Maryland Department of the Environment

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Stormwater Design Guidance – Green Roofs (March 2018)

Revisions to Maryland's stormwater management (SWM) regulations[i] in 2010 require that environmental site design (ESD) be used to the maximum extent practicable (MEP) to mimic natural hydrologic runoff characteristics and minimize the impact of land development on water resources. Because they are designed to grow plants on rooftops, the areas covered by green roofs have runoff characteristics that resemble grassed or open space areas. As a result, MDE considers green roofs to be an alternative surface that may be used to mitigate impervious cover, more closely mimic natural hydrology, and contribute to meeting ESD requirements.

As discussed in Chapter 5 of the 2000 Maryland Stormwater Design Manual[ii] (the Manual), the criteria for sizing ESD practices are based on reducing the volume of runoff to a level equivalent to a wooded site in good condition. The basic principle is that a runoff curve number or "CN" that is based on the Natural Resources Conservation Services (NRCS) method[iii] may be applied to post-developed conditions where ESD practices like green roofs are used. When Supplement 1[iv] was added to the Manual in April 2009, the typical green roof system consisted of a waterproof membrane, a drainage layer, growing substrate, and vegetation. Of these layers, the substrate stores runoff while supporting plants and the drainage layer allows for rapid drainage of excess rainfall. The capacity of a green roof to retain runoff is affected by several factors including substrate thickness and roof slope. Because these factors vary independently, determining CNs for individual green roofs is difficult. To address this issue, MDE developed a series of CNs (see Table 1 below) so that designers and plans reviewers would be able to assess the effects of generic green roof systems for meeting SWM requirements. This was a simple and effective solution to what would otherwise be a contentious problem.

Table 1*. Effective CNs for Extensive Green Roofs

Roof Thickness (in.):	2	3	4	6	8
Effective CN:	94	92	88	85	77

*reprinted from the 2000 Maryland Stormwater Design Manual (MDE, 2000 & 2009), Chapter 5 (p. 5.42)

Since 2009, the number of different green roof systems on the market has expanded greatly. With the advances in technology, including capturing additional runoff within modified drainage layers, the capacity of these newer green roof systems has increased. With each new and different green roof configuration, there is the potential for a different CN that must be considered by the local jurisdiction. This has led to another very contentious problem.

MDE originally adopted the CNs shown in Table 1 to simplify the plan review process. Assigning different CNs to each new variant or technology would complicate this process for both designers and plan reviewers. Initially, MDE determined that it would be easier and less costly to allow the local jurisdictions to account for or "credit" the additional storage volumes in these advanced green roof systems towards the ESD requirements. MDE understands that this has not resolved the issue, and offers the following additional guidance for determining the effect of green roof storage on ESD requirements.

CNs are an effective tool for modeling the amount of runoff that may be expected from a surface during rainfall events. However, they are not precise numbers. The assigned CN actually reflects the spread of runoff around a central trend depending on local antecedent conditions. Also, describing runoff conditions with a CN assumes that green roofs are a natural surface. This is not the case; green roofs are engineered systems with specific storage capacities and runoff behavior. Several recent studies, like Fassman-Beck E. et al (2016)[v], indicate that for most green roof designs, there is little to no runoff from small storm events (e.g., ≤ 1.2 inches of rainfall). However, there may be considerable runoff for larger, less frequent events. As a result, a step-based approach often is suggested when applying CNs to green roofs.

MDE understands that a different procedure for analyzing the performance of green roof systems for SWM purposes needs to be developed. This procedure will need to account for enhancements in green roof storage as well as anticipated changes to the NRCS CN methods. In the interim, MDE recommends that plan reviewers and designers use the reduced CNs shown in Table 2 below for assessing enhanced green roof systems for compliance with the ESD to the MEP mandate. These CNs reflect the broader range of storage options found in newer green roof systems.

Table 2. Effective CNs for Extensive Green Roofs - Revised

Retention* (in.)	0.6	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
Effective CN:	94	92	90	88	86	85	82	81	77

* Volume of water captured and stored by the green roof system as reported in manufacturers' specifications. This does not include any water that is detained (e.g., captured and released).

NOTE: Originally, the guidance found in Chapter 5 (see pp. 5.42 to 5.45) was developed as a simple method that applied to extensive green roofs (i.e., green roofs with soil layers ≤ 8 inches thick) only. Also, the ESD sizing criteria (see pp. 5.18-19) are based on capturing the runoff from the one-year 24-hour design storm (i.e., 2.7 inches of rainfall). Therefore, when determining ESD requirements, the amount of water retained (i.e., storage capacity) by green roofs is limited to a maximum runoff depth of 2.4 inches.

The CNs shown in Tables 1, 2, and in Chapter 5 of the Manual were developed using the methods described in Schwartz (2010)[vi]. These CNs reflect the hydrologic performance of extensive green roofs over a broader spectrum of rainfall events, including events exceeding five inches of rainfall (e.g., 10-year 24-hour design storm). Accordingly, MDE recommends that these values be used when modeling the effects of green roofs for all rainfall events in excess of the one-year storm.

[i] Code of Maryland Regulations (COMAR) 26.17.02
[ii] 2000 Maryland Stormwater Design Manual, Volumes I & II, MDE, October 2000 and Supplement 1, MDE, April 2009
[iii] National Engineering Handbook Part 630 (NEH 630) Hydrology, United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) 2003
[iv] 2000 Maryland Stormwater Design Manual, Volumes I & II, MDE, October 2000 and Supplement 1, MDE, April 2009
[v] Fassman-Beck, et al (2016) Curve Number and Runoff Coefficients for Extensive Living Roofs, J*ournal of Hydrologic Engineering*, Vol. 21 (3), 04015073
[vi] Schwartz, S.S. (2010) Effective Curve Numbers and Hydrologic Design of Pervious Concrete Stormwater Systems, *Journal of Hydrologic Engineering*, Vol. 15 (6), pp. 465-475