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THE ANALYSIS OF HYDROLOGY IN COMAL RIVER

Gunawan*, Saihul Anwar, Ohan Farhan****

*) Student of Civil Engineering Major, Faculty of Engineering, University of Swadaya Gunung Jati Cirebon
**) Lecturer of Civil Engineering Major, Faculty of Engineering, University of Swadaya Gunung Jati Cirebon

ABSTRACT

This research was conducted to find out the availability of water to the requirements of water and also predict flood plan discharge for return period based on hydrological analysis in Comal River.

Calculations are carried out using rainfall data obtained from PUSDATARU of Pemali - Comal from 1999 - 2017. Used the rain station in the region of Comal Watershed, there are 7 rain stations. Catchment area of rain station used Thiessen Polygon Method to know value of catchment area of each rain station. The Gumbel distribution (Generalized Extreme Value distribution Type-I) is used to model the distribution of the maximum (or the minimum) of a number of samples of various distributions. The calculation of the flood discharge design is using the Nakayasu, Rational, Weduwen, Weduweden, and Haspers method.

Based on the result of this research it can be concluded that the biggest water potential occurs in January is 199.60 m3/s and the smallest in August is 0.84 m3/s. Cropping pattern carried out with one year there are three cropping patterns, namely paddy - paddy - secondary crops. For the water requirements, enough can be fulfilled, but in August and September, where the planting period III for the secondary crops experiences a deficit. The method used to design flood discharge is the Nakayasu method. For the embankment construction and normalization is profitable.

Keywords: River, Flood, Embankment, Thiessen, Comal

I. INTRODUCTION

Comal River is one of the water sources that can be utilized for the area around the Comal River. Comal River area most in the Pemalang District, Central Java. Comal River entered in the Comal Watershed. As a system of hydrology, Watershed (DAS) accept input in the form of rainfall and then process it in accordance with its characteristics into the flow. The rain that fell in one watershed most would fall on the surface vegetation, soil or surface water bodies (Triatmodjo, 2009). Analysis of hydrology is required to know the availability of water to the requirements of water and can also predict flood plan discharge for return period.

The intention of doing the research for hydrological analysis of Comal River is to analyze the potential of water from rainfall data that available for 19 years and also analyze flood plan discharge from several methods. The results of this research are expected to be input or information which is useful and can provide solutions in hydrological analysis.

For the discussion of research that will be undertaken, given some of the restrictions on the issue, namely:

1) The rainfall data used is for 19 years. Starting from January of 1999 until December 2017.
2) Used the rain station in the region of Comal Watershed. There are 7 rain stations.
3) Analyze for water potential and water requirements.
4) Analyze for flood plan discharge from several methods (SUH of Nakayasu, Rational, Weduweden, and Haspers).

II. RESEARCH METHODOLOGY

A. Analysis of Water Balance

1. Analysis of missing rainfall data

There are many methods to analysis of missing rainfall data. One of method is Inverse distance weighted (IDW). The method used is the inverse distance weighted method. Inverse distance weighted (IDW) interpolation explicitly makes the assumption that things that are close to one another are more alike than those that are farther apart.

$$Px = \frac{\sum_{i=1}^{n}\left({Pi}/{d_i^2}\right)}{\sum_{i=1}^{n}\left({1}/{d_i^2}\right)}$$

2. Catchment Area of Rain Station

One of method to calculate catchment area, can use Polygon of Thiessen to know value of catchment area of each rain station.

If P1, P2, P3, P4, P5, and P6 are the rainfall in stations 1, 2, 3, 4, 5, and 6 respectively, average rainfall of the catchment is given by

$$P = \frac{P_1A_1 + P_2A_2 + P_3A_3 + P_4A_4 + P_5A_5 + P_6A_6}{(A_1 + A_2 + A_3 + A_4 + A_5 + A_6)}$$

Thus, in general, for N stations,

$$P = \frac{\sum_{i=1}^{N} P_iA_i}{\sum_{i=1}^{N} A_i}$$

A is the total area of the catchment.

3. Water Potential

Water potential is the amount of water contained in an area then the water potential of watershed is the potential amount of water contained in the watershed.

4. Water Requirements

Water Requirements is something that requires a certain amount of water to process activities. Water requirements of cropping pattern is amount of water to meet the cropping pattern activities.

5. Water Balance

Water balance is the balance of input and output of water within a certain period, so it can be to find out the amount of water surplus or deficiency. The usefulness of knowing the condition of the water surplus and deficits can anticipate disaster that is likely to occur, and can make the best use of water.

B. Discharge Analysis of Flood Design

1. Analysis of missing rainfall data

Analysis of missing rainfall data used IDW Method.

2. Catchment Area of Rain Station

Catchment area of rain station used Thiessen Polygon Method.

3. Frequency Analysis of Rainfall

One of frequency analysis of rainfall is Gumbel's Method. In probability theory and statistics,

$$Xt = Xr + K\sigma_{n-1}$$

where σ_{n-1} = standard deviation of the sample of size $N = \sqrt{\frac{\Sigma(x-\bar{x})^2}{N-1}}$

K = frequency factor expressed as

$$K = \frac{y_T - \bar{y}_n}{S_n}$$

in which y_T = reduced variate, a function of T and is given by

$$y_T = -\left[\ln.\ln\frac{T}{T-1}\right]$$

or $$y_T = -\left[0.834 + 2.303\log\log\frac{T}{T-1}\right]$$

$\bar{y}_n$ = reduced mean

S_n = reduced standard deviation.

4. Intensity of Rainfall

To calculate the flood plan discharge on a drainage of rational methods can be used. Before using the rational method to do an analysis of the intensity of the rain.

Rain intensity can be calculated using the equations include the equation of Mononobe.

$$I = \left[\frac{R_{24}}{24}\right]\left[\frac{24}{t}\right]^{\frac{2}{3}}$$

Where:

I = Intensity of Rainfall (mm/hr)

t = time of rainfall (hr)

R_{24} = maximum rainfall in 24 hours

5. Synthetic Unit Hydrograph of Nakayasu

The calculation of the flood discharge design is using the Nakayasu method. The general equation of the Nakayasu Hydrograph Synthetic Unit is as follows:

$$Qp = \frac{C\,.\,A\,.\,R_0}{3{,}6\,.\,(0{,}3Tp + T_{0,3})}$$

Tp = Tg + 0,8 Tr

Tg = 0,21 x L0,7 (L < 15 km)

Tg = 0,4 + 0,058 x L (L > 15 km)

$T_{0,3}$ = α x tg

Where:

Qp = flood peak discharge (m^3/s)

C = flow coefficient

R_0 = rain unit (mm)

A = watershed area (km^2)

Tp = the grace period from the beginning of the rain to the peak of the flood (hour)

$T_{0,3}$ = time required by the decrease of discharge, from peak discharge to 30% of peak discharge

Tg = concentration time (hour)

Tr = rain time unit, taken 1 hour

α = hydrograph parameter, worth between 1,5 – 3,5

L = river length (km)

6. Flood Discharge of Rational

The Rational equation is the simplest method to determine peak discharge from drainage basin runoff. It is not as sophisticated as the SCS TR-55 method, but is the most common method used for sizing sewer systems.

