

Chapter 3

Calculating the WQCV and Volume Reduction

Contents

1.0	Introduction	1
2.0	Hydrologic Basis of the WQCV.....	1
2.1	Development of the WQCV	1
2.2	Optimizing the Capture Volume	3
2.3	Attenuation of the WQCV (BMP Drain Time)	3
2.4	Excess Urban Runoff Volume (EURV) and Full Spectrum Detention	3
3.0	Calculation of the WQCV	5
4.0	Quantifying Volume Reduction.....	6
4.1	Watershed/Master Planning-level Volume Reduction Method.....	9
4.2	CUHP-SWMM Modeling of Volume Reduction.....	12
4.2.1	CUHP Imperviousness Parameters.....	12
4.2.2	Conveyance Losses	13
4.2.3	Detention and Water Quality Features	13
4.3	UD-BMP Runoff Reduction Spreadsheet	13
4.4	Other Types of Credits for Volume Reduction BMPs/LID	14
5.0	Example Calculation of WQCV	15
6.0	Conclusion.....	15
7.0	References	15

Tables

Table 3-1. Number of Rainfall Events in the Denver Area.....	2
Table 3-2. Drain Time Coefficients for WQCV Calculations	5

Figures

Figure 3-1. Water Quality Capture Volume (WQCV) Based on BMP Drain Time	6
Figure 3-2. Four Component Land Use Model.....	7
Figure 3-3. Effective Imperviousness Adjustments for Level 1 MDCIA	11
Figure 3-4. Effective Imperviousness Adjustments for Level 1 MDCIA	12

1.0 Introduction

This chapter presents the hydrologic basis and calculations for the Water Quality Capture Volume (WQCV) and discusses the benefits of attenuating this volume or that of the Excess Urban Runoff Volume (EURV). This chapter also describes various methods for quantifying volume reduction when using Low Impact Development (LID) practices. Use of these methods should begin during the planning phase for preliminary sizing and development of the site layout. The calculations and procedures in this chapter allow the engineer to calculate the WQCV and more accurately quantify potential volume reduction benefits of stormwater control measures (BMPs).

2.0 Hydrologic Basis of the WQCV

2.1 Development of the WQCV

The purpose of designing control measures based on the WQCV is both to improve water quality and reduce hydromodification and the associated impacts on receiving waters. (These impacts are described in Chapter 1.) Although flow-based BMPs can remove pollutants, in order to offset the hydrologic impacts of urbanization including increases to flow, volume, duration, and frequency, BMPs must be designed to reduce (infiltrate) a significant portion of the WQCV or to treat and slowly release the WQCV. This section provides a brief background on the development of the WQCV.

The WQCV is based on an analysis of rainfall and runoff characteristics for 36 years of record at the Denver Stapleton Rain Gage (1948-1984) conducted by Urbonas, Guo, and Tucker (1989) and documented in *Sizing a Capture Volume for Stormwater Quality Enhancement* (available at www.MHFD.org). In 2019, Mile High Flood District (MHFD) repeated this analysis for an extended period of record, including data from 1985 - 2013, using the Water Quality Capture Optimization and Statistical Model (WQ-COSM), Version 2.0 (Urban Watersheds Research Institute [UWRI] 2012). Results of the updated WQ-COSM analysis were essentially unchanged from the earlier analysis by Urbonas et al. for the mean storm depth, the 80th percentile runoff-producing event and the overall percentile distribution of rainfall depths.

Table 3-1 summarizes the relationship between total storm depth and the annual number of storms based on the updated WQ-COSM analysis. Development of the WQCV disregards storm events with no anticipated runoff, events 0.1 inches and smaller. As the table shows, these small storms that do not produce significant runoff represent 45 of the 74 storm events that occur on an average annual basis, or 61% of rainfall events. Urbonas et al. (1989) identified the runoff produced from a precipitation event of 0.6 inches as the optimal target for the WQCV, where treating larger volumes has a diminishing return of investment in terms of the number of storms captured and treated. The 0.6-inch precipitation depth corresponds to the 80th percentile of runoff-producing storms. The WQCV for a given watershed will vary depending on the imperviousness and the drain time of the BMP, but assuming 0.1 inches of depression storage for impervious areas, the maximum capture volume required is approximately 0.5 inches over the area of the watershed. Urbonas et al. (1989) concluded treating and detaining the volume of runoff produced from impervious areas during these storms can significantly improve water quality.

Using WQCV and Flood Control Hydrology

Channels are typically designed for an event that is large and infrequent, such as the 100-year event. A common misconception is that these large events are also responsible for most of the erosion within the stream. Instead, the *effective discharge*, by definition, is the discharge that transports the most sediment on an annual basis and this is a good estimate of the *channel-forming flow* or the discharge that shapes the stream through sediment transport and erosion. The effective discharge does not correlate with a specific return period, but often is characterized as a magnitude between the annual (1-year) event and the 5-year peak flow, depending on watershed-specific characteristics.

