Water Practice & Technology Vol 12 No 3
doi: 10.2166/wpt.2017.065

Development of integrated management system (ISTORMS) for efficient operation of first flush treatment system for urban rivers

Dongil Seo*, Tongeun Lee, Jaeyoung Kim and Youngmin Koo

Department of Environmental Engineering, Chungnam National University, Daejeon, Republic of Korea

*Corresponding author. E-mail: seodi@cnu.ac.kr

Abstract

An integrated management system was developed for the efficient operation of a storm water treatment unit to assist in the management of urban river water quality and flow. The SWMM hydrological model was calibrated and then used to predict the hydrograph and concentration graphs of surface runoff from a storm events based on weather forecasts. These results are used to decide how to operate the first flush treatment unit in the field by comparing water quality in the unit with that in runoff. This water quality monitoring system will also be used to reflect real-time field conditions, which will be used to improve the efficiency of the treatment system. The first flush treatment unit can be installed underground to use for storage of storm water. The system was tested against field data collected in a sub-basin of the Gwanpyung-cheon stream in Daejeon, Republic of Korea. Continuous monitoring results indicated that the first 4 hours of surface runoff exhibit higher concentrations than normal levels in the study site, and these levels can be used to determine the necessary volume for efficient treatment. When settling in the treatment system over 24 hours, the average removal efficiencies for TSS, TP and TN were 87.4%, 57.3%, and 43.6%, respectively.

Key words: automatic monitoring, first flush, modelling, stormwater management, SWMM

INTRODUCTION

Rainfall runoff from impervious urban areas rapidly delivers sediment and pollutant to streams and reduces groundwater recharge. These effects result in increased pollutant loadings to surface waters and decreased base flow in urban rivers. Managing rain water in urban basins is essential for maintaining surface water quality and quantity. While data on flow rates and concentration in surface runoff are necessary to develop management alternatives, those data are often not readily available. Seo & Fang (2012) reported on the development of an automatic rainfall runoff monitoring system for a sub-basin of the Gwanpyung-cheon, a small stream in Daejeon, Republic of Korea. The monitoring system promotes more efficient data collection for water quality modelling and management. Yin *et al.* (2015) reported the conceptual development of an integrated storm water management system in the same study area. Koo & Seo (2017) wrote about improved calibration of modelling parameters, especially Manning's roughness coefficient and depression storage depth in the SWMM model (USEPA 2015), using continuous rainfall and runoff data collected between July 2015 and June 2016. This paper describes an integrated management system developed to efficiently operate a first flush storm water treatment unit for urban streams. This management system is designed to improve water quality during wet weather and to augment flow during dry weather. It consists of three modules – basin modelling using the SWMM urban hydrological model, rainfall monitoring using a set of automatic water quality and flow sensors, and first flush management using a network

Water Practice & Technology Vol 12 No 3
doi: 10.2166/wpt.2017.065

of pumps and valves that control the treatment system from a central area. A pilot scale system was tested against field data collected in a sub-basin of the Gwanpyung-cheon in Daejeon, South Korea.

MATERIAL AND METHODS

The study site

The Gwanpyung-cheon is a small river flowing 5.35 km through industrial and residential areas totalling 10.85 km^2. We selected a part of this basin as a study site. Storm water runoff from a sub-basin area of 1.85 km^2 is connected to a detention pond as shown in Figure 1. The detention pond has a surface area of 5,000 m^2 and a maximum storage volume of 9,700 m^3. An automatic monitoring station was installed where the outlet of the storm sewer meets the inlet of the detention pond.

