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Performance Review of Sustainable Urban Drainage System with Lid Concept

Boris Karlop Lumbangaol, Agustinus Purna Irawan, Wati A. Pranoto
Civil Engineering Doctoral Program, Universitas Tarumanagara, Jakarta, Indonesia
Boris.karlop90@gmail.com, agustinus@untar.ac.id, watip@ft.untar.ac.id

ABSTRACT

Purpose: Land conversion reduces infiltration areas and increases runoff that causes flooding and inundation. Efforts to reduce the impact are very important to minimize economic losses. However, large-scale attempts by widening rivers and land acquisition are difficult to implement, especially in urban areas. It requires the management of rainwater runoff at the source. The new paradigm for sustainable urban drainage systems is the LID (low impact development) concept, which approaches hydrology as a framework, considers micromanagement, and controls rainwater at its source.

Design/methodology/approach: It also uses simple non-structural methods to create a multifunctional area.

Findings: LID can handle the flood water level and volume as well as the rise and fall of the base flow that will be released to the downstream site and filter waste. Its application consists of several units that depend on local needs, such as porous and semi-permeable pavements, retention and detention reservoirs, wetlands, infiltration trench, ditch, gulley, and well. It also includes a rooftop reservoir, green roofing, rainwater reuse, underground reservoir, grassed strips, and bioswale.

Originality/value: This paper is an original work.

Paper type: Research paper

Keywords: *Drainage, Land use, LID*

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I. INTRODUCTION

The impact of land use from rice fields to settlements, especially in recharge areas, is a change in the behavior and function of surface water. As a result, there is a reduction in base flow and water infiltration into the soil (infiltration). On the other hand, an increase in surface runoff during the rainy season causes an imbalance in the water system, called a change in the hydrological cycle.

The above change significantly increases inundation in urban areas. The predictor variables are 1. There is a negative and significant relationship between Open Water Space and inundation, 2. There is a positive and meaningful correlation between Building Open Space and inundation, and 3. There is a negative and significant connection between Green Open Space and inundation.

Regulation of the Minister of Public Works Number 12/PRT/M/2009 dated June 24, 2009, concerning Guidelines for the Provision and Utilization of Non-Green Open Spaces in Cities/Urban Areas, Planning for Infrastructure, Facilities, and RTNH utilities based on the concept of Low Impact Development (LID) and Regulation No.11/PRT/M/2014 states that there are three facilities for managing rainwater in urban areas, namely rainwater collection, retention, and detention facilities.

The explanation above shows that efforts to reduce the risk of flooding and inundation are very important to prevent economic losses. However, some related activities are difficult to implement, especially in urban areas. One way that can be done is the management of rainwater runoff at the source with the concept of Low Impact Development (LID).

ISSN : 2597-4785 (ONLINE)
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The principle of a Sustainable Urban Drainage System aims to integrate the management of Surface Water Runoff in a Quantitative, Qualitative, Natural Conservation, and Environmentally Friendly manner toward biodiversity. The approach for applying LID to manage rainwater runoff at the source Hood & Mukty (2007) is to conserve and use natural features to protect water quality (ARMCANZ, 2000).

The formulation of urban drainage problems is seen from the local urban geography and residents' expectations:

1. Problems related to the quantity of runoff. The increase in runoff volume and peak flow causes environmental and property damage. Extreme conditions can cost lives.
2. Problems related to the quality of urban runoff. Rainwater flows carry various pollutants, dirty water, heavy metals, and contaminated sediments. This pollution is difficult to control, reducing surface water quality.
3. Problems related to landscape aesthetics and damage to biodiversity.
4. Problems related to the difficulty of increasing the cross-sectional capacity collided with land and building acquisition.

This article aims to provide scientific information on sustainable urban drainage systems development based on the concept of Low Impact Development by managing rainwater runoff at the source.

II. LITERATURE REVIEW

A. Urban Drainage

It is one of the basic facilities designed as a system to serve the community. It is an important component of urban planning to reduce and remove excess rainwater from an area of land, then as a controller of groundwater quality in terms of salinity.

