Bulletin of the Geological Society of Malaysia, Volume 62, December 2016, pp. 7 – 11

Estimation of infiltration rate in major soil types of Kota Bharu, Kelantan, Malaysia

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Abstract: The present study is carried–out to have an idea about varying infiltration rates with varying soil types and cover in Kota Bharu- the capital of Kelantan state. The study area, covering a land area of about 394 km² lies between latitudes of 06˚10'N and longitude of 102˚20'E. Geologically, the area is mainly comprised of Quarternary alluvium having fluvial and marine origin which is constituted of mainly sand, gravel, silt and clay underlain by granite and meta-sedimentary rocks. The soil properties like texture, structure, water content, temperature and other factors like vegetation types and cover, and rainfall intensity play a significant role in controlling infiltration rate. Generally, coarse grained soils having large pore spaces with stable structure allows water from rainfall to enter unimpeded throughout a rainfall event. Otherwise, soils that have reduced infiltration may cause flooding in the area. From the soil classification map produced by Department of Agriculture (DOA), selected soils would be tested using double ring method to identify the infiltration rate in the study area. The method employed consists of two metal cylinders of diameter 30 cm and 60 cm that are driven partially into the soil. The ring is filled with specific level of water and the time at which water moves into the soil is measured, thus the rate of infiltration could be calculated in the field. An infiltration map will be produced at the end of the study which will be very useful for decision makers while dealing with flood management. The present study will be also very handy in agricultural field regarding the judicious and timely irrigation.

Keywords: infiltration, double ring method, flood, Kota Bharu, soil

INTRODUCTION

Infiltration is the process of surface water entering the soil. The rate of infiltration is the maximum velocity at which water enters the soil surface. When the soil is in good condition, it has stable structure and continuous pores to the surface. This allows water from rainfall to enter unimpeded throughout a rainfall event (Osuji *et al.*, 2010). A low rate of infiltration is often produced by surface seals resulting from weakened structure and clogged or discontinuos pores. Soils that exhibit reduced infiltration show an increase in the overall amount of runoff water.This excess water can contribute to local and regional flooding of streams and rivers or results in accelerated soil erosion of field or streambanks. A number of factors impact soil infiltration such as texture, crust on the soil surface, compaction, aggregation and structure, water content, frozen surface, organic matter and pores (USDA, 1998).

STUDY AREA

Kelantan is located at east coast of Peninsular Malaysia with latitude of 06˚10'S and 05˚55'S, and longitudes is 102˚10'E and 102˚20'E. The study area, Kota Bharu is one of the main districts in Kelantan. The total land area of Kota Bharu is about 394 km². It consist of seventeen sub districts: Badang, Kemumin, Panji, Bandar Kota Bharu, Sering, Kota, Kubang Kerian, Banggu, Pendek, Banggu, Pendek, Limbat, Peringat, Beta, Kadok and Ketereh which are separated from other district by Kelantan River on the west side, South China Sea is on the north side and district boundary on the east and south side of the study area (Figure 1) (JUPEM, 2005). The major land use in the study area is mainly agriculture and there is also urban area like Kota Bharu town. Paddy is the main crops grown in the study area due to its suitability as alluvium soil other than mixed horticulture and rubber (DOA, 2008).

METHODOLOGY

Sample Collection and Preparation

The preliminary studies for the infiltration test have been conducted over the last few weeks before the test. It consists of preparing the sampling location map, surveying for the suitable site to conduct the test and soil sampling for particle size distribution test (PSD) for the purpose to identify the texture of the soils. The sampling location for PSD was selected according to soil classification map produced by Department of Agriculture (DOA). There are few types of soil series in the study area and soil samples were collected in such a manner to cover all the soil series. Then, the double ring field test was conducted in a few selected locations based on the different types of soils found in the study area.

Particle Size Distribution Test

PSD test was conducted to identify the texture of the soil samples (Table 2). The test is divided into three parts which are the destruction of organic matter, silt and clay sampling using hydrometer analysis and sieve analysis to collect the samples with particle size >20 μm (USDA, 2009).

