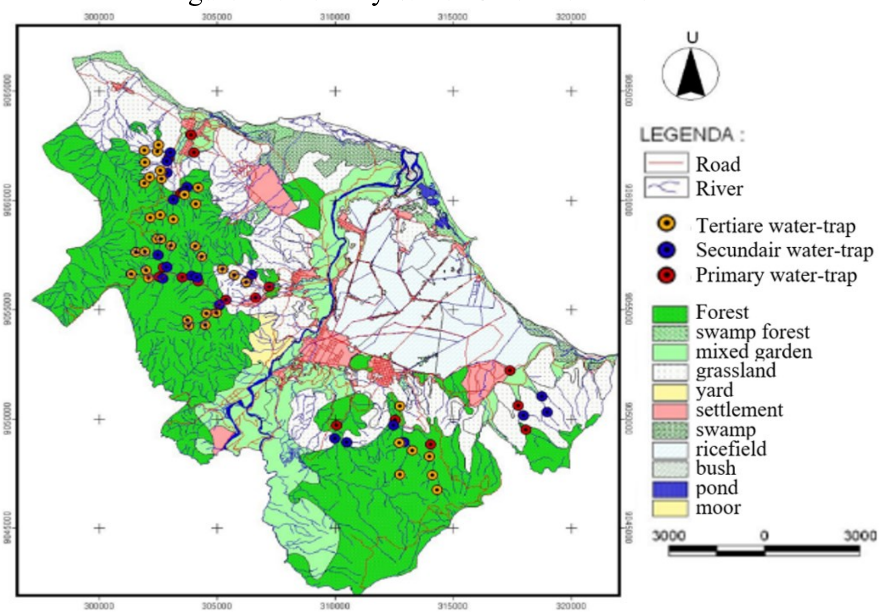

Figure 17. The Location of The Water-Trap in The Primary, Secondary and Tertiary Natural Drainage Streamflow

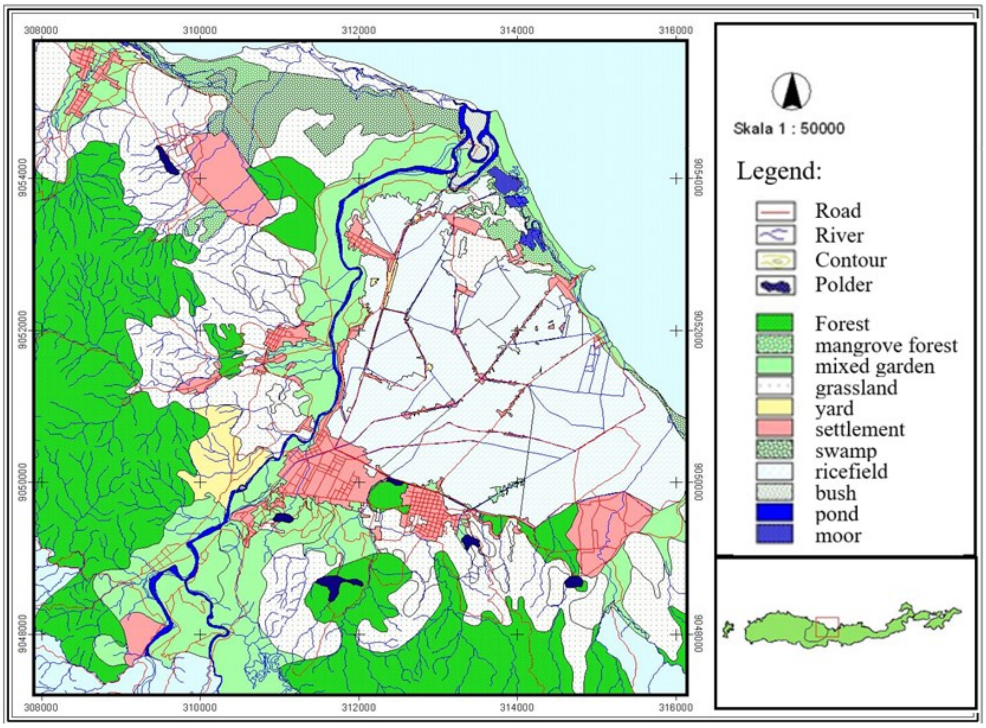

Figure 18. The Location of The City Pond

The runoff water flow that can be controlled in a 25% mainstay rain situation in the area category (1) through water traps in primary natural drainage is 2,421 m^3/s, secondary: 1,129 m^3/s and tertiary: 0.221 m^3/s. Likewise for the probability of 50%, through water trapping in primary natural drainage: 1.993 m^3/s, secondary: 0.998 m^3/s and tertiary: 0.186 m^3/s, as shown in Table 1.

