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Research Article

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Hydrological Basics of Analysis and Evaluation of Low Impact Development Methods in Surface Water Management

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Abstract Low Impact Development (LID) is one of the methods of urban runoff management to maintain or restore the natural hydrological conditions of a catchment area and improve the environment in that catchment area. In order to reduce the volume and discharge of the runoff peak, the runoff pollution is treated as well as the infiltration and feeding of groundwater is done. In general, in this method, the principles of urban planning are reviewed from a hydrological point of view, and based on this, construction and development are carried out according to the preservation of permeability characteristics, permanent and temporary storage before development. If the goals set in the low-impact development method are achieved by reducing pollution and also increasing nutrition to groundwater aquifers, in addition to increasing runoff quality, the inflow from urban drainage networks to current rivers in urban areas will also be higher than before. There will not be many changes in the development of the catchment area. Therefore, in this article, we tried to discuss the hydrological basics of analysis, design and evaluation of LID methods in the management and collection of surface water.

Keywords New methods, Modern Techniques, BMP, storm water management

1. Introduction

1.1. Background

Urban planning and the development of cities and the conversion of barren areas into urban lands greatly reduce the possibility of rainwater penetrating into the ground .Because the hydraulic efficiency of impermeable urban surfaces, streets and atmospheres is more than barren lands or agricultural lands, and these levels, including the collection and transfer of surface runoff caused by rainfall, are done more easily and quickly .In other words, due to the impenetrability of more urban areas than suburban lands, runoff in cities has flowed to streams and waterways with greater volume and speed.These conditions, in turn, increase the likelihood of flooding of public and private passages and places.The result of these changes will be the improvement of the drainage of the basin, the shortening of the concentration time and the increase of the discharge intensity of the floods of the basin (Peak).In addition to traffic problems, the flow of rainwater in urban lands intensifies the pollution of surface and underground runoff accepting urban runoff.

A new approach to surface runoff management in cities Low Impact Development (LID) and Best Management Practices (BMP) method basically refers to methods and techniques that are in line with the artificial rehabilitation of the natural water cycle in the city.

That is, the volume and peak of runoff irrigation and the amount of pollution in running water due to rainfall in the city is reduced to the extent that existed before, i.e. before the development of urban areas in the barren lands around the old city.Some countries have gone even further in this regard, identifying the contribution of pre-urban natural conditions as a series of quantitative objectives for surface runoff management projects .Proposed methods and measures in the form of new approaches to surface runoff management are given in many scientific texts. Some research has examined the effects of LID method directly in relation to floods [1-10] and another research has been done to other aspects[11-20]. From the point of view of geographical classification of the research, due to the frequency of urban floods in Iran, can be mentioned some good researches in Iran [3, 8, 10, 21-34].

2. Methodology

2.1. Hydrological Concepts

In the first part of the urban development design by LID method, calculations are performed to determine the maximum runoff production potential in the study area based on the details of the existing surface cover and the future situation after development.In fact, before designing, key parameters such as the type of surface cover, percentage of impermeable areas, soil texture and structure, and previous soil moisture status, which will change based on low-impact development method in the future, runoff production potential are calculated.The CN curve number in conventional methods is determined using the tables in Regulation TR-55.

However, in the low-impact development method, CN is determined by careful examination of the surface coating as well as the above-mentioned parameters. The most important low-impact development methods that reduce the CN of developed areas and consequently runoff volume are:

- **Protection of soil permeability:** By classifying the soil in the site to be designed, more structures and buildings are needed to be built in the part that has less permeability, and the areas that have more permeability have the least tampering.
- **Preservation of pre-development green space conditions:** Forests, parks and other existing green space are the best opportunity for infiltration and storage of runoff.In addition, green space will increase the roughness coefficient and consequently increase the focus time of the study site.
- **Reduction of impermeable areas:** Reduction of impermeable areas in a site will have a significant effect on reducing the need to build compensatory structures for temporary storage.Because there is a one-to-one ratio between rainfall and runoff volume in impermeable areas.
- **Discontinuity between impermeable spaces:** Discrete impermeable areas from a hydrological point of view refers to areas in which runoff is directly connected to the drainage network or another impermeable area.In these areas, the flow is directed in a sheet to the green space or similar areas for the opportunity to penetrate the ground. In this case, the amount of runoff produced will be significantly reduced compared to the case that enters directly into the drainage network.
- **Transfer areas:** Areas with green and vegetated cover that are located before the runoff is discharged into the drainage network in impermeable areas, and cause storage and infiltration of the runoff.These areas will also have a significant effect on the calculation of CN in the LID method.

