Infiltration Characteristics in Agriculture Area of Bahr al Najaf

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Abstract

Water applied to the soil surface through rainfall and irrigation events subsequently enters the soil through the process of infiltration. Soil water infiltration is controlled by the rate and duration of water application, soil physical properties, slope, vegetation, and surface roughness. Beyond the wetting front, there is no visible penetration of water.

Bahr Al-Najaf is a low land located in the south-central zone of Iraq on the western edge of the plateau.

The present paper focuses on investigating the rate of water infiltration through the base and side walls of the tested pits with area of 2m by 1.5m and 0.5m in depth excavated and filled with water in the two locations in agriculture area of Bahr Al Najaf. First location is to investigate the infiltration characteristics and the second one is to validate the results of the first location. The process of filling was repeated several times with full observation and continuous field measurements. The results revealed some useful characteristics and correlations regarding the infiltration of water in the agriculture area of Bahr Al-Najaf.

Keywords: Infiltration, Bahr Al-Najaf, Al-Najaf, Infiltration rate.

الخلاصة

عملية دخول ماء الامطار وعمليات الري المتواصلة الى التربة يتم بواسطة عملية الترشيح. يتم التحكم بعملية الترشيح وفقا لمعدل ومدة تسليط المياه، الخواص الفيزيائيه للتربة، الانحدار، المناطق ألمزروعة وخشونة السطح.

بحر النجف هو أرض منخفضة تقع في منطقة جنوب وسط العراق على الحافة الغربية للهضبة.

البحث الحالي يركز على التحقق في معدل ترشيح المياه خلال قاعدة وجدران حوض الترشيح بمساحه ٢م*١,٥م* وعمق ٠,٥م ولموقعين في المناطق الزراعية لبحر النجف. الموقع الأول هو دراسة خصائص الترشيح والثاني هو للتحقق من صحة النتائج من الموقع الأول. وتكررت عملية ملء عدة مرات مع مراقبة كاملة والقياسات الميدانية المستمرة. كشفت النتائج بعض الخصائص المفيدة والعلاقات المتبادلة فيما يتعلق بترشيح المياه في المنطقة الزراعية لبحر النجف.

الكلمات المفتاحية: الترشح، النجف، بحر النجف، معدل الترشح.

Introduction

Water movement in the vadose zone is generally conceptualized as occurring in the three stages of infiltration, redistribution, and drainage or deep percolation. For this conceptualization, infiltration is defined as the initial process of water entering the soil resulting from application at the soil surface. Capillary forces or matric potentials are dominant during this phase. Redistribution occurs as the next stage where the infiltrated water is redistributed within the soil profile after the cessation of water application to the soil surface. During redistribution, both capillary and gravitational effects are important. Simultaneous drainage and wetting takes place during this stage, and the impact of hysteresis may be important.

The infiltration rate is the rate at which a soil, in a given condition, can absorb water. It is defined as the volume of water passing into a unit area of soil per unit time, with dimensions of velocity (LT^{-1}). The infiltration velocity is the actual volume of water moving downward into the soil per unit area per unit time.[Al-Janabi, 2012]

The infiltration rate is generally the highest when the soil is dry. As the soil becomes wet, the infiltration rate slows to the rate at which water moves through the most restrictive layer, such as a compacted layer or a layer of dense clay. Infiltration rates decline as water temperature approaches freezing. Little or no water penetrates the surface of frozen or saturated soils. [Al-Janabi, 2012]

An ideal infiltration curves, based on theoretical analysis, is illustrated in Figure 1. [Al-Janabi, 2012]