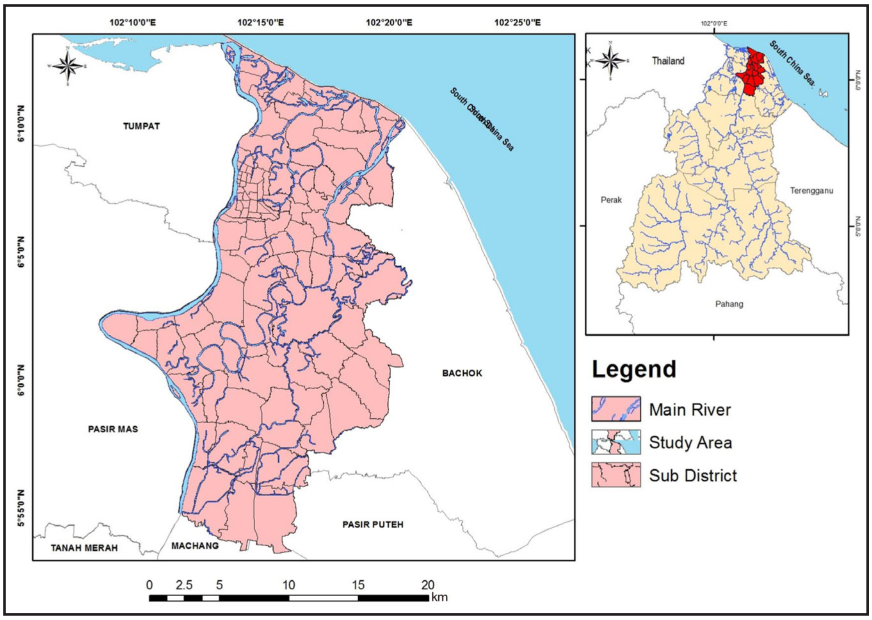

Figure 1: Location map of the study area.

Double-Ring Field Test

The double ring infiltration test is a simple method used to determine the infiltration rate of soil. The test was conducted in situ and it was conducted according to ASTM D3385 – 03 standard test methods (ASTM, 2003). The equipment of the test consists of an inner and outer ring with diameter of 30 cm and 60 cm each (Diamond & Shanley, 2003). The inner ring was placed first and impact absorbing hammer was used to insert the inner ring into the ground (Figures 2 and 3). Then, the outer ring was placed in the same manner. For measuring purpose, two rulers were inserted in the inner ring and outer ring. Then, the outer ring was filled with water. At the same time, the water was added to the space between the two rings at the same depth. The whole process was carried out without any time gap. After pouring the water into the ring, the measurements were started quickly by noting the water level in the inner ring as indicated on the ruler or measuring rod. After an interval of one or two minutes, the drop in the water level was observed and recorded. Then, the water was added into both rings until the level coincided with the same level as it was at the beginning of the experiment. Moreover, water in both the rings was kept at similar levels. The same procedure was repeated until the infiltration rate has reached a constant value. After that, both of the rings were removed.

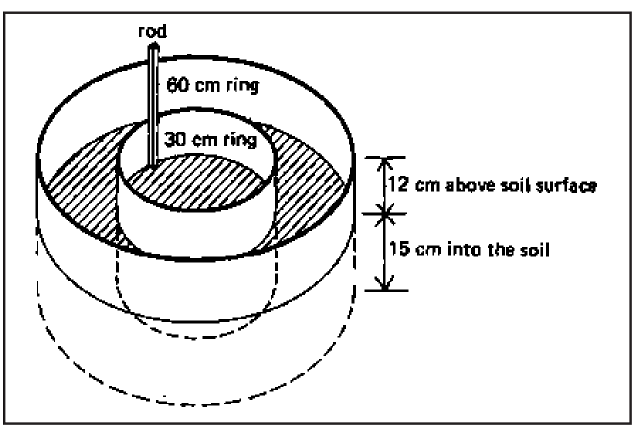

Figure 2: Set up of the double ring infiltrometer (after Diamond & Shanley, 2003).