B. Sustainable Urban Drainage System

Based on the Regulation of the Minister of Public Works Number 12/PRT/M/2009 dated June 24, 2009, the application of LID is to manage rainwater at its source, minimize surface water from rainwater, and control the resulting solution through natural retention and detention.

III. RESEARCH METHOD

The research uses scientific analysis, namely quantitative descriptive, which collects primary, secondary, and tertiary materials (Ali, 2011:23). It is chosen because many studies, papers, and other written materials explore sustainable urban drainage systems. The primary regulations and laws review consists of statutory regulations and related books.

RESULTS AND DISCUSSIONS

A. The surface flow control concept

Surface flow control as a result of development is carried out by paying more attention to the hydrological conditions of the development area. Hydrological functions such as storage, infiltration, and groundwater filling or the volume and frequency of runoff discharge are maintained by handling small-scale rainwater flows in a comprehensive and integrated manner, be it retention and detention areas, reduction of watertight surfaces, and extension of concentration time. The basic concept that describes the core of LID is planning, whose site plans can be implemented and implemented thoroughly for success. These basic concepts include Department of Environmental Resource (1999):

B. Using Hydrology as a Framework

The hydrological approach in the area planning process begins with identifying and maintaining sensitive areas that affect flows and their buffers, flood plains, wetlands, slopes, highly permeable soils, and protected forests. The subsequent analysis is to create an unavoidable watertight area to minimize the impervious surfaces in direct contact with each other. Bioretention areas, flow channel extensions, infiltration areas, drainage canals, retention areas, and other practices can control and modify the impervious area. Using hydrology in area planning is to maintain the condition of pre-development hydrological characteristics, add aesthetic elements, and provide recreational areas.

ISSN : 2597-4785 (ONLINE)
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C. Micromanagement

The key to creating a LID is the concept of micromanagement. It requires a change of perspective in looking at the micro sub-sheds to be controlled, the microtechniques, location, size of the control, and frequency of controlled rainwater flow. Small-scale management techniques are carried out on small sub-watersheds, residential, and public areas, providing a broad distribution of rainwater flow control in the observation area. It offers an opportunity to maintain the hydrological functions of the site, such as infiltration, external storage, and rainwater interception, to reduce the concentration-time (Tc).

D. Control of rain flow at the source

The key to improving the hydrological function of the developed site is to minimize and reduce the impact of land-use changes. It is based on the allocation of source area control strategies implemented with micromanagement techniques.

E. The use of simple and non-structural methods

Using the LID technique can reduce the use of materials such as concrete or steel. Materials such as local plants, soil, and gravel can more easily blend into the area, making their appearance more natural. The unity of this facility provides an opportunity to imitate the biological hydrological function and provide additional aesthetic value.

F. Create a multifunctional area

The LID unit offers an innovative alternative in an integrated urban stormwater flow management approach with area planning where runoff can be managed on a small scale and controlled at the source of pollution. Every city park or other infrastructure (roofs, roads, parking lots, and green areas) can be designed to be multifunctional by making it detention, retention, filter, or used for water flow.

G. The following explains the benefits of LID units.

Table 1. Benefits of LID unit in Sustainable Urban Drainage System (Author, 2022)

LID Unit	*Purpose*	*Benefit*
Permeable Pavement	*Suppress runoff rate*	*Take advantage of local ecosystems.*
Semi Permiable Pavement	*Absorb rainwater at the source*	*Reduce surface water pollution*
Retention and detention reservoirs	*Prevent groundwater subsidence*	*Catch rainwater for reuse*
Wetlands,	*Increase groundwater reserves*	*Enhance the look and feel of outdoor spaces*
Infiltration trench	*Improv the hydrological cycle in the built-up area*	*Bring economic benefits to the local area*
Infiltration ditch and gulley		*Improve the quality of life of people who use the space*
Infiltration well		*Improve the mental and physical health of people using the space*
Rooftop reservoir		*Provide recreational and educational benefits*
Green roofing		*Improve water quality*

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ISSN : 2597-4750 (PRINTED)