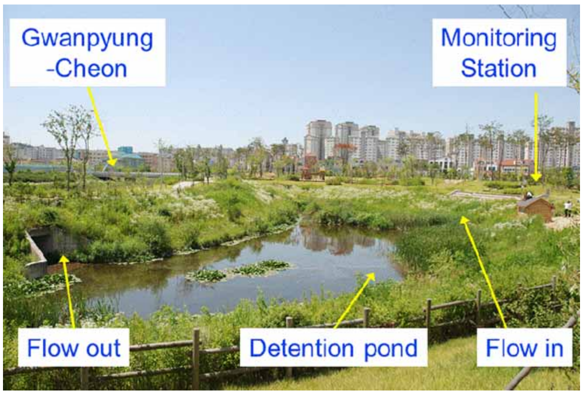

Figure 1 | Automatic storm water monitoring station, flow inlet, flow outlet in a storm water detention pond connected to the Gwanpyung-cheon in Daejeon, Republic of Korea.

Automatic monitoring system

Figure 2 shows the inside and outside of the automatic monitoring station installed at the study site. Equipment includes a rainfall gage on the roof, water quality sensors, an automatic water sampler,

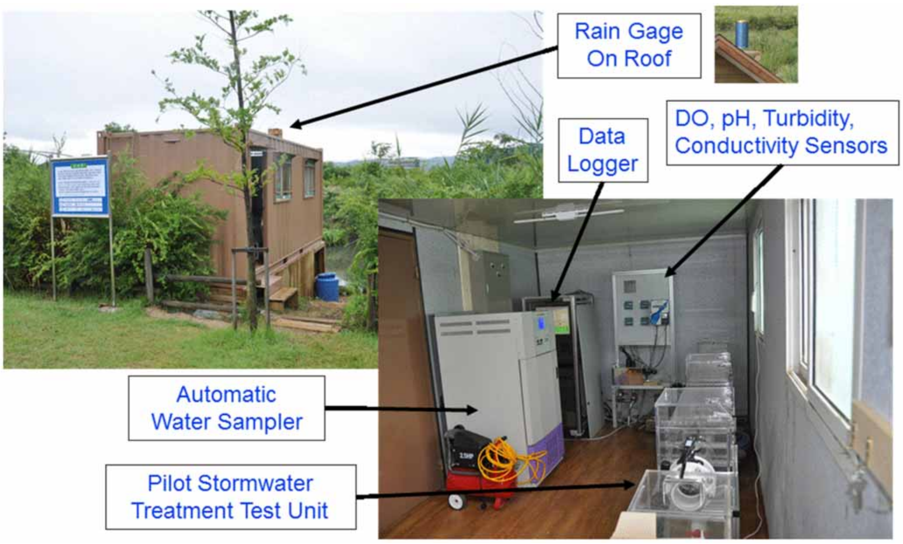

Figure 2 | Automatic storm water monitoring station in the study site.

Water Practice & Technology Vol 12 No 3
doi: 10.2166/wpt.2017.065

data logger and a pilot scale first flush treatment unit. The station pumps samples according to predefined conditions using rainfall volume and water depth in the storm sewer, or any rainfall related conditions defined by the user. General water quality variables including temperature, conductivity, turbidity, dissolved oxygen, and pH can be measured by water quality sensors at the site. An automatic water sampler collects samples at a predefined time interval and stores them at a controlled temperature for further water quality analysis in laboratory.

The flow rate in the storm sewer, Q (m^3/sec), can be continuously monitored using an ultrasonic water level meter as shown in Figure 3. Francis equation for a suppressed rectangular weir is used to estimate flow rate as shown in Equation (1) (Bengston 2011).

$$Q = KBH^{2/3} \quad (1)$$

where Q = Flow rate (m^3/sec), K = coefficient ($m^{4/3}$/sec); 1.84 for this study, B = width of weir (m), H = water depth (m).

Figure 3 | Ultra sonic water level meter in storm sewer and field measurements for validation (Seo *et al.* 2009).

