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Comparison between the Calculations of Surface Runoff Using Curve Number Method and the Observation Data in the Upstream Ciliwung Watershed – West Java

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ABSTRACT

Runoff (surface flow) is one of the most important hydrological variable in supporting the activities of water resources development. A reliable prediction method to calculate the amount and rate of runoff from the land surface caused by the rain that falls in a watershed that is not equipped with measuring devices (un gauge watershed) is a very difficult job and requires a lot of time. The research was conducted in the upstream Ciliwung watershed, which is an important area in relation to the incidence of flooding in Jakarta.Curve Number (CN) method can be used to predict the amount of runoff from a watershed. This model required input of rainfall; land cover maps; soil type maps, and topography. The maps are processed using ArcView software, so we get the value of CN. In this study, we used of rainfall and discharge data 2007-2009. Based on the analysis of calculation, known that amount of surface flow approaching 50% of rainfall depth. This condition indicates that the upstream Ciliwung watershed conditions were notable and proper to absorb of rainfall. The correlation between the results of run-off prediction models using CN with run-off observationwas quite good. This indicated that the Curve Number method could be able to represent the relationship of rainfall with surface flow (run off) and also to predict runoff.
KEYWORDS: Run off observation, run-off model, curve number.

INTRODUCTION

Physical Background

Watershed is an area of land which is an integral part ofthe river andits tributaries, which serves to hold, store and stream originating from rainfall to the lake or to naturally sea, on land that borders a topographic and boundary separation in the sea until the water area isstill affectedland activities. Sub-watershed is partof thewatershedthat receivesrain waterandrunning itthroughtributariesto themain river. Eachwatershedis dividedoutinto the several of sub-basin watershed.

Watershedalso be interpretedasahydrologicalsystem, which includesfoursub-systems, namely: surface water system, the water system in the unsaturated zone, saturated zone water systems and water systems in networking stream[1)]. Interactions between sub-systems within the watershed will maintain aprocess, like the rain water surface runoff, subsurface flow(interflow) and groundwater flow.

Runoff is one of the most important hydrological variables in supporting the activities of development of water resources. A reliable prediction method for calculating the amount and rate of runoff that comes from the ground surface and moved toward the river in a watershed that is not equipped with measuring devices (ungauged watershed) is a very difficult job and it takes a long time. The conventional model for calculating the amount of runoff entering the

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river must consider the meteorological and hydrological data. Where, data procurement efforts require time-intensive, high cost and difficult process.

Remote Sensing Technology to enhance the development ofa model study of the rainfall and runoff relationship conventionally.The main role of remote sensing technology in the calculation ofthe amount of runoff, the general is to provide input data and assist in the calculation of coefficients and model parameters. Based on experience, shows that from the interpretation of satellite imagery can be obtained various thematicinformation resources such as land cover, soil, vegetation, drainage patterns[2)].

Data resulting from the interpretation of satellite images combined with conventional measurement result data such as rainfall, temperature, altitude, contour, slope, we will get a patch of data (overlay) which required for model input rainfall-runoff. Overlay data that have been obtained can be processed by adding geographic information(geo reference data) which can then be processed with Geographic Information Systems (GIS). GIS is a system for the management, storage, processing or manipulation, analysis, and delivery of data, where the data isspatially in relation to earth[3).]

Hydrological model that reflects the relationship between rainfall andrunoff, are generally divided into two approaches, namely the concept of lump (lumped) parameters and the spatial distribution of physical concepts (spatially distributed physically). The concept of lump parameter does not take into account aspects ofwatershed response to spatial heterogeneity. This means that the concept will only use a single value for the model input parameters. While the concept o fspatial distribution very attentive to spatial heterogeneity in the response to the detailed watershed. Because the concept is different, then the calculationis different. The concept of spatial distribution of trying tosimulate realistic force in nature, that the production of runoff caused by rainfall that is controlled by the hydro-morphological characteristics of the watershed include :topography, soil, vegetation cover, soil and water depth. This approach becomes complex and difficult and relationships rainfall–runoff obtained in the form of non-linear. The advantage of lump parameter is a simple formulation. For the prediction of runoff on alarge scale and integrated, as estimates at the outletpoint of the watershed,it is known that the results of calculation of and distribution concepts are not distinctlump[4).]

