Effective Urban Drainage for Juata Laut Landfill

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Abstract: Urban drainage management is a science that studies flood control in urban areas. This water management system can be used for other water flow regulation settings, such as Housing drainage system, Waste Landfill drainage system, and densely populated drainage system. Tarakan is one of cities in Indonesia. Because of the amount of waste generation, Tarakan City requires a Final Waste Processing Site. Tarakan's municipal landfill is designed to accommodate garbage produced by Tarakan City residents. DED Sanitary Landfill of Tarakan City also requires a good drainage management so that rainwater does not flood the landfill. Drainage planning stage starts from measuring the landfill site plan, rainfall modeling, designing flood discharge, channels design and channel dimensions. Rainfall is measured using the estimated rainfall method. The data were obtained from rain stations located on the island of Tarakan. After obtaining the rainfall data, the next step was to estimate runoff discharge flowing around the landfill. Based on the results of measurements in the field, the area of the Tarakan landfill is planned to be 40 ha. With this area of land, landfill is divided into several cell zones. Based on the rainfall data, maximum rainfall occurred in July 2014 with a magnitude of 601 mm / month. Each of the maximum rainfall was used to determine the amount of rainwater runoff. Based on the results of the analysis, the types of channel used are primary, secondary and tertiary with a square channel shape. The maximum channel dimension is 11.19 m/s and the minimum channel dimension is 1.43 m/s.

1 INTRODUCTION

Indonesia is a tropical country which has a high rainfall level (Amien, 2011). Urban drainage management is important when the water flow is regulated so that the flow goes to a lower area. The surface drainage discharge is one of the indicators that influences drainage systems management (Valipour, 2012b).

Urban drainage management is a science that studies flood control in urban areas. The water management system can be used for other water flow regulation settings, such as housing drainage system, Waste Landfill drainage system, densely populated drainage system (Amien, 2011).

Landfill drainage is one of important parameters in the design of landfill. Landfill drainage will discharge water to lower areas. The design and construction of landfill drainage must consider land use, slope and large rainfall (Mursito & Amien, 2011). Water flow is set to control puddles and floods. Floods are avoided in the Waste Landfill. Rainwater outside the waste cell is expected to enter the water channel to the river while leachate enters the leachate processing system.

Tarakan is one of cities in Indonesia. Based on population projections for 2018 - 2037, Tarakan's urban population will reach 345,168 people. This will affect the amount of waste generated by the city population. With the amount of waste generation, Tarakan City requires a Final Waste Processing Site. Tarakan municipal landfill is designed to accommodate garbage produced by Tarakan City residents. In addition to designing landfill zones, the Tarakan City Landfill DED Sanitary landfill also requires a good drainage management so that rainwater runoff does not flood the Waste Landfill (Utama & Ardhianto, 2017).

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2 EVALUATION METHOD AND MEASUREMENTS

2.1 Measurements of Rainfall

Rainfall is measured using the estimated precipitation method. Some common methods used are Normal Distribution, Log Normal, Pearson type III, Log Pearson type III, and Gumbel. Some of these methods require the last 10 year rain data. Precipitation data can be obtained by recording the number of rainy days throughout the year within a period of 10 years (Suripin, 2004). This data can be obtained from rain stations located on the Tarakan Island. Rainfall data obtained were then matched with the rain model from several rain models; the smallest level of tilt will be the basis for planning drainage around the Waste Landfill.

2.2 Drainage Planning Stage

Drainage planning stage starts from measuring the landfill site plan, precipitation modeling, designing flood discharge, drainage channel design and channel dimensions (Amien, 2011). Site plan measurement employed the theodolite and google earth methods. The measurement with these methods will get results of the site plan area and location coordinates. Precipitation model is required to obtain large rainfall falling to the ground. Some of the models mentioned above will generate a statistical value that corresponds to the actual condition in the field.

After obtaining rainfall, the next step was to estimate runoff discharge that flows around the landfill. Runoff debit is calculated using the rational method. This method has the function of estimating the design flood discharge. Flood design in question is the peak flood discharge (Q_{peak}), included in the non-hydrograph design (Yanto, Warman, & Hatta, 2014).

The next step is to design the flow and dimensions of the drainage channel. The channel dimensions are closely related to channel slope and runoff discharge. The channel is expected to accommodate peak flood discharge and safely channel runoff water to a lower place (Amien, 2011).