SWMM basin modelling system

We applied the SWMM model to the study basin, calibrating surface runoff flow rate and concentration variations (Figures 4 and 5). Koo & Seo (2017) performed an intensive study to improve the accuracy of modelled flow rate using 59 continuous storm events in the study site between July 2015 and June 2016. They achieved a correlation coefficient of greater than 0.87 for the flow calibration. Figure 5 shows observed and modelled concentrations of TSS, TP and TN abruptly increasing in the initial phase of rainfall and then rapidly decreasing. As shown in Figure 5, it takes about 4 hours for pollutants concentrations become stabilized to their background level although flow rate can vary according to rainfall amount.

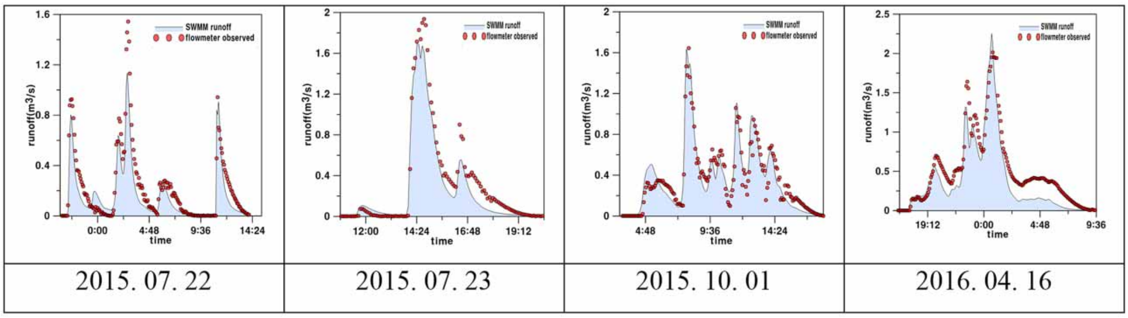

Figure 4 | Calibration of flow rate in surface runoff during rainfall in the study site.

Water Practice & Technology Vol 12 No 3
doi: 10.2166/wpt.2017.065

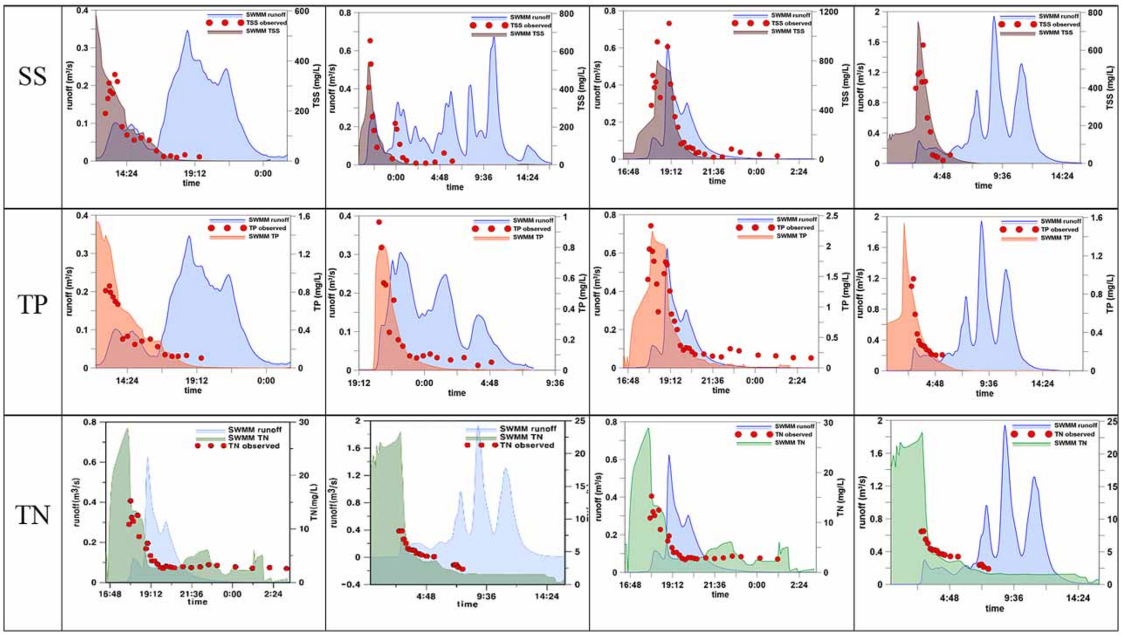

Figure 5 | Calibration of water quality in surface runoff during selected rainfall events in the study site (2016 April–June).