The use of the above-mentioned 5 methods in the development of cities and new constructions, in addition to lowering the costs of constructing drainage networks, will also reduce the costs related to the maintenance, inspection and future repairs of the mentioned network.

2.2. Keep the time of concentration constant (relative to the pre-development mode)

In the low-impact development method, as mentioned, it tries to have the least change in the concentration time of the developed areas compared to its original state. Keeping the laminar flow length constant by dispersing and re-collecting the mentioned flows using streams and natural drainage networks, increasing surface roughness, creating flow delay (streams and gardens), minimizing disturbances in the current situation (Reduction of green space), reduction of slope in effective areas, creation of discrete impermeable areas, creation of permeable space and interconnected vegetation are among the methods used for the development of sites and urban constructions in this method. When designing urban planning parameters with the appropriate combination of the above methods and calculations by trial and error, the amount of change in concentration time after development is minimized.

- Another thing that should be considered when designing the city is to use as little as possible covered canals or pipes in order to collect surface water. Streams and open streams will change the focus time of the basin less for reasons such as higher roughness coefficient, reduced flow velocity, sheet flow conditions, greater width and lower slope.
- After introducing all the options that keep the runoff production potential in a developed area constant. Also, activities that do not change the concentration time in a catchment area. If the volume of runoff produced in the catchment area is more than the pre-developed state, this problem can be solved by constructing and maintaining delayed structures. Biological storage facilities such as gardens, infiltration ponds, septic tanks or rainwater storage tanks are among the most common facilities and techniques for temporary (delayed) and permanent maintenance.

3. Computational Methods and Processes

Low-impact development method calculations involve a series of successive decisions. Several iterations are performed in each step to achieve the desired design result, which is to keep the hydrological parameters constant.

3.1. Determining the number of curves in LID method

Determining the number of curves in low-impact development will require a careful assessment of the coverage situation within the study site. This careful evaluation, as well as the application of the techniques described, allows the designer to use the maximum allowable amount of rainfall storage and penetration and to keep the number of the curve as constant as possible compared to the pre-development. In fact, the more natural methods such as protection of green space and reduction of permeable surfaces are used to keep the number of the curve constant, the less the need to build temporary and permanent maintenance structures decreases. The steps for determining CN in the developed site are as follows.

Step 1: The percentage of each coating is determined according to the common methods in hydrological calculations and using the tables of regulations TR-55, CN related to each area. In fact, the site is analyzed as separate units and is considered suitable for each CN unit.

Step 2: Calculate Composite CN:

The initial composite CN is calculated by weight exclusively by considering the surface cover of the ground without examining whether the impermeable surfaces are connected or not, as well as the area of each cover.

$$CN_c = \frac{CN_1 A_1 + CN_2 A_2 ... + CN_j A_j}{A_1 + A_2 ... + A_j} \qquad \text{(Eqn 1)}$$

Where:

- CNc is the composite curve number,
- Aj is the area of each separate region and
- CNj is the curve number corresponding to each separate region.

Another advantage of the LID method, which recommends increasing soil permeability in urban development, is the use of hydrological groups A and B in determining the CN of each area. Careful design in urban development and construction will lead to a significant reduction in runoff volume in developed areas and consequently reduce the cost of surface water collection network management.

Step 3: Calculation of CN by LID method based on the continuity of impermeable areas

In cases where impermeable areas make up about 30% of the site area, the amount of connected or unconnected areas of the impermeable areas will have a significant effect on the CN calculation. Disconnected impermeable areas have virtually no direct access to adjacent impermeable areas or drainage networks. For example, roof drainage can be connected to the green space adjacent to the house instead of being connected directly to the urban drainage network. By increasing the impermeable surfaces not connected to the total impermeable surfaces, the numerical value of CN and consequently the runoff volume decreases. Equation 2 is used to calculate CN for sites with less than 30% impermeability levels.

$$CN_c = CN_p + \left(\frac{P\ imp}{100}\right) * (98 - CN_p) * (1\text{-}0.5\ R) \qquad \text{(Eqn2)}$$

Where

- R is the ratio of impermeable areas unconnected to total impermeable surfaces,
- CNc is the composite runoff curve number,
- CNp is the initial composite runoff curve number and
- Pimp is the percent imperviousness.