One of the models that use the lump-parameter model is the Natural Resources Conservation Service (NRCS) Curve Number (NRCS, 1994). The first time the idea of this model is generated by SCS (SoilConservationService) in 1933,which aimed to calculate the flow ratein a simplesur face. This model is quite extensive and widely used in the world for the application of hydrological calculation [5)]mainlyfrom the nature of simplicity of form formula used.

Several previous studies indicate that the use of NRCS Curve Number method combined with the technology of Remote Sensing and GIS for calculating runoff in the water shed that are notequipped with a complete measuring equipment gives good resultsand is very useful forplanning and building hydrologyand peak discharge planning[2), 6); 7)]. In another studymentionedthat there is nodifference in outcome betweenthe distribution model(topmodel) withlumpmodel (NRCS-Curve Number) forlarge-scale and integrated[4)].

In general, this study aims to examine more deeply both analytical and experimental behavior ofthe components associated with the model NRCS Curve Number, and specifically studied

1.Antecedent Moisture Conditions (AMC) or previous conditionof soil moisture, soil moisture, a condition which his calculated by adding together the approach ofrain5 (five) days in advance.
2.Calculatingrun off prediction (runoff) with a model curve number.
3.Analyzing the results ofcomparison of runoffmodel (Q_{mod}) with run off measurements (Q_{obs}).

4.Create a model forrainfall runoff relationship with NRCS Curve Number met hod using remote sensing an dGIS, in order toobtainas patial picture of hydrological conditions(spatial).

METHODOLOGY

Research Locations

The research area in the upstream of Ciliwung watershed. The upstream Ciliwung watershed has an area are 15225.84 ha. The geographical position of the watershed is $6^0 38'$- $6^0 46'$ S and $106^0 49'$-$107^0 0'$ E. Map of upstream Ciliwung watershed contained in Figure 1.

The upstream Ciliwung watershed consists of 4 sub watershed is: SubWatershed Ciesek, Hulu Ciliwung, Cibogo-Cisarua, and Ciseuseupan-Cisukabirus.

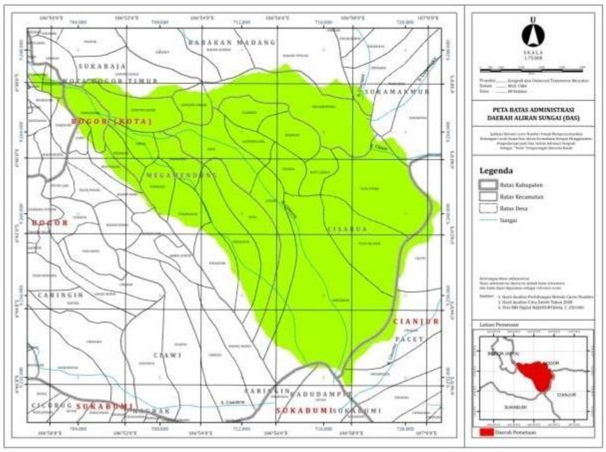


Figure 1. Boundary administrative map upstream Ciliwung watershead

Sampling and Analysis Data

The data used are:

1. The 2007-2009 rainfall data area Ciliwung Hulu
2. Data Katulampa dam water level (upper Ciliwung watershed outlet)
3. Indonesia Topographic Map 1:25,000 scale, the upstream Ciliwung watershed
4. Soil Map of the upstream Ciliwung
5. Landsat TM upstream Ciliwung watershed of 2001 and 2007

Tools used:

1.Image processing software
2.Arcview software
2.Ring permeabelitas
3. Digital cameras
4. Global Positioning System

Analysis ofCurveNumber (CN)

CN method is an empirical approach to estimate runoff of the relationship between rainfall, land cover, and soil hydrological groups (Cover complex classification). This mapping unit can be approximated based on the analysis of remote sensing data. In the analysis of remote sensing, geographic information systems program used is Arcview.