Rational Equation: Q = C . I . A

The Rational equation requires the following units:

Q = Peak discharge, m^3/s

C = Rational method runoff coefficient

I = Rainfall intensity, mm/hour

A = Drainage area, km^2

7. Flood Discharge of Weduwen

- run off coefficient (α)

$$\alpha = 1 - \frac{4{,}1}{\beta.q + 7}$$

- reduction coefficient (β)

$$\beta = \frac{120 + \frac{t_0+1}{t_0+9}\,.\,A}{120\,.\,A}$$

- max rainfall (q)

$$q = \frac{67{,}65}{t + 1{,}45}$$

- concentration time (t)

$$t = \frac{0{,}476\,.\,A^{3/8}}{(\alpha\,.\,\beta\,.\,q)^{1/8}\,.\,i^{1/4}}$$

- peak discharge (Q)

$$Q = \alpha\,.\,\beta\,.\,q\,.\,A\,.\,\frac{R_{24}}{240}$$

8. Flood Discharge of Haspers

- run off coefficient (α)

$$\alpha = \frac{1 + 0{,}012 f^{0,7}}{1 + 0{,}075 f}$$

- reduction coefficient (β)

$$\frac{1}{\beta} = 1 + \frac{t + (3{,}7x10^{-0{,}4t})}{(t^2 + 15)} x \frac{f^{3/4}}{12}$$

- concentration time (t)

$$t_x = 0{,}1L^{0{,}8} i^{-0{,}3}$$

- max rainfall (q)

$$q = \frac{Rt}{3{,}6t}$$

$$R_t = 0{,}707.R_{24}\sqrt{t+1}$$

- peak discharge (Q)

$$Q = \alpha\ .\ \beta\ .\ q\ .\ A$$

III. ANALYSIS AND DISCUSSION OF PROBLEM

A. Analysis of Water Balance

1. Rainfall data

Rainfall data for Hydrological Analysis of Comal River will be taken from the representative stations of Comal Watershed. Rainfall data that used are 7 rain stations from 11 rain stations in Comal Watershed for 19 years (January 1999 until December 2017), there are:

- The Moga Station Rainfall Data (1999-2017)
- The Randudongkal Station Rainfall Data (1999-2017)
- The Belik Station Rainfall Data (1999-2017)
- The Watukumpul Station Rainfall Data (1999-2017)
- The Sipedang Station Rainfall Data (1999-2017)
- The Sokawati Station Rainfall Data (1999-2017)
- The Karangtengah Station Rainfall Data (1999-2017)

2. Analysis of Missing Rainfall Data

Table 1. The Moga Station Rainfall Data 1999 - 2017 (mm)

Year	January		February		March		April		May	
	1	2	1	2	1	2	1	2	1	2
1999	1676	1264	1191	1233	427	803	482	398	1059	196
2000	1014	1478	1402	1242	645	765	369	211	538	206
2001	395	449	489	511	0	0	460	151	244	31
2002	1313	1008	1651	365	125	308	419	179	335	230
2003	405	326	1070	818	1351	477	218	159	288	44
2004	525	600	1080	702	1015	166	240	107	159	284
2005	197	892	262	159	215	86	115	267	315	42
2006	576	1217	360	150	212	172	88	241	101	117
2007	103	182	618	310	341	204	154	130	91	113
2008	827	671	1087	835	146	184	219	94	30	40
2009	380	847	341	486	171	46	199	62	103	170
2010	316	1370	186	141	143	170	64	93	151	217
2011	101	1308	296	358	91	164	131	39	176	129
2012	198	328	437	210	225	161	287	141	-	-
2013	361	523	385	318	257	209	227	127	109	103
2014	425	578	591	500	304	143	415	505	171	296
2015	167	639	451	430	250	166	208	312	237	35
2016	208	231	222	266	196	230	558	249	185	310
2017	595	333	458	394	126	193	402	97	134	68
Max	1676	1478	1651	1242	1351	803	558	505	1059	310
Avrg	514,8	749,7	661,9	496,2	328,4	244,6	276,6	187,5	245,9	146,2
Min	101	182	186	141	0	0	64	39	30	31

Table 2. Result of Analysis of Missing Rainfall Data at the Moga Station (mm)

Year	January		February		March		April		May	
	1	2	1	2	1	2	1	2	1	2
1999	1676	1264	1191	1233	427	803	482	398	1059	196
2000	1014	1478	1402	1242	645	765	369	211	538	206
2001	395	449	489	511	323	192	460	151	244	31
2002	1313	1008	1651	365	125	308	419	179	335	230
2003	405	326	1070	818	1351	477	218	159	288	44
2004	525	600	1080	702	1015	166	240	107	159	284
2005	197	892	262	159	215	86	115	267	315	42
2006	576	1217	360	150	212	172	88	241	101	117
2007	103	182	618	310	341	204	154	130	91	113
2008	827	671	1087	835	146	184	219	94	30	40
2009	380	847	341	486	171	46	199	62	103	170
2010	316	1370	186	141	143	170	64	93	151	217
2011	101	1308	296	358	91	164	131	39	176	129
2012	198	328	437	210	225	161	287	141	249,20	109,82
2013	361	523	385	318	257	209	227	127	109	103
2014	425	578	591	500	304	143	415	505	171	296
2015	167	639	451	430	250	166	208	312	237	35
2016	208	231	222	266	196	230	558	249	185	310
2017	595	333	458	394	126	193	402	97	134	68
Max	1676	1478	1651	1242	1351	803	558	505	1059	310
Avrg	514,8	749,7	661,9	496,2	345,4	254,7	276,6	187,5	246,1	144,3
Min	101	182	186	141	91	46	64	39	30	31

3. Catchment Area

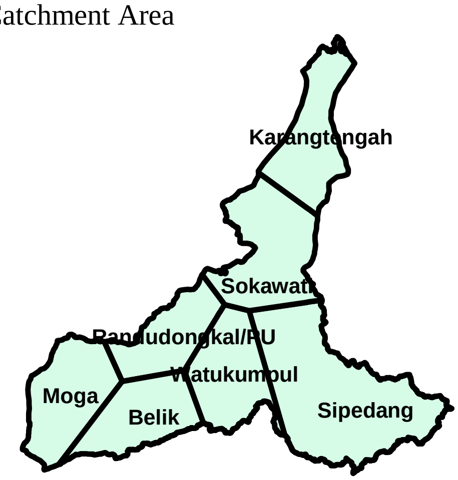

Figure 1. Thiessen Polygon of Comal Watershed

Table 3. Catchment Area of Rain Station

No	Station	DTA (Km^2)	%
1	Moga	110,08	13%
2	Belik	94,72	11%
3	Randudongkal	81,49	9%
4	Watukumpul	102,96	12%
5	Sipedang	240,44	28%
6	Sokawati	135,60	16%
7	Karangtengah	104,94	12%
Amount		870,25	100%

4. Potential Water

Table 4. Potential Water of Comal Watershed (m^3)

