Monitoring guideline based on low impact development

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Abstract

Urban planning changes the regime, resulting in a new annual and seasonal hydrologic balance, causing frequency distribution changes of peak flows, magnitude and duration of high and low flows. These changes increase the surface runoff volume, decrease evapotranspiration volume, and groundwater recharge rate. Low Impact Development (LID) is used to create, retain, and restore natural hydrologic and water-quality conditions caused by human activities. Monitoring by element is necessary to confirm for LID. A streamlined monitoring guideline is presented that aids the development of strategies to assess the performance and effectiveness of sustainable storm water management. The guideline focuses on hydrology and water quality monitoring, site-specific, and watershed scales. This study puts emphasis on hydrology and water quality monitoring of an LID test site in South Korea.
Keywords: low impact development, monitoring guideline, hydrology, water quality.

1 Introduction

Since the 1950s after the Korean War, urbanization (24.5%) has centered on Seoul [1]. Urbanization in Korea has progressed rapidly, with the urbanization rate increasing from 41.2% in 1970 to 74.4% in 1990, 79.7% in 2000, and 85.4% in 2010 [2]. The increase in pavement area resulting from urbanization has decreased the infiltration rate and the amount of evaporation, damaging the ecological system and contributing to temperature changes [3]. In addition, the ensuing decrease in base flow has led to a reduction in groundwater,

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triggering stream flow depletion and ground weakness. Excessive urbanization has also increased impervious cover and resulting runoff. This has led to outbreaks of flooding and nonpoint source pollution. When a flood occurs, runoff is pushed out of cities, with water resource management focusing on detention ponds. The water cycle of urban river valleys is considerably different after urbanization than prior to the development. Accordingly, countries across the world have taken measures to resolve the issue of water management according to such climate change and urbanization. In response to urbanization and its effect on climatology, countries across the world have launched various water-management initiatives. Among these, LID was initiated by the US Maryland Department of Environmental Resources of Prince George's County to minimize the effects of development and to improve water circulation by simulating the hydrological cycle before development [4]. LID is not a complex or costly engineering approach to rainfall-runoff management; it can minimize the effects of rainfall runoff and nonpoint pollution sources in areas to be developed by ensuring there are sufficient green spaces and natural spaces, and that the functions of the hydrological cycle are maintained.

Recently, in the US, best management practices (BMP), together with LID technology, have been expanded in the construction and integrated management of the overall water circulation system of cities. LID-BMP is an urban water management technology for conservation, flood control, and the environment [5]. Its aim is to maintain natural hydrology and rainfall-runoff patterns of river valleys (i.e., those prior to urbanization and development), to minimize the effects of development on the environment and to accomplish quantitative hydraulic goals.

In Korea, research has largely focused on element technologies and partial application of these, such as the development of rainwater utilization and infiltration facilities, analysis of runoff reduction, size of installation type, and measures that can be partially applied to residential complexes. Research has also concentrated on the long-term effects, the development of infiltration facilities applicable to Korea's drainage system, the measurement of facilities' water infiltration and detention, and the effects of runoff reduction on particular areas [6]. LH (Korea Land and Housing Corporation), Seoul City and Suwon City have developed organic institutional devices to recover rainwater circulation in relation to city management and building site development. In particular, LH has focused on decentralized rainwater management in urban infrastructure and has incorporated this idea in the development of Asan New City land. As part of this process, LH has conducted research on the application of LID techniques to rainwater management, using a guideline that considers the characteristics of each land type, including loads, detached houses, residential complexes, parks, commercial and business facilities, schools, and commercial-residential complexes [7]. However, the partial application of element technologies on a broad scale is risky. Therefore, this study intends to present a guideline for LID facility verification and monitoring suitable for use when constructing a city-wide water circulation system.

2 Trends in domestic-overseas integrated LID monitoring

Precise collection and analysis of hydraulic and hydrological data forms the most important part in LID monitoring research and is an essential element in ensuring the accuracy of LID techniques and the functioning of LID sites. Rainfall and meteorological data are a key element in the evaluation of LID areas. Measurement of discharge affects the evaluation of precipitation concentration and water pollution. For design and application of LID, hydraulic and hydrologic monitoring information is needed.

2.1 Overseas integrated LID monitoring

North Carolina State University in the US built a test bed of approximately 33,000m^2 in downtown Carrboro to assess LID facilities. Monitoring of LID facilities was conducted by dividing the period into before construction, during construction, and after construction from 2003 to 2008. Based on the aforementioned, a monitoring concept and approach for LID verification were developed [8].