Reuse of rainwater

Underground reservoir

Grassed strips

Bioswale

H. Review of relevant laws/regulations

As a state of law, regulating sustainable urban drainage system management requires non-discriminatory legal instruments. It is the legal umbrella and policy base in accelerating the program development implementation. The following are the relevant laws and regulations:

1. Law No.26 of 2007 concerning spatial planning where the area of green open space is at least 30% of the size of a city,
2. Regulation of the Minister of Public Works Number 12/PRT/M/2009 dated June 24, 2009, concerning Guidelines for Provision and Utilization of Non-Green Open Spaces in Cities/Urban Areas, Planning for RTNH Infrastructure, Facilities, and Utilities based on the LID Concept,
3. Regulation of the Minister of the Environment Number 12 of 2009 concerning the use of rainwater:
4. Article 3: Every person in charge of the building must use rainwater, one of which is biopore infiltration holes, holes made vertically into the ground, with a diameter of 10-25 cm and a depth of about 100 cm or not exceeding the depth of groundwater level.
5. Location requirements are areas around settlements, parks, parking lots, and trees. In regions where rainwater passes, the depth is about 100 cm or does not exceed the depth of the groundwater level.
6. Regulation of the Minister of Public Works and Public Housing No. 15/PRT/M/2015 concerning the Organization and Work Procedure of the Ministry of PUPR with the Principles of a Sustainable Urban Drainage System for the integration of Quantitative, Qualitative, Natural Conservation, and Environmentally Friendly Surface Water Runoff management for biodiversity. This system is a new paradigm for handling environmental drainage using the zero runoff method.
7. Minister of Public Works Regulation number 12/PRT/M/2014 concerning implementing urban drainage systems, a new paradigm that is environmentally friendly and is becoming a major concept in the international community. It is also performing a new understanding of the eco-hydraulic concept.
8. Governor Regulation No. 20 of 2013 concerning rainwater infiltration wells
9. Article 1: Infiltration wells are artificial infiltration systems that can accommodate and absorb water into the ground sourced from rainwater, water used for ablution, air conditioning, and other wastewater treated following the water quality standards required by laws and regulations. It can be in the form of wells, ponds, channels, or infiltration fields.
10. Article 6: In addition to infiltration wells, infiltration ponds can be made with the following requirements: Must be in an open space, the bottom of the pond must not be impervious to water, and the infiltration depth is at least 1 m from the original ground surface.
11. Indonesian National Standard 8456:2017 concerning rainwater infiltration wells and ditches: The cross-section of rainwater infiltration wells is rectangular or circular. It is possible to take other shapes. The cross-sectional side of rainwater infiltration wells is 80 cm to 100 cm. The soil structure that can be used must have a coefficient of soil permeability > 2.0 cm/hour.

I. Performance review of Sustainable Urban Drainage System LID concept

LID has a variety of methods needed to maintain hydrological conditions, such as the pre-development period. The first step is to retain the potential runoff by controlling or making the runoff coefficient as small as possible. It can be done by combining the following (Department of Environmental Resources, Prince George's County, Maryland, 1999): Making roads narrower/smaller, maximizing plant maintenance, minimizing disturbance, opening drainage channels, keeping soils with high infiltration, and placement in soils with high infiltration. The comparison of hydrological responses to existing conditions after construction without and with LID is below.

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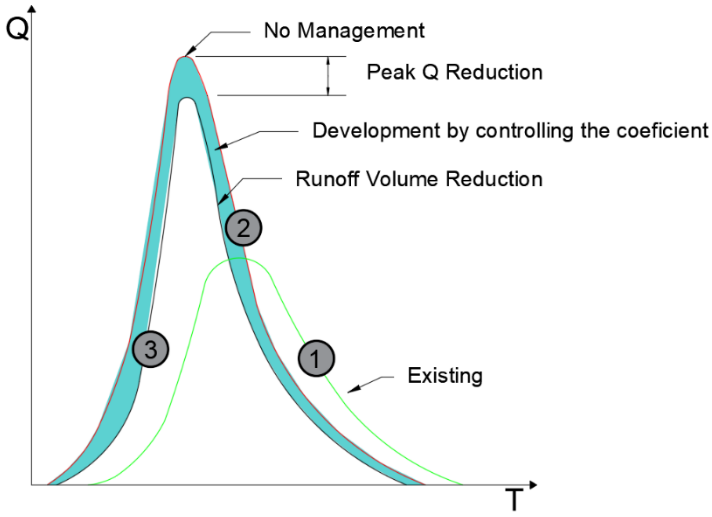