CN method described in NEH - 4 (SCS 1986)[8)] defined by the following equation:

$$Q = \frac{(P - 0.2\,S)^2}{(P + 0.8\,S)}$$

where:
Q = depthof runoff (mm)
P = rainfall (mm)
S = maximum potential water retention or maximum storage capacity after the run-off occurs, or water that infiltrated into the soil (mm)

where, $S = \frac{25400}{CN} - 254$

CN = Curve Number

CN value can be estimated when the soil classification and land cover note[9]. In determining the value of CN should also pay attention to soil moisture conditions prior or antecedent moisture conditions called (AMC). Water-saturated soils, contributing to generate large surfacewater and ground with dry conditions contributed little to generate runoff.

NRCS has identified three types of multi level humidity conditions (antecedent moisture condition -AMC) as a factor affecting CN on land, namely: dry(condition 1, condition wilting point has not been reached), the mean(condition2), and saturated water (condition 3)

CN tables used in this study are shown in Table 1. Table 1 represents the value at AMC II CN. To Determine the value of CN at AMC I and III, using Table 2. AMC classification in Table 3. AMC calculation in this study is the amount of rainfall the previous 5 days.

To determine the hydrological characteristics of the soil, in a study conducted infiltration tests. Groupings are Hydrological Soil Group Table 3.

Stages in the use of models to predict the amount of curve number runoff, are presented in Figure2. The amount of run-off flowobtainedin this study include: Run-off observations (Qobs) and run-off model (Qmod). Runoff and rainfall observations derived from data that is paired with the flow hydrograph. While the run-off model is obtained by the method of Curve Number. Rainfall data used in year 2007 - 2009, selected 30 rain events.

Furthermore, to determine the correlation Qobs and Qmod we using statistical analysis.

RESULTS AND DISCUSSION

By using of image processing and Arcview, and also the results of field surveys, acquired:

- Land Cover Map of Upstream Ciliwung watershed 2001 (Figure 3).
- Land Cover Map of Upstream Ciliwung watershed 2008 (Figure 4).
- Map of Hydrological Soil Group upstream Ciliwung watershed (Figure 5). Table 4 shows the characteristics of the soil hydrological group, and Table 5 shows the type and area of coverage.

Table1.Value of CN Land Cover by Remote Sensing Image Processing

No	Land Cover	Hydrological Soil Groups			
		A	B	C	D
1	Forest	25	55	70	77
		30	58	72	78
		25	55	70	77
2	Pasture	36	60	73	78
3	Industry, parking and parking area	90	93	94	94
		90	93	94	95
4	Residential	60	74	83	87
5	Open area	72	82	88	90
		77	86	91	94
6	Overgrown farmland	52	68	79	84
7	Agricultural land	64	75	83	87
8	Water	98	98	98	98

Source :Ragan & Jackson [14], Slack &Weleh [15], Bondelid et al

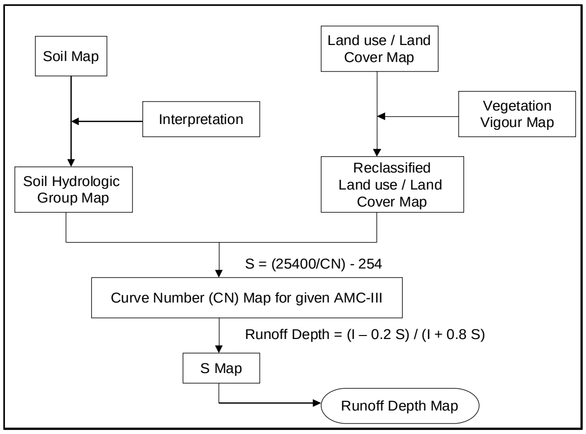


Figure 2. Flow chart Curve Number

Table 2. CN for AMC Group I and III

CN for AMC	CN for AMC	
II	I (dry)	III (wet)
100	100	100
95	87	99
90	78	98
85	70	97
80	63	94
75	57	91
65	45	83
60	40	79
55	35	75
50	31	70
45	27	65
40	23	60
35	19	55
30	15	50
25	12	45
20	9	39
15	7	33
10	4	26
5	2	17
0	0	0