2.3 Precipitation Analysis

If the observation points in the area are not evenly distributed, then the method of calculating the average rainfall is done by calculating the area of influence of each observation point (Arora & Singh, 1989; Yeshoda, Meenambal, & Manikandan, 2015). Rainfall in that area can be calculated by the following equation:

$$\begin{aligned}\bar{R} &= \frac{A_1R_1 + A_2R_2 + A_3R_3 + \ldots + A_nR_n}{A_1 + A_2 + A_3 + \ldots + A_n} \\ &= \frac{A_1R_1 + A_2R_2 + A_3R_3 + \ldots + A_nR_n}{A} \\ &= W_1R_1 + W_2R_2 + W_3R_3 + \ldots + W_nR_n \quad \ldots\ldots\ldots\ldots \quad (1)\end{aligned}$$

2.4 Precipitation Analysis

Precipitation analysis can be estimated by the model. For this maximum daily precipitation analysis, several methods can be used

2.4.1 Normal Distribution

The first step of normal distribution is calculating the average rainfall using the following equation:

$$R_{rt} = \frac{\sum R}{n} \quad \ldots\ldots\ldots\ldots \quad (2)$$

The second step is calculating deviation standard, and the third step is calculating variation coefficient using the following equation:

$$\delta R = \frac{\sum \sqrt{(R - R_{rt})}}{(n-1)} \quad \ldots\ldots\ldots\ldots \quad (3)$$

Where R is the maximum annual rainfall, Rrt is average annual rainfall, and δ_R is deviation standard.

2.4.2 Pearson Type III

The first step of Pearson Type III is calculating the average rainfall using:

$$R_{rt} = \frac{\sum R}{n} \quad \ldots\ldots\ldots\ldots \quad (4)$$

The second step is calculating the deviation standard and the third step is calculating variation coefficient with

$$\delta R = \frac{\sum \sqrt{(R - R_{rt})}}{(n-1)} \quad \ldots\ldots\ldots\ldots \quad (5)$$

The third step is calculating the deviation standard and Skewness Coefficient with

$$C_s = \frac{n \sum (R - Rrt)^3}{(n-1)(n-2)\delta_R^3} \quad \ldots\ldots\ldots\ldots \quad (6)$$

Where R is maximum annual rainfall, Rrt is average annual rainfall, δ_R is deviation standard, and Cs is skewness coefficient.

2.4.3 Gumbel Distribution

The first step of gumbel distribution calculating the maximum average rainfall, the second step is calculating the deviation standard, and the third step is calculating the variation coefficient.

$$C_v = \frac{\delta_R}{Rrt} \quad \text{............} \quad \textbf{(7)}$$

Next, expected mean reduced from n is calculated; then, the fifth step is calculating frequency factor with

$$K = \frac{y - y_n}{\delta_n} \quad \text{............} \quad \textbf{(8)}$$

The sixth step is calculating y

$$y = 1 - \ln\left(\frac{T}{T-1}\right) \quad \text{............} \quad \textbf{(9)}$$

The seventh step is calculating R_{rp}

$$R_{rp} = R_{rt} + R_{rt} \cdot K \cdot C_p \text{............} \quad \textbf{(10)}$$

Based on the four methods mentioned, models were selected based on the smallest skewness. Model selection was based on the smallest rate of infestation to reduce errors in the design of flood discharge.

2.5. Precipitation Intensity Analysis

Short-term precipitation is expressed in hourly intensity formulas. This intensity is called rainfall intensity (mm / hour). The amount of rainfall intensity varies. This is caused by the length of rainfall or the frequency of occurrence. Some formulas of precipitation intensity associated with these things have been calculated as experimental formulas:

2.6 Maximum Plan Debit Analysis

The size of the maximum (m^3 / second) Debit plan is calculated by the regional formula:

$Q = 0.278 \times C \times I \times A$ (m^3/s) .... **(11)**

The amount of the maximum plan debit corresponds to the return period and the estimated area obtained as follows:

a. The direction of drainage in the channel follows a continuous decrease in the existing altitude line so that the drainage is gravitational.

b. Utilization of rivers/creeks for receiving water bodies from the planned outfall, for drainage of work site locations and drainage of water flows as large as stockpiling.

3 RESULTS AND DISCUSSION

Based on the results of measurements in the field, the area of the Tarakan TPA site plan is planned to be 40 ha. With this area of land, TPA is divided into several waste cell zones. Drainage flowing from the landfill Trash follows the perimeter of the waste cell and is connected to the TPA inspection road drainage channel (Gristlier, 1993; Jensen, 1967; Madani & Brenton, 1995). According to the contour of the land, the direction of the flow utilizes the slope of the land and flows in gravity.

