TIME OF CONCENTRATION FOR DRAINAGE DESIGN CHARACTERISTICS

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ABSTRACT

Time of concentration became the important parameters for the drainage design. Time of concentration is time it takes for the particles of water hydraulic flow from the point furthest in catch area towards end of the stream in design. The time it takes the water to flow related to velocity rate to achieve peak discharge conditions, so that several factors will affect this time. Urban drainage concept uses water balance concept, rainfall equals to runoff and infiltration. The concept of the drainage, can give a sense that time of concentration is affected by the amount of rain, the conditions of land use and land cover, soil type, the treatment of the channel, and the slope of the land. The time of concentration can be classified on the planning of drainage for the channel, overland flow, and to pipe. For overland flow, the water flow is affected by infiltration. Time for channel, the flow channel roughness was influenced by and for pipe flow is affected by the loss of water due to the turn and viscosity of water, as well as the pressure. The drainage design characteristics is always require time of concentration as the parameters in discharge determining, so the equations used to time of concentration determine is different. In this study found that some designs do not use the exact concentration time formula, according to drainage design characteristics. This research resulted in the correct timing of concentration according to the design characteristics of drainage in accordance with its designation.

Keywords: Channel, Drainage design, Overland flow, Pipe, Time of Concentration

1. INTRODUCTION

The process of flowing rain falling into the oil undergoes various treatments and it moves with time. This case, there is a maximum time occurring in the water flow with soil surface behavior conditions. Time of concentration is the time it takes the water to flow from the start of the rain until the maximum water flow reaches its output. The output is can be a flow of water in the channel, land, and pipes.

Drainage design system takes Tc becomes an important parameter in determining runoff discharge as the basis of design calculation. The process of flowing rain falling into the soil undergoes various treatments and it moves with time. In this case there is a maximum time occurring in the water flow with soil surface behavior conditions.

The equation developed by Kirpich, the time of concentration is a function of the length of the channel and the slope of the land in the channel. The time of concentration equation of Kirpich method is to flow in the channel. Then, according to Richard, 1984, the time of concentration for drainage can be done on channels, pipes and on a plot. Time of concentration on land with land condition in Indonesia will be studied in this research. The error that occurs is to place the Tc calculation not according to its designation. For example Tc channel equations but used for drainage in the field or in roof gutters of buildings, and the design is not appropriate, which can be over design or under design.

The purpose of this paper is to know the effect of parameters that affect the various Tc formula that already exist and the preceding, on land, channels and pipes. Another goal is to obtain an analysis for the difference in time of concentrations on land of different equations.

2. MATERIAL AND METHOD

2.1 *Definition*

The time of concentration in this study have definition as follows (McCuen, 2009): (i) the time from the end of the rainfall excess to the point of the total storm hydrograph; (ii) the time of the center of mass of rainfall excess to the center of mass of direct runoff; (iii) the time from the maximum rainfall intensity to the time of the peak discharge; (iv) the time from the center of mass of rainfall excess to the time of the peak of direct runoff; (v) the time from the center of the mass of rainfall excess to the time of the peak of total runoff; and (vi) the time from the start of the total runoff to the time of the peak discharge of the total runoff.

The drainage planning includes planning in the field, in this case can be a recharge well, biopory and the other, can be channel, in this case is drainage network, and there is also in the form of pipe, for example gutter drainage, channel and pipe.

Planning of drainage, dimension and time is an important parameter (Mccuen, 1984) the determination of channel magnitude does not directly affect the time of concentration. Time of concentration affects the flow of water that flows and will soon be discharge, in the form of water runoff can flow on the land, in the pipeline and in the pipe on the land water that comes from the rainfall. In the land treatment, the amount of water that flows will depend on land cover surface of land, and runoff will reduce by infiltration.

Effective rainfall that flows from the surface of the land to a channel is called overland flow (Subramaya, 2002). While the flow moves above the surface of the land as an overland flow which further leads to several small channels and joins in a larger channel with an open channel hydraulic flow then this runoff is called surface runoff. Both are differentiated with time. The time it takes is dependent on the parameters present in the field and the channel during the flowing water process.