Source : NRCS [8]

Tabel 3. Classification Antecedent Moisture Condition

AMC	The amount of rain the previous 5 days (cm)
Group I (dry)	< 3,6
Group II (average)	3,6 – 3,3
Group III (wet)	> 5,3

Sumber : NRCS [8]

Tabel 4. *Hydrological Soil Group*

Group A :	Potential low drainage, infiltration rate and high drainage rate. Especiallyfor the land of sand and gravel
Group B :	Moderate infiltration rate. For medium-grained soil
Group C :	Slow infiltration rate. For medium tofine grained soil
Group D :	Potential high drainage. Infiltration rate is very slow. For clay with a high flower power and ground with permanently high ground water

Sumber : NRCS [8]

Table5. Area of Hydrological Soil Group in upstream Ciliwung watershed

No	HSG	Area (Ha)
1	A	3424,66
2	B	49,.59
3	C	9433,00
4	D	1872,56
Total		15255,84

Sumber : Field Data Analysis

Land Cover

Related to the type of land cover appearance on the surface of the earth, while the land use associated with human activity on the object [10).]

Land cover affect the hydrology of an area. Activities are changing the type or types of land use can increase or decrease the yield of water (water yield) [11).]

Based on the analysis of Landsat TM images of 2001 and 2008, in the upstream Ciliwung watershed there have been changes of land cover. Changes inland cover are included in Table 6. Land Cover Map 2001found in Figure 3 and the Land Cover Map2008 are in Figure 4.

Based on Table 6, the forest is the largest area of the entire watershed. In 2001 the forest area9114.42 ha (59.86%) and the 2008 forest area 6065.56 ha(39.845). This shows that in the year 2001 to 2008, the forest area was reduced 20%. Settlement in 2001covering an area of 222.00 ha (1.46%), while in 2008 covering an area of 983.96 (6.46%). This represents an increase of settlement area in 2001 – 2008 by 5%.