Year	January		February		March	
	1	2	1	2	1	2
1999	396.581.713	442.910.703	451.920.916	455.160.789	183.355.392	259.765.649
2000	413.122.450	466.828.455	545.754.204	263.784.035	416.314.669	297.507.374
2001	182.183.731	259.435.462	168.870.319	238.362.632	262.412.204	185.256.997
2002	325.527.711	431.598.740	453.933.739	201.267.532	196.958.456	165.799.726
2003	78.293.668	204.195.855	402.524.194	425.545.574	440.349.299	248.525.353
2004	251.463.953	306.636.978	315.451.323	218.694.777	314.549.225	141.867.545
2005	203.628.411	364.543.053	244.158.199	171.464.620	185.856.562	128.921.278
2006	282.410.833	496.923.036	369.843.778	196.755.785	144.786.867	233.800.171
2007	77.012.160	231.965.837	279.547.571	202.326.330	206.046.064	261.882.414
2008	255.406.723	255.682.094	401.873.022	279.598.284	102.753.503	111.701.779
2009	434.087.853	330.751.892	344.665.793	307.010.276	214.913.225	157.906.589
2010	265.148.695	556.921.713	248.998.044	314.616.017	295.542.749	418.283.181
2011	230.472.814	465.301.131	260.570.699	349.951.435	210.191.309	1.170.820.460
2012	425.462.521	636.764.613	340.720.955	346.599.065	263.545.449	143.481.898
2013	573.999.483	552.086.231	308.323.435	314.814.673	172.807.857	170.560.969
2014	191.701.102	401.567.578	508.900.294	229.344.375	138.141.886	79.878.369
2015	228.511.750	332.794.100	229.023.766	191.079.853	296.801.094	146.317.584
2016	132.265.132	234.841.393	284.982.514	273.114.213	246.095.511	152.929.148
2017	366.254.805	277.801.977	229.836.694	171.559.585	172.940.017	158.760.741
Max	573.999.483	636.764.613	545.754.204	455.160.789	440.349.299	1.170.820.460
Avrg	279.659.764	381.555.307	336.310.498	271.107.887	234.966.386	243.893.012
Min	77.012.160	204.195.855	168.870.319	171.464.620	102.753.503	79.878.369

Table 5. Potential Water (m^3/s)

Year	January		February		March		April		May		June		July		August		Septemer		October		November		December	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1999	306,00	341,75	348,70	351,20	141,48	200,44	136,45	77,97	154,96	46,23	42,73	18,24	60,37	5,08	36,44	46,02	3,17	36,56	123,90	170,07	132,03	116,20	181,99	225,14
2000	318,77	360,21	421,11	203,54	321,23	229,56	100,95	90,06	93,68	78,15	138,66	54,35	11,30	54,53	6,18	4,31	11,30	64,59	30,55	91,51	269,25	266,62	129,69	138,74
2001	140,57	200,18	130,30	183,92	202,48	142,95	174,83	74,30	63,00	79,23	170,13	15,16	33,60	48,94	11,58	0,00	49,26	49,72	225,49	134,76	188,96	356,61	122,50	202,09
2002	251,18	333,02	350,26	155,30	151,97	127,93	111,95	164,59	84,00	57,26	5,67	0,00	4,65	5,44	2,91	0,00	0,73	0,00	1,03	53,73	139,00	96,20	177,72	178,56
2003	60,41	157,56	310,59	328,35	339,78	191,76	96,05	94,83	128,39	38,06	77,73	44,13	0,00	0,94	7,64	22,44	4,64	3,67	88,38	96,02	107,66	204,26	159,84	294,70
2004	194,03	236,60	243,40	168,75	242,71	109,47	130,65	94,24	91,00	113,19	75,52	17,31	36,18	13,83	0,00	0,00	47,57	28,78	29,45	34,43	63,02	150,40	115,01	265,24
2005	157,12	281,28	188,39	132,30	143,41	99,48	116,81	127,87	105,10	46,05	48,66	54,40	15,53	11,99	10,99	7,15	6,94	50,52	67,33	145,93	115,32	96,32	131,28	307,71
2006	217,91	383,43	285,37	151,82	111,72	180,40	111,09	87,71	62,03	62,12	2,97	4,39	0,00	6,96	0,00	0,00	0,00	0,00	0,00	0,00	56,80	112,92	80,30	183,98
2007	59,42	178,99	215,70	156,12	158,99	202,07	155,37	110,50	70,00	103,21	54,79	31,22	29,08	75,69	0,00	11,57	0,52	2,09	15,54	32,96	167,25	55,47	148,93	209,59
2008	197,07	197,29	310,09	215,74	79,29	86,19	86,92	66,85	48,13	52,44	23,85	15,22	4,03	0,00	5,41	23,97	24,39	20,92	99,16	223,46	176,38	395,38	118,99	200,17
2009	334,94	255,21	265,95	236,89	165,83	121,84	231,88	176,51	138,72	104,47	128,54	43,86	22,11	25,46	0,32	0,00	22,33	17,28	78,14	157,13	145,28	173,59	114,57	121,22
2010	204,59	429,72	192,13	242,76	228,04	322,75	72,20	203,65	130,87	133,28	108,48	84,68	93,24	114,88	52,15	131,98	160,75	164,53	133,13	150,78	115,51	179,09	192,75	279,11
2011	177,83	359,03	201,06	270,02	162,18	903,41	509,69	684,85	169,83	108,40	8,66	13,41	19,71	34,71	0,94	0,00	12,70	5,49	5,89	220,42	168,47	249,48	150,84	371,91
2012	328,29	491,33	262,90	267,44	203,35	110,71	198,46	59,27	158,69	61,90	15,96	0,99	10,19	3,89	0,00	1,36	0,00	0,00	93,41	133,61	86,56	167,52	164,16	226,24
2013	442,90	425,99	237,90	242,91	133,34	131,61	140,42	104,69	58,16	77,79	86,39	57,68	117,85	58,28	8,77	11,93	7,08	2,60	10,65	100,74	119,10	104,02	257,46	144,01
2014	147,92	309,85	392,67	176,96	106,59	61,63	136,83	114,65	70,39	107,51	29,90	131,95	132,72	40,02	45,57	4,65	0,00	0,00	5,61	48,52	72,09	120,22	144,74	176,31
2015	176,32	256,79	176,72	147,44	229,01	112,90	102,82	132,05	73,91	40,13	24,77	0,00	0,40	4,17	0,84	0,00	0,00	0,00	3,66	12,40	103,69	139,07	212,69	195,88
2016	102,06	181,20	219,89	210,74	189,89	118,00	184,24	159,25	106,24	136,74	119,95	246,26	88,91	94,36	46,53	57,99	130,50	263,76	166,89	156,17	190,47	215,71	182,55	232,48
2017	282,60	214,35	177,34	132,38	133,44	122,50	181,75	136,54	54,79	59,33	79,19	47,87	19,33	21,05	0,73	5,10	5,61	51,99	72,67	73,62	196,84	116,51	80,19	279,49

Table 6. Sorted Potential Water (m3/s)

