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The Effect of Infiltration Rate on Flood Hazards in Gorontalo City

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Abstract:- Infiltration rate is a measurement of the physical properties of soil. The classification of infiltration rates according to ILRI (1974) based on the results of changes by Rickard and Cossens (1965) is an important characteristic to indicate land drainage conditions. The aim of this research is to determine the classification of infiltration and its extent. The research method uses a grid system by dividing the city area into 250 m x 250 m consisting of 108 grids with 46 grids representing the lowlands. The infiltration rate in Gorontalo City as a whole is classified as very slow 2189.44Ha or 32.81%, the meaning of this percentage shows that an infiltration rate of less than 2.5 cm/hour occurs in Gorontalo City. For the infiltration rate with a slow classification, the speed is 2.5–15 cm/hour, covering an area of 2615.38 Ha or 39.17%.

Keywords:- *Classification, Infiltration, Extent and Flooding.*

I. INTRODUCTION

Soil property parameters related to hydrology such as infiltration rate are one measure of the physical properties of soil. Measuring the infiltration rate is very necessary in planning and designing a project related to regional development, for example a river basin (DAS).

In situ infiltration rate testing is intended to determine the speed and magnitude of water entering or seeping vertically into the soil body. By observing or testing this characteristic, it is hoped that it will be able to provide an idea of the soil's ability to absorb water and the speed of water entering the soil, if a flood occurs with the assumption that the water is slow to flow to a landfill or sea. This assumption was taken in relation to the geographic conditions of surface flow in the research area. The geographical condition of Gorontalo City is with a low slope and a narrowing or "bottle neck" before surface flow leads to the sea.

II. LITERATURE REVIEW

Inundation (cm) is the volume of rainfall exceeding the rate of water infiltration into the soil (Asdak, 2007). Meanwhile, the infiltration rate (cm/hour) is the entry of a certain amount of water into the soil within a certain time through the soil surface vertically (Public Works Department, 1987).

Meijrink (1982) stated that the infiltration process is a complex hydrological process, which is influenced by the stability of the soil structure. This soil structure is influenced by the presence of holes in the soil due to rotting plant roots or digging by animals, soil surface conditions, spatial conditions in the soil, ground water levels, and the presence of obstacles in the soil horizon. Variations in the rate of water infiltration into the soil range from 10-30 cm/hour in soil that is sandy or gravelly or contains organic matter. Meanwhile, for clay soil, the infiltration rate is very small, namely 0.1 cm/hour.

Meijrink (1982) divided methods for measuring infiltration rates in the field into 5 (five) ways, namely: a). one ring method (single ring infiltrometer), b) two ring method (double ring infiltrometer), c) hydrograph method, d) spraying method (sprinkler) and e) plot test (pond test). The classification of infiltration rates according to ILRI (1974) based on the results of changes by Rickard and Cossens (1965) is an important characteristic to indicate land drainage conditions as stated in Table 1.

Table 1 Classification of Infiltration Rates by Rickard and Cossens (1965)

Class	Infiltration Rate	Infiltration Speed (cm/hour)
I	Very fast	> 53
II	Fast	28 – 53
III	Currently	15 – 28
IV	Slow	2.5 – 15
V	Very slow	< 2.5

Source: ILRI (1974)

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To produce an overview of the infiltration capacity due to rain in a flow area with all its characteristics, Horton put forward the following equation:

f = fc + (fo + fc) c –kt .....(1)

where: f = infiltration capacity at time t (mm/hour),

fc= infiltration capacity when t is large (mm/hour)
fo= infiltration capacity at time t = 0 (mm/hour)
t = time when the rain starts (minutes)
k= constant for soil type and surface (minute – 1)

III. RESEARCH METHODS

Research on infiltration rates in Gorontalo City, Gorontalo Province, northern Sulawesi, was carried out for 10 (ten) months from December 2009 to October 2010. The research method used a grid system by dividing the city area into 250 m x 250 m consisting of 108 grids with The 46 grids represent the lowlands.The land unit approach is used to conduct flood hydrogeomorphology studies. A hydrogeomorphological land unit is a mapping unit that combines landform characteristics, soil type, slope slope, land use, rainfall, infiltration and drainage conditions.

Sampling was systematic and according to the infiltration rate classification based on the type of land use as follows, namely: 13 samples for road use (3.17 km^2), 10 samples for shopping areas (2.49 km^2), 11.38 km^2 for residential areas (11.38 km^2). as many as 44 samples and mixed gardens (49.68 km^2) as many as 194 samples. Infiltration rate data samples are taken based on land units according to landform conditions, with sample point observations no sooner than 6 hours and no later than 24 hours (at some observation points there are up to 3 days). Measurement of infiltration rate in the field uses the single infiltrometer method. The single infiltrometer method is easy to implement but difficult to obtain the constant value "k". So far, infiltration rate measurements have always used the double ring method, with the reason that the constant value "k" is faster and easier to obtain. As computerization develops, calculations of logarithmic values and constants can easily be solved.