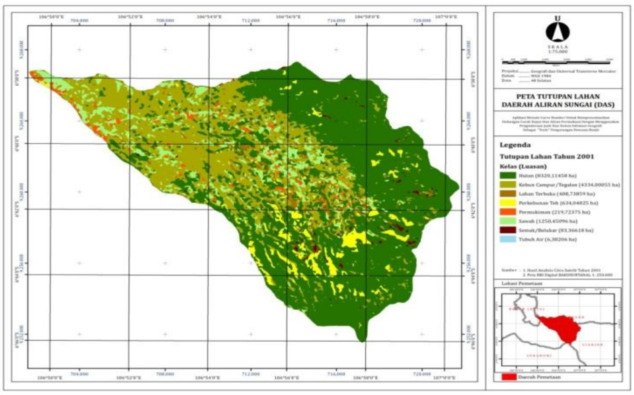


Figure 3. Land CoverMap2001

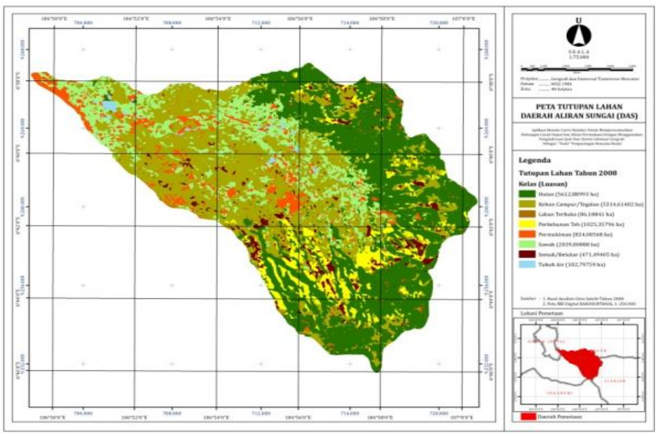


Figure 4. Land CoverMap2008

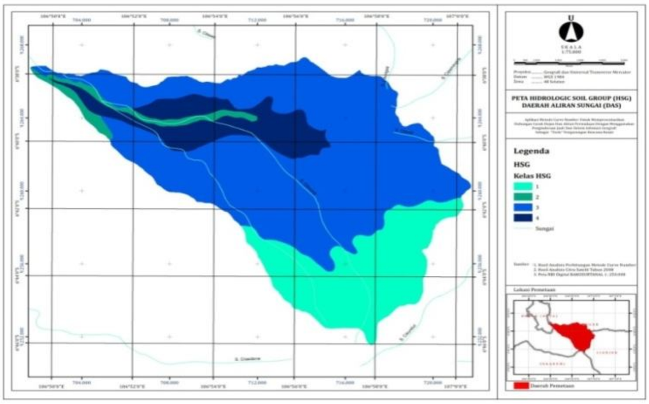


Figure 5.Map of Hydrological Soil Group Upstream Ciliwung Watershed

Antecedent Moisture Conditions (AMC)

Antecedent Moisture Conditions indicate conditions that are affected by the rain. AMC values in the study area are shown in Table 7.

Tabel 6. Land Cover Change in the upstream Ciliwung watershed

Land Cover	2001		2008	
	Area (Ha)	Proc (%)	Area (Ha)	Proc (%)
Forest	9114,42	59,86	6065,56	39,84
Mix crop	4353,43	28,59	5369,87	35,27
Open area	408,75	2,68	87,00	0,57
Tea Plantation	634,05	4,16	1056,33	6,94
Settlement	222,00	1,46	983,96	6,46
Paddy	1254,84	8,24	1928,94	12,67
Bush	84,78	0,56	483,63	3,18
Water body	6,38	0,04	103,30	0,68
Total	15225,84	100,00	15225,84	100,00

Source: Analysis ofLandsat TM 2001 and 2008

Based on Table 7, AMC III dominates the maximum potential water retention or maximum storage capacity after the run-off occurs, or water that infiltrated into the ground. This suggests that high soil moisture levels, before run-off occurs. This certainly affects the resulting runoff.

Based on Table7 andis associated with Table 9, shows that at AMC III, the average run-off observations generated more than 50% of the rain that happened.

Curve Number

CN values influenced land cover, hydrological circumstances, and AMC. By overlay ing maps hidrological soil group and land cover maps of 2008, acquired the mapping unit as found in Table8.

CN value at each different rain events. This difference was highly influenced by the AMC. CN value in mapping the same unit but different AMC conditions, of course, the value of CN was alsodifferent.

Forest and hydrological Soil Group of type C, dominates in the upstream Ciliwung watershed.This condition, which affects the value of CN generated.

Run Off

After we obtained the CN, the value ofrun off (Q) can be determined. Run off which obtained by observation we noted as Q observation (Qobs) and Runoff which obtained by calculation model we noted as Qmodel (Qmod). Values of runoff are shown in Table9. From the 30 rain day events, 10 rain day events indicate that the rain was produced, more than 50% to be runoff, and the rest infiltrated. This describes thecondition of the land in the watershed is already very saturated, so the rain was going on, a lot of runoff.

While 20 rain day events showed less than 50% of rainfall becomes runoff and the rest infiltrated. It is highly we expected, because it does not contribute to the incidence of flooding in the center of the basin, and the most of rain water be infiltrated water, as input for ground water reserves in the region and will be very useful in times of drought.

Table 7. Antecedent Moisture Condition (AMC)
in upstream Ciliwung watershed

No	Date	AMC previous 5 day	Groups AMC
1	23/01/2007	2,29	I
2	28/01/2007	94,00	III
3	29/01/2007	121,71	III
4	15/02/2007	46,00	III
5	16/02/2007	88,71	III
6	26/02/2007	24,43	II
7	04/11/2007	73,29	III
8	12/11/2007	84,14	III
9	30/11/2007	8,29	I
10	13/12/2007	6,07	I
11	01/01/2008	72,14	III
12	02/01/2008	101,57	III
13	20/01/2008	21,30	I
14	23/01/2008	22,30	I
15	27/01/2008	26,57	II
16	28/01/2008	36,54	II
17	29/01/2008	41,54	III
18	30/01/2008	60,06	III
19	13/03/2008	102,14	III
20	18/03/2008	122,86	III
21	14/01/2009	130,74	III
22	16/01/2009	202,46	III
23	02/02/2009	79,83	III
24	03/02/2009	125,00	III
25	04/02/2009	158,50	III
26	07/03/2009	23,50	II
27	09/03/2009	50,67	II
28	10/03/2009	80,50	III
29	12/03/2009	118,67	III
30	26/03/2009	49,17	III