Table 1. Runoff Discharge in The Primary, Secondary and Tertiary Natural Drainage Streamflow

Streamflow	Q_{runoff} (m^3/s)				
	25%	50%	75%	97%	Area
Primary	2.461	1.993	1.373	0.499	1
Secondary	1.219	0.988	0.702	0.207	
Tertiary	0,221	0.186	0.148	0.054	
Primary	4.481	3.671	2.506	1.158	2
Secondary	1.721	1.103	0.772	0.492	
Tertiary	0.773	0.421	0.341	0.180	
Primary	6.625	5.368	4.467	1.625	3
Secondary	1.916	1.546	1.291	0.468	
Tertiary	0.486	0.393	0.108	0.039	
Primary	1.237	0.221	0.185	0.068	4
Secondary	0.472	0.002	0.002	0.001	

The flood discharge that occurs for a certain return period is shown in Table 2 below.

Table 2. Flood Discharge for Several Return Period

Area (km^2)	Q Flood (m^3/s) for the Certain Return Period		
	5	10	25
1 = 99.43	1.3408	1.6199	1.9725
2 = 138.33	2.0111	2.4298	2.9587
3 = 181.56	2.6815	3.2397	3.9450
4 = 12.97	0.6704	0.8099	0.9862

3.4 Discussion

Table 1, explains that when a wet yearly occurs (probability of 25%), the surface water runoff that can be controlled is quite significant [18], namely in the primary natural drainage area (1) of 2,462 m^3/s, area (2) of 4,481 m^3/s, area (3) of 6,625 m^3/s, and area (4) is 1,237 m^3/s. This means that in the downstream hills, namely the area (2) and (3) the runoff discharge that can be controlled is 11,106 m^3/s (Figure 19) [19][20].

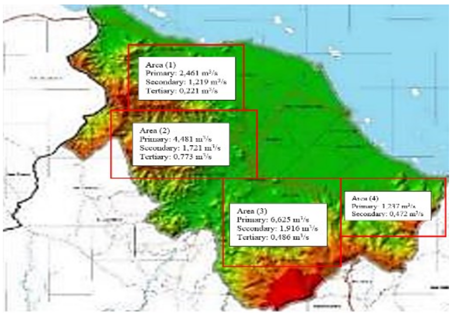

Figure 19. Controlled Discharge for a 25% Probability of Rainy Years or Wet Yearly

The controlled discharge for all possible rainy years in total for area 1, 2, 3 and 4 are shown in Figure 20.

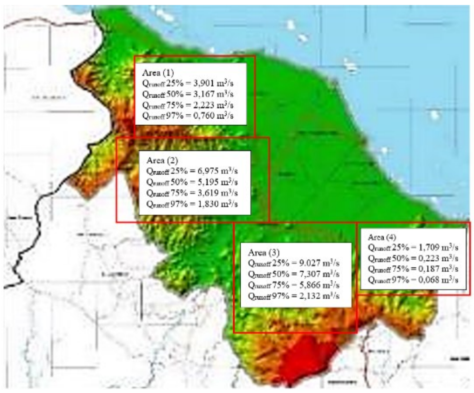

Figure 20. Total Controlled Discharge for All Probability Rainy Years

From the Tables 1 and 2, it can be analysed that for flood discharge in 25 years return period, area 1 is 1.9725 m^3/s while runoff that can be controlled: 1.373

m^3/s, area 2 flood discharge: 2.9587 m^3/s and controllable runoff: 2,506 m^3/s. This means that the water trap series installed are able to control water runoff. When a flood occurs with a return period of 25 years, the remaining runoff is only 0.6 m^3/s for area 1, so that its destructive power is significantly reduced. The same can be explained for other areas. The remaining runoff can be accommodated in flat residential areas in some city ponds or polder as shown in Figure 18.

4. Conclusion

Finally, by applying a series of water traps on the tertiary, secondary and primary runoff from the Mbay hilly area, the destructive power of the runoff can be controlled, so that it does not impact and burden the residential plains of the town of Mbay. The remaining of the runoff discharge that flows downstream is accommodated in the city ponds. This solution is more environmentally friendly and does not require high construction costs when compared to previous studies that resolved this Mbay city drainage problem by constructing a large main drainage channel to overcome runoff from the hills before entering Mbay city, and directly draining it into the Aesesa River. When the runoff flow increases and the main drainage channel cannot cope, then flooding continues to hit Mbay city.

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