Figure 3: Field infiltration test using double ring infiltrometer.

Infiltration Analysis

The results of infiltration test are given in Table 3. The analysis was carried out according to Horton Equation which was developed by Horton (Horton,1940).

$$f = fc + (fo - fc)e-kt$$

where, f = infiltration capacity (mm/hr)

fo = initial infiltration capacity (mm/hr)

fc = final infiltration capacity (mm/hr)

k = empirical constant (hr-1)

RESULTS AND DISCUSSION

Based on the result of infiltration test, an infiltration map was prepared for the study area (Figure 11). While preparing this map prime consideration was given to permeability capacity of soil for each location which ranges from low permeability to high permeability soil (Table 1). The measurement of permeability capacity was determined according to the fo/fc ratio which is calculated from the results in the field (Yusuf *et al.*, 2005). Overall, the present study shows that soil in the study area have

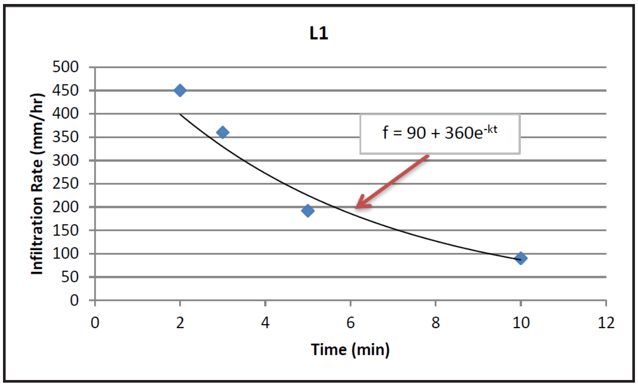

Figure 4: Infiltration curve of infiltration rate (mm/hr) versus time (min) for Location 1.

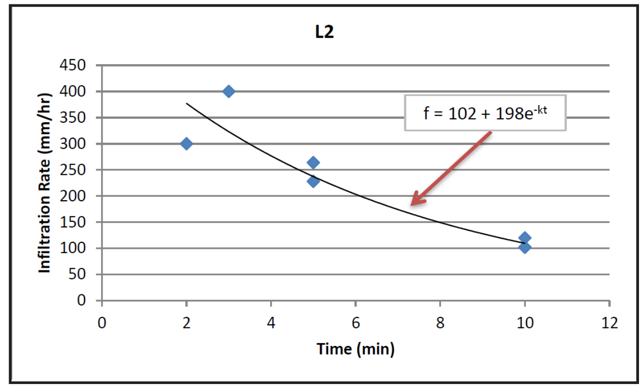

Figure 5: Infiltration curve of infiltration rate (mm/hr) versus time (min) for Location 2.

low to moderate permeability except for location 4 which exceptionally exhibits very high permeability, where as the lowest permeability capacity was recorded in location 5. The permeability ratio of fo/fc ranges from as low as 2.00 mm/hr to as high as 13.20 mm/hr. From the analysis of particle size distribution which was determined from the same soil samples collected from the same field test sites, it has been identified that the clay soil has low to intermediate permeability capacity with the value of fc/fc ratio from 2.00 mm/hr to 3.64 mm/hr. Silty clay soil exhibited moderate to high permeability with fc/fc ratio ranging from 5.00 mm/hr to 6.11 mm/hr. Sandy clay soil shows high permeability capacity with fc/fc ratio of 13.20 mm/hr. The whole description indicates that the type and texture of soil exhibit a great bearing on permeability capacity values, thus the amount of water that can infiltrate through the soil varies with the texture of soil. The amount of water that can infiltrate is highest if the pore size of the soil increased. Otherwise the reduction in pore size would results in decrease in the amount of water infiltration into the soil.