The typical flood control facility design may include peak reduction of the 5- or 10-year storm event as well as the 100-year event. Widespread use of minor and major event detention reduces flooding of streets and streams. However, this practice does little to limit the frequency of channel-forming flows. MHFD recommends *Full Spectrum Detention*, a concept developed to replicate historic peak flows for a broad spectrum of storm events. This method is described in more detail in the *Storage* chapter of Volume 2 of the USDCM.

Widespread use of full spectrum detention would, in theory, improve channel stability and reduce erosion; however, full spectrum detention does not necessarily reduce volume, duration, and frequency, which also contribute to instability.

Therefore, this manual provides a variety of BMPs that provide the WQCV and address hydrologic effects of urbanization through storage, infiltration, and/or evapotranspiration.

Table 3-1. Number of Rainfall Events in the Denver Area.

(Adapted from Urbonas et al. 1989, updated with additional data [1985 – 2013] by MHFD 2019)

Total Rainfall Depth (inches)	Average Annual Number of Storm Events	Percent of Total Storm Events	Percentile of Runoff-producing Storms
0.0 to 0.1	45	60.9%	0.0%
0.1 to 0.5	22	29.4%	75.2%
≤ 0.6	68	92.2%	80%
0.5 to 1.0	4.6	6.3%	91.1%
1.0 to 1.5	1.5	2.1%	96.6%
1.5 to 2.0	0.6	0.8%	98.6%
2.0 to 3.0	0.2	0.3%	99.4%
3.0 to 4.0	0.15	0.2%	99.9%
4.0 to 5.0	0.015	<0.1%	100%
> 5.0	0	<0.1%	100%
TOTAL:	74	100%	100%

2.2 Optimizing the Capture Volume

Optimizing the capture volume is critical. If the capture volume is too small, the effectiveness of the BMP will be reduced due to the frequency of storms exceeding the capacity of the facility and allowing some volume of runoff to bypass treatment. On the other hand, if the capture volume for a BMP that provides treatment through sedimentation is too large, the smaller runoff events may pass too quickly through the facility, without the residence time needed to provide treatment.

Small, frequently occurring storms account for the predominant number of events that result in stormwater runoff from urban catchments. Consequently, these frequent storms also account for a significant portion of the annual pollutant loads. Capture and treatment of the stormwater from these small and frequently occurring storms is the recommended design approach for water quality enhancement, as opposed to flood control facility designs that focus on less frequent, larger events.

The analysis of precipitation data at the Denver Stapleton Rain Gage revealed a relationship between the percent imperviousness of a watershed and the capture volume needed to significantly reduce stormwater pollutants (Urbonas, Guo, and Tucker, 1990). Subsequent studies (Guo and Urbonas, 1996 and Urbonas, Roesner, and Guo, 1996) of precipitation resulted in a recommendation by the Water Environment Federation and American Society of Civil Engineers (1998) that stormwater quality treatment facilities (i.e., post-construction BMPs) be based on the capture and treatment of runoff from storms ranging in size from "mean" to "maximized" storms. The "mean" and "maximized" storm events represent the 70th and 90th percentile storms, respectively. Based on these studies, water quality facilities for the Colorado Front Range should capture and treat the 80th percentile runoff-producing event. Capturing and properly treating this volume should remove between 80 and 90% of the annual total suspended solids (TSS) load, while doubling the capture volume was estimated to increase the removal rate by only 1 to 2%.

2.3 Attenuation of the WQCV (BMP Drain Time)

The WQCV must be released over an extended period to provide effective pollutant removal for post-construction BMPs that use sedimentation (i.e., extended detention basin, retention ponds and constructed wetland ponds). A field study of basins with extended detention in the Washington, D.C. area identified an average drain time of 24 hours to be effective for extended detention basins. This generally equates to a 40-hour drain time for the brim-full basin. Retention ponds and constructed wetland basins have reduced drain times (12 hours and 24 hours, respectively) because the hydraulic residence time of the effluent is essentially increased due to the mixing of the inflow with the permanent pool.

When pollutant removal is achieved primarily through filtration such as in a sand filter or rain garden BMP, MHFD still recommends an extended drain time to promote stability of the receiving stream. In addition to counteracting hydromodification, attenuation in filtering BMPs can also improve pollutant removal by increasing contact time, which aids adsorption/absorption processes. The minimum recommended drain time for a post-construction BMP is 12 hours; however, this minimum value should only be used for BMPs where filtration is the primary treatment process, sometimes referred to as "filtration BMPs."