The dimensions of the drainage channel are based on hydrological analysis. The analysis includes rainfall data per 10 years. Then, the data are matched by statistical rain analysis. Maximum debit plan is very dependent on the availability of supporting data. Discharge measurement is derived from rainfall data theoretically based on methods commonly used. The average maximum daily rainfall in Tarakan Subdistrict from 2005–2015 was 378.3 mm / day in 2011. The rainfall table can be seen below.

Table 1: Rainfall data in Tarakan Island 2005 - 2015

Bulan	Curah Hujan (MM/Bulan)										
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Januari	234.7	155.2	253.2	443.6	397	288.4	397.1	288.4	267.5	278.5	197.4
Februari	124.9	235.9	79.7	293.6	315.6	163	430.3	163	289.5	161.1	283.1
Maret	260.4	335.6	311.9	404.1	212.1	337.6	358	337.6	340.3	386	358.9
April	412.8	476.9	276.6	377.1	390.4	297.3	145.7	297.3	327.5	490.6	260.1
Mei	322.1	368	323.1	375.5	357.7	428.9	572.7	428.9	378.9	265.8	232.6
Juni	280.4	588.9	431.2	320.9	189.1	226.7	370.4	226.7	280.9	269.9	224.8
Juli	159.2	409.4	385.8	312.8	234.9	455.8	244.3	455.8	598.9	601.1	200.2
Agustus	274.8	275.4	396.8	208.1	248.4	397.5	414.5	395.7	566.1	459.1	220.1
September	309.6	288.5	251.4	309.2	195.6	337.8	311.5	337.8	456.3	185.4	284.1
Oktober	339.4	422.5	323.3	206	334.1	362	474.8	362	356.5	317.7	208.2
November	352.9	337.5	405.9	426.5	368.7	359.8	306	359.8	343.2	259	375.1
Desember	271.1	268.7	515.9	291.8	218.1	593.5	513.8	593.5	261.1	408.3	329.8

Based on the rainfall data, the maximum rainfall occurred in July 2014 with a magnitude of 601 mm / month. Each of the maximum rainfall is used to determine the amount of rainwater runoff.

3.1 Frequency Analysis

Frequency analysis of the hydrological data is related to the magnitude of extreme rainfall events that are related to the frequency of occurrence through the distribution of possibilities. Design rain is obtained from the analysis of frequency distribution and distribution match test. There are several methods that can be used in frequency analysis, namely the Gumbel method, Normal Log, Type III and Normal Log-Person (Kidson & Richards, 2005; Otti, Ejikeme, & Nwafor, 2013; Sangal & Biswas, 1970; Shao et al., 2015; Valipour, 2012a). The results of statistical parameter analysis in Table 2 show the values of Cs and Ck. From this value, the most suitable type of distribution uses the Gumbel method. The analysis of distribution selection can be seen in table 3.

Table 2: Statistical Analysis

Year	Maximum rainfall (mm/month)	(Xi-X)	$(Xi-X)^2$	$(Xi-X)^3$	$(Xi-X)^4$
2005	413	-105	10972	-1149226	120376231
2006	589	71	5091	363300	25923079
2007	516	-2	3	-4	7
2008	444	-74	5468	-404329	29898261
2009	397	-121	14531	-1751671	211155966
2010	594	76	5769	438189	33282434
2011	573	55	3042	167781	9253909
2012	594	76	5769	438189	33282434
2013	599	81	6619	538450	43805364
2014	601	84	6981	583325	48739416
2015	375	-142	20291	-2890319	411712812
Total	5693		84536	-3666316	967429913
Average	518				
Deviation Standard(S)	77.71				
Skewness Coefficient (Cs)	-0.64				
Kurtosis Coefficient (Ck)	2.73				
Variation Coefficient (Cv)	0.15				

Table 3: Distribution Analysis

No	Method	Statistics	Results
1	Gumbel	$Cs \leq 1,1396$	$0,64 \leq 1,1396$
		$Ck \leq 5,4002$	$2,73 \leq 5.4002$
2	Log Normal	$Cs = 3\ Cv + Cv^2$	$0,4 < 0.5056$
		$Cs = 0,8125$	$0,4 < 0,8125$
3	Log-Person type III	$Cs \approx 0$	$0,4 > 0$
4	Normal	$Cs = 0$	$0,4 > 0$

3.2 Distribution Match Test

This distribution suitability test is intended to find out the distribution that has been chosen to represent the statistical sample of the analyzed data (San, Selamat, & Ghani, 2009). After analyzing data for distribution match testing, the appropriate method uses the Chi-Square test. The results of the Chi-Square test analysis are presented in Table 4.