First flush storm water treatment system

Based on previous lab scale research by Koo *et al.* (2015) and Seo and Kim (2016), the first flush storm water treatment unit is illustrated in Figure 6. Figure 7 shows a picture of the pilot scale treatment unit installed in the test bed site. The system consists of settling tanks followed by filtration devices for

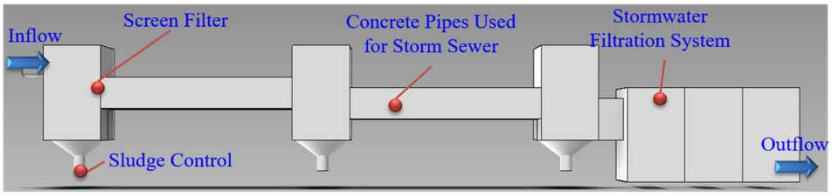

Figure 6 | Conceptual diagram of first flush storm water treatment system.

Figure 7 | Pilot scale treatment system filled with first flush storm water for experiment at the study site.

Water Practice & Technology Vol 12 No 3
doi: 10.2166/wpt.2017.065

additional treatment. This can be installed underground in upland areas along urban rivers. If the water level in the river falls below a specified value, treated water from the system can be discharged to maintain the minimum flow of river. Kim *et al.* (2017) performed an intensive study between March 2015 and October 2016, reporting removal efficiencies of 87.4% for TSS, 57.3% for TP and 43.6% for TN when first flush runoff events were allowed to settle for 24 hours.

Integrated storm water runoff management system (ISTORMS)

This integrated management system is designed for operating the first flush storm water treatment unit effectively (Yin *et al.* 2015). The management system first calculates a hydrograph and concentration graphs using weather forecast data and the calibrated SWMM model. Based on the modelling results, managers can decide whether to discharge newly-treated water or stored water from previous events. Figures 8 and 9 show components and interface screens of ISTORMS developed in this study.

