Long term behaviour of an infiltration trench

Comportement à long terme d'une tranchée d'infiltration

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RESUME

Les tranchées de rétention / infiltration sont une des techniques utilisées pour réduire les flux d'eau et de polluants rejetés par la ville en temps de pluie. L'objectif de ce programme de recherche, mené conjointement avec SOGAE Rhône-Alpes et le Grand Lyon, est d'optimiser le dimensionnement des tranchées. Cette communication présente le comportement à long terme d'une tranchée d'infiltration et la perte d'efficacité hydraulique due au phénomène de colmatage. Une méthode originale pour accélérer le phénomène de colmatage est proposée. Le fonctionnement hydraulique est modélisé en utilisant un modèle de type stock et le modèle de Bouwer. Les résultats expérimentaux montrent que le colmatage est rapide au début du fonctionnement de la tranchée. Le modèle est capable de représenter le fonctionnement hydraulique d'une tranchée colmatée.

ABSTRACT

Detention / infiltration trenches are one of the techniques that can be used to reduce the flow of water and pollutants discharged by cities during rainy period. The objective of the research programme, carried out jointly by URGC, SOGEA Rhone-Alpes and the Grand Lyon, is to optimise trench design. This paper presents the long term behaviour of an infiltration trench the loss of the hydraulic efficiency due to the clogging phenomena. An original method for accelerating the clogging phenomena is proposed. The hydraulic behaviour of the trenches is modelled using a storage model and Bouwer's model. The experimental results show that the effects of the clogging phenomena are quicker at the beginning of the trench operation. The model is able to represent hydraulic behavior of a infiltration trench clogged.

KEYWORDS

BMP's, Infiltration trench, clogging phenomena, modelling.

1 INTRODUCTION

BMPs (Best Management Practices) have been developed to reduce sewer system failures. Detention and / or infiltration trenches are classified as BMPs. Many studies (Warnaars *et al*., 1998, Schutler & Jefferies, 2004) have proved the capacity of these practices to reduce stormwater flow rates. The objective of the current research program is to optimise trench design. This communication presents a part of this program that aims to measure the risk of clogging of infiltration trenches due to their ageing.

The operational objectif is to improve infiltration trenches design in order to fit safety factor taking into account the clogging phenomena.

2 METHOD

2.1 Apparatus

The studied infiltration trench is 12 meters long, the cross section is shown in Figure 1.

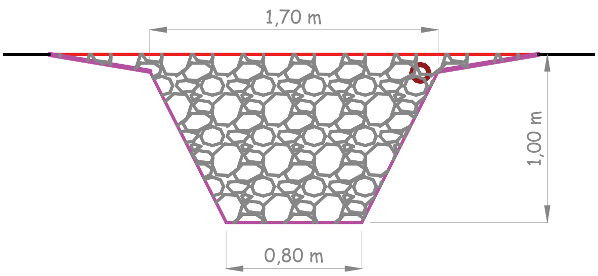

Figure 1. Cross section

The Infiltration trench is located in an experimental apparatus specifically built for this research program. The experimental apparatus (see Figure 2) collects stormwater from an urban highway. During rainy periods, stormwater is stored in a detention basin. During the experimentations, water is pumped and injected to the infiltration trench through a supply pipe. The pump system allows experiments to be reproduced thus the experimental apparatus can be operated under fully controlled conditions. The description of the full system can be found in Proton & Chocat (2005).

