Development of a Physically based 3D Bio-retention System Model

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Highlights

- A 3D physically based bioretention model
- Mechanisms of flow movement are modelled in every layer of bioretention cell.
- The LID performance can be evaluated by the 3D physically based model.

Introduction

The bio-retention systems are great pollution removal facilities. They have been deployed worldwide for the water quality treatment. However, the mechanisms of flow movement through the bio-retention system and pollution removal have not been modelled in detail. This presentation shows a 3D bio-retention model that describes water movement in various layers of a designated bio-retention cell. The layers include ponding layer, growing media layer, gravel layer and underdrain and outflow layer. A carefully designed monitoring system was built to support the modelling efforts. The preliminary results show that the flow movement in the system can be modelled quite adequately, but water quality removal mechanisms need more data and time to verify.

Methodology

Experiment set up

A bio-retention cell was built in a wastewater treatment plant to treat the rainwater (Figure 1). The cell consists of three layers with different thickness as presented in Table 1. A perforated pipe was installed in the gravel layer to convey the treated runoff to the drainage network. The design is shown in Figure 2.

Figure 1 The bioretention cell built for modelling development, calibration and validation.

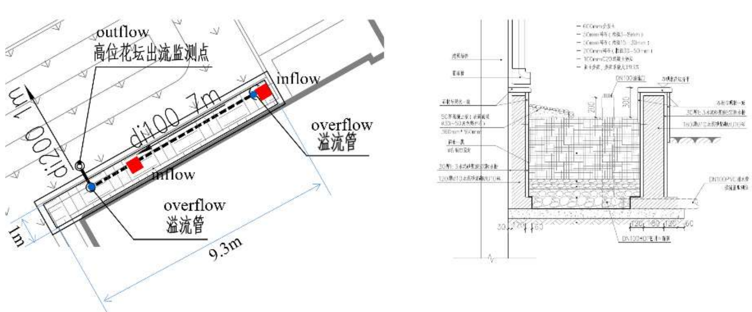


Figure 2 The design of the bioretention cell for the modelling.

Table 1. Layers of the bio-retention system

	Thickness [mm]
Ponding layer	200
Growing media layer	600
Gravel layer	300
Underdrain layer	100

Model set up

Richards equation for unsaturated flow with van Genuchten retention curve were used for modelling the bio-retention cell. Richards equation and advection-dispersion equation are solved numerically for variably-saturated water flow and pollutant transport i, respectively. The water content in the system was measured as the initial condition. The upper boundary condition was set as variable flux based on the precipitation measurements and flow received from the adjacent areas. The seepage face is used as outflow boundary condition for the perforated pipe.

Richards Equation

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x_i}\left[K\left(K_{ij}^{A}\frac{\partial h}{\partial x_j} + K_{iz}^{A}\right)\right] - S$$

van Genuchten function

$$\theta(h) = \begin{cases} \theta_r + \dfrac{\theta_s - \theta_r}{[1+|\alpha h|^n]^m} & h < 0 \\ \theta_s & h \geq 0 \end{cases}$$

$$K(h) = K_s S_e^l [1 - (1 - S_e^{1/m})^m]^2$$

Monitoring design

The challenge in this study is to measure the small flows out of bioretention cell. To do so, a set of ninety-degree v-notch and compound weirs were installed at the inflow and outflow of the bioretention systems. Differential pressure transducers related water height to flow rate. A time-based discrete sampling methodology was tested and found to adequately sample multiple points throughout the inflow and outflow. A weather station is also installed to measure rainfall volumes. The monitoring system is shown in Figure 3.

Figure 3 Flow monitors and weather station installed at the site.

Results and discussion

In this presentation we show the modelling results for single storm events, which are in good agreement with the monitoring data. The continuous simulations need more computing resource which will be presented in the next step. The calibration and validation data are shown in Figure 4. Figure 5 shows the results of calibration and validation.

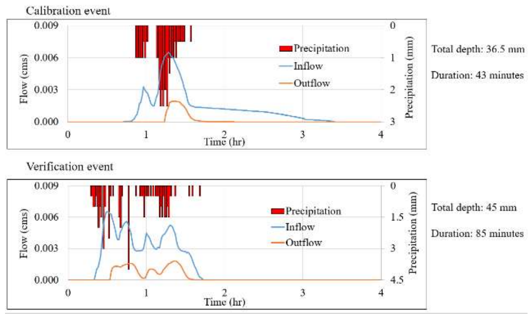
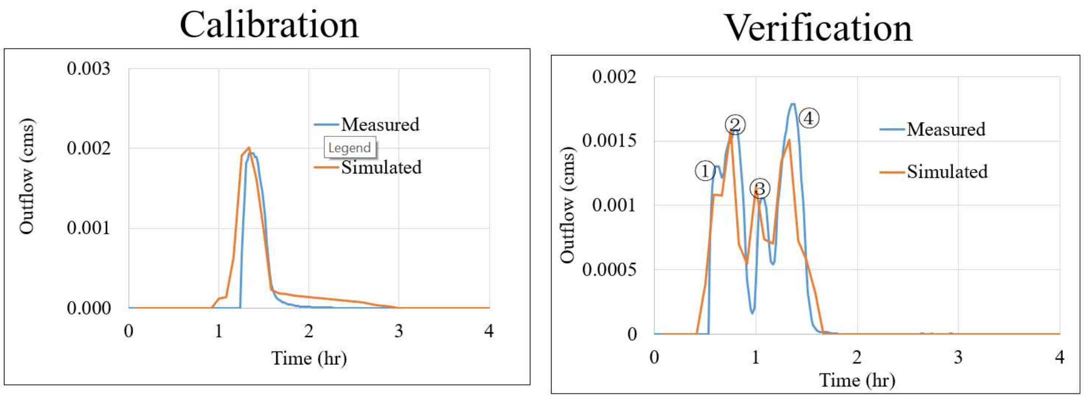


Figure 4 Storm events chosen for calibration and validation



R^2: 0.726, Δt_p: 2 min, ΔQ_p: 4.0%

R^2: 0.706

Figure 5 Calibration and validation results

Conclusions and future work

The flow movement in the bioretention cell can be modelled quite adequately. It can be used as a bioretention performance evaluation tool. This model can be an alternative to popular SWMM model, which is difficult adequately modelling the water movement in bioretention cell and results unrealistic designs. In the future, optimizing the model setup is needed to reduce the computational resources.

References

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