CURVE NUMBER AND GROUNDWATER RECHARGE CREDITS FOR LID FACILITIES IN NEW JERSEY

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ABSTRACT

A credit system for implementation of innovative stormwater management practices such as LID facilities will encourage the use of such practices. Such credit system should be based on the expected role of the facilities in meeting the local stormwater management requirements. A series of simplified tools were developed to quantify the impact of various LID facilities in controlling the runoff volume and providing groundwater recharge in New Jersey. Simple equations and charts were developed to evaluate credit in terms of Curve Number (CN) reduction for the LID facilities that directly receive runoff from an impervious area or are located within a development lot. Also, a chart was developed to provide estimates of the annual groundwater recharge volume provided by buried exfiltration facilities. This paper presents these LID impact quantification equations and charts and discusses the implementation of these tools in New Jersey and elsewhere. Also, example applications are provided to demonstrate the use of these tools and to put the relative role of LID facilities in CN reduction and groundwater recharge enhancement in perspective.

Key Words: *LID, Stormwater Management Credit, Groundwater Recharge, Curve Number Reduction.*

INTRODUCTION

The State of New Jersey has been working to find ways to encourage implementation of innovative stormwater management techniques such as Low Impact Development (LID). At the same time, the State is requiring that the post-development groundwater recharge volumes must match those of the pre-development natural conditions. Logically, the developers expect some sort of credit for utilizing LID practices, perhaps in form of a size reduction for the traditional stormwater facilities serving the same development. They also need computational tools to estimate the pre- and post-development groundwater recharge volumes and to quantify the amount of annual recharge volume expected from a given facility at a given location. Dewberry worked with New Jersey Department of Environmental Protection and Department of Agriculture to develop computational tools to facilitate implementation of LID and groundwater recharge preservation for area undergoing development in various locations in the State.

A general theoretical investigation using common hydrological tools was conducted to get a sense of the impact of LID implementation in runoff control from a development area. Preliminary conclusions of the study show that LID practices would be generally ineffective in controlling the design peak flow rates. However, they may be effective in controlling the runoff volume and quality and in providing groundwater recharge. This study focused on potential runoff volume control (Curve Number reduction) and groundwater recharge benefits provided by LID.

CURVE NUMBER REDUCTION METHODS

Since the NRCS Curve Number (CN) procedure for estimating runoff volume is commonly in use it was decided to develop an LID credit calculation procedure in terms of CN reduction. The NRCS runoff equations were manipulated to consider the additional runoff reduction due to the storage provided by the LID facility. The additional hydrological loss provided by the LID facility would result in an effective CN that would be potentially smaller than the original CN. It must be noted here that the CN reduction discussed here is only relevant to calculation of the design runoff volume (e.g. water quality control volume) and not to the design peak flow rates. Two cases were considered for CN reduction estimation.

The first case involves diversion of runoff from an impervious area to a LID facility resulting into a possible reduction of the effective CN of the impervious area. The effectiveness of this method in reducing runoff volume is directly related to the volume of the storage provided by the facility as well as the area of the impervious surface. Since most LID facilities are small in terms of their footprint area, the facility would have to be relatively deep to provide any considerable storage volume. Also, the facility would have to have good infiltration potential to allow dissipation of the water after it is filled during a storm. LID Integrated Management Practices (IMP) that have considerable depth and infiltration rates best represent the type of practices for which CN reduction calculations can be applied. Such facilities are labeled here as deep Infiltration LID-IMPs. Examples of these IMPs include rooftop runoff connected to a dry well and parking lot runoff diverted to a vegetated buffer strip. The assumption here is that the runoff from the entire impervious area of the interest is diverted to the infiltration facility. This does not mean that the facility would have to have enough capacity to contain all of the runoff from the impervious area.

Table 1 presents the equations and an example application of the CN reduction by deep infiltration LID-IMPs. In the example given in Table 1 connecting the rooftop runoff to a dry well reduces the CN of the rooftop area from 98 to 94. The nomograph presented here as Figure 1 was developed to facilitate the use of these equations. As seen in Figure 1 the original CN of the impervious area is 98 but depending on the ratio of the facility area to the impervious area and the effective depth of the facility this CN is effectively reduced to a lower value. Figure 1 also contains an explanation of how to use this nomograph.

In New Jersey, the Water Quality Design Storm is 1.25 inches. Since the water quality storm is the most commonly used design storm in runoff volume calculations, the author developed a separate simplified chart for this storm (not shown here for brevity).