2.4 Excess Urban Runoff Volume (EURV) and Full Spectrum Detention

The EURV represents the difference in stormwater runoff volume between the developed and pre-developed runoff volume for the range of storms that produce runoff from pervious land surfaces. The EURV is relatively constant volume for a given imperviousness regardless of recurrence interval. Consistent with the concept of treating and slowly releasing the WQCV, the EURV is a greater volume than the WQCV and is detained over a longer time. It typically accommodates the recommended drain

time of the WQCV and is used to better replicate peak discharge in receiving waters for runoff events exceeding the WQCV. The EURV is associated with full spectrum detention which refers to a design method that includes slow release of the EURV as well as flood control detention. Designing a detention basin to capture the EURV and release it very slowly results in reduced flow rates for frequent storm events and thus reduced erosion. This method, however, does not address volume and duration which also contribute to stream and stability. This is why volume reduction practices are also necessary.

For additional information on the EURV and full spectrum detention, including calculation procedures, please refer to the *Storage* chapter of Volume 2.

¹The term "maximized storm" refers to the optimization of the storage volume of a BMP. The WQCV for the "maximized" storm represents the point of diminishing returns in terms of the number of storm events and volume of runoff fully treated versus the storage volume provided.

3.0 Calculation of the WQCV

The WQCV is calculated as a function of imperviousness and BMP type using Equation 3-1 and Table 3-2, and as shown in Figure 3-1:

$$WQCV = a(0.91I^3 - 1.19I^2 + 0.78I) \quad \text{Equation 3-1}$$

Where:

WQCV = Water Quality Capture Volume (watershed-inches)

a = Coefficient corresponding to BMP type and based on WQCV design drain time (Table 3-2)

I = Imperviousness (percent expressed as a decimal) Note: At a planning level, the watershed imperviousness can be estimated based on the zoned density. When finalizing design, calculate imperviousness based on the site plan.

Table 3-2. Drain Time Coefficients for WQCV Calculations

Drain Time (hours)	Coefficient, a
12 hours (filtration BMPs and retention ponds)	0.8
24 hours (constructed wetland ponds)	0.9
40 hours (extended detention)	1.0
No attenuation (e.g., grass buffer or swale)	1.0

Figure 3-2, which illustrates the relationship between imperviousness and WQCV for various drain times, is appropriate for use in Colorado's high plains near the foothills. For areas beyond this region, use WQCOSM (UWRI 2013) and local rainfall data to determine precipitation depth for WQCV event.

After calculating WQCV in watershed-inches, convert this to a volume using Equation 3-2. Note that the area in this equation is the entirety of the area tributary to the control measure. This is regardless of the volume treated upstream.

$$V = \frac{WQCV}{12} A \quad \text{Equation 3-2}$$

Where:

V = required storage volume (acre-feet)

A = watershed tributary area upstream (acres)

WQCV = Water Quality Capture Volume (watershed-inches)