The water flowing in the channel, the difference in channel length and channel slope, as well as the channel branching, as well as the channel dimension, will affect the abundant water discharge in the channel. Similarly, the drainage of the pipe, the flow of water in the pipe that flow depends on the viscosity of the water, the material of the pipe, the dimensions of the pipe and the length of the pipe and its slope.

The difference in processes that occur in the flow of land and in the channel is located on q and its flow media. In the flow in the field, q is the unity flow discharge width, while the channel flow is Q with wet cross section. The flow depth that occurs in the flow in the fields is the depth due to water absorption in the soil, while the depth of water in the channel is the water depth from the bottom of the channel. Based on that, the parameters that affect each flow are different, this runoff process, time of concentration will occur in each case, different drainage characteristic, with different solutions.

Table 1 The parameters of time of concentration that influence to drainage characteristic

Main of flow	**Parameter of Time of Concentration**			
	Detained flow	Size of land	Slope	Water input
Overland flow	n, C,CN, I	L, A	S	i
Channel flow	N, ϕ	Lc, L_{10-85}	Sc, S_{10-85}	R, i, Q
Pipe flow	n	L	S	R, q

Source : Richard (1984, p.890)

where *n* is Manning's coefficient, *C* is runoff coefficient, *CN* is *SCS* Curve Number, *I* is precent loss, land cover type, *L* is length channel or land, *i* is Rainfall, *Q* is discharge, *q* is discharge per unit and *R* is the hydraulic radius.

Drainage of water since the start of rain that descends, from running water, until the water begins to seep and flow, this process uses the concept of water balance. Similarly, for drainage of channel and pipes, the concept of water balance takes into account the water loss factor. On land, the water reduction factors from infiltration. In the channel, the watr loss factor is due to the roughness of the channel. In the pipeline, the loss factor is due to pipe bends, and the length of the pipe.

2.2 Time of Concentration in Channel

The channel dimension, channel length, and channel slope are parameters in determining drainage channel planning. Since the water starts flowing at a point to the furthest point is the time of concentration (Bedient, 2008). In this case, the concentration time on the channel depends on the intensity, the rainwater discharge, the slope of the channel, the wet channel cross section and the channel length.

Here are some time concentration equations in the channel:

1) Time of concentration formula (Tc), Kirpich Method

$$Tc = 0{,}0195\, x \left(\frac{L}{\sqrt{S}}\right)^{0{,}77} \quad (1)$$

Where L is channel length (m), S is channel slope $m.m^{-1}$, Tc is time of concentration

2) Time of concentration (Tc) (Williams, et al., 1985)

The channel flow time can be computed using the equation:

$$Tc = \frac{0{,}62.(L)(n)^{0{,}75}}{(A)^{0{,}125}(\sigma)^{0{,}375}} \quad (2)$$

Where, Tc is time of concentration in (hour), L is channel length from the most distant point to the watershed outlet in km, n is manning's, σ is the average channel slope in $m.m^{-1}$

2.3 Time of Concentration in Overland Flow

Time of concentration on the land uses a kinematic wave principle that combines the law of water balance with the law of momentum (Wong, 2009). The concentration time in the field is a primary basin parameter that represents the travel time from the hydraulically furthest point in a watershed to the outlet (Chibber, 2008). The parameters that influence the concentration time in the field are length of the watershed (L), Surface roughness (n), Slope of watershed, and rainfall intensity (i).

The only loss factor in overland flow is the water absorption in the soil or called infiltration (Mccuen, 1984). Infiltration is a reduction factor for runoff in the field.