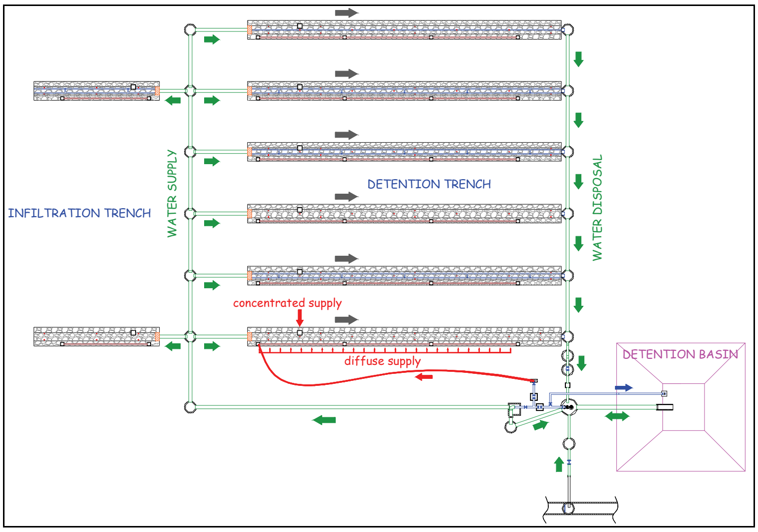

Figure 2.Experimental apparatus.

Within the experimental trench, incoming flow is measured with an electromagnetic flowmeter, water levels within the infiltration trench are measured with six pressure sensors (Figure 3).

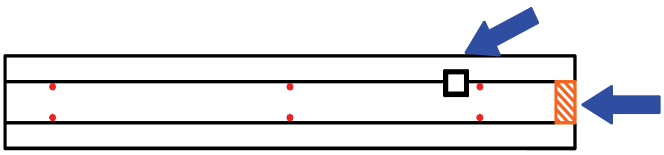

Figure 3. Flow rate (arrows) and water level (spots) measurement points within the trench.

2.2 Method

The objective of the experiments is to observe the decrease of the infiltration rate in relation with the ageing of the trench. The strategy of the procedure consists in simulating the functioning of the trench for a long rainfall time series and measuring the evolution of the infiltration capacity. An artificial catchment area is assigned to the infiltration trench. This catchment area corresponds to about 150 m² of active area.

The infiltration capacity is periodically measured by studying the operation of the trench for a synthetic hydrogramme corresponding to a 1 year return period. (Figure 4).

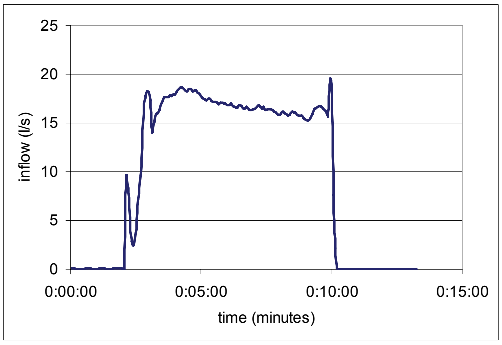

Figure 4. Storm event test hydrograph

For the simulation we use a real rainfall time series observed between 1986 and 2006 on one of the raingauge of the Urban Community of Lyon. The rainfall runoff model is very simple : an initial abstraction of 1 mm. and continuous losses of 1 mm/h.

The events of the storm time series are injected in the infiltration trench faster than in the reality. The dry periods are reduced and the trench is supplied as often as possible. We do not monitor water levels and infiltration flow rates for each event. But each "fictitious" year we inject the same synthetic hydrograph and monitor the operation of the trench. Effects of clogging phenomena can be clearly observed since we always supply with the same input.

3 RESULTS AND DISCUSSION

3.1 Experimentation

The infiltration experiments began in May 2005. Up to now, we managed to simulate 4 years of pluviometry. We will present the results of the full period (10 years) at the conference. Figure 5 shows the water levels at a point of measure after each fictitious year of supply.