The US California Department of Water Resources constructed an integrated LID facility test bed in 2011 and initiated empirical research on the efficiency, constructability, and maintainability of LID facilities. The research is aimed at establishing design and maintenance standards for LID facilities appropriate for this area [9]. In this complex, planter boxes, a permeable paver system, porous concrete, biofiltration, bioretention, and infiltration basins were installed. Through an integrated monitoring and testing system, including rainfall, inflow, outflow, and nonpoint water quality, it is leading development in technologies appropriate for the area.

The Wetland Studies and Solutions, Inc. has constructed an LID building and monitoring site in Virginia Gainesville in the US and is conducting ongoing research on LID facilities [10]. The company installed LID facilities and networks in a total area of 16,000m^2 and evaluated the performance of a hydraulic system through flow analysis.

Oregon Portland in the US has conducted a number of LID projects and undertakes continuous monitoring of each LID facility [11]. Its LID facilities are located all over Portland. The city has created diverse facilities and made efforts to include them in monitoring. Facility types include ecoroofs, green streets, and infiltration. The city is improving LID design and functions for maintenance and public stability and performing research on water circulation by increasing the number of LID monitoring points.

2.2 Domestic LID monitoring

Early domestic LID research focused on the analysis of outflow characteristics of river valleys using rainfall-runoff models. Jaeeung *et al.* [12] examined rainfall-runoff characteristics of Munsan as a demonstration area and applied the results to permeable pavement under different scenarios. They proved that with a higher percentage of permeable pavement, total outflow and peak outflow rates were reduced, and peak and outflow hours were delayed, thereby decreasing the rainwater concentration.

Eunjin *et al.* [13] focused on water circulation in improving urban green land functions. As alternatives to it, they applied LID, including stormwater wetlands, rain gardens, grassed swales, filter strips, buffer strips, and rooftop runoff management. They verified the efficiency of the aforementioned and measured the amount of outflow during rainfall, showing that it decreased during rainfall. To verify the efficiency of LID techniques, Saebom [14] built a model with a detention function and permeable and nonpermeable layers. They ran this model on Hydrological Simulation Program-Fortran and verified their findings in various studies of river valley management. Based on their simulations, the amount of outflow was decreased by about 30%, and peak flow was reduced by about 50%, showing a smooth hydraulic curve.

Domestic LID research has largely employed rainfall runoff models and derived outflow simulation results based on curve number values according to land use rates and soil characteristics prior to and after LID. In the US, LID techniques have been monitored and integrated LID facilities have been constructed and studied with empirical and comprehensive research. In contrast, research on LID techniques in Korea has concentrated only on permeable pavement techniques. Research on other LID techniques is lacking.

Recently, a research group at Busan University, Korea has commenced scientific inquiry into LID urban water circulation technologies. The research group will develop an experimental test bed and apply the results of their study to a domestic integrated LID test bed. Comprehensive monitoring of the test bed and apply the results of their study to a domestic integrated LID test bed. Comprehensive monitoring of the test bed will be conducted.

3 Guidelines for LID monitoring

Guidelines for LID monitoring identify which monitoring elements to select to verify the effects of LID. As described in the Introduction, LID was largely developed to reduce rainwater outflow and nonpoint pollution sources. Thus, monitoring of LID elements should focus primarily on these factors. In addition, to verify the effects of LID, changes resulting from LID facilities need to be predicted. The latter may be selected as a secondary element of LID monitoring.

The guideline for LID monitoring in this study consists of a comprehensive description of the hydraulic and meteorological area, selection of monitoring tools necessary to verify LID effects, and selection of monitoring tools necessary to verify other changes. Later, this guideline will be applied to monitor the test bed.

3.1 Meteorological monitoring

The purpose of meteorological monitoring is to examine current meteorological conditions. The elements of meteorological monitoring include precipitation, wind, temperature, and air pressure.

- Precipitation monitoring: observing precipitation is the most important element to verify outflow reduction effects of LID facilities. At present, precipitation observation in Korea involves the use of rain gauges and radars.
- Wind velocity monitoring: atmospheric movement is an important element for precipitation prediction and warning issuance, but it has a low correlation with LID and therefore is excluded from monitoring items.
- Ground temperature monitoring: ground temperature does not directly affect LID, but it is changed by LID facilities. Therefore, it may be considered as a secondary monitoring element.