The second case involves a small LID such as a bioretention facility within a lot potentially decreasing the effective CN of the lot. In this case, the reduction of the CN not only depends on the relative size of the facility but also on the original CN of the drainage area and the design rainfall depth. Table 2 shows the equations and two example applications of the CN reduction by a small LID facility in a drainage area. In the first example, two bioretention ponds used in a 1-acre lot under a design rainfall of 4.5 inches reduce the lot CN from 85 to 84. In the second example, the same two bioretention ponds are used in a ½ acre lot under a design rainfall of 3" and reduce the lot CN from 75 to 73. These examples indicate the fact that small LID facilities will have limited impact in reduction of the lot CN even for calculation of runoff volumes. To enforce a meaningful impact several LID facilities would have to be implemented in a given lot.

A nomograph was also prepared to allow quick estimation of the CN reduction credit for this case. However, this nomograph is more complex than Figure 1 and is not presented here.

GROUNDWATER RECHARGE CREDIT METHOD

The New Jersey stormwater management regulations require the post-development annual groundwater recharge volumes match those of the pre-development conditions. To comply with this regulation one has to be able to estimate the pre- and post-development recharge volumes and calculate the annual recharge volume provided by infiltration LID or BMPs designed for compensatory recharge under post-development conditions.

To allow these estimations the author developed a comprehensive method and implemented it in the format of the New Jersey Groundwater Recharge Spreadsheet. This spreadsheet is currently available through the New Jersey Department of Environmental Protection Web Site as part of The New Jersey Stormwater Best Management Practices Manual (see NJDEP, 2004). Chapter Six of this reference contains an explanation of the theoretical developments of the spreadsheet as well as a user manual for it. Additional developments by the author to the New Jersey Groundwater Recharge Spreadsheet also allow evaluation of the annual groundwater recharge provided by discharging surface runoff over forested buffer zones in New Jersey (Zomorodi, 2003).

For detailed evaluation of the groundwater recharge volume and the recharge credit for any infiltration facility in any township of New Jersey one would use the spreadsheet as described above. However, for a preliminary overall estimate of the performance of an infiltration facility a simpler tool may be in order. Based on the New Jersey Groundwater

Recharge Spreadsheet, the author developed a simplified nomograph that can be used for any location in New Jersey or possibly for neighboring areas with similar rainfall regimes. Figure 2 shows this chart which can be used to quickly estimate the recharge credit of an infiltration facility operating at near 100% recharge efficiency. In order for a facility to have 100% recharge efficiency (meaning that virtually all of the water in the facility actually infiltrates deeper than the prevailing root zone in the area) it must be a deep LID-IMP as discussed in the previous section.

Figure 2 also presents an explanation of how to use the nomograph. For example consider the case of a dry well 3-ft in diameter and 5-ft deep. The Effective Depth of the well considering the void ratio of the fill material is 2-ft or 48-inches. If this dry well is connected to a rooftop area of 1000 sq-ft, the ratio of the LID-IMP Surface Area to Impervious Area would be approximately 0.007. Entering the chart with this value on the X-axis and moving vertically up to the 48" curve a value of 225 cu.ft/sq.ft is read from the Y-axis. This value is the Annual Recharge Volume per Unit Area of the LID-IMP Surface Area. Considering the surface area of the dry well (7.07 sq-ft) the annual recharge volume is found by multiplying 225 by 7.07 which gives an annual recharge volume of 1590 cu.ft This volume can be used as recharge credit towards satisfying the annual groundwater recharge volume deficiency expected due to development.

Sample calculations showed that recharge volumes provided by small LID facilities are typically only a small fraction of the recharge deficit caused by representative developments. Therefore, normally several LID facilities per lot would be needed to compensate the recharge lost to development.

CONCLUSIONS

The computational tools discussed in this paper help in quantifying the LID impacts. They can be used in assigning CN reduction and annual groundwater recharge credits resulting from implementation of LID techniques.

Sample calculations showed that under typical development scenarios several LID facilities per lot would be needed to have a considerable impact in reduction of runoff volumes and providing groundwater recharge.

The groundwater recharge tools discussed here were specifically developed for the New Jersey conditions and data. However, the CN reduction tools may be used anywhere the NRCS CN method is acceptable for runoff volume estimations.

Table 1. Curve Number Credit Equations for Deep Infiltration LID-IMPs

Notation:

P: Design Precipitation Depth (in),
$\mathbf{A_{LID}}$: The Surface Area of the LID-IMP (sq.ft),
$\mathbf{A_{IMP}}$: The Area of the Impervious Surface Connected tot the LID-IMP (sq.ft),
Qr: Revised Runoff Depth (in),
d = Depth of the LID-IMP (in),
VR = Void Ratio of the Fill Material in LID-IMP,
CNr = Revised CN of the Impervious Area Connected to the LID-IMP.