No.	January 1	January 2	February 1	February 2	March 1	March 2	April 1	April 2	May 1	May 2	June 1	June 2	July 1	July 2	August 1	August 2	Septemer 1	Septemer 2	October 1	October 2	November 1	November 2	December 1	December 2
1	442,90	491,33	421,11	351,20	339,78	903,41	509,69	684,85	169,83	136,74	170,13	246,26	132,72	114,88	52,15	131,98	160,75	263,76	225,49	223,46	269,25	395,38	257,46	371,91
2	334,94	429,72	392,67	328,35	321,23	322,75	231,88	203,65	158,69	133,28	138,66	131,95	117,85	94,36	46,53	57,99	130,50	164,53	166,89	220,42	196,84	356,61	212,69	307,71
3	328,29	425,99	350,26	270,02	242,71	229,56	198,46	176,51	154,96	113,19	128,54	84,68	93,24	75,69	45,57	46,02	49,26	64,59	133,13	170,07	190,47	266,62	192,75	294,70
4	318,77	383,43	348,70	267,44	229,01	202,07	184,24	164,59	138,72	108,40	119,95	57,68	88,91	58,28	36,44	23,97	47,57	51,99	123,90	157,13	188,96	249,48	182,55	279,49
5	306,00	360,21	310,59	242,91	228,04	200,44	181,75	159,25	130,87	107,51	108,48	54,40	60,37	54,53	11,58	22,44	24,39	50,52	99,16	156,17	176,38	215,71	181,99	279,11
6	282,60	359,03	310,09	242,76	203,35	191,76	174,83	136,54	128,39	104,47	86,39	54,35	36,18	48,94	10,99	11,93	22,33	49,72	93,41	150,78	168,47	204,26	177,72	265,24
7	251,18	341,75	285,37	236,89	202,48	180,40	155,37	132,05	106,24	103,21	79,19	47,87	33,60	40,02	8,77	11,57	12,70	36,56	88,38	145,93	167,25	179,09	164,16	232,48
8	217,91	333,02	265,95	215,74	189,89	142,95	140,42	127,87	105,10	79,23	77,73	44,13	29,08	34,71	7,64	7,15	11,30	28,78	78,14	134,76	145,28	173,59	159,84	226,24
9	204,59	309,85	262,90	210,74	165,83	131,61	136,83	114,65	93,68	78,15	75,52	43,86	22,11	25,46	6,18	5,10	7,08	20,92	72,67	133,61	139,00	167,52	150,84	225,14
10	197,07	281,28	243,40	203,54	162,18	127,93	136,45	110,50	91,00	77,79	54,79	31,22	19,71	21,05	5,41	4,65	6,94	17,28	67,33	100,74	132,03	150,40	148,93	209,59
11	194,03	256,79	237,90	183,92	158,99	122,50	130,65	104,69	84,00	62,12	48,66	18,24	19,33	13,83	2,91	4,31	5,61	5,49	30,55	96,02	119,10	139,07	144,74	202,09
12	177,83	255,21	219,89	176,96	151,97	121,84	116,81	94,83	73,91	61,90	42,73	17,31	15,53	11,99	0,94	1,36	4,64	3,67	29,45	91,51	115,51	120,22	131,28	200,17
13	176,32	236,60	215,70	168,75	143,41	118,00	111,95	94,24	70,39	59,33	29,90	15,22	11,30	6,96	0,84	0,00	3,17	2,60	15,54	73,62	115,32	116,51	129,69	195,88
14	157,12	214,35	201,06	156,12	141,48	112,90	111,09	90,06	70,00	57,26	24,77	15,16	10,19	5,44	0,73	0,00	0,73	2,09	10,65	53,73	107,66	116,20	122,50	183,98
15	147,92	200,18	192,13	155,30	133,44	110,71	102,82	87,71	63,00	52,44	23,85	13,41	4,65	5,08	0,32	0,00	0,52	0,00	5,89	48,52	103,69	112,92	118,99	178,56
16	140,57	197,29	188,39	151,82	133,34	109,47	100,95	77,97	62,03	46,23	15,96	4,39	4,03	4,17	0,00	0,00	0,00	0,00	5,61	34,43	86,56	104,02	115,01	176,31
17	102,06	181,20	177,34	147,44	111,72	99,48	96,05	74,30	58,16	46,05	8,66	0,99	0,40	3,89	0,00	0,00	0,00	0,00	3,66	32,96	72,09	96,32	114,57	144,01
18	60,41	178,99	176,72	132,38	106,59	86,19	86,92	66,85	54,79	40,13	5,67	0,00	0,00	0,94	0,00	0,00	0,00	0,00	1,03	12,40	63,02	96,20	80,30	138,74
19	59,42	157,56	130,30	132,30	79,29	61,63	72,20	59,27	48,13	38,06	2,97	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	56,80	55,47	80,19	121,22
R80	146,45	199,60	191,38	154,60	133,42	110,46	102,45	85,76	62,81	51,20	22,27	11,61	4,52	4,90	0,26	0,00	0,42	0,00	5,83	45,70	100,26	111,14	118,19	178,11
Used	146,45	199,60	191,38	154,60	133,42	110,46	102,45	85,76	62,81	51,20	22,27	13,41	4,65	4,17	0,84	4,65	3,17	3,67	5,61	34,43	100,26	111,14	118,19	178,11

5. Cropping Pattern

Table 7. Cropping Pattern

I Cropping Pattern

Group	Crop Type	Planting Period (ha) I	II	III
I	Paddy	9005	9005	0
	Sec Crop	0	0	9005
	Amount	9005	9005	9005

Planting Period I (MTI): October – February; Planting Period II (MTII): March – June; Planting Period III (MTIII): July – September. Paddy: 9005 ha (November – June); Secondary crop: 9005 ha (July – September).