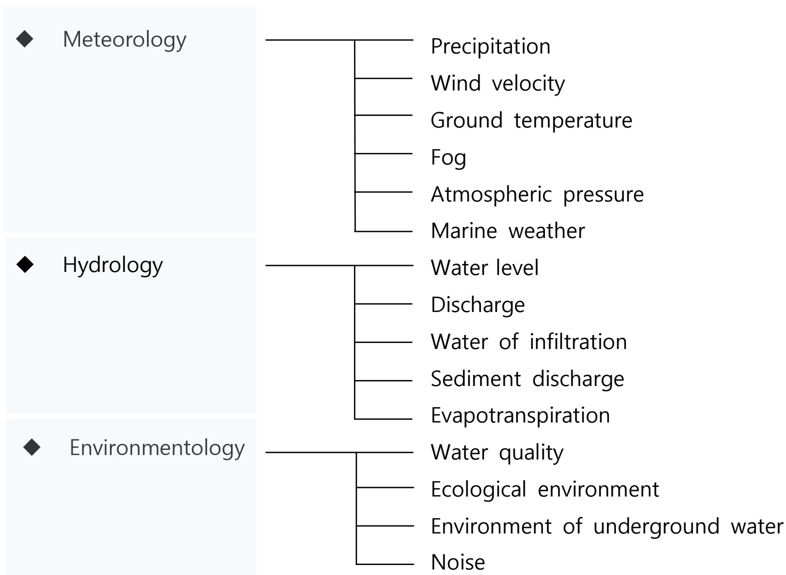

Figure 1: Diagram of major items monitored in the study.

3.2 Hydraulic monitoring

Hydraulic observation is a means to quantitatively clarify the water circulation process. Water-level and discharge monitoring in hydraulic observation are the most important elements to verify outflow reduction effects of LID. Sediment discharge and evapotranspiration monitoring are also included in hydraulic monitoring.

- Water-level monitoring: water-level observation should precede discharge observation. It is a crucial element to verify outflow reduction effects of LID. The groundwater level may affect the amount of outflow in larger LID facilities.

- Discharge monitoring: verification of LID includes discharge observation. Appropriate methods to measure discharge should be selected according to the shapes of rivers and measurement purposes.
- Sediment discharge monitoring: observation of sediment discharge from rivers is one of elements necessary for river plans aimed at developing and managing water resources. Sediment discharge observations may be considered in LID verification in large cities.
- Evapotranspiration monitoring: the amount of evapotranspiration can influence the amount of discharge when LID facilities are distributed in a wide range or when spaces retain a lot of water. Therefore, evapotranspiration monitoring is a secondary element to verify the effects of LID facilities.
- Water infiltration monitoring: in LID facilities, permeable pavement and rainwater detention facilities are mostly used to reduce discharges. The amount of water infiltration is an essential element that requires observation using direct and indirect methods.

3.3 Environmental monitoring

Environmental monitoring is a technology to detect pollution of air, water, soil, and groundwater. Environmental pollutants do not exist separately in the three media. The process of the production, diffusion, movement, and disappearance of pollutants in air, water, and soil is linked. In particular, water environment is an environmental factor most closely related to ordinary life among the pollution media, and industrial and ordinary human activities are the most direct source of pollution.

- Water quality monitoring: the purpose of water quality monitoring is to analyze long-term water quality changes through various water quality investigations of rivers, lakes, and groundwater within a river valley. Dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, suspended materials, hydrogen ion concentration, and the number of colon bacillus are investigated in water quality observations.
- Ecological environment monitoring: changes in the ecological environment due to LID facilities are expected to be very small. However, areas sensitive to change may be included in ecological environment monitoring of LID facilities.

3.4 LID monitoring selection

Sections 3.1 to 3.3 described the major elements monitored in LID. Table 1 shows the correlation between each LID facility unit and observational elements. The facilities were divided into Site A, Site B, and Site C, and each unit has a different size. Site C contains a river. The number of monitoring items increases when the size of the facilities increases and when the facilities are influenced by a river.

Table 1: Correlation between each facility unit and each monitoring element.

		Site A	Site B	Site C
Meteorology	Precipitation	High	High	High
	Wind velocity	Low	Low	Low
	Ground temperature	Medium	Medium	High
	Atmosphere pressure	Low	Low	Low
	Fog	Low	Low	Medium
Hydrology	Water-level	High	High	High
	Discharge	High	High	High
	Water of infiltration	High	High	High
	Sediment discharge	Low	Low	High
	Evapotranspiration	Low	Low	Medium
	Ground water level	Low	Low	Medium
Environmentology	Water quality	High	High	High
	Ecological environment	Low	Low	Medium
	Environment of ground water	Medium	Medium	Medium
	Noise	Low	Low	Low

4 Application of the guideline

4.1 Applied river valley

This study constructed a test bed (4,800m^2) in the second campus of Busan University in Yangsan City, Korea to establish technology for verifying the efficiency of diverse LID element technologies. A test bed reflects the characteristics of a hydrophilic zone (proximity to a river, groundwater level, and soil characteristics). In the present study, it was used to verify the efficiency of diverse LID element technologies.