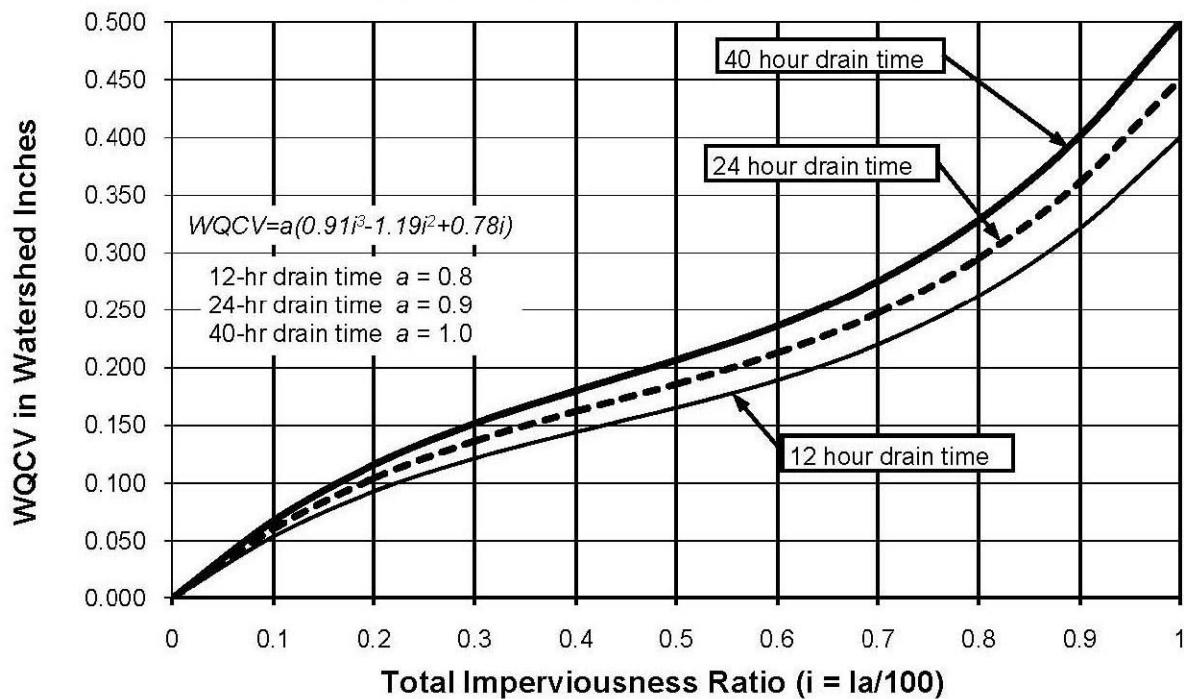


Figure 3-1. Water Quality Capture Volume (WQCV) Based on BMP Drain Time

4.0 Quantifying Volume Reduction

Runoff volume reduction is an important part of the Four Step Process for stormwater management as discussed in Chapter 1 and is fundamental to effectively manage stormwater runoff. Quantifying volume reduction associated with LID practices and other BMPs is important for watershed master planning as well as conceptual and final site design. It is also important in a regulatory context with the Runoff Reduction Standard that is included in the 2016 General MS4 Permit. A variety of approaches have been developed in the past to quantify volume reduction including “Level 1” and “Level 2” MDCIA curves for watershed-level models, Effective Imperviousness curves developed from modeling for site-level design, and others. The hydrologic response of watersheds and sites utilizing MDCIA and other volume reduction practices is an area of ongoing monitoring and research in the field of urban hydrology. Methods of quantifying runoff reduction are evolving and improving. The approaches recommended in this section are backed by physically-based modeling of rainfall-runoff, using input parameters that can be easily measured or estimated. These methods have been compared with field data from infiltration tests on receiving pervious areas including swales and provide good agreement with field data.

The approach recommended in this section is based on the Four-Component Land Use Model that is used by the Colorado Urban Hydrograph Procedure (CUHP) and the EPA Stormwater Management Model (SWMM). This conceptual model, illustrated in Figure 3-3, represents a drainage area by four components:

- Directly Connected Impervious Area (DCIA) – DCIA is impervious area that drains to the storm drain system or stream without flowing over surfaces that would allow for infiltration.

- Unconnected Impervious Area (UIA) – UIA is impervious area that drains to a receiving pervious area, where there is an opportunity for infiltration.
- Receiving Pervious Area (RPA) – RPA is pervious area that receives runoff from UIA and allows for infiltration.
- Separate Pervious Area (SPA) – SPA is pervious area that does not receive runoff from impervious surfaces.

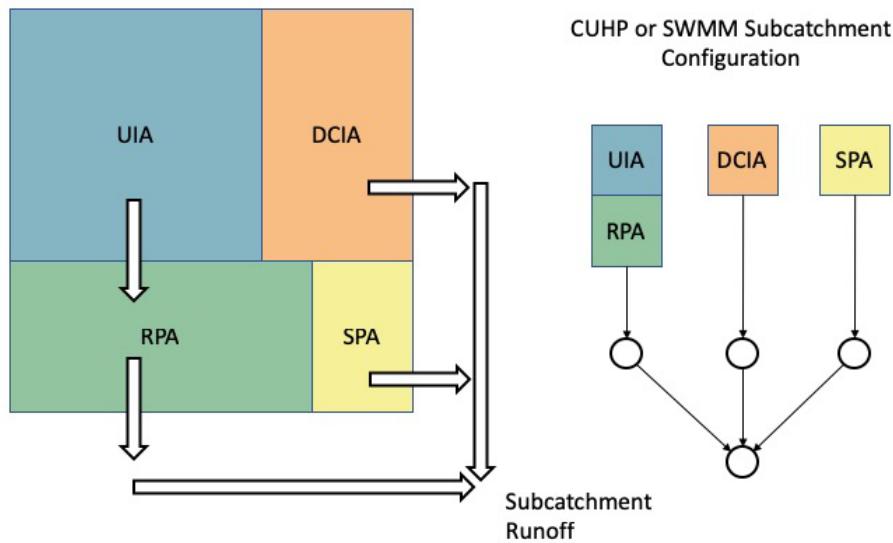


Figure 3-2. Four Component Land Use Model



Photograph 3-1. Separate Pervious Area (SPA) is permeable but does not receive runoff from impervious areas, such as the tree lawn in this photo. The drive and street are examples of DCIA.

Photograph 3-2. Directly Connected Impervious Area (DCIA) drains directly to a storm drain inlet with no opportunities for infiltration.



Photograph 3-3. Unconnected impervious area (UIA) draining to receiving pervious area (RPA). Vegetated buffer strips and/or raingardens are common ways to disconnect impervious area in parking lots.

Three approaches for quantifying runoff volume reduction are discussed in this section:

- Level 1 and 2 MDCIA: MHFD has developed curves for approximating LID effects at early planning stages. Level 1 and 2 MDCIA curves allow users to evaluate runoff reduction for two conceptual levels of LID implementation, described below. Only use these curves at early planning stages. Once the four land use fractions can be quantified, apply a more detailed method (CUHP-SWMM or the UD-BMP Runoff Reduction spreadsheet).
- CUHP and EPA SWMM: Use this approach to explicitly model directly connected and unconnected impervious areas, vegetated conveyances and BMPs, including LID practices. This method is appropriate at scales ranging from several acres (block or neighborhood scale) to several square miles (watershed scale, with appropriate sub-basin discretization).
- UD-BMP Runoff Reduction spreadsheet: This spreadsheet was developed by MHFD based on thousands of SWMM scenarios with variations of total area, ratio of UIA to RPA, hydrologic soil group, slope, roughness, depression storage, and length-to-width ratio. This approach is best-suited for small watersheds, where UIA-RPA pairs total less than 1 acre and sheet flow conditions prevail.