From the data measured, the infiltration curve of infiltration rate (mm/hr) versus time (min) was plotted for every site location (Figure 4 to Figure 10).

CONCLUSION

From the analysis of infiltration conducted, it has been identified that most of the soil in the study area exhibit low permeability comprising about 70% of the soil. A few patches show moderate to high permeability comprising 15%, where as 5% of the soil is constituted of very high permeability. Any sizeable reduction in the infiltration of water will subsequently increase the chances of flood occurrences. This situation will become a disaster when the runoff is high and the soil's ability to infiltrate the water is low. The study of infiltration rate of soil as one of the factors affected the flood condition is still new in the study area and in Malaysia also. The outcome of this study provides useful informations to city planner and policy makers to carry out mitigation operations and strategies for flood hazards.

Table 1: Permeability indication ratio (Mc Cuen, 1998; Yusof *et al*., 2005).

RATIO	PERMEABILITY CAPACITY
>5	High permeability
3 – 5	Moderate permeability
<3	Low permeability

Table 2: Particle size distribution analysis.

Sampling location	Soil type	Location name	Silt (%)	Clay (%)	Sand (%)	Soil texture classification
PSD 1 Pendek	LIK-LSG, Lubok Itek-Lubok Sendong	Kg Pendek Dalam	44.8	41.9	13.1	Silty clay
PSD 2 Kota	TYG-CPA-LDG, Tokyong-Chempaka-Lundang	Kg Tini, Pasir Hor	32.7	50.2	17.1	Clay
PSD 3 Panji	TYG-CPA-LDG, Tokyong-Chempaka-Lundang	Kg Chekok	22.4	63.7	13.9	Clay
PSD 4 Banggu	BHM-TPS-SAN, Batu Hitam-Kampung Tepus- Sungai Amin	Taman Banggu Jati	11.5	42.5	46.0	Sandy clay
PSD 5 Peringat	TYG-CPA-LDG, Tokyong-Chempaka-Lundang	Simpang Pauh Lima (Kubang Tin)	24.8	45.4	29.8	Clay
PSD 6 Ketereh	LIK-LSG, Lubok Itek-Lubok Sendong	Kg. Hj Husin, Kg Dendang	43.2	44.3	12.5	Silty clay
PSD 7 Beta	TYG-CPA-LDG, Tokyong-Chempaka-Lundang	Kg Beta Hulu, Lundang Paku	31.5	52.2	16.2	Clay

Table 3: Results of infiltration analysis.

Location	f_o(mm/hr)	f_c(mm/hr)	Horton Equation (mm/hr)	f_o/f_c (mm/hr)	Permeability capacity
L1	450	90	$f = 90 + 360e^{-kt}$	5.00	Moderate to high permeability
L2	300	102	$f = 102 + 198e^{-kt}$	2.94	Low permeability
L3	180	60	$f = 60 + 120e^{-kt}$	3.00	Low permeability
L4	990	75	$f = 75 + 915e^{-kt}$	13.20	Very high permeability
L5	60	30	$f = 34 + 30e^{-kt}$	2.00	Low permeability
L6	660	108	$f = 108 + 552e^{-kt}$	6.11	Moderate to high permeability
L7	720	198	$f = 198 + 522e^{-kt}$	3.64	Moderate to high permeability

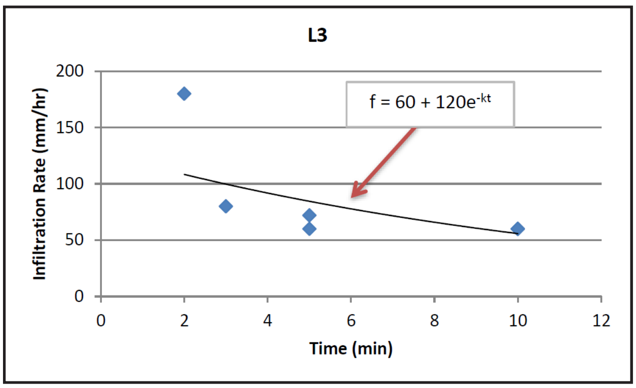

Figure 6: Infiltration curve of infiltration rate (mm/hr) versus time (min) for Location 3.