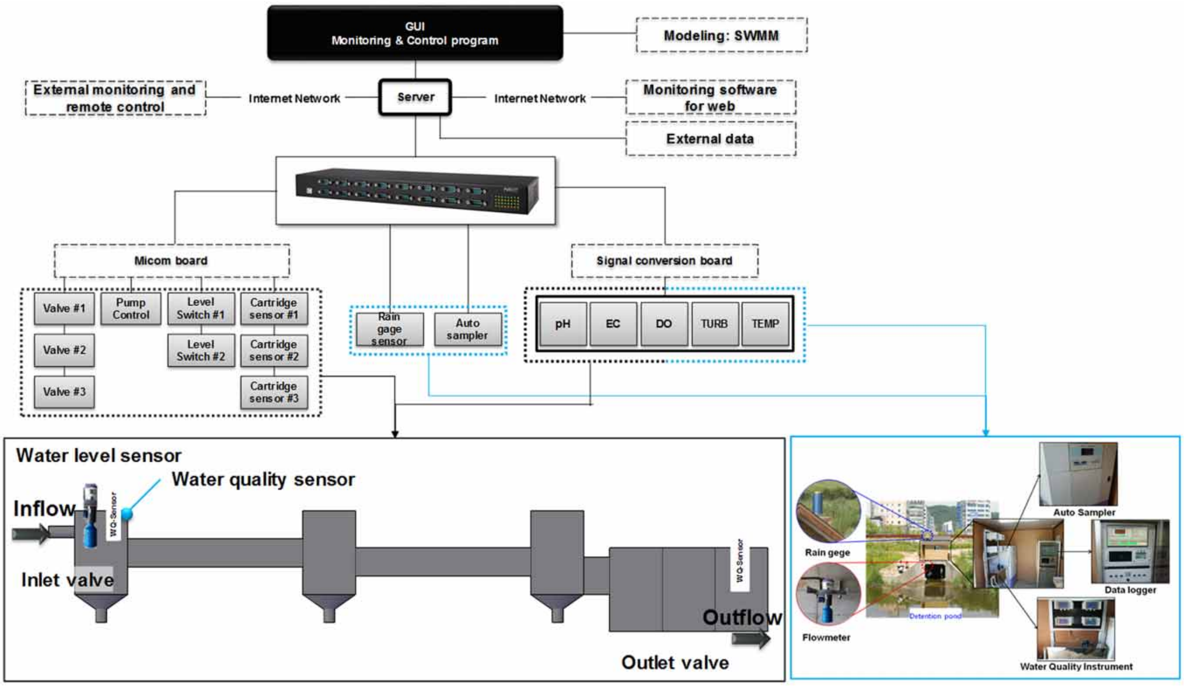

Figure 8 | Components of Integrated storm water runoff management system (Yin *et al.* 2015).

RESULTS AND CONCLUSIONS

An automatic storm water monitoring system was installed in a sub-basin of the Gwanpyung-cheon, a small urban stream in Daejeon, Republic of Korea. The initial monitoring system installed in 2009 has been improved to monitor continuous flow rate and concentration variations during storm events. A first flush runoff treatment unit for settling and fibre filtration was developed, and a pilot scale system was tested in the field. This system removed 87.4% of TSS, 57.3% of TP, and 43.6% of TN without any additional energy and chemicals. The SWMM urban hydrological model was calibrated intensively using this continuous storm water monitoring system.

Finally, the integrated storm water management system ISTORMS was developed for efficient operation of the first flush treatment and storage system by integrating weather forecast information, SWMM modelling results, and automatic storm water quality and quantity monitoring data.

This first flush treatment system can be installed underground in upland areas without interfering with recreational or aesthetic functions. This can be important in urban catchments where land