4.1 Watershed/Master Planning-level Volume Reduction Method

For watershed-level assessments and master planning, CUHP provides options for users to model effects of LID through the "D" and "R" curves that are embedded in the model. The "D" curve relates the ratio of DCIA to total impervious area ($D = A_{DCIA}/A_{Imp}$). The "R" curve relates the ratio of RPA to total pervious area ($R = A_{RPA}/A_{Perv}$). Since site-level details (i.e., specific percentages of DCIA, UIA, RPA and SPA for a parcel or site-level drainage basin) are not generally known at the master planning level, MHFD has developed default values for D and R in CUHP based on SWMM modeling and analysis of typical developments in the Denver metropolitan area. For any given value of total imperviousness, the

Infiltration Parameters for Runoff Reduction Analysis

Infiltration parameters used to evaluate runoff reduction from frequently occurring storms may vary from infiltration parameters for modeling larger flood events. A degree of conservatism is appropriate for flood modeling to account for unknowns including antecedent moisture conditions, heterogeneity of subsurface conditions, compaction of pervious areas, and others. When evaluating infiltration associated with frequent events, rates somewhat higher than those in the *Runoff* chapter that are based on Hydrologic Soil Groups (HSGs) are appropriate.

As an example, a Fondis Silt Loam soil is classified as HSG C, which corresponds to a final infiltration rate of 0.5 inches per hour in Table 6-7 of the *Runoff* chapter of Volume 1. Based on the NRCS Web Soil Survey, the saturated hydraulic conductivity (final infiltration rate) is 1.3 inches per hour. The value from Table 6-7 of the *Runoff* chapter (0.5 inches per hour) is appropriate for evaluating flood events, where it is appropriate to be more conservative, while the saturated hydraulic conductivity from the Web Soil Survey (1.3 inches per hour) may be appropriate for evaluating water quality events.

To determine appropriate infiltration rates for evaluating volume reduction from small storm events, use information on saturated hydraulic conductivity from the NRCS Web Soil Survey or data from a geotechnical report. Field measurements of infiltration rates using an infiltrometer also provide useful site-specific data for quantifying volume reduction.

CUHP model assigns values of D and R based on overall imperviousness and typical development patterns for two levels of LID implementation, MDCIA Level 1 and MDCIA Level 2:

MDCIA Level 1. The primary intent is to direct the runoff from impervious surfaces to flow over grass-covered areas and/or permeable pavement, and to provide sufficient travel time to facilitate the removal of suspended solids before runoff leaves the site, enters a curb and gutter system, or enters another stormwater collection system. Thus, at Level 1, to the extent practical, impervious surfaces are designed to drain over grass buffer strips or other pervious surfaces before reaching a stormwater conveyance system.

MDCIA Level 2. As an enhancement to Level 1, Level 2 replaces solid street curb and gutter systems with no curb or slotted curbing, low-velocity grass-lined swales and pervious street shoulders, including pervious rock-lined swales. Conveyance systems and storm drain inlets are still needed to collect runoff at downstream intersections and crossings where stormwater flow rates exceed the capacity of the swales. Small culverts will be needed at street crossings and at individual driveways. The primary difference between Levels 1 and 2 is that for Level 2, a pervious conveyance system (i.e., swales) is provided rather than continuous pipes. Disconnection of roof drains and other lot-level impervious areas is essentially the same for both Levels 1 and 2.

Figure 3-3 and Figure 3-4 provide effective imperviousness values for Level 1 and Level 2. Because rainfall intensity varies with return interval, the effective imperviousness also varies, as demonstrated by the separate curves for the 2-, 10- and 100-year return intervals. Effective impervious values from these figures are appropriate only as an estimate of the WQCV. These figures should not be used for final design. Figure 3-3 and Figure 3-4 are intended for use at the planning level before the specific D and R relationships in CUHP are known.

Note that the reductions in effective imperviousness shown in Figure 3-3 and Figure 3-4 are relatively modest, ranging from little to no benefit for large events up to a reduction of approximately 12% (from 50% to 38%) for Level 2 MDCIA during the 2-year event. At a more advanced stage of design and when site-specific disconnected areas, receiving pervious areas, flow paths, and other design details are available, the site-level methods in Sections 4.2 and 4.3 will better quantify volume reduction. Results will typically show greater reductions in effective imperviousness for aggressive LID implementation than reflected in the default D and R relationships used to create Figure 3-3 and Figure 3-4. Even so, it is unlikely that conveyance-based BMPs alone will provide adequate pollutant removal and volume reduction for most project sites, and a storage-based BMP will also be required.