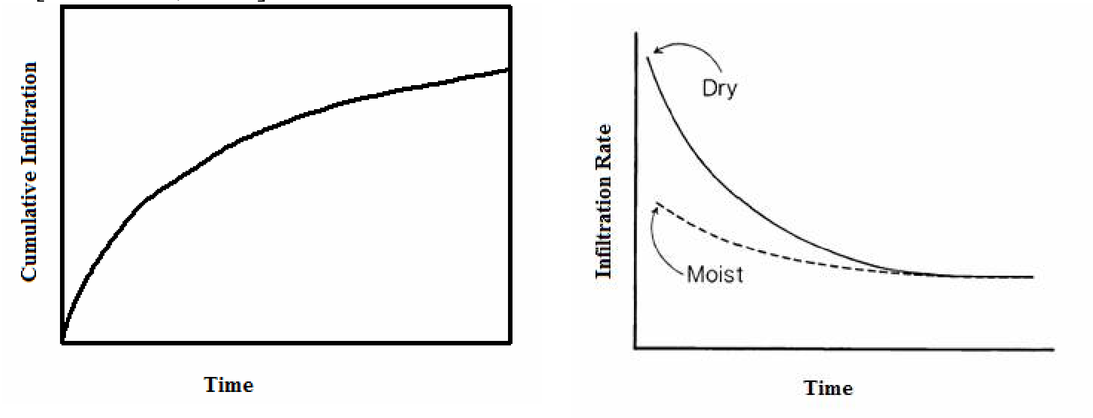


Figure (1): Ideal Infiltration Curves.[1]

DESCRIPTION OF TESTED SITE

Bahr Al-Najaf represents an extension of the alluvial plain in the form of the tongue on the plateau extends from the south to the north of the judicial of Al-Manathira. Extends to the west of the Bahr Al-Najaf. [Al-Janabi, 2012]

The width of Bahr Al-Najaf ranges between (6-60) km and the area is about 2700 km2 (about 250,000 hectares). The available agricultural area is about 40,000 hectares (or 16% of Al Bahr area). At the present, the agriculture area is about 15,000 hectares.[Al Fartosy *et al.*, 2005]

In Bahr Al Najaf, the border irrigation method is adopted by farmers depending on two rivers, first, Al Gazi (previously named Al Sadeer) with discharge of 3.28 cumecs per second, Al Bedairiyah with discharge of 3.28 cumecs.[1] The dimensions of borders are 10m*5m. The water volume of irrigation is 35m3 per 5 hrs per half hectares.

The elevation of Bahar Al Najaf ranges from 0 m to 10 m, the elevation of highest level in the city of Al Najaf is 60 m. [Al-Janabi, 2012]

Work Methdology and Materials

Number, Distribution and Dimensions of Trail Pits

The two pits were excavated to perform the infiltration test in south of Bahr Al-Najaf. These points were determined by available Global Position System device (GPS). The coordinates (x,y) of the pits are (435143, 3538380), (433473, 3535848), respectively.

The dimensions of tested pits test are 2 meter in length, 1.5 meter in width, and 0.5 meter in depth. The area of the pit (2m*1.5m) was selected randomly because the water pressure depends only on water head which pushes the water to infiltrate into the soil. The depth of the pit is 0.5m to minimize the lasted time of infiltration process.

Soil Classification

The disturbed soil samples were taken from each tested pit to perform the classification and chemical test of soil such as total soluble salt (TSS). The TSS test was performed before and after all stages of infiltration process and for each pit. The laboratory tests were made in laboratories of quality control and the laboratories of civil engineering department at Kufa University.

Figure 2 shows the grain size distribution of the soil samples from each two locations. Table 1 summarizes the results of soil samples tests for each location. These results revealed that the soil in both tested locations is mainly sand with more than 85 percent.

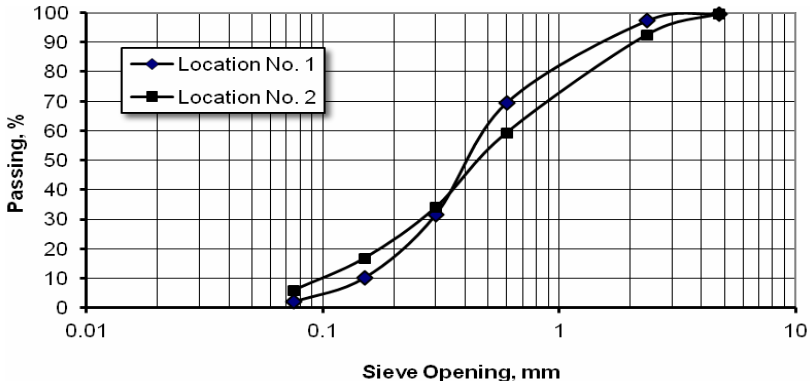


Figure (2): Grain Size Distribution Curves of Soil Samples.