Water Practice & Technology Vol 12 No 3
doi: 10.2166/wpt.2017.065

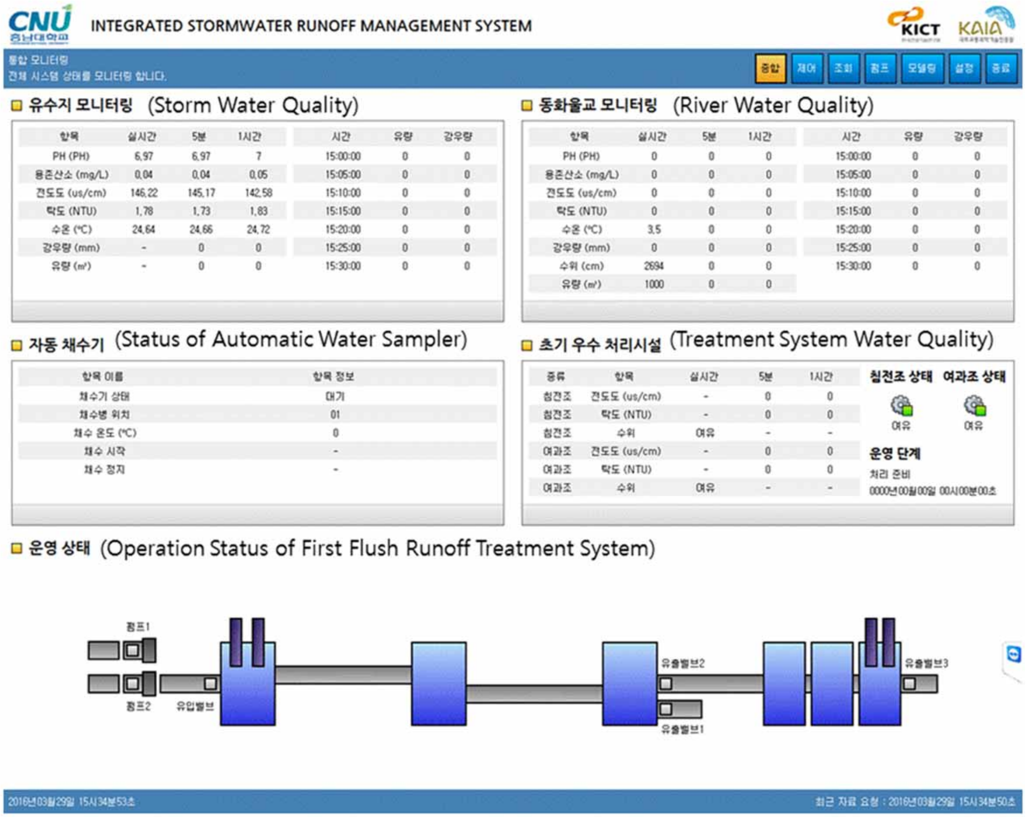

Figure 9 | Interface Screen of ISTORMS (Integrated Storm Water Runoff Management System) developed in this study.

space for treating nonpoint source pollutant is often limited. The system is designed to receive only the first flush of surface runoff, which was 4 hours of surface runoff for this study site. Treatment of the remaining clear part of storm water is not necessary to maintain acceptable stream water quality. The treated water can be discharged locally, if necessary, to provide sufficient moisture to the nearby ecosystem.

We plan to expand this study with full-scale testing at the study site, and aim to promote wider application in urban areas to protect surface water quality and its environment.

ACKNOWLEDGEMENT

This Research was Supported by a Grant (12-TI-C02) from Advanced Water Management Research Program funded by Ministry of Land, Infrastructure and Transport of Korean Government.

REFERENCES

Bengston, H. 2011 An excel spreadsheet as a rectangular weir flow calculator, http://www.engineeringexcelspreadsheets.com/tag/francis-equation.

Kim, J. Y., Seo, D. & Lee, T. E. 2017 Effectiveness of settling treatment system to reduce urban nonpoint source pollutant load by first flush. *J. Korean Soc. Environ. Eng.* **39**(3), 140–148.

Koo, Y. M. & Seo, D. 2017 Parameter estimations to improve urban planning area runoff prediction accuracy using stormwater management model (SWMM). *J. Korea Water Resour. Assoc.* **50**(5), 303–313.

Koo, Y. M., Kim, J. Y., Kim, B. R. & Seo, D. 2015 Development of suspended solid removal method from stormwater runoff using fabric filter system. *J. Korean Soc. Environ. Eng.* **37**(3), 165–174(2015).

Seo, D. & Fang, T. H. 2012 Application of automatic stormwater monitoring system and SWMM model for estimation of urban pollutant loading during storm events. *J. Korean Soc. Environ. Eng.* **34**(6), 373–381.

Water Practice & Technology Vol 12 No 3
doi: 10.2166/wpt.2017.065

Seo, D. & Kim, J. Y. 2016 Reduction of pollutant concentrations in urban stormwater runoff by settling. *J. Korean Soc. Environ. Eng.* **38**(4), 210–218.

Seo, D., Lee, E., Joo, M., Oh, H. J. & Oh, H. S. 2009 Automatic waste load monitoring system from stormwater in Daedeok Tech Valley, Daejeon, Korea. In: *13th International Conference on Integrated Diffuse Pollution Management (IWA DIPCON 2009)*, Seoul, Korea.

USEPA 2015 *Storm Water Management Model User's Manual Version 5.1*, EPA/600/R-14/413b.

Yin, Z., Koo, Y. M., Lee, E. H. & Seo, D. 2015 Development of integrated management system of stormwater retention and treatment in waterside land for urban stream environment. *J. Korean Soc. Environ. Eng.* **37**(2), 126–135.