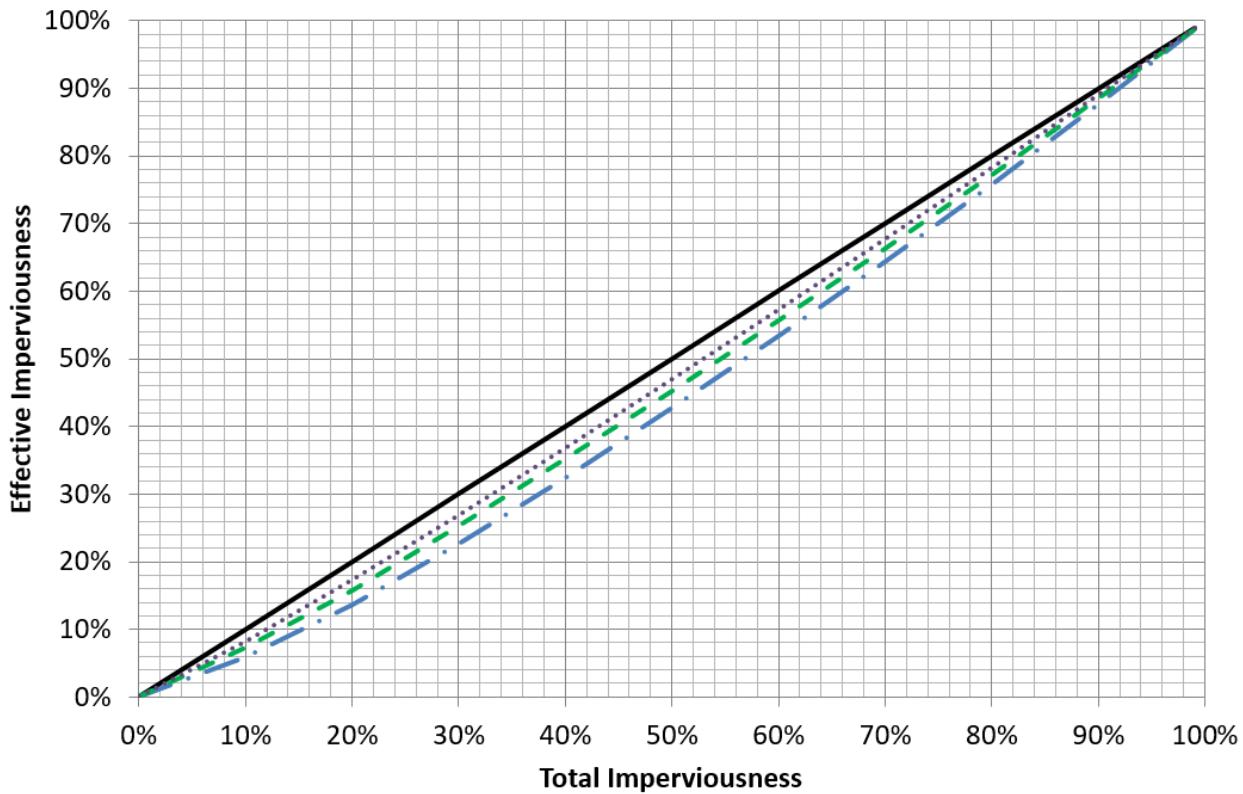


Figure 3-3. Effective Imperviousness Adjustments for Level 1 MDCIA

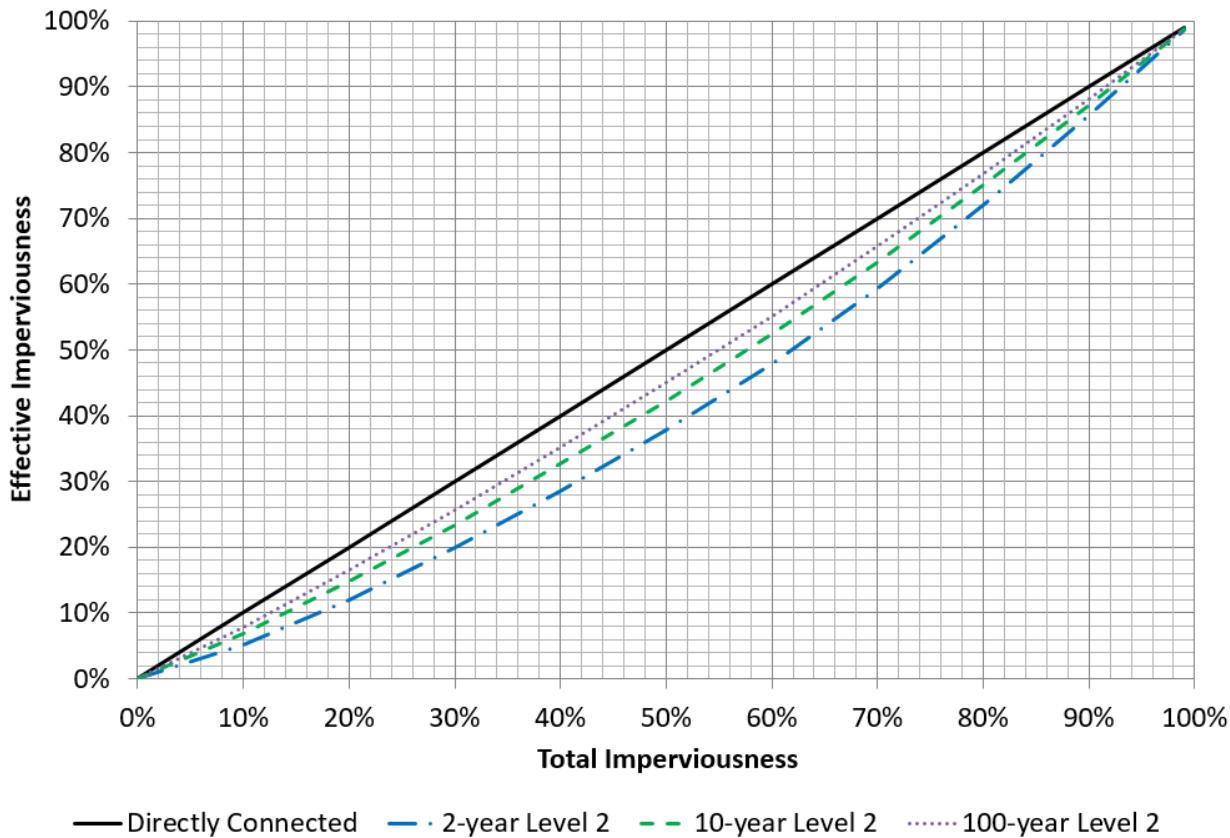


Figure 3-4. Effective Imperviousness Adjustments for Level 2 MDCIA

4.2 CUHP-SWMM Modeling of Volume Reduction

CUHP-SWMM is used for MHFD master plans at the watershed scale and for planning and design of infrastructure at the master development and filing scales. CUHP-SWMM can be applied at a lot or block scale as well, but simplified modeling methods, including UD-BMP, UD-Rational and/or UD-Detention (all of which are available at MHFD.org, are more common at the finer scales. The CUHP-SWMM approach uses CUHP to perform hydrologic calculations and SWMM to route hydrographs and represent detention and water quality features. The following sections provide methods to account for runoff reduction using CUHP-SWMM.

4.2.1 CUHP Imperviousness Parameters

Using standard settings, CUHP performs calculations that make implicit assumptions about connected and unconnected fractions of impervious area for typical development in the metropolitan area. The default assumptions in CUHP are for “incidental” disconnection of impervious area, typical of a development that is not intentionally designed with LID features. For watersheds or developments with deliberate implementation of LID to reduce runoff rates and volumes, the Subcatchment Override Parameters provide a way to specify the fractions of DCIA and RPA represented in Figure 3-2:

- The Directly Connected Impervious Fraction (DCIF) is a decimal fraction (e.g. 0.5 = 50%). The DCIF is equal to the percent of the impervious area that is directly connected to the drainage system. Based on the conceptual model in Figure 3-2, $DCIF = DCIA/(UIA+DCIA)$.