Item		Oct I	Oct II	Nov I	Nov II	Dec I	Dec II	Jan I	Jan II	Feb I	Feb II	Mar I	Mar II	Apr I	Apr II	May I	May II	Jun I	Jun II	Jul I	Jul II	Aug I	Aug II	Sep I	Sep II
II Water Requirement																									
1. Unit of Water Requirement (SKA)	Paddy	0	0	1,25	1,25	0,725	0,725	0,725	0,725	0,52	0	1,125	1,125	0,85	0,85	0,85	0,85	0,52	0	0	0	0	0	0	0
	Sec Crop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,3	0,3	0,3	0,3	0,3	0,3
2. Water Requirement in The Field KAS = SKA x Areal	Paddy	0,0	0,0	11.256,3	11.256,3	6.528,6	6.528,6	6.528,6	6.528,6	4.682,6	0,0	10.130,6	10.130,6	7.654,3	7.654,3	7.654,3	7.654,3	4.682,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Sec Crop	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2.701,5	2.701,5	2.701,5	2.701,5	2.701,5	2.701,5
	Amount	0,0	0,0	11.256,3	11.256,3	6.528,6	6.528,6	6.528,6	6.528,6	4.682,6	0,0	10.130,6	10.130,6	7.654,3	7.654,3	7.654,3	7.654,3	4.682,6	0,0	2.701,5	2.701,5	2.701,5	2.701,5	2.701,5	2.701,5
3. Tertiary Water Requirement	1,25	0,0	0,0	14.070,3	14.070,3	8.160,8	8.160,8	8.160,8	8.160,8	5.853,3	0,0	12.663,3	12.663,3	9.567,8	9.567,8	9.567,8	9.567,8	5.853,3	0,0	3.376,9	3.376,9	3.376,9	3.376,9	3.376,9	3.376,9
4. Secondary Water Requirement	1,10	0,0	0,0	15.477,3	15.477,3	8.976,9	8.976,9	8.976,9	8.976,9	6.438,6	0,0	13.929,6	13.929,6	10.524,6	10.524,6	10.524,6	10.524,6	6.438,6	0,0	3.714,6	3.714,6	3.714,6	3.714,6	3.714,6	3.714,6
5. Primary Water Requirement	1,05	0,0	0,0	16.251,2	16.251,2	9.425,7	9.425,7	9.425,7	9.425,7	6.760,5	0,0	14.626,1	14.626,1	11.050,8	11.050,8	11.050,8	11.050,8	6.760,5	0,0	3.900,3	3.900,3	3.900,3	3.900,3	3.900,3	3.900,3
6. Crop Water Requirement	l/s	0,0	0,0	16.251,2	16.251,2	9.425,7	9.425,7	9.425,7	9.425,7	6.760,5	0,0	14.626,1	14.626,1	11.050,8	11.050,8	11.050,8	11.050,8	6.760,5	0,0	3.900,3	3.900,3	3.900,3	3.900,3	3.900,3	3.900,3
7. Water Requirement Etc.	l/s	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
8. Total Amount (6+7)	l/s	50,0	50,0	16.301,2	16.301,2	9.475,7	9.475,7	9.475,7	9.475,7	6.810,5	50,0	14.676,1	14.676,1	11.100,8	11.100,8	11.100,8	11.100,8	6.810,5	50,0	3.950,3	3.950,3	3.950,3	3.950,3	3.950,3	3.950,3
9. Total Amount	m^3/s	0,05	0,05	16,30	16,30	9,48	9,48	9,48	9,48	6,81	0,05	14,68	14,68	11,10	11,10	11,10	11,10	6,81	0,05	3,95	3,95	3,95	3,95	3,95	3,95

Description

	Time / Month	MT I	MT II
Treatment & Drying	± 1,0	(l/s/ha)	(l/s/ha)
Land Preparation & Seeding	1,0	1,25	1,125
Growing	2,5	0,725	0,85
Harvest	0,5	0,00	0,00

	Time / Month		
Secondary Crop	± 3,5	0,3	l/s/ha

6. Water Balance

Table 8. Water Balance

Month	Water Potential (m^3/s)	Water Requirement (m^3/s)	Water Balance (m^3/s)
1	2	3	3 - 2
October I	5,61	0,05	5,56
October II	34,43	0,05	34,38
November I	100,26	16,30	83,96
November II	111,14	16,30	94,84
December I	118,19	9,48	108,72
December II	178,11	9,48	168,64
January I	146,45	9,48	136,97
January II	199,60	9,48	190,13
February I	191,38	6,81	184,57
February II	154,60	0,05	154,55
March I	133,42	14,68	118,74
March II	110,46	14,68	95,79
April I	102,45	11,10	91,35
April II	85,76	11,10	74,66
May I	62,81	11,10	51,71
May II	51,20	11,10	40,10
June I	22,27	6,81	15,46
June II	13,41	0,05	13,36
July I	4,65	3,95	0,70
July II	4,17	3,95	0,22
August I	0,84	3,95	-3,11
August II	4,65	3,95	0,70
September I	3,17	3,95	-0,78
September II	3,67	3,95	-0,28

B. Analysis of Flood Discharge

1. Maximum Daily Rainfall Data

Table 9. The Monthly of Rh Max in Moga Station (mm)

Year	January	February	March	April	May	June	July	August	Septembe	October	Novembe	Decembe	Rh max
1999	210	160	121	120	223	32	40	90	90	107	121	180	223
2000	200	306	176	120	208	179	120	0	0	0	210	110	306
2001	105	86	0	108	124	190	20	0	0	180	200	140	200
2002	197	200	100	140	80	0	0	0	0	51	180	200	200
2003	100	150	180	40	100	120	0	90	10	110	148	124	180
2004	95	140	209	90	74	72	40	0	110	50	100	92	209
2005	100	70	100	90	96	80	40	21	42	93	50	90	100
2006	180	90	40	36	32	9	30	0	0	0	70	110	180
2007	44	120	80	40	27	40	45	0	0	21	90	110	120
2008	140	150	70	40	40	40	0	70	48	87	50	110	150
2009	146	110	42	50	40	40	14	0	37	25	25	31	146
2010	200	40	40	25	56	26	42	140	28	60	50	40	200
2011	170	120	40	27	70	30	45	0	55	80	27	90	170
2012	57	110	52	86	165	20	19	16	0	35	75	159	165
2013	134	100	72	59	57	65	60	20	0	33	0	95	134
2014	100	148	90	110	70	90	71	40	0	26	70	94	148
2015	134	120	40	48	68	45	0	0	0	25	72	75	134
2016	75	65	55	120	85	480	88	100	130	177	190	105	480
2017	147	192	83	90	40	40	41	30	34	77	126	190	192

Table 10. Average Rainfall for Polygon of Thiessen (mm)

Year	Moga 12,65%		Randudongkal 9,36%		Belik 10,88%		Watukumpul 11,83%		Sipedang 27,63%		Sokawati 15,58%		Karangtengah 12,06%		Rh Plan 100%
	Rh	CRh	Rh	CRh	Rh	CRh	Rh	CRh	Rh	CRh	Rh	CRh	Rh	CRh	
1999	223	28,21	84	7,91	112	12,19	193	22,83	150	41,44	85	13,24	52	6,27	132,10
2000	306	38,71	93	8,71	110	11,97	105	12,42	95	26,25	128	19,94	50	6,03	124,04
2001	200	25,30	131	12,27	108	11,76	89	10,53	94	25,97	86	13,40	56	6,75	105,98
2002	200	25,30	284	26,59	125	13,61	127	15,03	147	40,62	94	14,65	40	4,82	140,61
2003	180	22,77	178	16,67	163	17,74	155	18,34	176	48,63	127	19,79	87	10,49	154,43
2004	209	26,44	198	18,54	82	8,93	97	11,48	111	30,67	178	27,74	102	12,30	136,09
2005	100	12,65	106	9,93	202	21,99	90	10,65	89	24,59	118	18,39	118	14,23	112,42
2006	180	22,77	165	15,45	160	17,42	117	13,84	166	45,86	76	11,84	78	9,41	136,59
2007	120	15,18	218	20,41	115	12,52	125	14,74	142	39,19	112	17,45	116	13,99	133,47
2008	150	18,97	80	7,49	162	17,63	174	20,59	172	47,52	115	17,92	104	12,54	142,67
2009	146	18,47	90	8,43	216	23,51	95	11,24	120	33,16	92	14,34	160	19,29	128,43
2010	200	25,30	155	14,51	142	15,46	120	14,20	120	33,16	148	23,06	563	67,89	193,57
2011	170	21,50	155	14,51	220	23,95	960	113,58	450	124,33	130	20,26	108	13,02	331,16
2012	165	20,89	179	16,77	198	21,55	216	25,56	215	59,40	89	13,87	122	14,71	172,75
2013	134	16,95	129	12,08	210	22,86	250	29,58	260	71,84	95	14,80	95	11,46	179,56
2014	148	18,72	99	9,27	313	34,07	100	11,83	218	60,23	187	29,14	166	20,02	183,28
2015	134	16,95	114	10,67	180	19,59	142	16,80	87	24,04	116	18,08	109	13,14	119,28
2016	480	60,72	151	14,14	476	51,81	132	15,67	357	98,64	190	29,61	190	22,91	293,49
2017	192	24,29	164	15,36	334	36,35	115	13,61	101	27,91	141	21,97	104	12,54	152,02