The study area, Yangsan City, is surrounded by the Taebaek Mountains to the east and the Sobaek Mountains to the west and is located south-east.

Table 2 shows meteorological data from Busan Weather Station, which is located near Yangsan City. The annual average temperature is 14.7ºC, the annual average wind velocity is 3.3 m/s. The annual precipitation amount is 1,585.0 mm, and about 74% of precipitation falls between April and August.

The study area is covered by alluvial layers formed through the accumulation of pebbles, sand, and mud by the river activities.

Figure 2: Study area.

4.2 The current status of guideline application

The test bed that applies the guideline quantitatively embodies the results of researching, developing, and applying LID element technologies. It is an integrated complex of water circulation type aimed at expansion and on-the-spot distribution of LID element technology application cases. The LID monitoring guideline may be differentiated by site size, verification facilities, and monitoring period. The final purpose of this study is to apply the guideline to the entire test bed (as displayed in Figure 3). Thus far, the guideline has been applied to only roads and parking lots. Site A is the smallest of all the sites.

The parking lot monitoring elements in the guideline are defined by meteorological parameters, such as precipitation and ground temperature, hydraulic parameters, such as the water level, discharge, and water infiltration, and environmental parameters, such as the water quality and the groundwater environment. The road monitoring elements are the same as the parking lot monitoring elements. However, the area covered by roads is small, and they are adjacent to the parking lots. Thus, precipitation, ground temperature, water level, and discharge were selected as the monitoring items.

Table 2: Monthly average weather conditions for 10 years measured at Busan Weather Station (from 2002 to 2011).

Item / Month	Temperature (°C)			Precipitation (mm)	Wind velocity (m/s)	
	Ave.	Max	Min		Ave.	Max
1	3.2	7.7	-0.4	24.5	3.5	11.4
2	5.8	10.5	2.1	59.0	3.4	11.7
3	8.7	13.4	4.9	79.6	3.6	12.2
4	13.4	17.9	9.9	160.5	3.7	13.2
5	17.3	21.4	14.1	201.5	3.2	12.3
6	20.9	24.5	18.1	174.7	2.9	11.8
7	23.8	26.8	21.5	396.5	3.2	12.9
8	25.7	29.0	23.3	235.9	3.3	13.1
9	22.6	26.3	20.0	129.1	3.3	14.1
10	17.9	22.5	14.6	60.9	2.9	10.6
11	11.9	16.4	8.4	38.4	3.1	11.2
12	5.6	10.0	1.9	24.5	3.3	11.0
Ave.	14.7	18.9	11.5	132.1	3.3	12.1

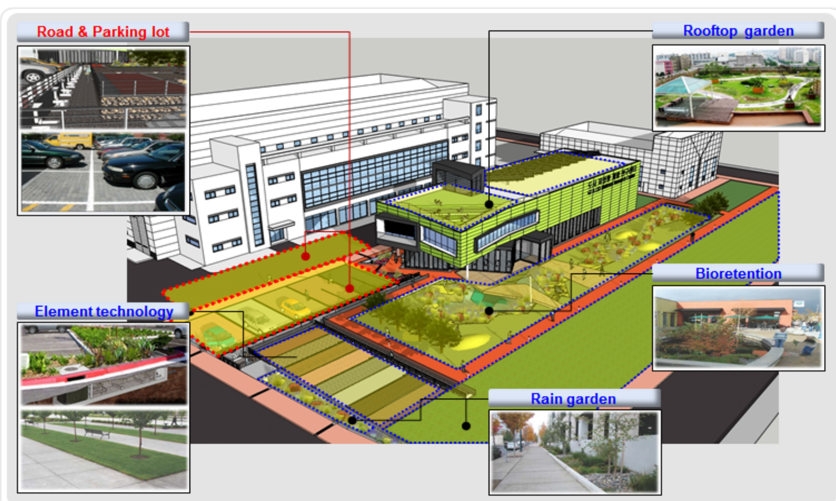

Figure 3: The plan for the facilities for the LID verification experiment.