- The Receiving Pervious Fraction (RPF) is the decimal fraction of receiving pervious area to total

pervious area. Based on the conceptual model in Figure 3-3, $RPF = RPA/(SPA+RPA)$.

Peak runoff rates and volumes can vary significantly depending on these fractions, so the engineer should avoid overestimating the amount of RPA in a watershed. A common error in defining RPA is assuming that the entirety of drainage corridors, water quality features, and detention features act as RPA. Consider only the portion wetted by the design event. For example, the RPA associated with a drainage swale receiving runoff from an impervious area (UIA) would be the wetted perimeter of the swale for the design event multiplied by the length of the swale. This means a trapezoidal swale typically will be more efficient at reducing volume than a triangular swale. Upper portions of the swale side slopes that are not wetted by the design event are SPA, not RPA.

Along with accurately representing the extents and locations of RPAs to account for infiltration losses due to disconnected area, selection of soil infiltration parameters for pervious areas also may have significant effects on peak runoff rates and volumes. The values for infiltration parameters presented in Table 6-7 of the *Runoff* chapter of the USDCM for Hydrologic Soil Groups A, B and C/D are appropriate for flood modeling. For water quality events and channel forming events, infiltration rates for pervious areas may be adjusted based on site-specific data or soil permeability data from the NRCS Web Soil Survey to more accurately represent infiltration capabilities of pervious areas.