The Overland flow time can be computed using the equation:

1) Time of concentration formula

Overland Flow formula by Morgali dan Linsley (2008). Time of concentration from regression model :

$$Tc = 0{,}553 \times n^{0{,}32} \times \emptyset^{0{,}277} \times S^{0{,}172} \times i^{-0{,}646} \times L^{0{,}5} \quad (3)$$

Where , tc is time of concentration, L is length of land, K is constant, n is land roughness, I is rain intensity Φ is water content, a, b,y,z = exponent

2) Time of concentration formula by Mc. Dermott

$$Tc = 0{,}76 \times A^{0{,}38} \quad (4)$$

Where, Tc is time of concentration (minute), A = Cathcment Area (km^2), (Limantara, 2010)

3) Time of Concetration for overland flow by Richard

$$Tc = 0{,}04690 \times L_f^{0{,}4550} \times i_2^{-0{,}7231} \times \emptyset^{0{,}5517} \times S_{fm}^{-0{,}2260} \quad (5)$$

Where , Lf is length of waterflow, $i2$ is rain intensity, Sfm is slope, $\emptyset$ is the holding variable

2.4 Time of Concentration in Pipe

The climates of the dry lands are conducive to piping. During the hot, dry summers the soils dry out, and the precipitation, which characteristically falls intermittently during or at the close of summer, is generally of the thunderstorm type. This appears to be the commonest mode of pipe origin in consolidated materials, as contrasted to unconsolidated materials. It operates not only at depth to produce pipes but also appears to be most effective in bringing about shallow and surficial badlands erosion, resulting in riling, gullying, and sheet-erosion (Parker, 1987).

3. RESULT

3.1 Time of concentration Analysis

Figure 1. Overland Flood Path

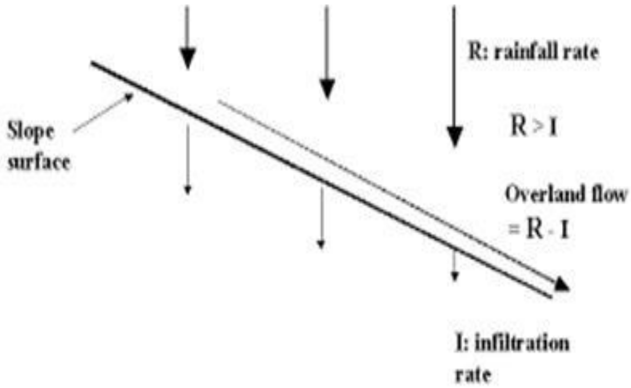

Figure 2 Water Balance Processes for Overland Flow

The surface overland flow affected by the land surface conditions. As shown in *Figure 1*, the surface of the land is covered by grass. This grass will affect the flow velocity. In addition, this grass will affect the ability of the soil to permeate the water. In overland flow, infiltration is a factor in reducing the runoff from rainwater input. Infiltration rate in overland drainage system is the one factor as reduce rainfall rate, show in *Figure 2*. Rapid determination of the flow rate is indicated by time. The time required for the flow of water from a point to a maximum of the furthest point is called the concentration time.

Time of Concentration in Channel analysis

Figure 3 Drainage Channel

Figure 4 Drainage Channel in Household

The drainage channel design is composed of the channel discharge plan components and flow velocity, as shown as in *figure 3*. Length of channel, slope, and roughness of channel are influence the time of concentration, time to peak. Time of concentration will be higher as length of drainage channel longer. The flow velocity with the concept of water balance is interpreted in rain intensity with mm / hr unit and the drain coefficient as the factor of the abundance of water overflow with the land use parameter. For a uniform rain, the duration equals the equilibrium time, whose flow rate is equal to the rate of additional rain (Fang, 2007).

Time of concentration in the drainage channel in household is take continuity concept. The primary channel is large and smaller to the next channel. Flow design in the drainage channel in household is augmented from dirty or brown water, so time of concentration would be different, *figure 4*.

3.2 Time of Concentration on Land

A residential settlement area, the area of the catchment is as big as 0.19 km^2. the extent of the catchment area is divided into 3 zones of land flow in accordance with contours.