Sampling of infiltration rates in the field was carried out at flood locations for flood heights of 0–25 cm, 25–50 cm, 50–75 cm, 75–100 cm, and greater than 100 cm. Other variations of measurements were carried out in residential areas, mixed field/moor areas, green open space areas, shops and offices. Apart from that, 10 points of infiltration rate were measured outside the research area as a comparison.

IV. RESULTS AND DISCUSSION

Measurement of infiltration rate in the field uses a single ring infiltrometer method. The speed rate displayed is the infiltration rate after the observation process for 6 hours, which can be seen in Table 2.

Table 2 Equation of Infiltration Rate After Six Hours of Observation

No	Code Grid	Infiltration Equation	R2	GENES (cm)	PL	INF (cm/hour)
1.	G1	y = 4E-05x2 – 0.112x + 85.32	0.974	0-25	Kc	50.18
2.	E5	y = 6E-05x2 – 0.096x + 34.19	0.995	0-25	Sw	24.56
3.	H5	y = 0E-04x2 – 0.18x + 43.55	0.997	50-75	Pt	-21.25
4.	G6	y = 5E-05x2 – 0.11x + 57.68	0.998	75-100	Pm	4.27
5.	I7	y = 1E-06x2 – 0.006x + 5.961	0.998	75-100	Jl	3.93

Source: Field Research Results (Appendix I, pages 1, 30, 33, 38, 44)

Informationy = infiltration rate equation. x = time required.
R2 = Coefficient of determination, GEN = Flood Height, PL = Land Use
INF = Infiltration Rate after 6 hours

➢ *Results*

Infiltration rate analysis of 294 sample points represented by five observation pointsas in Table 2 using a second order polynomial equation, shows that the determination factor (R2) has an average value of 0.974, meaning that the infiltration rate equation (y) as the dependent variable is greatly influenced by rain thickness (mm) and infiltration time (hours). Measurement of the infiltration rate at several sample points shows that there is a determination factor (R2) with a value close to 1 (one) such as for the Tomulobutao sample point (R2 = 0.997), the South Tomulobutao sample point (R2 = 0.980), the Liluwo sample (R2 = 0.995), the Tenilo (R2 = 0.919), Paguyaman sample (R2 = 0.999), Wumialo sample (R2 = 0.999). Based on the determination factor (R2) which is close to one, it is concluded that the use of a single ring infiltrometer can be used. This means that the second order polynomial equation used to estimate the rate of water infiltration into the soil can be used.

The results showed that after 6 hours (360nminutes) based on the polynomial formula the infiltration speed on grid G1 was 50.18 cm/hour. This means that the infiltration speed according to Rickard and Cossens (1965), the speed classification is fast because it is in the range of 28–53 cm/hour. Measuring the infiltration rate for the same location

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and point, after 24 hours the speed ranges between 0–2 cm/hour and is classified as very slow. This means that at these points after 24 hours they start to experience saturation. One illustration of the measurement results is as shown in Figure 1.