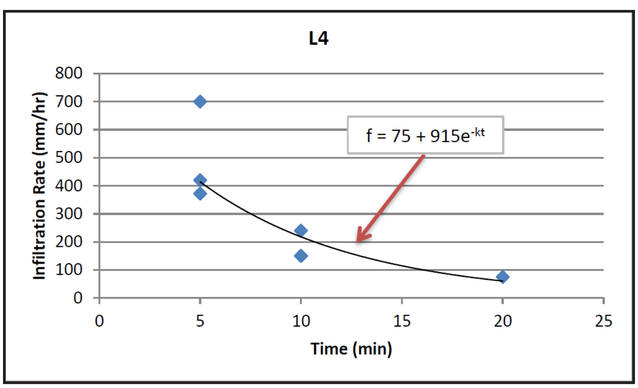

Figure 7: Infiltration curve of infiltration rate (mm/hr) versus time (min) for Location 4.

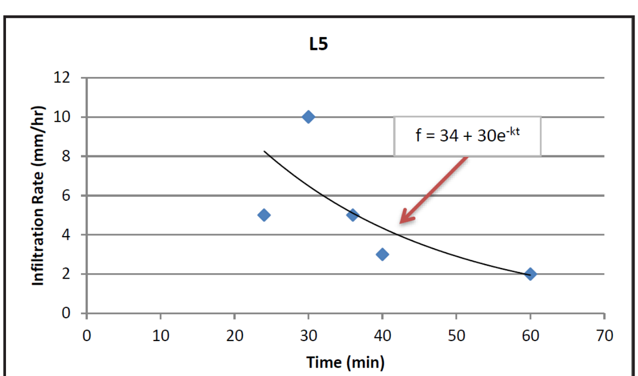

Figure 8: Infiltration curve of infiltration rate (mm/hr) versus time (min) for Location 5.

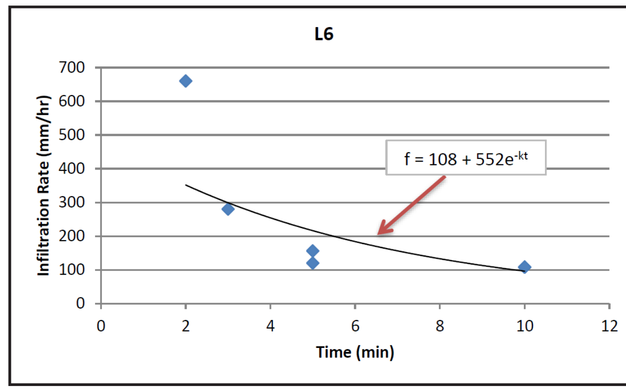

Figure 9: Infiltration curve of infiltration rate (mm/hr) versus time (min) for Location 6.

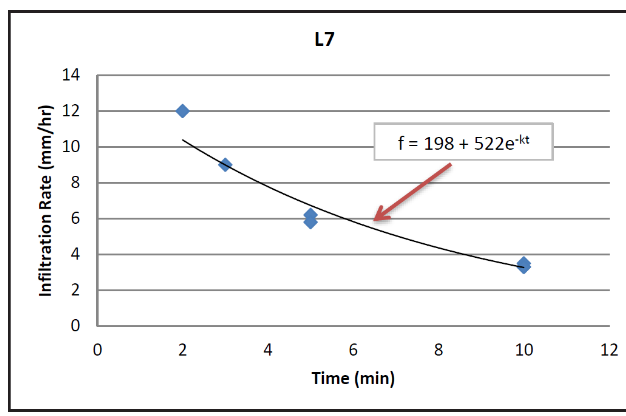

Figure 10: Infiltration curve of infiltration rate (mm/hr) versus time (min) for Location 7.