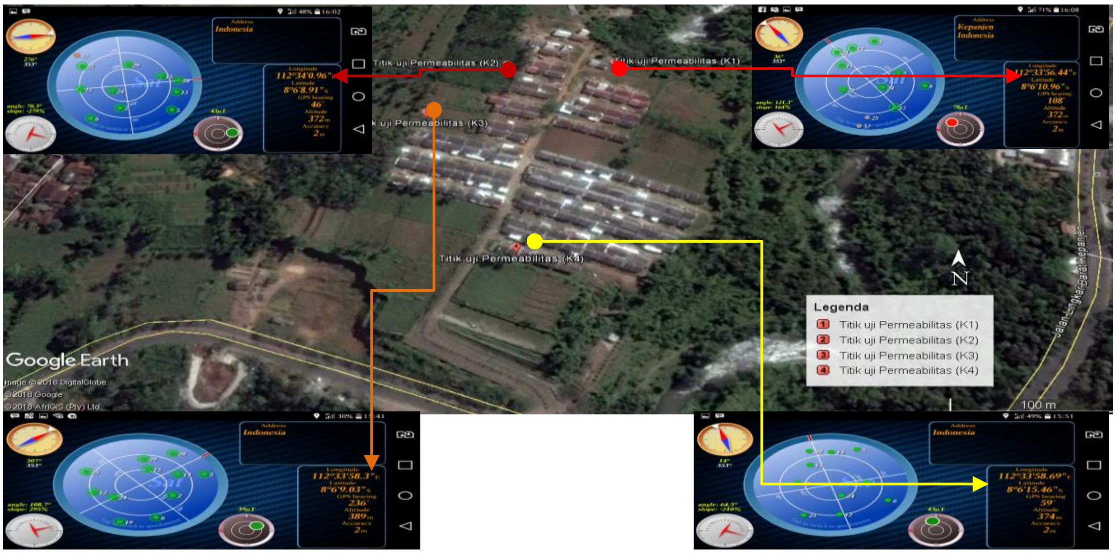

Figure 5 The Point Test Plot Map for Permeability (K) (*Google EarthPro2018 & Ulysse Gizmos)*

Time of concentration in overland flow needs to measure permeability (K). This research use testing methods directly in the field by measuring the coefficient of permeability of the soil at a depth of 50 cm (30 cm 20 cm of soil and Minerals:: pipe penetration) use the single Ring (an iron pipe. The coefficient of permeability of the Soil conducted on 4-point planned, *figure 5*.

Table 2 The Area Study

Area (A)			**Unit**
Zone I	ZoneII	Zone III	
69615	71907	47700	m^2
6.96	7.19	4.77	Ha
0.07	0.07	0.05	km^2

The catchment area observation is divided into 3 zones. This division is based on topography as shown as *table 2*. The soil condition of this area is 40% clay, and the soil is black. The black color indicates the presence of organic material contained therein. Based on this, the predicted soil will be able to absorb water about 30 to 40%, but potentially erosion.

The following *table 3* is the result of the measurement of the permeability level of the soil of this area from the 3 zone of measurement results. The average value of K, the permeability of the soil, is 0.1444 cm / h. This means that the soil with granular and its properties can absorb water averaging 0.1444 cm in one hour and it is in middle categories.

Table 3 Coefficient of Permeability

No	Test Point	Coordinate	K (cm/minute)	Keterangan
1	Point 1	8° 6'8.91"LS - 112°34'0.96"BT	0,006	Middle
2	Point 2	8° 6'9.03"LS - 12°33'58.30"BT	0,555	Very Fast
3	Point 3	8° 6'10.96"LS - 12°33'56.44"BT	0,0083	Middle
4	Point 4	8° 6'15.46"LS - 12°33'58.69"BT	0,0081	Middle
		Average K	**0,144**	**Middle**

From the calculation of monthly maximum monthly rainfall data in Table 4 behind, there are calculated of the maximum annual rainfall data of the average method of calculation as daily maximum rainfall in average.