2. Frequency Analysis of Rainfall

Table 11. Statistical Parameter (E.J Gumbel)

Year	X (1) (mm)	Xr (2) Σ(1)/N	(X - Xr) (3) (1) - (2)	$(X - Xr)^2$ (4) $(3)^2$
1999	132,0997	161,6803	-29,5806	875,0130
2000	124,0352	161,6803	-37,6451	1.417,1562
2001	105,9768	161,6803	-55,7035	3.102,8782
2002	140,6108	161,6803	-21,0695	443,9237
2003	154,4262	161,6803	-7,2541	52,6219
2004	136,0851	161,6803	-25,5952	655,1123
2005	112,4172	161,6803	-49,2631	2.426,8538
2006	136,5913	161,6803	-25,0890	629,4557
2007	133,4732	161,6803	-28,2071	795,6385
2008	142,6687	161,6803	-19,0116	361,4423
2009	128,4317	161,6803	-33,2486	1.105,4683
2010	193,5750	161,6803	31,8947	1.017,2720
2011	331,1591	161,6803	169,4788	28.723,0693
2012	172,7453	161,6803	11,0650	122,4350
2013	179,5618	161,6803	17,8815	319,7470
2014	183,2804	161,6803	21,6001	466,5662
2015	119,2754	161,6803	-42,4049	1.798,1739
2016	293,4898	161,6803	131,8095	17.373,7378
2017	152,0229	161,6803	-9,6574	93,2658
Amount	3.071,9255	3.071,9255	0,0000	61.779,8309
Max	331,1591		169,4788	28.723,0693
Min	105,9768		-55,7035	52,6219
Stdev	58,5851			

Table 12. Calculation of Rainfall Plan for Return Period T (mm/day)

Return Period	Yt (1)	K (2)	Xr (3)	Sx (4)	Xt (5) (3) + (2)*(4)
2	0,3665	-0,1472	161,6803	58,5851	153,05821
5	1,4999	0,92564	161,6803	58,5851	215,90906
10	2,2504	1,63594	161,6803	58,5851	257,52180
25	3,1985	2,5334	161,6803	58,5851	310,09960
50	3,9019	3,19918	161,6803	58,5851	349,10481
100	4,6001	3,86006	161,6803	58,5851	387,82202

Table 13. Rainfall Plan of Gumbel's Method

Return Period (Years)	Rainfall Plan (mm/day)
2	153,0582
5	215,9091
10	257,5218
25	310,0996
50	349,1048
100	387,8220

3. Intensity of Rainfall

Table 14. Ratio of Intensity of Rainfall

Hour to (t)	Rainfall Distribution (Rt) for about one hour	Hourly Rainfall	Ratio	Cumulative
1	0,5503	0,5503	55,03%	55,03%
2	0,3467	0,1430	14,30%	69,34%
3	0,2646	0,1003	10,03%	79,37%
4	0,2184	0,0799	7,99%	87,36%
5	0,1882	0,0675	6,75%	94,10%
6	0,1667	0,0590	5,90%	100,00%
	Amount	1,0	100%	

Table 15. Effective Rainfall

Hour to	Ratio	Hourly Rainfall (mm) 2	5	10	25	50	100
1	55,03%	58,96	83,17	99,20	119,46	134,48	149,40
2	14,30%	15,33	21,62	25,79	31,05	34,96	38,83
3	10,03%	10,75	15,16	18,09	21,78	24,52	27,24
4	7,99%	8,56	12,07	14,40	17,34	19,52	21,69
5	6,75%	7,23	10,19	12,16	14,64	16,48	18,31
6	5,90%	6,32	8,91	10,63	12,80	14,41	16,01
Rainfall Plan		153,06	215,91	257,52	310,10	349,10	387,82
Flow Coefficient		0,70	0,70	0,70	0,70	0,70	0,70
Effective Rainfall		107,14	151,14	180,27	217,07	244,37	271,48

4. Synthetic Unit Hydrograph of Nakayasu

Table 16. Parameter of Synthetic Unit Hydrograph of Nakayasu

Watershed Area (A)	=	870,25 km^2
River Length (L)	=	91,78 km
Unit Hujan Efektif (R0)	=	1 mm
Time lage (Tg)	=	5,72 hour
Rain Time Unit (Tr)	=	4,29 hour
Peak Time (Tp)	=	9,16 hour
Hydrograph Parameter (α)	=	**2,00**
T_{03}	=	11,45 hour
0,5 T_{03}	=	5,72 hour
1,5 T_{03}	=	17,17 hour
2 T_{03}	=	22,89 hour
Tp + T_{03}	=	20,60 hour
Tp + T_{03} + 1,5 T_{03}	=	37,77 hour
Qp	=	6,8125 m^3/s