Table (1): Results of Soil Tests.

Terms	Location No.	
	1	2
Gravel, %	2.7119	7.474
Sand, %	95.241	86.722
Fine, %	2.047	5.804
TSS, ppm		
Soil Classification According to USCS	SP	SP to SW-SM

Infiltration Processes

For each pit, infiltration process was made to determine the infiltration characteristics. This process started with flooding of the pit, recording the variation of water height in pit with time and repeating of flooding, as shown in plate (1), which is called "stage".

The infiltration process was repeated four times in pits No.1 and No.2, whereas this process was repeated three times in pits No.3, 4, and 5. The process of infiltration in each stage continued for different periods depended on the location of pit and the stage of infiltration in each pit.

The water of flooding process was brought using a tanker of 7000 liters.

a. After Excavation

b. After Flooding

Plate (1):The Stages of After Excavation and After Flooding.

Modeling

Statistical analyses were made to correlate the infiltration and time for both locations in addition to determination of average infiltration rate with standard deviation. The results of the two locations were correlated to validate the results.

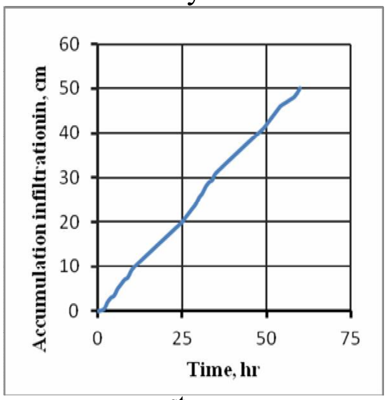
Results and Discussion

Location No.1

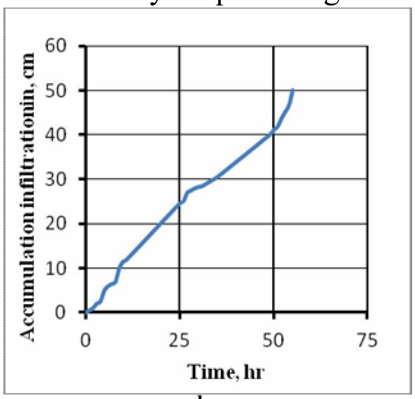
The infiltration process in location No. 1 was repeated four times (four stages of infiltration process) to satisfy the steady state. The first and second stages of infiltration lasted for about 60 hours and 55 hours respectively, in contrast, the third and fourth stages lasted about 34 hours.

Figure 3 illustrates the results of accumulative infiltration versus time for each stage of infiltration in the pit No.1.

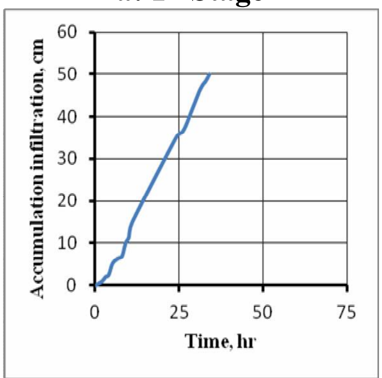
All infiltration curves are similar an exhibit an approximate liner trend. The time decreases with progress of the second and third stages, then remains at a constant value. The shape of the curves for all stages differs from the ideal curves, Figure (1), and this behavior may be due to the leaching process of soil by frequent irrigation.