3.2. Determine the time of concentration

The time of time of concentration in the LID method can be calculated as it is commonly done in hydrological calculations.

$tc = t_{sheet} + t_{shallow} + t_{channel}$

Where

- t_{sheet} is the total travel time of laminar flows on catchment lands ,
- $t_{shallow}$ is the total travel time in shallow areas such as streams and ridges along the street and
- $t_{channel}$ is the total travel time in the canal.

3.3. Building requirements for runoff management in the low development method

After determining the CN and the concentration time in the studied catchment area, the volume required for the construction of building supplies in the area will be designed. As mentioned before, in spite of the activities and cases done in the field of creating the least amount of tampering at the level of the basin and the site, due to construction, the volume and peak discharge of urban runoff will still change. Temporary and permanent maintenance structures are constructed to reverse this change.

The volume of maintenance can be calculated using graphs prepared in the LID method. These graphs are based on CN in the pre-development and CN post-development states, as well as the intensity of rainfall designed for medium depth for the construction of maintenance structures throughout the site. One of the graphs used in this method is presented for design rainfall with 24 hour rainfall duration and type 2 rainfall distribution equal to 2 inches and construction of delayed structures. In this graph, the average depth for creating a delayed structure across the basin is determined based on the amount of CN changes before and after development.

4. Items Offered and Suggestions:

4.1. LID – BMP Selection factors:

Table 1: Important factors for implementing Low Impact Development methods (LID) and Best Management Practices (BMPs)

Items	Suggestion
Slope:	The steep slope limits the use of some methods.
	Porous surfaces S <5%
	Atmospheric gardens S <5
	Various trenches and southern treatment strip S <20%
Groundwater level:	Shallow groundwater depth
Soil condition:	Type C and D soils and soil penetration of less than 0.68 cm per hour in the upper part of the profile are limiting.
	High permeability soils also create unfavorable conditions for wetland construction conditions.
Leakage status (to drinking water sources)	The distance of the infiltration facilities should be at least 30 meters away from the drinking well.
Climatic conditions	Long-term assessment of rainfall (drought and frost) is necessary to determine the structural dimensions. It is necessary to have a constant flow for permanent ponds in order to prevent wetland and the spread of disease and insects.
Structural depth of BMPs	Methods such as infiltration trench, retaining pond, infiltration well,

	permeable surfaces should be drained of rainwater after 2 to 3 days, if soil infiltration is restrictive, installation depth may be limited.
Availablespace conditions in the selection	Some methods, such as permeable surface methods and storage ponds, require sufficient space.
Impact of input sediments	Infiltration-based methods are prone to clogging in the presence of large sediments. These methods should not be applied in areas where the soil is not stable or in upstream areas where construction is taking place.
	Pre-treatment methods prior to this mechanism should be used to adsorb sediment.
	Permeable surfaces should not be applied in areas receiving coarse-grained sediments.
Aesthetic and landscape impact	The implementation of some methods, such as the construction of artificial lakes, increases the price of adjacent land, and on the other hand, the implementation of linear penetration and lined detention can have adverse effects on the landscape and the surrounding area. Aesthetics will be very important in choosing these methods in an area.

4.2. Obstacles to the implementation of LID techniques

- Many projects can only be implemented on a small scale.
- Many cities traditionally ignore the new plan.
- Lack of space / high cost
- Discharge from the facility must be matched to the existing drainage network floor
- They interfere with subsurface structures (sewage, etc.)
- Soil pollution
- Lack of familiarity of design engineers with correct design details
- Natural waterways have either been altered or removed
- Underground quality improvement is expensive.
- It is not possible to achieve all the goals in the whole project
- Inadequacy to urban growth based on the beneficial use of all urban spaces

4.3. Recommendations in designing new methods in densely populated areas

- A single design method is required.
- Observe the standard landscape for urban view
- Use specific urban LID
- Focus on green street design
- Use parallel funding using incentives
- Ensuring the reduction of phosphorus and nitrate levels through the implementation of these methods

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