Table 17. Calculation of Synthetic Unit Hydrograph of Nakayasu

No	Time (hour)	t/Tp	(t-Tp)	(t-Tp)/T_{03}	((t-Tp)+(0,5T_{03}))/(1,5T_{03})	((t-Tp)+(1,5T_{03}))/(2T_{03})	UH (m^3/s)
1	0,00	0,00	-9,16	-0,80	-0,20	0,35	0,00
2	1,00	0,11	-8,16	-0,71	-0,14	0,39	0,03
3	2,00	0,22	-7,16	-0,63	-0,08	0,44	0,18
4	3,00	0,33	-6,16	-0,54	-0,03	0,48	0,47
5	4,00	0,44	-5,16	-0,45	0,03	0,52	0,93
6	5,00	0,55	-4,16	-0,36	0,09	0,57	1,59
7	6,00	0,66	-3,16	-0,28	0,15	0,61	2,47
8	7,00	0,76	-2,16	-0,19	0,21	0,66	3,58
9	8,00	0,87	-1,16	-0,10	0,27	0,70	4,93
10	9,00	0,98	-0,16	-0,01	0,32	0,74	6,54
11	9,16	1,00	0,00	0,00	0,33	0,75	6,81
12	10,00	1,09	0,84	0,07	0,38	0,79	6,23
13	11,00	1,20	1,84	0,16	0,44	0,83	5,61
14	12,00	1,31	2,84	0,25	0,50	0,87	5,05
15	13,00	1,42	3,84	0,34	0,56	0,92	4,55
16	14,00	1,53	4,84	0,42	0,62	0,96	4,09
17	15,00	1,64	5,84	0,51	0,67	1,01	3,68
18	16,00	1,75	6,84	0,60	0,73	1,05	3,32
19	17,00	1,86	7,84	0,69	0,79	1,09	2,99
20	18,00	1,97	8,84	0,77	0,85	1,14	2,69
21	19,00	2,07	9,84	0,86	0,91	1,18	2,42
22	20,00	2,18	10,84	0,95	0,96	1,22	2,18
23	20,60	2,25	11,45	1,00	1,00	1,25	2,04
24	21,00	2,29	11,84	1,03	1,02	1,27	1,99
25	22,00	2,40	12,84	1,12	1,08	1,31	1,85
26	23,00	2,51	13,84	1,21	1,14	1,35	1,73
27	24,00	2,62	14,84	1,30	1,20	1,40	1,61
28	25,00	2,73	15,84	1,38	1,26	1,44	1,50
29	26,00	2,84	16,84	1,47	1,31	1,49	1,40
30	27,00	2,95	17,84	1,56	1,37	1,53	1,31
31	28,00	3,06	18,84	1,65	1,43	1,57	1,22
32	29,00	3,17	19,84	1,73	1,49	1,62	1,13
33	30,00	3,28	20,84	1,82	1,55	1,66	1,06
34	31,00	3,39	21,84	1,91	1,61	1,70	0,99
35	32,00	3,49	22,84	2,00	1,66	1,75	0,92
36	33,00	3,60	23,84	2,08	1,72	1,79	0,86
37	34,00	3,71	24,84	2,17	1,78	1,84	0,80
38	35,00	3,82	25,84	2,26	1,84	1,88	0,74
39	36,00	3,93	26,84	2,35	1,90	1,92	0,69
40	37,00	4,04	27,84	2,43	1,95	1,97	0,65
41	37,77	4,13	28,62	2,50	2,00	2,00	0,61
42	38,00	4,15	28,84	2,52	2,01	2,01	0,61
43	39,00	4,26	29,84	2,61	2,07	2,05	0,57
44	40,00	4,37	30,84	2,69	2,13	2,10	0,55
45	41,00	4,48	31,84	2,78	2,19	2,14	0,52
46	42,00	4,59	32,84	2,87	2,25	2,18	0,49
47	43,00	4,70	33,84	2,96	2,30	2,23	0,47
48	44,00	4,80	34,84	3,04	2,36	2,27	0,44
49	45,00	4,91	35,84	3,13	2,42	2,32	0,42
50	46,00	5,02	36,84	3,22	2,48	2,36	0,40

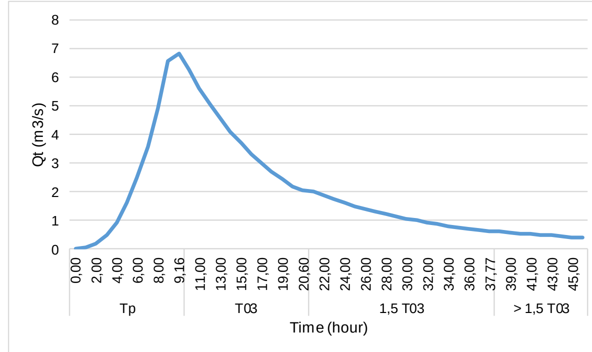

Figure 2. Unit of Hydrograph of SUH of Nakayasu

Table 18. Calculation of Design Flood for Return Period 25 Year of SUH of Nakayasu

t	UH	Hourly Rainfall (mm/hr)						Qb	Qn
		R1	R2	R3	R4	R5	R6		
(hr)	$m^3/s/mm$	119,46	31,05	21,78	17,34	14,64	12,80	(m^3/s)	(m^3/s)
0,00	0,00	0,00						3,41	3,41
1,00	0,03	4,00	0,00					3,41	7,41
2,00	0,18	21,12	5,49	0,00				3,41	30,02
3,00	0,47	55,90	14,53	10,19	0,00			3,41	84,02
4,00	0,93	111,49	28,98	20,33	16,18	0,00		3,41	180,39
5,00	1,59	190,47	49,51	34,73	27,65	23,35	0,00	3,41	329,10
6,00	2,47	295,02	76,68	53,79	42,82	36,16	31,61	3,41	539,50
7,00	3,58	427,10	111,01	77,87	61,99	52,35	45,76	3,41	779,50
8,00	4,93	588,45	152,95	107,29	85,41	72,13	63,05	3,41	1.072,69
9,00	6,54	780,69	202,92	142,34	113,32	95,69	83,65	3,41	1.422,01
9,16	6,81	813,81	211,53	148,38	118,13	99,75	87,20	3,41	1.482,20
10,00	6,23	744,77	193,58	135,79	108,10	91,29	79,80	3,41	1.356,75
11,00	5,61	670,41	174,25	122,24	97,31	82,18	71,83	3,41	1.221,63
12,00	5,05	603,48	156,86	110,03	87,60	73,97	64,66	3,41	1.100,00
13,00	4,55	543,23	141,20	99,05	78,85	66,59	58,20	3,41	990,52
14,00	4,09	488,99	127,10	89,16	70,98	59,94	52,39	3,41	891,96
15,00	3,68	440,17	114,41	80,26	63,89	53,95	47,16	3,41	803,25
16,00	3,32	396,22	102,99	72,24	57,51	48,57	42,45	3,41	723,39
17,00	2,99	356,67	92,70	65,03	51,77	43,72	38,21	3,41	651,51
18,00	2,69	321,06	83,45	58,54	46,60	39,35	34,40	3,41	586,80
19,00	2,42	289,00	75,12	52,69	41,95	35,42	30,96	3,41	528,56
20,00	2,18	260,15	67,62	47,43	37,76	31,89	27,87	3,41	476,13
20,60	2,04	244,14	63,46	44,51	35,44	29,93	26,16	3,41	447,04
21,00	1,99	237,45	61,72	43,29	34,47	29,11	25,44	3,41	434,88
22,00	1,85	221,37	57,54	40,36	32,13	27,13	23,72	3,41	405,66
23,00	1,73	206,38	53,64	37,63	29,96	25,30	22,11	3,41	378,42
24,00	1,61	192,40	50,01	35,08	27,93	23,58	20,62	3,41	353,03
25,00	1,50	179,37	46,62	32,71	26,04	21,99	19,22	3,41	329,35
26,00	1,40	167,23	43,47	30,49	24,27	20,50	17,92	3,41	307,28
27,00	1,31	155,90	40,52	28,43	22,63	19,11	16,70	3,41	286,70
28,00	1,22	145,34	37,78	26,50	21,10	17,82	15,57	3,41	267,52
29,00	1,13	135,50	35,22	24,71	19,67	16,61	14,52	3,41	249,63
30,00	1,06	126,33	32,83	23,03	18,34	15,48	13,54	3,41	232,96
31,00	0,99	117,77	30,61	21,47	17,09	14,44	12,62	3,41	217,41
32,00	0,92	109,80	28,54	20,02	15,94	13,46	11,76	3,41	202,92
33,00	0,86	102,36	26,61	18,66	14,86	12,55	10,97	3,41	189,41
34,00	0,80	95,43	24,80	17,40	13,85	11,70	10,22	3,41	176,81
35,00	0,74	88,97	23,12	16,22	12,91	10,91	9,53	3,41	165,07
36,00	0,69	82,94	21,56	15,12	12,04	10,17	8,89	3,41	154,12
37,00	0,65	77,32	20,10	14,10	11,22	9,48	8,28	3,41	143,91
37,77	0,61	73,24	19,04	13,35	10,63	8,98	7,85	3,41	136,50
38,00	0,61	72,38	18,81	13,20	10,51	8,87	7,75	3,41	134,92
39,00	0,57	68,67	17,85	12,52	9,97	8,42	7,36	3,41	128,18
40,00	0,55	65,15	16,93	11,88	9,46	7,99	6,98	3,41	121,79
41,00	0,52	61,81	16,07	11,27	8,97	7,58	6,62	3,41	115,73
42,00	0,49	58,64	15,24	10,69	8,51	7,19	6,28	3,41	109,97
43,00	0,47	55,64	14,46	10,14	8,08	6,82	5,96	3,41	104,51
44,00	0,44	52,79	13,72	9,63	7,66	6,47	5,66	3,41	99,33
45,00	0,42	50,09	13,02	9,13	7,27	6,14	5,37	3,41	94,42
46,00	0,40	47,52	12,35	8,66	6,90	5,82	5,09	3,41	89,75