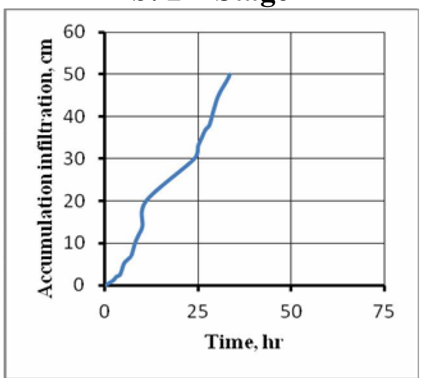
a: 1st Stage



b: 2nd Stage



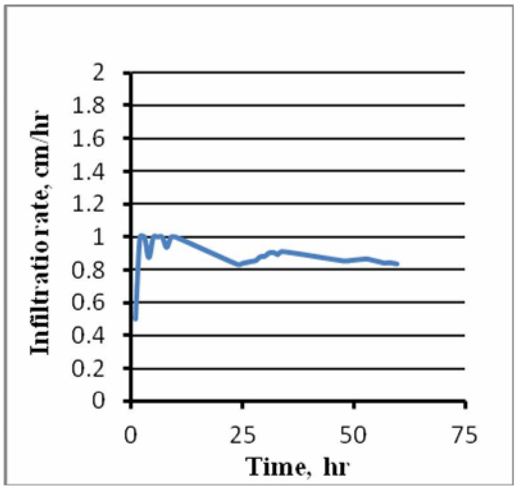
c: 3rd Stage



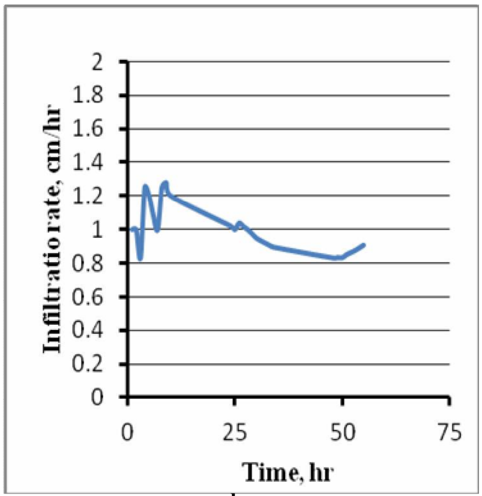
d: 4th Stage

Figure (3): Accumulated Infiltration Rate For The First Pit.

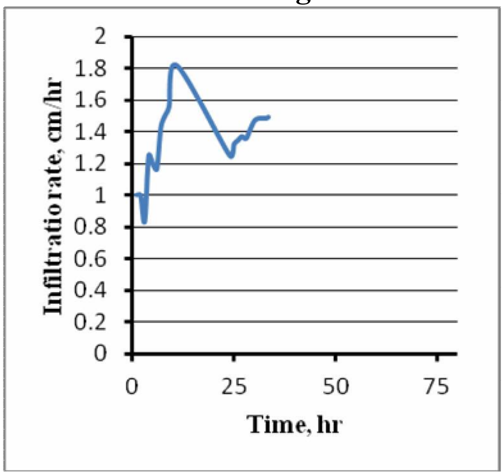
Figure 4 shows the computed infiltration rates for each stage of pit No.1. It can be noticed that the values of infiltration rate demonstrate a peak value with change in small differences and this differs from ideal curve, Figure 2. Such behavior may be due to the irrigation processes.