Source: Field Data Analysis

Table8. Land cover and Hydrological Soil Group in upstream Ciliwung watershed

No	Land Cover	HSG	Area (Ha)
1	Forest	A	2601.64
		C	3471.24
		D	33.22
2	Mix crop	A	203.34
		B	135.10
		C	3953.82
		D	1172.64
3	Open area	A	16.59
		C	23.34
		D	19.53
4	Tea plantation	A	434.48
		C	416.95
5	Settlement	A	15.87
		B	122.83
		C	266.66
		D	137.15
6	Paddy	B	214.82
		C	1056.24
		D	531.28
7	Bush	A	123.00
		C	174.96
		D	20.24
8	Water	B	16.82
		C	47.66
		D	16.39
	Total		15225.84

Source: Analysis of Landst 2008 and Hydrological Soil Group*)Soil type characteristic shown in Table 4.

Table9. Run Off Observation and Model CN in upstream Ciliwung watershed

No	Date	Rain (mm)	*Run Off* Obs (mm)	*Run Off* Model (mm)
1	23/01/2007	36	10	8
2	28/01/2007	41	8	10
3	29/01/2007	86	43	30
4	15/02/2007	41	15	10
5	16/02/2007	43	15	10
6	26/02/2007	15	10	5
7	04/11/2007	51	20	13
8	12/11/2007	23	15	5
9	30/11/2007	20	8	5
10	13/12/2007	25	10	5
11	01/01/2008	48	28	13
12	02/01/2008	43	25	10
13	20/01/2008	13	5	5
14	23/01/2008	8	3	8
15	27/01/2008	15	10	5
16	28/01/2008	13	8	5
17	29/01/2008	23	10	5
18	30/01/2008	20	13	5
19	13/03/2008	43	30	10
20	18/03/2008	36	23	8
21	14/01/2009	58	41	30
22	16/01/2009	33	18	10
23	02/02/2009	53	38	38
24	03/02/2009	46	36	38
25	04/02/2009	43	23	10
26	07/03/2009	30	20	10
27	09/03/2009	33	25	15
28	10/03/2009	41	28	20
29	12/03/2009	36	13	10
30	26/03/2009	23	20	13

Sumber: Hasil Pengolahan Data

Statistical Analysis

Once the value (Qmod) and (Qobs) produced, performed the comparison. With a simple statistical analysis, the value of correlation(r) and the coefficient of determination(R^2). Statistical description (Qmod) and (Qobs) contained in Table10. Based on Table10,the year 2007 was very good correlation is r=0.95, a slight decreasein 2008, r=0.75, and in 2009 slightly increased to r=0.78. When viewed as a whole with 30 data replications correlation values ranging from r=0.78.

Of all the above correlation values indicate tha tthe models with the CN method reasonably good level of correlation to the results of observation. Or in other words the results predictedby the curve number method is good enough to estimate the amount of surface runoff caused by rainfall in the upstream Ciliwung watershed. In addition to the correlation analysis, the relationship (Qmod) and(Qobs) is depicted graphically in Figure 6.

Based on Figure 6, indicating that the overall value of the fluctuation model is able tofollow the rhythm fluctuation observations. Designated in 2007, the level of rhythm fluctuations between the models with the observations can be well portrayed.

Based on the comparison results graphically indicate that at relatively high flow model is able to give a fairly good prediction results. However,at low flows less good outcome prediction models. This condition corresponding in the upstream Ciliwung watershed in 2007 period have a lot of rain and encountered high flow rates. This means that on a fairly saturated soil conditions/high soil moisture, Curve Number method is able to present the prediction results were pretty good.