Table 19. Design Flood for Return Period of Synthetic Uni Hydrogaph of Nakayasu

Return Period (yr)	Design Flood (m^3/s)
2	733,30
5	1.033,03
10	1.231,47
25	1.482,20
50	1.668,21
100	1.852,84

5. Rational Method

Table 20. Calculation of Flood Discharge of Rational Method

T (years)	A (km^2)	L (km)	i	tc (hr)	R24 (mm/day)	I (mm/hr)	Q (m^3/s)
2	870,25	91,78	0,0013	27,81	153,06	5,78	559,45
5	870,25	91,78	0,0013	27,81	215,91	8,16	789,18
10	870,25	91,78	0,0013	27,81	257,52	9,73	941,28
25	870,25	91,78	0,0013	27,81	310,10	11,71	1.133,46
50	870,25	91,78	0,0013	27,81	349,10	13,19	1.276,02
100	870,25	91,78	0,0013	27,81	387,82	14,65	1.417,54

6. Weduwen Method

Table 21. Calculation of Flood Discharge of Weduwen Method

No	t_0 (jam)	β	q ($m^3/s/km^2$)	α	t (jam)
1	1,01000	0,29765	27,50000	0,73000	25,37714
2	25,37714	0,79549	2,52170	0,54475	31,38141
3	31,38141	0,82590	2,06053	0,52883	32,15214
4	32,15214	0,82916	2,01326	0,52707	32,24313
5	32,24313	0,82953	2,00783	0,52686	32,25376
6	32,25376	0,82958	2,00719	0,52684	32,25500
7	32,25500	0,82958	2,00712	0,52684	32,25515
8	32,25515	0,82958	2,00711	0,52684	32,25516
9	32,25516	0,82958	2,00711	0,52684	32,25517
10	32,25517	0,82958	2,00711	0,52684	32,25517
T (years)	α	β	q	R_{24} (mm)	Qn (m^3/s)
2	0,53	0,83	2,01	153,1	486,85
5	0,53	0,83	2,01	215,9	686,77
10	0,53	0,83	2,01	257,5	819,13
25	0,53	0,83	2,01	310,1	986,37
50	0,53	0,83	2,01	349,1	1110,44
100	0,53	0,83	2,01	387,8	1233,59

7. Haspers Method

Table 22. Calculation of Flood Discharge of Haspers Method

T (years)	A (km^2)	L (km)	i	t (hours)	β	α	R_{24} (mm)	Rt (mm)	q $m^3/s/km^2$	Q (m^3/s)
2	870,25	91,78	0,0013	27,29	0,68	0,25	153,06	575,57	5,86	768,48
5	870,25	91,78	0,0013	27,29	0,68	0,25	215,91	811,92	8,26	1.084,05
10	870,25	91,78	0,0013	27,29	0,68	0,25	257,52	968,40	9,86	1.292,98
25	870,25	91,78	0,0013	27,29	0,68	0,25	310,10	1.166,12	11,87	1.556,96
50	870,25	91,78	0,0013	27,29	0,68	0,25	349,10	1.312,80	13,36	1.752,80
100	870,25	91,78	0,0013	27,29	0,68	0,25	387,82	1.458,39	14,84	1.947,19

Table 23. Result of Flood Design Discharge

Return Period (years)	Flood Design Discharge (m^3/s)			
	Rational	Weduwen	Haspers	SUH Nakayasu
2	559,45	486,85	768,48	733,30
5	789,18	686,77	1.084,05	1.033,03
10	941,28	819,13	1.292,98	1.231,47
25	1.133,46	986,37	1.556,96	1.482,20
50	1.276,02	1.110,44	1.752,80	1.668,21
100	1.417,54	1.233,59	1.947,19	1.852,84

Based on the calculation of flood discharge, the method used is the result of the SUH of Nakayasu method because meet from the three factors (Technical, Environment, and Economic).

8. Embankment

In this study, planned flood control is the construction of embankment. The basis of planning is as follows:

Discharge design	:	1482,20 m^3/s (Q_{25} of Nakayasu)
Height of embankment	:	4 m
Large of embankment	:	4 m
Slope from cross-sectional area of flow	:	1:2
Width of river, a	:	90 m
Depth of river, t	:	6 m

Total cost estimation is about **Rp 180.000.000.000** (+Rp 36.000.000.000 for normalization). Total for losses due to flooding per year is about **Rp 13.442.300.000.**

C. Benefit Cost Ratio (BCR)

Cost, C = Rp 180.000.000.000
Interest, i = 5,5%

$$P = F[1/(1+i)^n]$$

$$P = \frac{13442300000}{(1+5{,}5\%)\text{^}1} = Rp\ 12.741.516.588$$

$$BCR = \frac{B}{C} = \frac{180.314.106.947}{180.000.000.000} = 1{,}002$$

BCR ≥ 1 → investation of project is feasible.

So conclusion from the embankment construction is profitable.

IV. CONCLUSION AND SUGGESTION

A. Conclusion

From the results of the discussion, conclusions can be taken as follows:

1. The Comal watershed has an area of 870,25 km^2.
2. Nineteen years of rainfall data are used from 1999 - 2017.
3. From 11 stations, 7 stations were used to calculate and the Sipedang Station representing the largest catchment area with a percentage of 28% of the total watershed.
4. The biggest water potential occurs in January is 199,60 m^3/s and the smallest in August is 0,84 m^3/s.
5. Cropping pattern carried out with one year there are three cropping patterns, namely paddy - paddy - secondary crops. For the water requirements, enough can be fulfilled, but in August and September, where the planting period III for the secondary crops experiences a deficit.
6. Gumbel Method is used for frequency analysis.
7. From the results of the calculation of flood discharge with several methods, that the result of the Nakayasu method are used.
8. Cost for embankment and normalization is Rp 180.000.000.000, then losses due to flooding is Rp 13.442.300.000 per year, and then for BCR is 1,002. So the embankment construction and normalization is profitable.

B. Suggestion

Based on the results of the research that has been done, then it can be advised as follows:

1. The number of years of observation it would be better if it could be enlarged again, this allows a better result.
2. In using the method of discharge calculation should preferably be adapted to the conditions of the watershed.
3. Further research is still needed, so that the results of the analysis can be utilized more optimal.

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