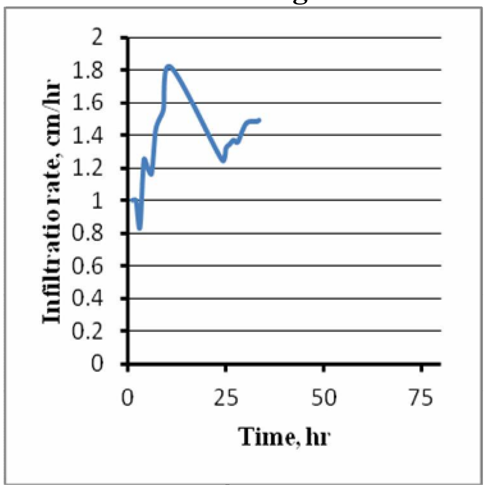
a: 1st Stage



b: 2nd Stage



c: 3rd Stage



d: 4th Stage

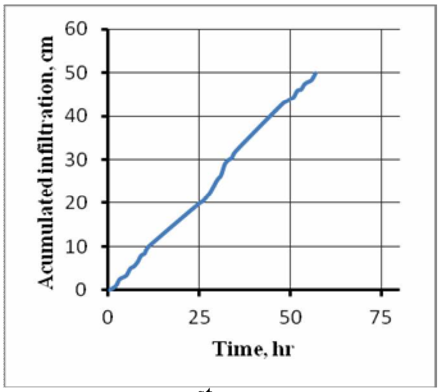
Figure (4): Infiltration Rate for The First Pit.

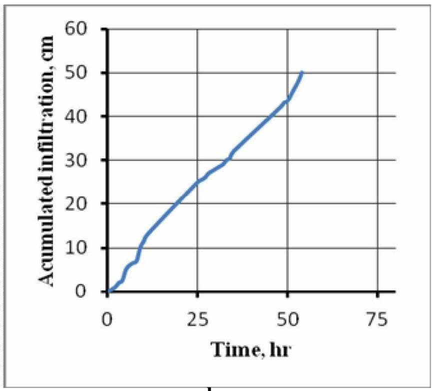
4.3.2. Pit No.2

Similar to pit No.1, the infiltration process repeated four times (stages) to satisfy the steady state. Moreover, the time periods for first and secont stages are 57 hours and 54 hours respectively, however the third and fourth stages lasted about 34 hours, as in pit No.1.

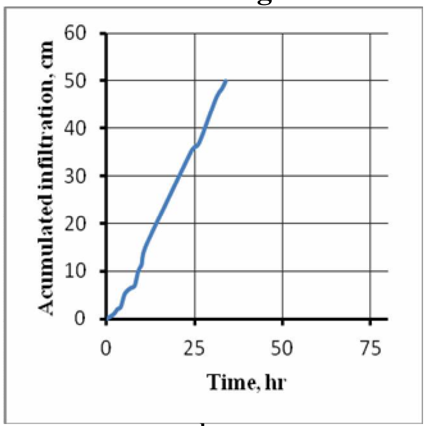
Figure 5 illustrates the results of accumulative infiltration versus time for each stage of infiltration in the pit No.2.

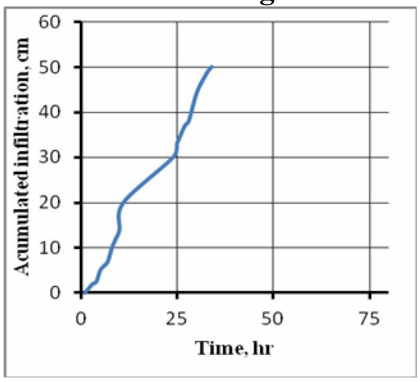
Also, all the infiltration curves are similar in behavior exhibiting a linear trend. The time elapsed decreases with increasing the flooding stages. However the time elapsed for stages 3 and 4 was very close indicatly an approximate steady state condition. Similarly the resulted curve for all stages differs from the ideal curves as in Figure 1 and this behavior may caused by the leaching process of soil by frequent irrigation.