Figure 1. Impact of using LID post-development Source: DERPGC, 1999

Hydrograph 1 shows the existing conditions before construction, where the peak discharge is still low and the time required to reach it is quite long. Hydrograph 2 shows the flow response in the area after development without environmentally sound management. It shows the short concentration time as a reflection of the increase in the total watertight area compared to the existing condition and a decrease in time to peak discharge, a significant increase in peak discharge, and runoff volume and velocity. Meanwhile, Hydrograph 3 proves the area's response to hydrology after construction by using flow management that reduces the watertight size and increases storage volume. It can be seen that there is a reduction in both the volume and peak discharge. It occurs because the smaller runoff coefficient causes the flow velocity to be smaller and more rainwater infiltrates into the soil due to the availability of permeable land.

The next step in the LID management system is maintaining the concentration-time (Tc) as in the pre-development period. Techniques that can be used are as follows Department of Environmental Resources (DERPGC) (1999): Maintain flow path length, increase surface roughness value/provide plant area, restrain flow/bio-retention, minimize disturbance (e.g., minimizing compaction and alteration of existing vegetation), making slopes as small as possible in built-up areas, breaking impervious areas, and connecting escape areas and greenery. The hydrological response for the concentration time before and after the construction can be seen below.

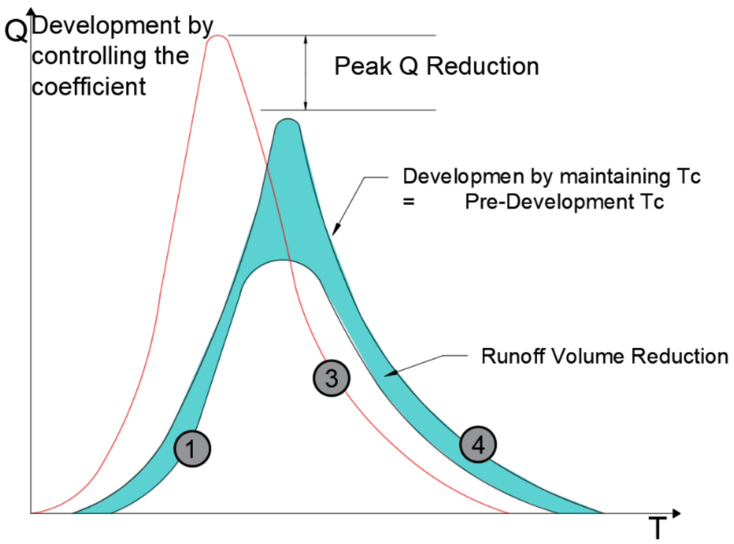

Figure 2. Hydrograph in the area with reduced runoff coefficient and timing of concentration

Source: DERPGC, 1999

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Hydrograph 1 shows the existing conditions before construction, where the peak discharge is still low and the time required to reach it is quite long. Hydrograph 3 offers the area's response to hydrology after construction using flow management that reduces the impervious area and increases storage volume. It can be seen that there is a reduction in both the volume and peak discharge. It occurs because more rainwater infiltrates the soil due to the availability of permeable land. Meanwhile, Hydrograph 4 keeps the concentration time the same as in the pre-development period. It is seen that the peak discharge value is below that of the peak of development without taking into account the concentration-time. Meanwhile, the time to reach peak discharge is longer than construction without considering the time of concentration and is the same as the existing conditions before construction.

Runoff volume control is carried out using LID. It reduces the flow volume after construction and peak discharge due to increased storage volume and infiltration capacity. LID units to maintain water storage are Bioretention, Infiltration Ditches, filter/buffer vegetation, and rainwater storage tanks.

If enough water enters the LID unit, the peak discharge will be reduced to the same level as the pre-development period, perhaps even smaller, which can be explained below.