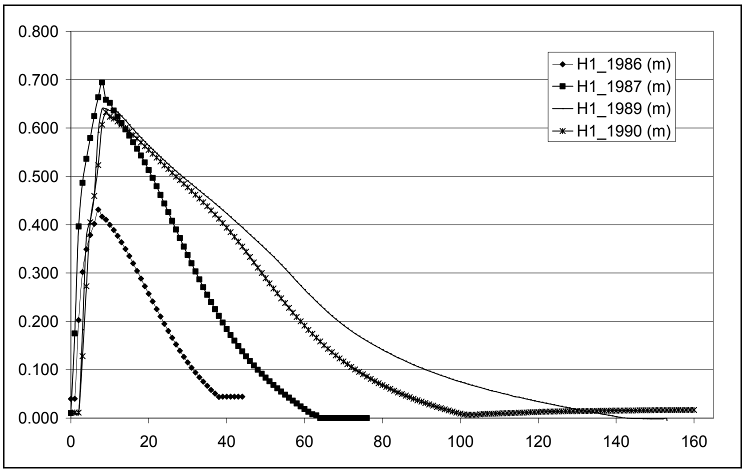

Figure 5. Water levels measurements upstream the infiltration trench

The clogging phenomena can be observed in Figure 5. The infiltration rate of the trench decreases with time. We can observe that the effects of the clogging phenomena are quicker at the beginning of the trench operation. The hydraulic behavior is similar for the 2 last years; the trench seems to reach a stabilized clogged situation. We are waiting for the simulation of the last 6 years to see whether this result is confirmed.

3.2 Modelling

The model used to describe the hydraulic behaviour of the trenches is a storage-based conceptual model. The main hypothesis is that the flow is stationary at each duration and space step. This model was previously designed by Chocat (1978) and developed by Motiee (1996) and Blanpain (1993).

The model is controlled by two relationships that can be written at each space step:

the equation of conservation: $$\frac{dV_s}{dt} = Q_e - Q_s \quad \text{Eq. 1}$$

and a non-linear storage relationship: $$V_s = \beta(\alpha S_o + (1-\alpha)S_1)dx \quad \text{Eq. 2}$$

where V_S is the volume stored in the trench for one space step, Q_e and Q_s are the incoming and the outcoming flow rates in the reach, *dx* the length of the reach, S_0 and S_1 the water cross-sections respectively upstream and downstream of the reach, and α a coefficient with a value between 0 and 1. β is a non-dimensional coefficient intended to take into account the average porosity of the gravel filling the trench (see Figure 6).

Water levels and outgoing flows are calculated at each space and duration step by solving this two-equation system using a finite differences method.

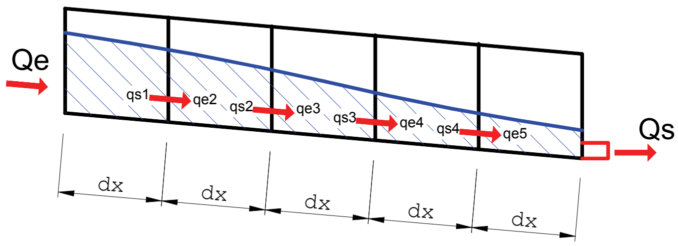

Figure 6. Trench discretisation

The storage model has been presented in a previous paper (Proton & Chocat, 2006). We will just describe here the specific module we use to describe the clogging phenomena. One method to assess the clogging level of an infiltration basin or trench is to evaluate its global hydraulic (Caramori *et al*, 2002, Le Coustumer & Barraud, 2006). The hydraulic resistance R represents the time that is necessary for a unit infitration amount to move through the clogging layer at unit head loss (Bouwer, 2002). The assumptions made are the following ones (Bouwer, 1969) :

- The clogged layer has very small hydraulic conductivity compared to the underlaying soil.
- The underlaying soil is unsaturated. In this case, the hydraulic flow in the soil is only due to the gravity and the hydraulic gradient is equal to one. The pressure head is supposed to be constant in the vadoze zone.

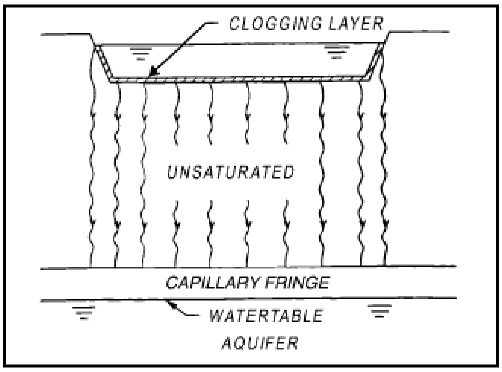

Figure 7. Infiltration in a clogged basin (Bouwer, 2002).