ACKNOWLEDGMENT

The financial assistance provided by short term research grant project (Ac No.R/SGJP/A08.00/00644A/001/2012/000080), Universiti Malaysia Kelantan, is gratefully acknowledged. The authors are also thankful to all the laboratory staff, Universiti Malaysia Kelantan, Jeli Campus for providing facilities to carry out this work.

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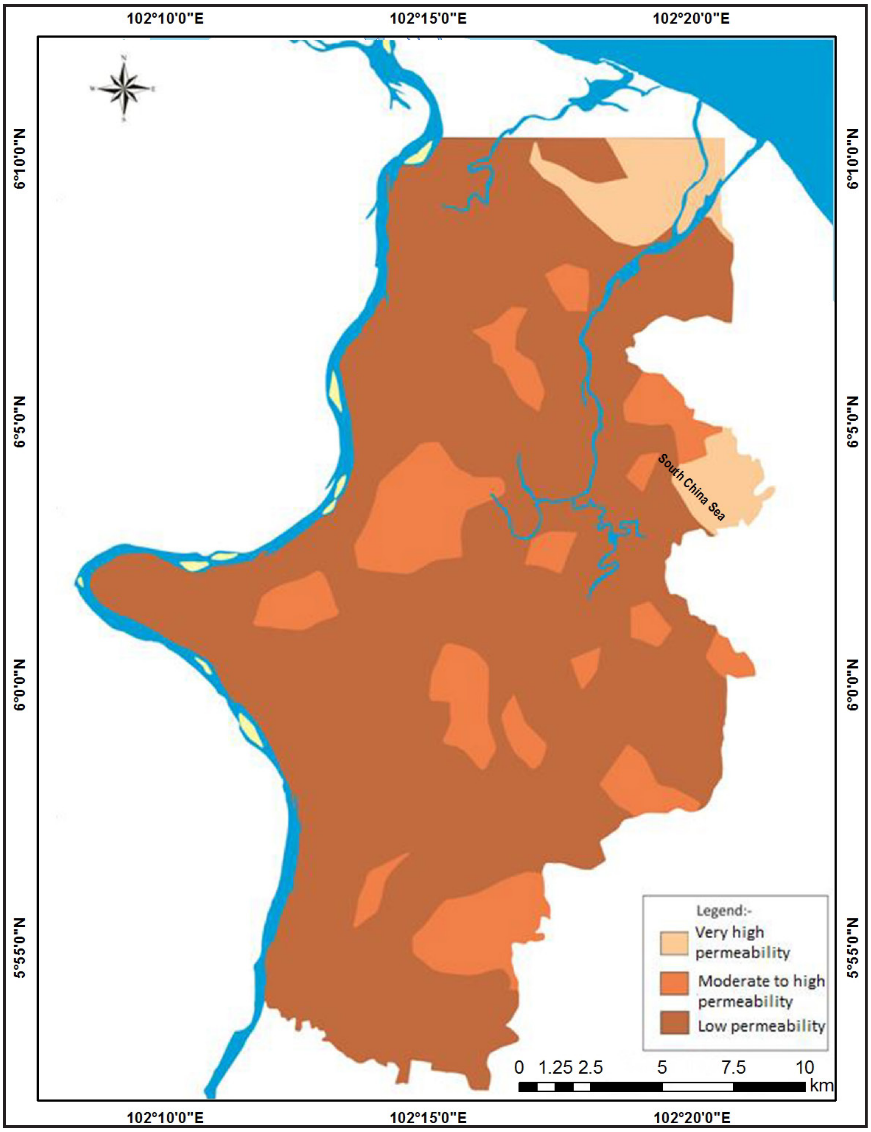

Figure 11: Infiltration map of the study area.

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Manuscript received 12 June 2013
Revised manuscript received 1 May 2014
Manuscript accepted 3 June 2014