a: 1st Stage   b: 2nd Stage

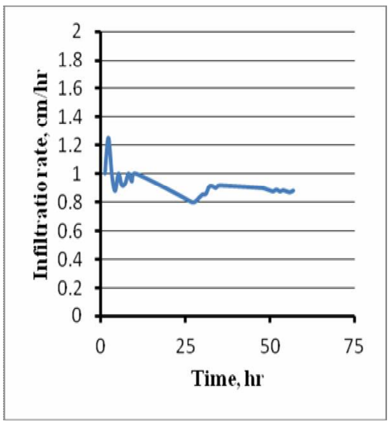


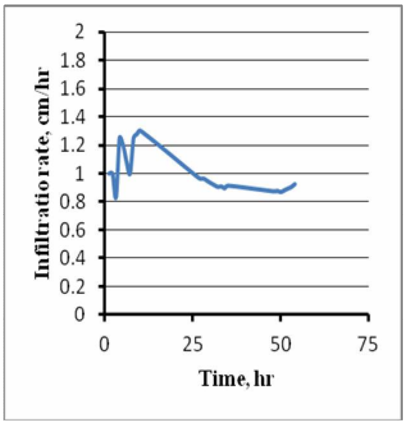


c: 3rd Stage   d: 4th Stage

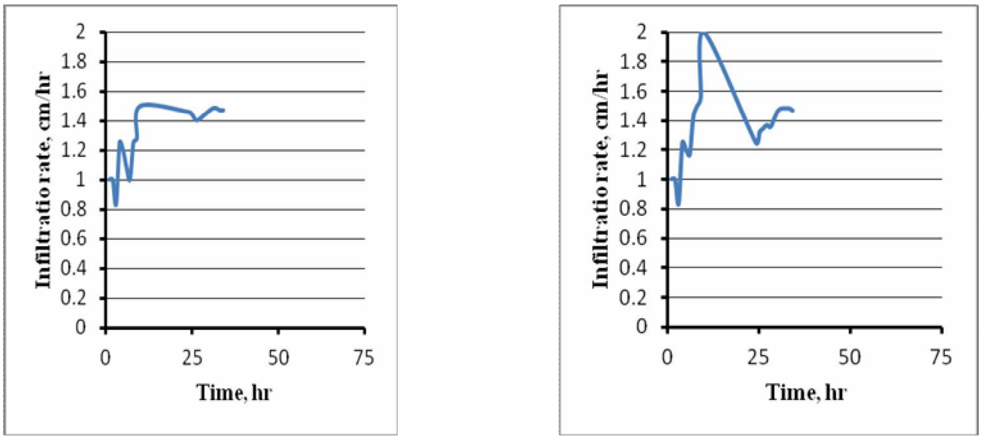
Figure (5): Accumulated Infiltration Rate for The Second Pit.

Figure 6 show the computed infiltration rates for each stage for pit No.2. Similarly, the results confirm the previous behavior, i.e., peak value with changes within narrow range, may be due to same reason, irrigation. The average values of infiltration rate are 0.9 cm/hr, 1.0 cm/hr, 1.2 cm/hr and 1.4 cm/hr for stages 1,2,3 and 4, respectively. The overall average value in pit No.2 in steady state is 1.35 cm/hr and standard deviation is 0.24 cm/hr.





a: Stage No.1   b: Stage No.2



c: Stage No.3 d: Stage No.4

Figure (6): Infiltration Rate for The Second Pit.

Statistical Analysis

Figure 7 shows the accumulated curve of infiltration versus time for all stages. Statistical analysis shows a good agreement between experimented data curve and fitting line, Eq. (4-4), with R^2 equal to 0.97.

Where: -

I: cumulative height of water infiltrates into the soil in cm,

t: time from the beginning of the infiltration in min., and

Constant (a) being equal to 1.226 and the constant (b) equal to 0.95 which is within the range of b values 0.5 and 1.0 representing wet conditions.