Equations:

$$Q_r = \{ (P-0.0408)^2 / (P+0.1632) \} - (d\ VR\ (A_{LID}/A_{IMP}))$$

$$CN_r = 100 / (0.5\ P + Q_r - (1.25\ P\ Q_r + Q_r^2)^{(0.5)} + 1)$$

Example:

Problem Statement
Find the revised CN for a 1500 sq.ft rooftop connected to a dry well with surface area of 15 sq.ft and depth of 12 ft. The well is filled with gravel with a void ratio of 0.33. The design 24-hr precipitation is 4.5 inches.
The expected infiltration depth in three days of operation (considering seepage from sides of the well) is 6 feet.
Solution
Because the expected infiltration depth (6 ft) is larger than well depth multiplied by void ratio (4 ft) the effective depth is not restricted by 3-day infiltration depth.
Q_r = { (4.5-0.0408)2 / (4.5+0.1632)} - (12 x 12 x 0.33 x (15/1500)) = 3.79 inches
CN_r = 100 / (.5 x 4.5 + 4.22 - (1.25 x 4.5 x 4.22 + $4.22^2)^{(0.5)}$ + 1) = 93.76 use 94.

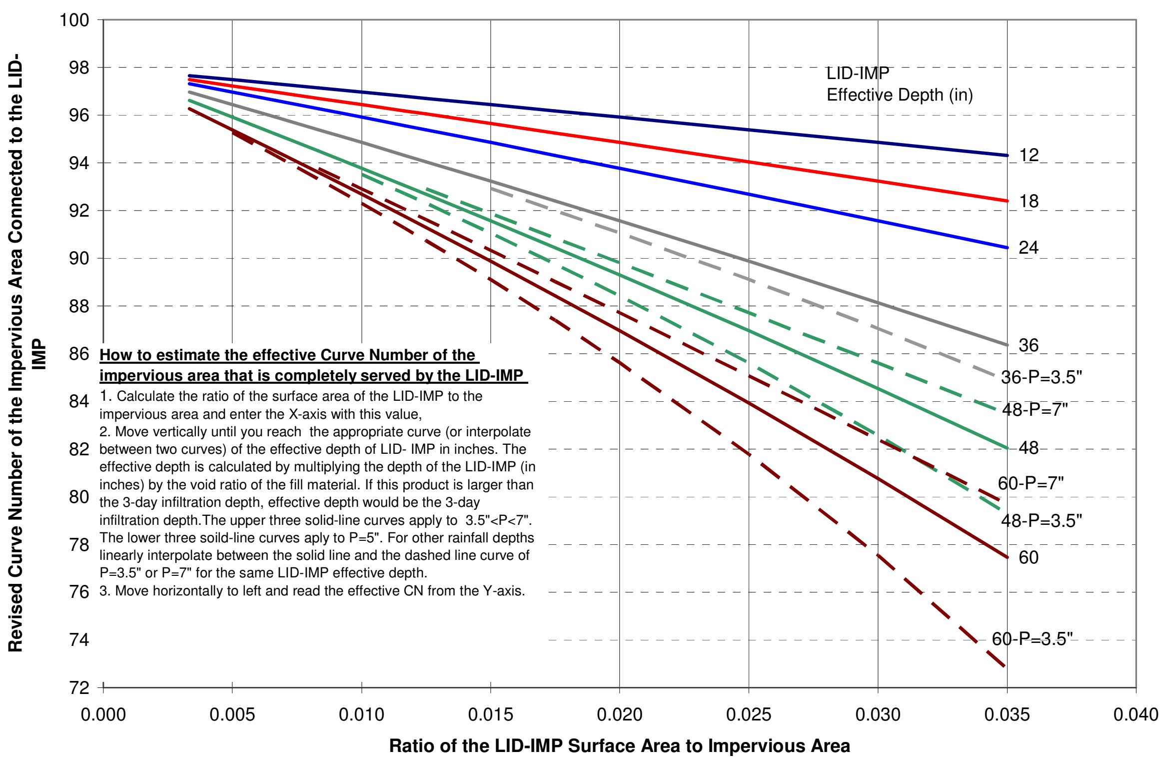

Figure 1. CN Reduction for Deep Infiltration LID-IMPs.