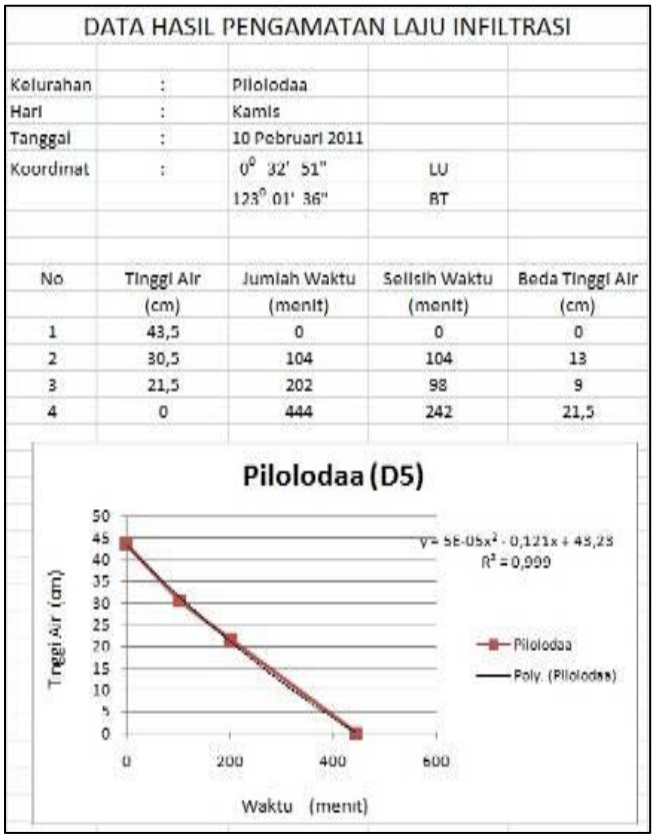

Fig 1 Data on Infiltration Rate Measurement for Pilolodaa Village (Grid D5)
Source: Field Measurement Results

➢ *Discussion*

The spatial distribution of infiltration based on the rate/speed of water infiltration into the soil can be seen in Figure 3 and Table 3.

Table 3 Classification of Gorontalo City Infiltration Rate

No	Infiltration rate (cm/hour)	Class	Area (Ha)	Percentage (%)
1	Very fast	I1	75.52	1.13
2	Fast	I2	1,333.43	19.98
3	Currently	I3	461.13	6.91
4	Slow	I4	2,614.50	39.17
5	Very slow	I5	2,189.44	32.81

Source: Analysis of Infiltration Rate Map for Gorontalo City

The infiltration rate in Gorontalo City as a whole is classified as very slow 2189.44Ha or 32.81%, the meaning of this percentage shows that an infiltration rate of less than 2.5 cm/hour occurs in Gorontalo City. For the infiltration rate with a slow classification, the speed is 2.5–15 cm/hour, covering an area of 2615.38 Ha or 39.17%. Looking at the broad classification of infiltration rates as very slow and slow, it can be said that the lowlands in Gorontalo City have infiltration rates classified as slow (2.5–15 cm/hour). The soil conditions in Gorontalo City based on Table 3 are basically almost saturated, because the infiltration rate according to map analysis is categorized as slow (class I4) and very slow (class I5) with the percentage of both being 71.98%.

The spatial distribution of infiltration rates based on sub-district areas and their classification is as shown in Table 4.

Table 4 Classification of Infiltration Rates Per District Area in Gorontalo City

SUBDISTRICT	I1	I2	I3	I4	I5	Grand Total
Dungingi	0.73	156.33	115.43	128.38	34.32	435.18
West City		104.90	64.25	742.39	734.02	1,645.56
South City	16.34	85.95	85.98	738.90	355.88	1,283.05
Central City		403.55	47.00	19.32	15.37	485.25
East City	58.45	112.42	100.92	623.28	623.04	1,518.11
North City		470.29	47.54	360.82	427.27	1,305.92
Grand Total	75.52	1,333.44	461.14	2,613.08	2,189.88	6,673.06

Source: Analysis of Infiltration Rate Map for Gorontalo City

Based on Table 4 and the results of the map analysis show the distribution of infiltration rates in Dungingi District, the absorption capacity is classified as slow (I4), medium (I3) and fast (2). For absorption capacity, the classification is very slow and slow, covering an area of 162.69 Ha or 37.3% spread across 5 (five) sub-districts. The infiltration rate in Kota Barat District varies in classification from very slow to fast. For the very slow and slow classification, the area reaches 1476.41 Ha or 89.7%, meaning that the land absorption capacity in Kota Barat District is only 10.3%, the absorption capacity is still medium and fast. If the infiltration capacity is the reference for groundwater infiltration for 6 hours, then 89.7% of the West City District will experience saturation after six hours and the remaining 10.3% will experience a slowdown in infiltration.

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For the very slow and slow classification, the area reaches 1094.79 Ha. With this classification area, if it rains for 6 hours, it is certain that Kota Selatan District with an area of 1094.79 Ha will start to be flooded. The infiltration rate in Kota Tengah District is still good, because the absorption capacity with fast classification is still around 83.16% or an area of 403.55 Ha. This Central City area was previously a rice field area, but along with urban development, this rice field area changed its function to a residential area. The infiltration rate with very slow, slow and medium absorption is around 16.84%.

The infiltration classification with very fast absorption was found in Kota Timur District covering an area of 58.45 Ha or 3.85%. In terms of percentage, this value seems small, but if you look at the infiltration rate, where the speed is more than 53 cm/hour, then an area this large will quickly reduce the height of flood inundation. The infiltration rate for very slow and slow absorption is 1246.31 Ha (82.10%) while for the medium and fast absorption capacity classification it is 213.3 Ha or 14.05%. Kota Utara District has a very slow and slow infiltration classification covering an area of 788.12 Ha (60.35%) of the total area of Kota Utara District. This area is a technical agricultural/rice field area for Gorontalo City, but along with urban development, this rice field has begun to change its function to become an office and residential area.