$$I = 1.226\ t^{0.95} \quad .... (4\text{-}4)$$

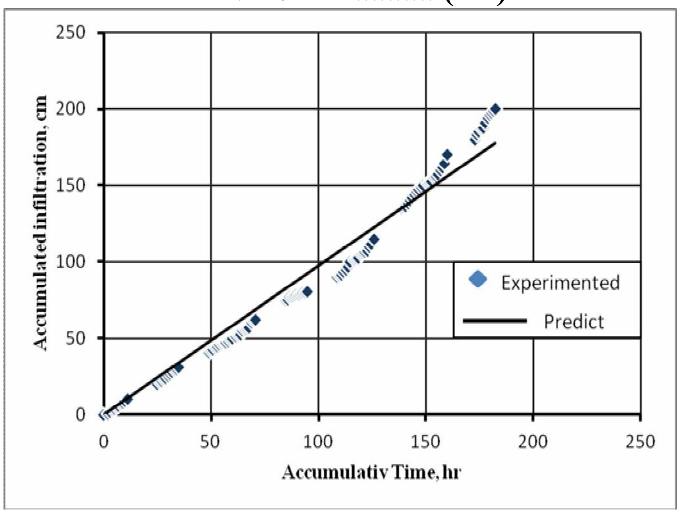


Figure (7): Total Accumulated Infiltration for the First Pit.

The average rate values are 0.9 cm/hr, 1.0 cm/hr, 1.2 cm/hr and 1.4 cm/hr for stages 1, 2, 3 and 4 respectively. The average value of the infiltration rate for pit No.1 in steady state is 1.34 cm/hr and the standard deviation is 0.22 cm/hr.

Figure 8 shows the total accumulated infiltration of all four stages (2m) versus accumulated time. Statistical analysis shows a good agreement between experimented data curve and fitting line, Eq. (4-5), with R^2 equal to 0.97.

Where: -

I: cumulative height of water infiltrates into the soil in cm,

t: time from the beginning of the infiltration in min., and

Constant (a) being equal to 2.27 and the constant (b) equal to 0.9 which is within the range of b values 0.5 and 1.0 representing wet conditions.

$$I = 2.27\, t^{0.9} \text{ .... (4-5)}$$

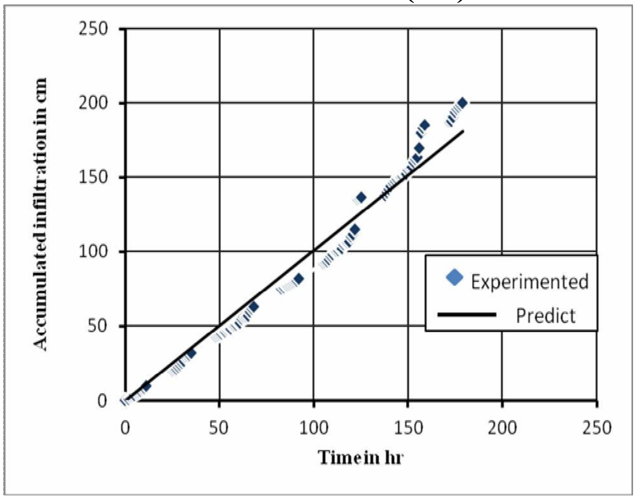


Figure (8): Total Accumulated Infiltration for the Second Pit.

The average values of infiltration rate are 0.9 cm/hr, 1.0 cm/hr, 1.2 cm/hr and 1.4 cm/hr for stages 1,2,3 and 4, respectively. The overall average value in pit No.2 in steady state is 1.35 cm/hr and standard deviation is 0.24 cm/hr.

Conclusions

1- The type of soil of the five selected locations consists mainly of 90% sand and 10% gravel with texture from SW – SW-SM.
2- Field permeability tests revealed values range between 1.738 m/day to 19.747 m/day with average value.
3- The infiltration rate exhibited a different shape compared to the ideal curves. The infiltration rate remains constant. Pits 1 & 2 exhibited low infiltration rate (1.34 cm/hr and 1.35 cm/hr) because they are in the irrigated zone. Pits 3, 4, and 5 are located on the dry zone and exhibited higher infiltration rate (4.19 cm/hr, 4.6 cm/hr, and 4.15 cm/hr).
4- The design of infiltration basin depends on the lowest average value of infiltration rate (1.35cm/hr) which represents the infiltration rate of the agriculture area that requires infiltration basins,
5- The developed charts 5-2, 5-3, and 5-4 and Eq. 5-1 can be used directly for the design of infiltration basin in Bahr Al Najaf.
6- 5.6% of the agriculture area is required to be used as infiltration basin.

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