If Darcy'law is applied to the system shown in Figure 7, with the assumptions made before, the relashionship between the infiltration rate and the water depth in the trench can be expressed as :

$$v = K_c \frac{h_0 + e - h_{cr}}{e} \quad \text{Eq. 3}$$

Where v is the infiltration rate (m/s), e the thickness of the clogged layer (m), h_{cr} the water pressure head in the unsaturated porous media (m), h_0 the water depth in the trench (m), and K_c the hydraulic conductivity of the clogged layer (m/s).

If the clogged layer is very thin compared to the water depth, the infiltration rate can be assessed by :

$$v = K_c \frac{h_0 - h_{cr}}{e} = \frac{h_0 - h_{cr}}{R} \quad \text{Eq 4}$$

Were R is the hydraulic resistance (in seconds) and represents the thickness of the clogged layer divided by its hydraulic conductivity.

3.3 Calibration

The hydraulic resistance is calibrated for each synthetic hydrograph. Figure 8 to Figure 11, represent water levels (m) (y axis) measured and calculated for each event. The time step (x axis) is one minute. The Bouwer's model gives good results after one year of functioning (it is not possible to calibrate the model for the first test, which corresponds to the initial state of the trench). That seems to indicate that the clogged layer is quickly installed.

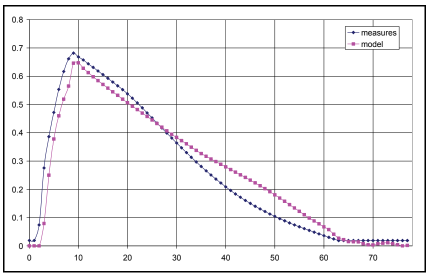

Figure 8. Calibration 1987

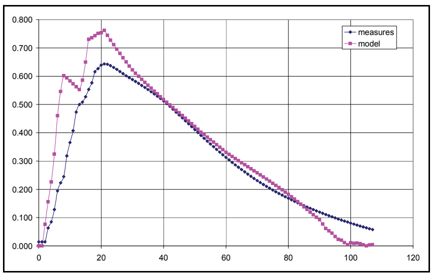

Figure 9. Calibration 1988

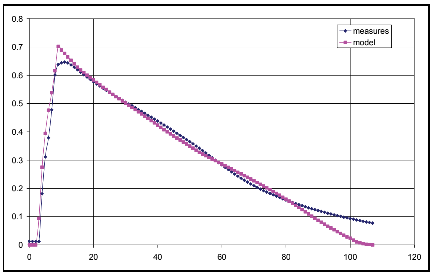

Figure 10. Calibration 1989

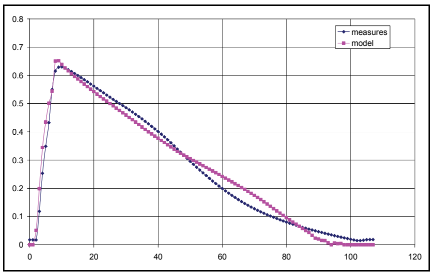

Figure 11. Calibration 1990

Table 1 gives the calibrated value of the only parameter (the hydraulic resistance) of the model after each of the 4 years.

	1987	1988	1989	1990
R (seconds)	5000	6500	8000	7500

Table 1. Evolution of the hydraulic resistance

The hydraulic resistance increases quickly the first 3 years and seems to reach a limit value. The increase of the hydraulic resistance between the 3rd and the 4th year can be due to measurements uncertainties or to variations of the soil humidity.

4 CONCLUSION AND PERSPECTIVES

The protocol seems to be adapted to the objective of this research. Experimental results show the clogging effect on the emptying of the infiltration trench. The Bouwer's model is able to represent the hydraulic behaviour of a partially clogged infiltration trench and the variation of the hydraulic resistance gives a good indication of the clogging level. We are now going to try to confirm these results by simulating the last 4 years. The next objective will consist in establishing a relationship between the hydraulic resistance and the operation duration.

5 ACKNOWLEDGEMENTS

This research has been carried out within the frame of an industrial research program funded by SOGEA Rhône-Alpes, benefitting from the support of the Urban Community of Lyon and ANRT (Association Nationale de la Recherche Technique – National Association for Technical Research). It is integrated in the OTHU project.

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