Table 4 Daily Maximum Rainfall

Years	Kepanjen Station of Rain gauge	Karangkates Station of Rain gauge	Ngajum Station of Rain gauge	Daily Maximum Rainfall in average
2012	67	126	75	**89,33**
2013	176	115	118	**136,33**
2014	84	75	88	**82,33**
2015	95	126	118	**113,00**
2016	54	117	101	**90,67**

Table 5 Rainfall Design with Return Periode

Tr	**Log R_x Average**	**K**	**S**	**Log Rx**	**Rainfall Design (antilog RX)**
5	2,010	0,823	0,081	2,077	119,389
10	2,010	1,310	0,081	2,116	130,761
20	2,010	1,761	0,081	2,153	142,290

1) The concentration time is calculated by using 3 equations of the formula based on each parameter. It is means that the value of Time Concentration (tc) Land (OverLand flow) was using Dr. Dermot Formula

Tc = 0,76 x $A^{0,38}$ (if A >50 km^2)

Tc = **4,578 hour**

When Tc calculating for 3 zone, there are:

Table 6 the calculating Tc with Dermont Formula

Catchment Area (A)			**Unit**	**Area**
Zona I	Zona II	Zona III		
69615	71907	47700	m^2	
0.07	0.07	0.05	km^2	
0.276084	**0.279503**	**0.239139**	Hour	**TC**
16.57	**16.77**	**14.35**	Minute	

The Dermot formula have one parameter, just area, and it is mean that wider an area so that the concentration time will be longer. And how if *Tc* with the other formula :

Table 7 Tc with other formula

Tc Formula	*n*	*Ø*	*S*	*i*	*L*	*Tc (hour)*
$Tc = 0,553 \times n^{0,32} \times Ø^{0,277} \times S^{0,172} \times i^{-0,646} \times L^{0,5}$ **Morgaly's formula**	0.02	0.2	0.002	87.68	0.435	9.579079
$Tc = 0,04690 \times L_f^{0,4550} \times i_2^{-0,7231} \times Ø^{0,5517} \times S_{fm}^{-0,2260}$ **Richard's formula**	-	0.2	0.002	87.68	0.435	46.20539

Based on Tc calculations using different formulas, *Table 7*, can produce different Tc. this is because the influential variable used to calculate Tc is different. Morgaly's formula uses n variables whereas Richard does not, so does Dermont which only takes into account the extent. Different Tc results will certainly greatly affect drainage planning, since Tc is an important parameter in determining the value of the plan discharge.

4. CONCLUSIONS

The formula time of concentration is already very much. The formulas are based on the results of the study. The results of the research also have taken into account the rules of water balance. The formula of calculating the time of concentration is supposed to pay attention to the characteristics of the local condition of the location of the drainage plan. This will greatly affect the discharge plans that result in over design and under design.

The involvement of variables is crucial in determining the time of concentration. As it has been produced above, Tc on Richard Fomula will produce a larger Tc value than the others. this is due to the roughness of the land is not taken into account so that the runoff of water on the surface is considered a little and the time required long.

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REFERENCES

Bedient, W. (2008). *Hydrology and Floodpain Analysis* (Vol. 3). Canada: Prentice Hall Pearson Education Inteernational.

Chibber, M. (2008). Overland Flow Time of Concentration. *133-140*.

Limantara, L. M. (2010). *Hidrologi Praktis* (Vol. 1). Bandung: CV. Lubuk Agung.

Mccuen, R. (1984). Estimating Urban Time of Concentration. *110*(887-904).

Parker, G. G. (1987). Piping, A Geomorphic Agent in Landform Development of The Drylands. (103 - 113).

Subramaya, K. (2002). Engineering Hydrology.

Williams, J. R., Nicks, A. D., & Arnold, J. G. (1985). Simulator for Water Resources Rural Basins. *111*(970 - 988).

Wong, T. S. (2009). Evolution of Kinematic Wave Time of Concentration Formulas for Overland Flow. 739-744.