Research Curve Number in Indonesia has not been much. CN research ever conducted in the subwatershed Kaduang, Wonogir is how over estimate the Qmod with Qobs. Over-estimation is due to the large area of watershed. So far, the CN method applied to small watersheds[12]. DAS Kaduang, Wonogiri has a 40664 ha.

Value (Qmod) with (Qobs) Upper Ciliwung not over estimate, because Ciliwung Hulu has a relatively small (15225.84 ha). Research CN (Curve Numbers) in upper sub-watershed Aopa, providing an alternative model of land use can reduce the CN[13].

When associated with flooding, the smaller CN, then the value of Q will shrink. With at least the value of Q indicates that little or run off can be said, that happens a lot of rain infiltrated.

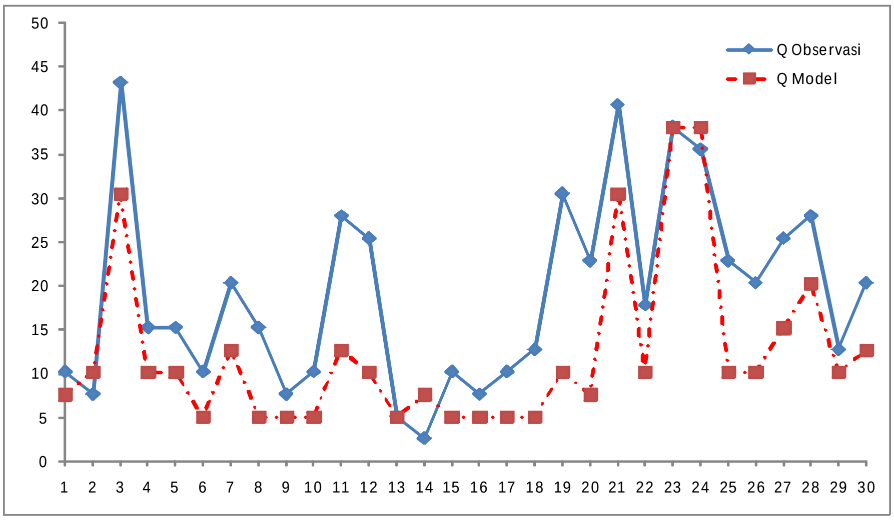
CN values in the upper Ciliwung could be minimized by management of land cover. But in the middle and lower reaches also need to do the same, so the flooding can be avoided.

Flooding often occurs in the slope ofa gentle slope or terrain. Flooding occurs due to natural factors and human factors. Natural factors such as rainfall, sea level rise and storms. Human intervention causing spatial changes and impact on natural change, and environmental degradation such as loss of ground cover plants in the watershed, siltation of rivers due to sedimentation, and the narrowing of the river flow.

Table10. Correlation *Runoff* Model vs *Runoff* Observation in upstream Ciliwung watershed

Year	Numbers Data (N)	(r) Coef. Correlationi	R^2 (Coef. Determination)
2007	10	0.95	91 %
2008	10	0.71	51 %
2009	10	0.75	57 %
2007 - 2009	30	0.78	61 %

Source: Results data processing



Source:Results data processing

Figure6. Correlation analysis, the relationship (Qmod) and (Qobs) for 30 rains

CONCLUSION AND RECOMENDATIONS

Conclusions

1) The results of correlation analysis (Qmod) with(Qobs) showed good results. For the year 2007 the value of r: 0.95; 2008, the value of r: 0.71; year 2009 the value of r: 0.75 and for the combined years 2007 to 2009 obtained values of r: 0.78. Correlation value obtained issufficient to provide an indication that the Curve Number Method was quite well to calculate runoff
2) Based on the graphical analysis that describes the relationship (association) between (Qmod) with (Qobs) shows the fluctuationsof the same rhythm. This means that the model is good enough to calculate run-off in the Upper Ciliwung watershed and the model is good enough to represent the relationship between rainfall and runoff.
3) The results of correlation analysis and graphics taken together indicate that at high flow model is able todeliver good results count, where as at low flows a little less good.
4) Changes in land cover and AMC will contribute to the value of CN, and the influence on the surface run-off.

Recommendations

Curve Number method should be developed considering the number of watersheds in Indonesia and can be used as an evaluation method of water resources management.

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