Table 2. Curve Number Credit Equations for Small LID-IMPs

Notation:

P: Design Precipitation Depth (in),
A_{LID}: The Surface Area of the LID-IMP (sq.ft),
A: The Area of the Lot (sq.ft),
Qr: Revised Runoff Depth (in),
d = Depth of the LID-IMP (in),
CN = Post-development CN without the LID-IMP.
CNr = Revised CN of the lthe lot with the LID-IMP.

Equations:

$$Q_r = \{ (P - 0.2\ (1000/CN-10))^2 / (P+0.8*\ (1000/CN-10)) \} - (d\ (A_{LID}/A_{IMP}))$$

$$CN_r = 100 / (0.5\ P + Q_r - (1.25\ P\ Q_r + Q_r^2)^{(0.5)} + 1)$$

Example Applications

Example A
Find the revised CN for a 1-ac lot with the post development CN of 85 considering the effects of a two 6-inch-deep bioretention ponds with a combined surface area of 300 sq.ft. The design 24-hr precipitation is 4.5 inches.
Solution
Q_r = {{ (4.5- 0.2 (1000/85-10))2 / (4.5+0.8* (1000/85-10)) } - (6 (300/(1.0 x 43560))= 2.83 inches
CN_r = 100 / (.5 x 4.5 + 2.83- (1.25 x 4.5 x 2.83 + $2.83^2)^{(0.5)}$ + 1) = 84.1 use 84.

Example B
What if the same ponds were built in a 1/2-acre lot with a post-development CN of 75 and a design 24-hr rainfall of 3 inches?
Solution
Qr = {{ (3 - 0.2 (1000/75-10))2 / (3+0.8* (1000/75-10)) } - (6 (300/(0.5 x 43560))= 0.88 inches
CNr = 100 / (.5 x 3+ 0.88 - (1.25 x 3 x 0.88+ $0.88^2)^{(0.5)}$ + 1) = 73.4 use 73.

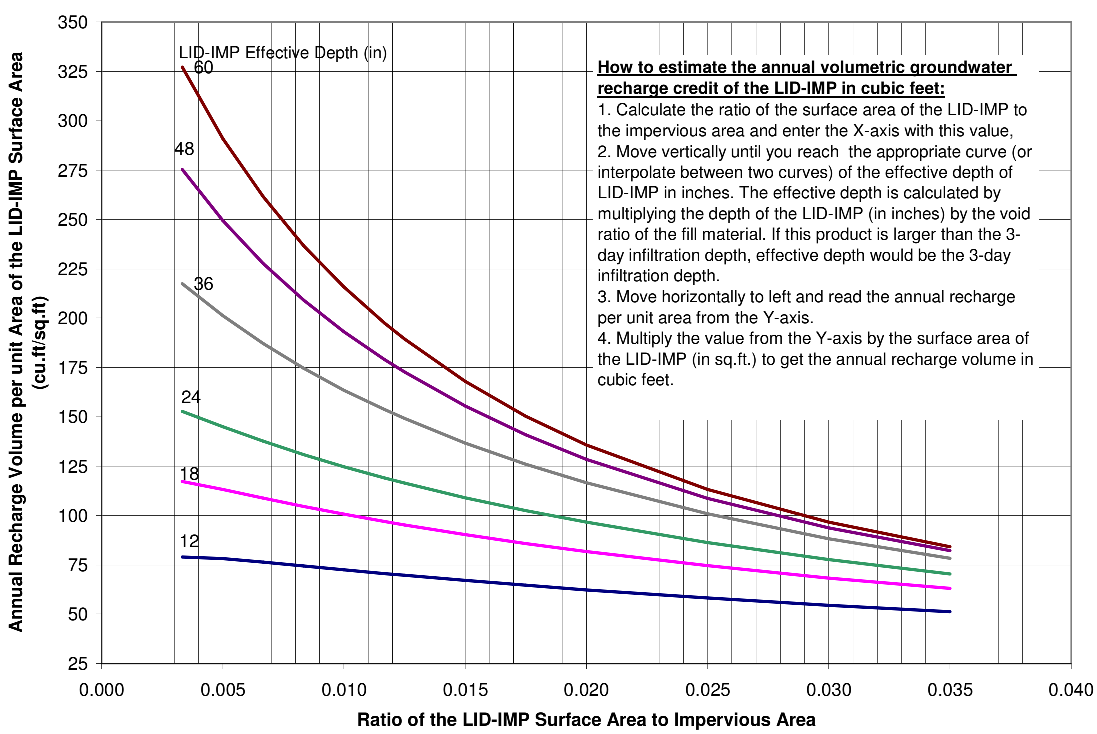

Figure 2. Simplified Groundwater Recharge Credit Chart for Deep LID-IMPs in New Jersey.

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