4.2.2 Conveyance Losses

EPA SWMM provides several options for evaluating conveyance losses that occur with permeable conveyances including vegetated swales and buffers. The option that is most compatible with the CUHP-SWMM modeling approach recommended by MHFD is the constant loss rate approach, which specifies constant infiltration rates for conveyance elements based on soil characteristics. To use this approach, the constant infiltration rate for the conveyance element (link) should be set to the saturated hydraulic conductivity for the type of soil underlying the swale or buffer area. Determine this value based on field measurements. In areas where the NRCS Web Soil Survey provides reliable data (e.g., undeveloped land), the Soil Survey may also be used for this purpose. In reality, infiltration will begin at an initial rate and decay to the final rate (saturated hydraulic conductivity); however, sensitivity analysis using typical decay coefficients from the *Runoff* chapter shows that the decay to the final rate is fairly rapid and that over a multi-hour runoff event, the saturated hydraulic conductivity is a reasonable and slightly conservative estimate of infiltration potential.

4.2.3 Detention and Water Quality Features

SWMM provides a seepage option for storage nodes to account for infiltration that occurs while runoff is stored in a water quality or detention facility. When using this option, the infiltration rate should be set to the saturated hydraulic conductivity based on field testing of the underlying soils. If evaluating long-term performance, consider further reducing the rate to account for clogging of pores due to sedimentation that will occur over time. Only use seepage losses in detention and water quality features when evaluating water quality events (not flood events) and when supporting infiltration data are available to justify parameter selection. Additionally, where underdrains are used, do not equate flow discharged from underdrain with infiltration.

4.3 UD-BMP Runoff Reduction Spreadsheet

Another approach for quantifying site-scale volume reduction is a simplified approach that is based on SWMM modeling of thousands of variations of UIA and RPA combinations with varying slopes, geometry, infiltration characteristics, roughness and depression storage. Based on this modeling analysis, MHFD developed a multi-variable regression equation that calculates volume reduction for the WQCV

based on input parameters including UIA, RPA, DCIA, and SPA, Hydrologic Soil Groups, the average RPA slope and the UIA:RPA interface width (Piza and Rapp 2018). The regression equation is incorporated into the UD-BMP workbook on the Runoff Reduction tab. The spreadsheet provides a simple tool that can be used to demonstrate compliance with the Runoff Reduction Standard in the MS4 General Permit. This spreadsheet is intended for application at the site scale rather than the watershed scale. Additional information on this spreadsheet, including a design example, are located in Fact Sheet T-0, *Quantifying Runoff Reduction* which is in Chapter 4 of this manual.

4.4 Other Types of Credits for Volume Reduction BMPs/LID

In addition to facility sizing reduction credits following the quantitative procedures in Section 4.0, communities can also consider other incentives to encourage volume reduction practices. Such incentives will depend on the policies and objectives of local governments. Representative examples include:

- Stormwater utility fee credits.
- Lower stormwater system development fees with certain minimum criteria.
- Density bonuses that allow greater residential densities with the implementation of LID techniques.
- Variances for requirements such as number of required parking spaces or road widths.
- Flexibility in bulk, dimensional and height restrictions, allowing greater building heights and floor area ratios, reduced setbacks and others.
- Fast-tracking the review process to provide priority status to LID projects with decreased time between receipt and review. If LID projects typically result in a longer review process, ensure equal status.
- Publicity, such as providing recognition on websites, at Council meetings and in utility mailers.
- Opportunities for grant funding for large public projects serving as demonstration projects.
- Sustainable SITES Initiative or LEED credits.
- Flexibility with landscaping requirements (i.e. allowing vegetated BMPs to count toward landscape requirements or allowing BMPs in the right-of-way).

5.0 Example Calculation of WQCV

Calculate the WQCV for a 1.0-acre sub-watershed with a total area-weighted imperviousness of 50% that drains to a rain garden:

1. Determine the appropriate drain time for the type of BMP. For a rain garden, the required drain time is 12 hours. The corresponding coefficient, a , from Table 3-2 is 0.8.
2. Either calculate or use Figure 3-2 to find the WQCV based on the drain time of 12 hours ($a = 0.8$) and total imperviousness = 50% ($I = 0.50$ in Equation 3-1):

$$WQCV = 0.8(0.91(0.50))^3 - 1.19(0.50)^2 + 0.78(0.50)$$

$$WQCV = 0.17 \text{ watershed-inches}$$

Calculate the WQCV in cubic feet using the total area of the sub-watershed and appropriate unit conversions:

$$WQCV = 0.17 \text{ w.s.in.} \cdot 1 \text{ ac} \cdot \frac{1 \text{ ft}}{12 \text{ in}} \cdot \frac{43560 \text{ ft}^2}{1 \text{ ac}} \approx 600 \text{ ft}^3$$

6.0 Conclusion

This chapter provides the computational procedures necessary to calculate the WQCV and adjust imperviousness values used in these calculations due to implementation of LID/MDCIA in the tributary watershed. The resulting WQCV can then be combined with BMP-specific design criteria in Chapter 4 to complete the BMP design(s).

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