Monitoring for LID verification is divided into real-time monitoring (precipitation, ground temperature, water level, discharge, and water infiltration) and non-real-time monitoring (water quality and groundwater environment). At each site, the water quality analysis will be conducted using samples collected with an automotive sampler. Therefore, the monitoring results will also be required. An automotive sampler for the analysis of water levels, discharge, and water filtration will be applied to the test bed using an improvement of the method employed by Washington Stormwater Center (as displayed in Figure 4).

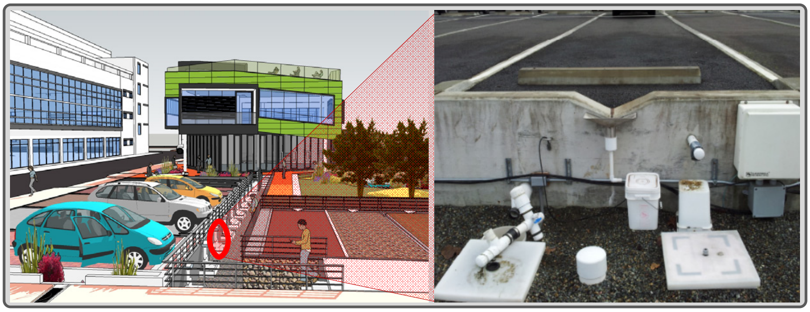

Figure 4: Design plan for LID monitoring.

5 Conclusion

This study is aimed at developing technologies for low impact development, construction, and the operation of a healthy urban water circulation infrastructure. The test bed is being designed to establish the efficiency of the technology necessary for the development and evaluation of diverse LID element technologies. The guideline that is under development for monitoring and verification was applied to parking lots and roads. In the future, the guideline will be applied to facilities other than parking lots and roads.

The technological ground to determine design parameters for LID element technologies, to present Korean evaluation standards, and to improve applicability and feasibility of technologies is intended by monitoring the whole hydraulic process using the data obtained with the monitoring system constructed by the guideline for LID verification. In addition, the results of the application of the guideline to the test bed will be applied to Asan Tanjung District (Site-B; 1,750,000m^2) and Eco Delta City (Site-C; 12,000,000m^2) to construct an LID monitoring guideline suitable for Korea.

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References

[1] Myungrae J., Political Economy of Regional Differentiation, Seoul, Hanul, 1991.

[2] Myungrae J., Trends and Prospects of Urbanization, *Economy and Society*, 2003.

[3] Seungho L. & Inhye H., The Impacts of Urbanization on Changes of Extreme Events of Air Temperature in South Korea, *Journal of the Korean Geographical Society*, 2011.

[4] Marcus H. & Michael C., Using Low Impact Development (LID) Techniques to Retrofit an Existing Urban Mall, The Annapolis Mall Case Study, 2007.

[5] Sangjin L., Yeongjin H., Gyunam L. & Yonggyu G., Waterfront Planning Based on Low Impact Development. *Magazine of Korea Water Resources Association*, Water for Future, 2013.

[6] Jongsang S., Taegoo L., Younghae H., Yengeum K. & Namhee K., Development and Application of the Rainwater Infiltrating Equipment for the Decentralized Stormwater Managements, *Journal of the Korean Institute of Landscape Architecture*, 2004.

[7] Kyounghak H., Jongnam K., Jeongik O., Giltae K., Gihong L. & Yonghwan K., Application of the Rainwater Management and Cnstructed Wetland System for Implementation of Water-cycle in Asan New town, Korea Land & Housing Corporation, 2008.

[8] Poresky A., Quigley M., Leisenring M., Strecker E. & Clary J., Site-level LID Monitoring and Data Interpretation: New Guidance for International BMP Database Studies(Part 2), *American Society of Civil Engineers(ASCE)*, 2010.

[9] Riverside County Flood Control and Water Conservation District, www.rcflood.org

[10] Wetland Studies and Solutions, Inc. (WSSI), http://lidweb.wetlandstudies.com

[11] 2014 Stormwater Management Manual, the City of Portland, 2014.

[12] Jaeeung Y., Woongwang Y., Shimjae H. & Taeho K., Analysis of Stormwater Runoff Reduction Effects by Using Porous Pavement, *Journal of the Korean Society of Civil Engineers*, 2001.

[13] Eunjin P., Kyuyi K. & Hyunjung L., Improving the Function of Urban Green Space for Stormwater Management, Gyeonggi Research Institute, 2007.

[14] Saebom L., BASINS/HSPF-LID development for watershed management in Korea, 2011.

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