Table 4: Chi-Square Test

No	Limit Value	Of	Ef	$(Of - Ef)^2$	$((Of - Ef)^2:Ef)$
1	$346,85 \leq X \leq 403,350$	2	2.20	0.04	0.0
2	$403,350 \leq X \leq 459,850$	2	2.20	0.04	0.0
3	$459,85 \leq X \leq 516,35$	1	2.20	1.44	0.7
4	$516,35 \leq X \leq 572,85$	1	2.20	1.44	0.7
5	$572,85 \leq X \leq 629,35$	5	2.20	7.84	3.6
Total					4.9

The calculation results of Table 4 above obtained X2 value of 4.9, while less than X2 value in the Chi-Square test table whose magnitude was 7.815. Then, from the compatibility test, the distribution of Gumbel distribution can be accepted. The Gumbel distributions is often considered as competing models when the variable of interest takes values from $-\infty$ to $+\infty$ (Qaffou, 2017).

3.3 Maximum Daily Rainfall Period

Frequency analysis is to confirm the return on rainy events. This analysis aims to determine rainfall or discharge with a certain return. The maximum rainfall results with various returns are presented in Table 5 .

Table 5: Maximum rainfall

No	Repeat Period (Year)	Average	S	Yt	Yn	Sn	Maximum Rain (mm)	Rain Intensity (I)
1	2	518	77.71	0.3665	0.4996	0.9676	506.8570	25.34
2	5	518	77.71	1.4999	0.4996	0.9676	598.3394	29.92
3	10	518	77.71	2.2504	0.4996	0.9676	658.6078	32.93
4	20	518	77.71	2.9702	0.4996	0.9676	716.4187	35.82
5	50	518	77.71	3.9019	0.4996	0.9676	791.2490	39.56
6	100	518	77.71	4.6001	0.4996	0.9676	847.3238	42.37

3.4 Drainage Dimension Plan

Drainage design plan in the Juwata Laut TPA is determined by hydrological calculations. This calculation determines the amount of rainwater runoff. Then, hydraulic calculations are done to determine the dimensions of the channel. Drainage planning is certainly based on the existing landfill layout (Bhagat, 2017). The following is the picture of the existing layout of the Juwata landfill site which will be built by the drainage channel.

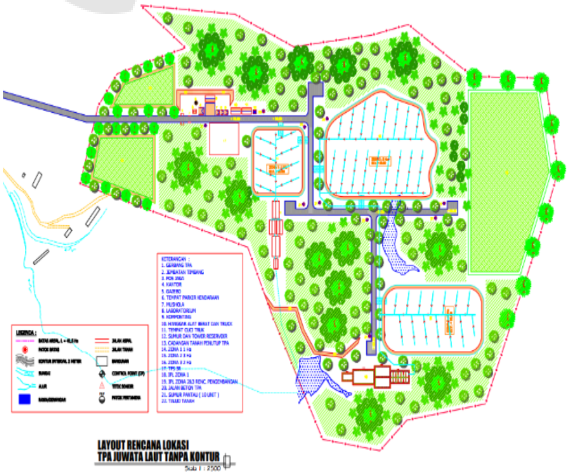

Figure 1: Juata Laut landfill siteplam

Land use that is used as a guide to determine the runoff coefficient value in the Juwata TPA usually has a flat elevation in urban areas, which is 0.3. This runoff coefficient value will affect the analysis of the drainage channel design plan. Runoff coefficient value in Juwata TPA is presented in table 6 .

Table 6: Runoff Coefficient

Land Use	Run off Coefficient
Garden	0,3
Rubber Forest	0,45
Jungle	0,35
Mining Area	0,10
Open Land	0,75

Drainage design is based on the channel material used. This type of material will affect the maximum and minimum speed of water. Flow velocity will affect the process of sedimentation and erosion. Flow velocity is less than 0.6 m / s will cause sedimentation at the bottom of the channel while the flow velocity that exceeds 2 m/s will cause drainage channels to erode. The material used as a drainage channel will affect the Manning coefficient. Manning coefficient value used is 0.035 which is a channel on finely cut rock. The Manning coefficient value can be seen in table 7 .