The spatial distribution of infiltration rates for each class in each type of land use such as residential areas, shopping areas, rice fields, roads and mixed farming areas is shown in Table 5.

Table 5 Infiltration Rate Classes and Their Relationship to Land Use

K_PL	I1	I2	I3	I4	I5	Jl. Total	% Wide
Jl	3,204	63,360	22,389	65,840	44,153	198,946	2.98
Mr	8,036	401,828	96,289	226,748	131,639	864,540	12.95
Pm	20,973	346,014	175,032	355,524	240,550	1,138,093	17.05
Pt	7,480	93,990	44,459	50,472	53,227	249,628	3.74
SB	2,921	6,022	4,652	1,032,589	1,027,833	2,074,017	31.08
Sw	30,424	402,105	104,837	269,448	381,069	1,187,883	17.80
Tg			0.524	542,842	298,835	842,201	12.62
TA	2,486	20,108	12,950	71,039	12,130	118,713	1.78
Amount Total	75,524 1.13%	1,333,427 19.98%	461,132 6.91%	2,614,502 39.17%	2,189,436 32.81%	6,674,021 100%	100.00

Source: Results of 2010 Land Use Map Analysis

Information: I1 to I5 are Infiltration classes, Jl = Road, KC = Mixed Fields (Pk = Plantation, Tg = Fields/Moorlands, Sb = bushes), Pm = Residential, Sw = Rice Fields, and Pt = Shops. TA = Body of water

The results of the map analysis are shown in TableThe 5 infiltration rate classifications for class I4 highway areas are the largest at 65,840 Ha. Class I4 means the infiltration speed is 2.5 – 15 cm/hour. If there is heavy rainfall above 2.5 cm/hour then the roads covering an area of 65,840 Ha will start to be submerged. The main problem with the main structure of a highway, which is in the form of flexible pavement or an asphalted road structure, is that if it is submerged in water for a long time, it will experience damage. The largest infiltration classification in residential areas is class I4 with a slow absorption character covering an area of 355,524 Ha, followed by land class I2 with a fast absorption character covering an area of 346,014 and then class I5 with a very slow infiltration character covering an area of 240,650 Ha. If we look closely at residential areas, the soil conditions that have slow and very slow absorption have a percentage of 52.375% (596,074 Ha out of 1138,039 Ha). The rate of infiltration in shopping areas that have a fast absorption capacity is class I2 covering an area of 93.99 Ha followed by class I5 with a very slow absorption capacity covering an area of 53,227 Ha and then class I4 with a slow absorption capacity of I4 covering an area of 50,472 Ha followed by class I3 with a medium absorption capacity covering an area of 44,459 Ha and so on. The smallest I1 has very fast absorption capacity covering an area of 7,480 Ha. The land absorption capacity of rice fields is almost the same as residential areas, shops and roads, where class I2 with fast absorption capacity is still the largest zone covering an area of 402,105 Ha, followed by units with very slow absorption capacity, class I5, covering an area of 381,069 Ha and class I4 with slow absorption capacity covering an area of 269,448, while for land units I3 with medium absorption capacity covering an area of 104,837 and the smallest class I1 covering an area of 30,424 Ha. Mixed farming area consisting of plantations, fields and bushes. This area has an infiltration rate with a very slow and sluggish character.

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V. CONCLUSION

The infiltration rate in Gorontalo City as a whole is classified as very slow2189.44Ha or 32.81%, the meaning of this percentage shows that an infiltration rate of less than 2.5 cm/hour occurs in Gorontalo City. For the infiltration rate with a slow classification, the speed is 2.5–15 cm/hour, covering an area of 2615.38 Ha or 39.17%. The lowland area in Gorontalo City is 3551 Ha (65.85%) and the hilly area is 2279.64 Ha or 34.15%. If you pay attention, the infiltration rate of the classification is very slow and slow covering an area of 4803.94 Ha covering almost the entire city of Gorontalo, meanwhile the area of the lowlands is 3551 Ha.

The soil absorption capacity after 6 hours of 4803.94 Ha (71.98%) will experience a slowdown in infiltration and after 24 hours it will experience saturation and the remaining 1870.08 Ha (28.02%) will experience a slowdown in infiltration.

The classification infiltration rate is very slow and the classification is slow based on land use spread as follows, namely roads 109,039 Ha, plantations 358,376 Ha, residential areas 596,046 Ha and shops 103,704 Ha and rice fields 650.52 Ha.

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