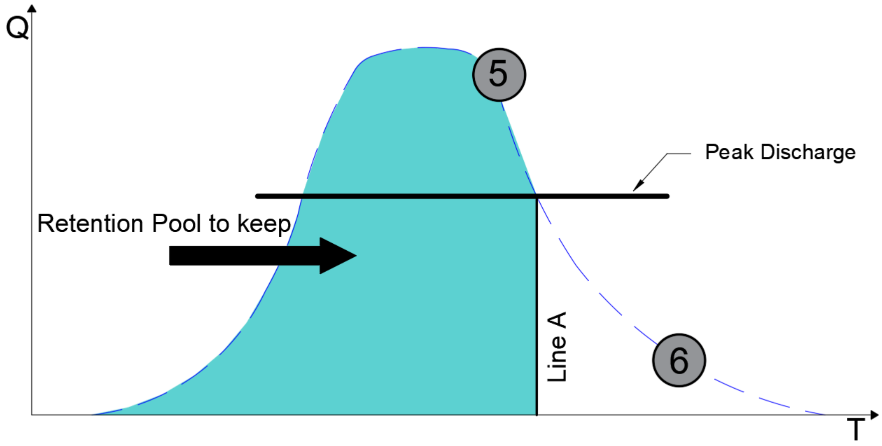

Figure 3. The need for retention ponds to maintain peak discharge in the built-up area,

Source: DERPGC, 1999

Hydrograph 5 shows the incoming flow after construction. Due to the presence of a LID, runoff is not released until the maximum capacity is exceeded. Line A shows the LID limit. Once passed, the water will be drained out, as demonstrated by Hydrograph 6. It maintains the runoff volume and controls the peak discharge from the runoff. Although the runoff coefficient and concentration-time are maintained as in the pre-construction period, it is sometimes necessary to add a flow containment area due to limitations in space availability. The number of storage areas to maintain runoff volume may not be sufficient to maintain peak discharge. Therefore, a flow containment area is needed. Several techniques for retaining flow include channels with check dams, pipe drainage, inlet restriction, wider pipelines, and rainwater catchment tanks.

The results of implementing water flow containment are shown below.

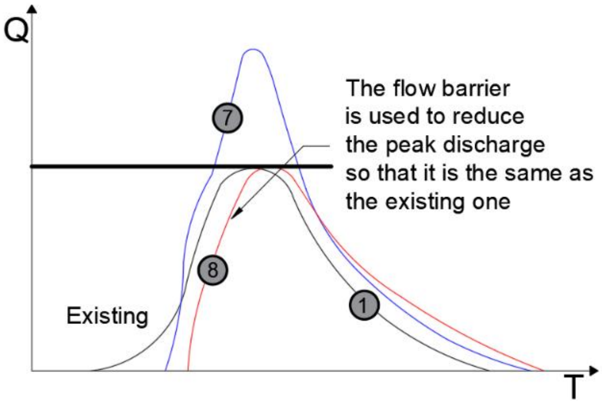

Figure 4. The effect of adding a flow barrier on the built-up area Source: DERPGC, 1999

Hydrograph 7 shows the response of conditions after construction using LID. The size is insufficient to maintain the peak runoff discharge during the pre-development period, so a flow containment area is needed. Hydrograph 8 proves that using flow containment techniques can decrease the peak runoff discharge.

IV. CONCLUSIONS AND SUGGESTIONS

A. Conclusions

Implementation of Sustainable Urban Drainage Systems LID concept means evolution in drainage systems. It is a hydrological approach as the basis for development, which results in changes in the pattern of buildings' physical development by maintaining an area's natural characteristics.

B. Suggestions

The increase in land use and land cover in urban areas is a source of urban drainage problems. As a consequence, the government's role is needed to implement several legislations. The first is Law No. 26 of 2007, regarding spatial planning in which the area of Green Open Space is at least 30% of the size of a city. The second is Minister of Public Works Regulation No. 12/PRT/M/2009 dated June 24, 2009, regarding guidelines for the provision and utilization of Non-Green Open Space in urban areas and planning for RTNH Infrastructure, Facilities, and Utilities that is guided by the concept of Low Impact Development (LID).

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