Table 7: Manning Coefficient

Type of materials	N
Brick: Open channel	0.014 – 0.017
Concrete: Open channel	0.013 – 0.022
Gravel: Open channel	0.014 – 0.033
Rock: Open channel	0.035- 0.045

Source : (Lin, 2007)

The flowrates in channel can be calculated by manning formula

$$v = \frac{1}{n} . R^{\frac{2}{3}} . S^{\frac{1}{2}} \ldots\ldots\ldots\ldots \qquad (12)$$

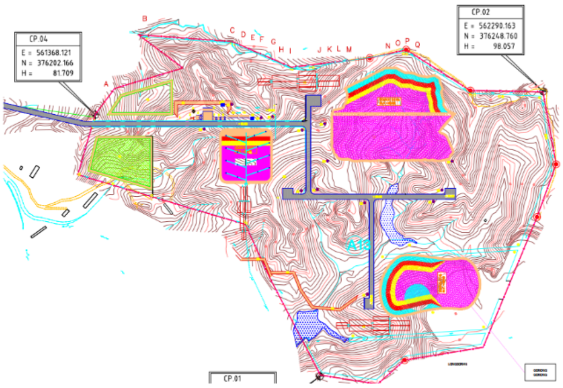

Figure 2: Juata Laut Landfill Drainage Plan

The channel dimension can be calculated by a

$$R = \frac{b \ x \ h}{b \ + \ 2.h} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (13)$$

From the data obtained and explained previously, the results of the analysis of the design plan for the design of drainage dimensions in the Sea Juwata Landfill are presented in Table 8 .

Table 8: Dimension of drainage channels

Block	Catchment Area (ha)	Q cumulatif (m3/det)	A (m2)	Channel	Dimension		Rs	Freeboard (m)	H plan (m)
					B	H			
A1	3.4500	0.429	0.328	square	0.6	0.6	0.19	0.17	0.74
A2	1.4000	0.174	0.132	square	0.4	0.4	0.12	0.11	0.47
A3	0.9700	0.121	0.091	square	0.3	0.3	0.10	0.09	0.39
A4	0.7500	0.214	0.135	square	0.4	0.4	0.12	0.11	0.48
A5	0.2100	0.214	0.120	square	0.3	0.3	0.12	0.10	0.45
A6	0.0750	0.009	0.014	square	0.1	0.1	0.04	0.04	0.15
A7	3.7050	0.470	0.692	square	0.8	0.8	0.28	0.25	1.08
A8	3.8000	0.473	0.666	square	0.8	0.8	0.27	0.24	1.06
A9	2.6800	0.702	0.949	square	1.0	1.0	0.32	0.29	1.27
A10	2.9500	1.283	0.665	square	0.8	0.8	0.27	0.24	1.06
A11	1.4100	0.175	0.351	square	0.6	0.6	0.20	0.18	0.77
A12	6.6400	1.007	0.950	square	1.0	1.0	0.32	0.29	1.27
A12	6.6400	1.841	1.737	square	1.3	1.3	0.44	0.40	1.71
A13	6.6500	2.674	2.522	square	1.6	1.6	0.53	0.48	2.06

Drainage planning in the Sea Juata Landfill is made around the landfill embankment. This channel prevents the flow of water into the landfill and drain rainwater out of the landfill. Drainage channels are separated with leachate collection channels. Drainage channels will carry rainwater runoff safely outside the landfill and do not mix with leachate. That way, this planning is an integrated part of the overall planning of the Juata Laut Landfill.

4 CONCLUSION

Drainage planning stage starts from measuring the landfill site plan, precipitation modeling, designing flood discharge, drainage channel design and channel dimensions. Precipitation is measured using the estimated rainfall method. This data can be obtained from rain stations located on the island of Tarakan. After obtaining rainfall data, the next step is to estimate runoff discharge that flows around the landfill. Based on the results of measurements in the field, the area of the Tarakan TPA site plan is planned to be 40 ha. With this area of land, TPA is divided into several waste cell zones.

Based on rainfall data, maximum rainfall occurred in July 2014 with a magnitude of 601 mm / month. Each of the maximum rainfall is used to determine the amount of rainwater runoff. Based on the results of the analysis, the types of channel used are primary, secondary and tertiary with a square channel shape. The maximum channel dimension is 1.6 x 1.6 m^2 with o.48m freeboard channel. The minimum channel dimension is 0.3 x 0.3 m^2 with 0.1m freeboard channel. The flowrate of water in channel maximum is 3.19 m/s and the minimum flowrate is 1.43 m/s. The flowrate which exceeds 3 m/s can be reduced by terracing trap at channel so that the flowrate can be reduced and erosion can be minimized.

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